National Air Quality Forecast Capability

Ivanka Stajner
NOAA NWS/OSTI

with contributions from the entire NAQFC Implementation Team

Outline:

- Background on NAQFC
- Recent progress and updates
  - -Ozone predictions
  - -Smoke predictions
  - -Dust predictions
  - -Prototype PM2.5 predictions
  - -Outreach and feedback
- Summary and plans

National Air Quality Forecast Capability
Capabilities as of 9/2015

- Improving the basis for air quality alerts
- Providing air quality information for people at risk

Prediction Capabilities:

- **Operations:**

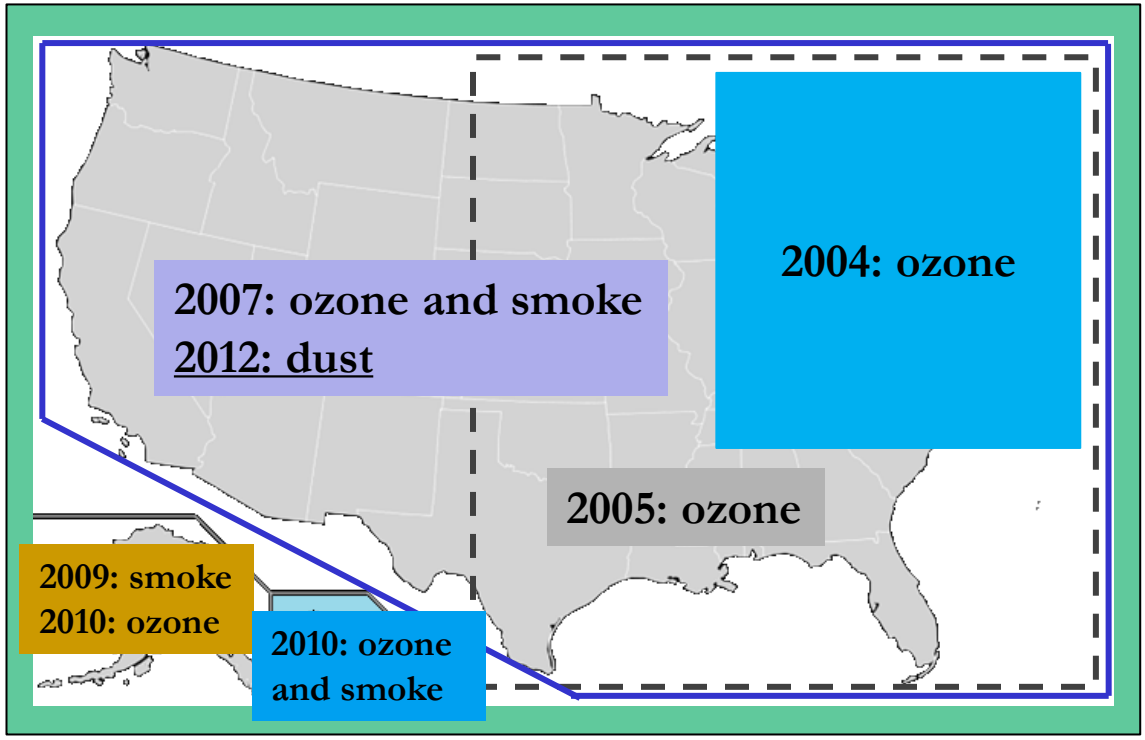
  Ozone nationwide

  Smoke nationwide

  Dust over CONUS

- **Developmental testing:**

  Components for particulate matter (PM) predictions



National Air Quality Forecast Capability
End-to-End Operational Capability

Model: Linked numerical prediction system

Operationally integrated on NCEP's supercomputer

- *NOAA NCEP mesoscale numerical weather prediction*
- *NOAA/EPA community model for air quality: CMAQ*
- *NOAA HYSPLIT model for smoke and dust prediction*

Observational Input:

- *NWS weather observations; NESDIS fire locations; climatology of regions with dust emission potential*
- *EPA emissions inventory*

Gridded forecast guidance products

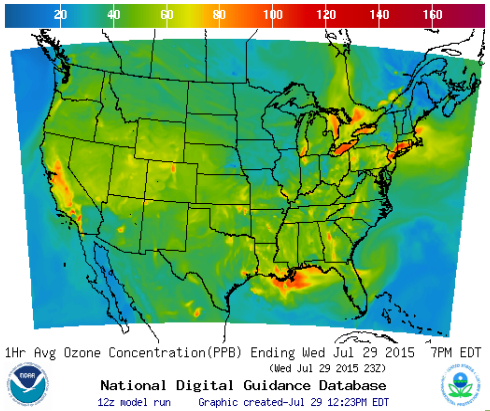
- *On NWS servers: airquality.weather.gov and ftp-servers (12km resolution, hourly for 48 hours)*
- *On EPA servers*
- *Updated 2x daily*

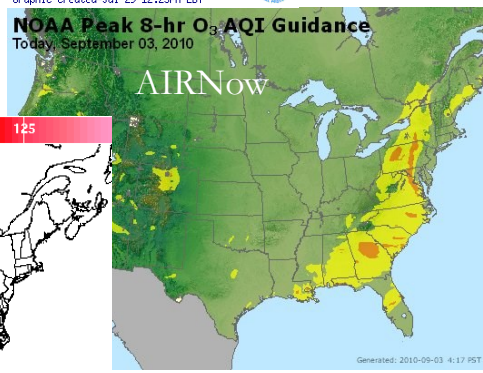
Verification basis, near-real time:

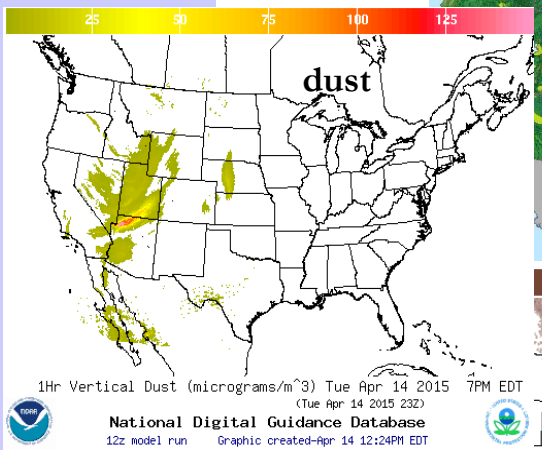
- *Ground-level AIRNow observations of surface ozone*
- *Satellite observations of smoke and dust*

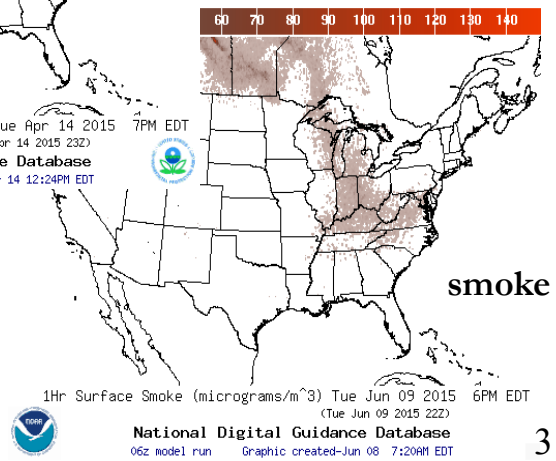
Customer outreach/feedback

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



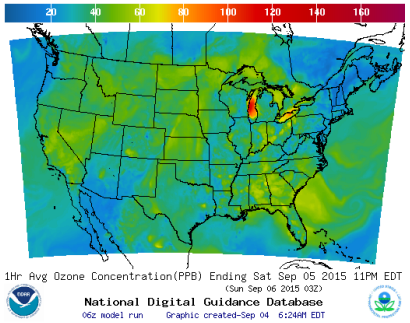




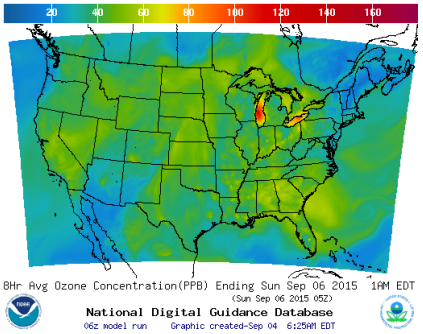


Ozone predictions

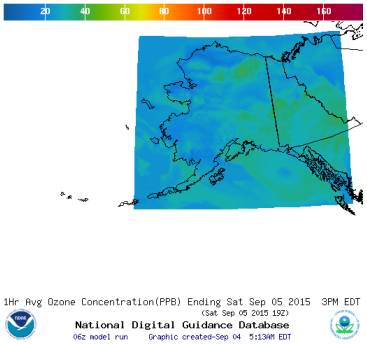
Operational predictions at http://airquality.weather.gov over expanding domains since 2004



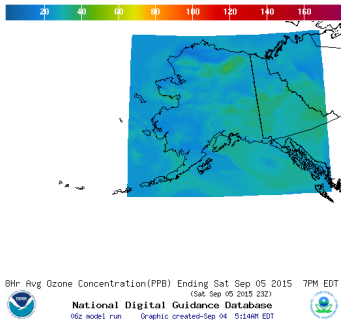
1-Hr Average Ozone



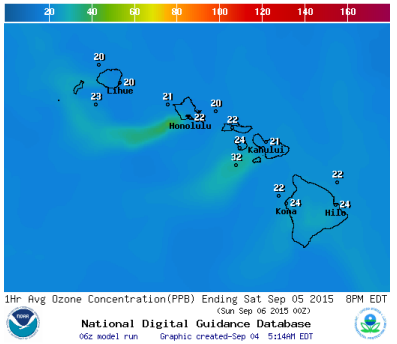
8-Hr Average Ozone



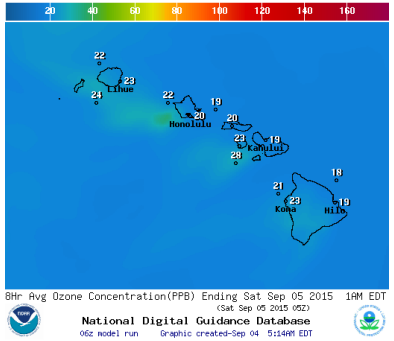
1-Hr Average Ozone



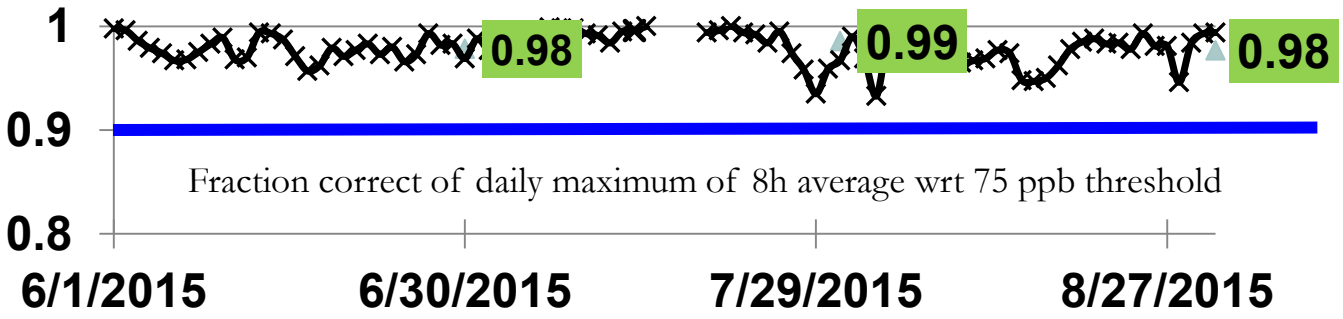
8-Hr Average Ozone



1-Hr Average Ozone



8-Hr Average Ozone



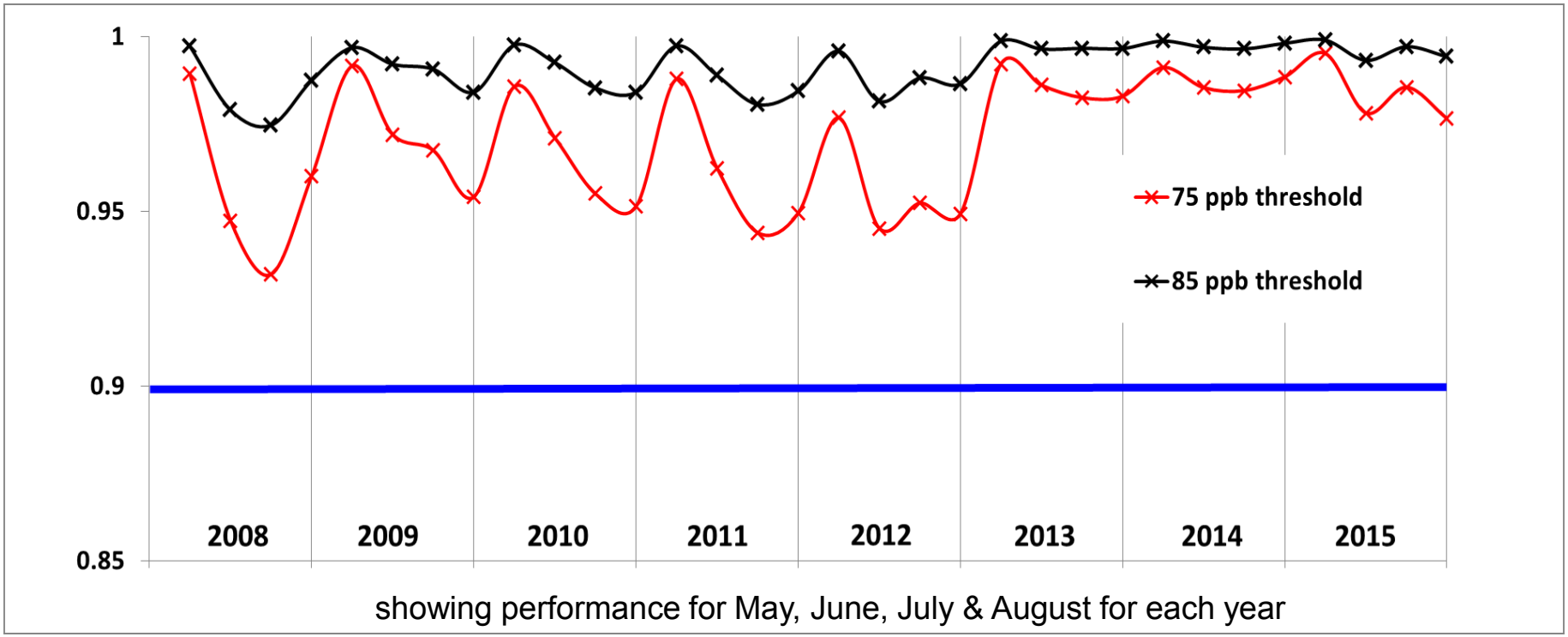
Operational

CONUS, wrt 75 ppb Threshold

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

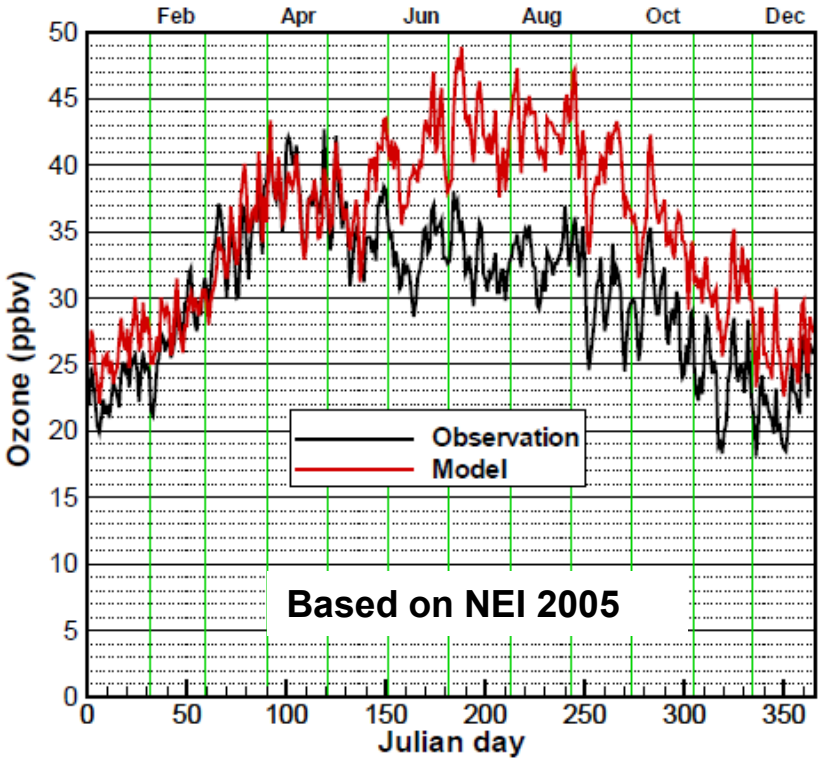
Performance of operational ozone predictions

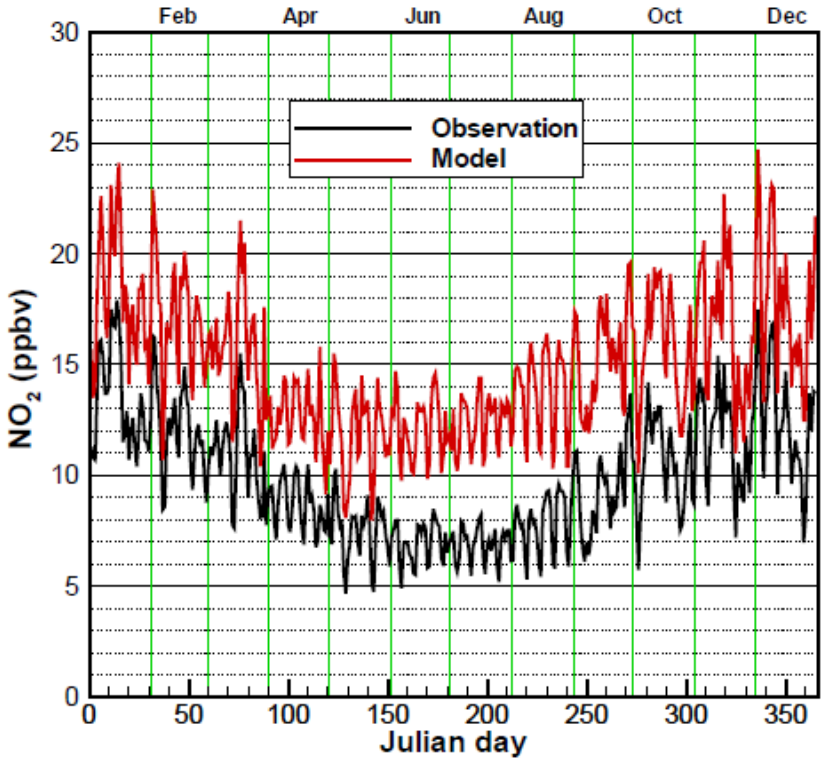
Fraction correct for 8h daily maximum of NOAA's operational ozone predictions for CONUS with respect to two thresholds



showing performance for May, June, July & August for each year

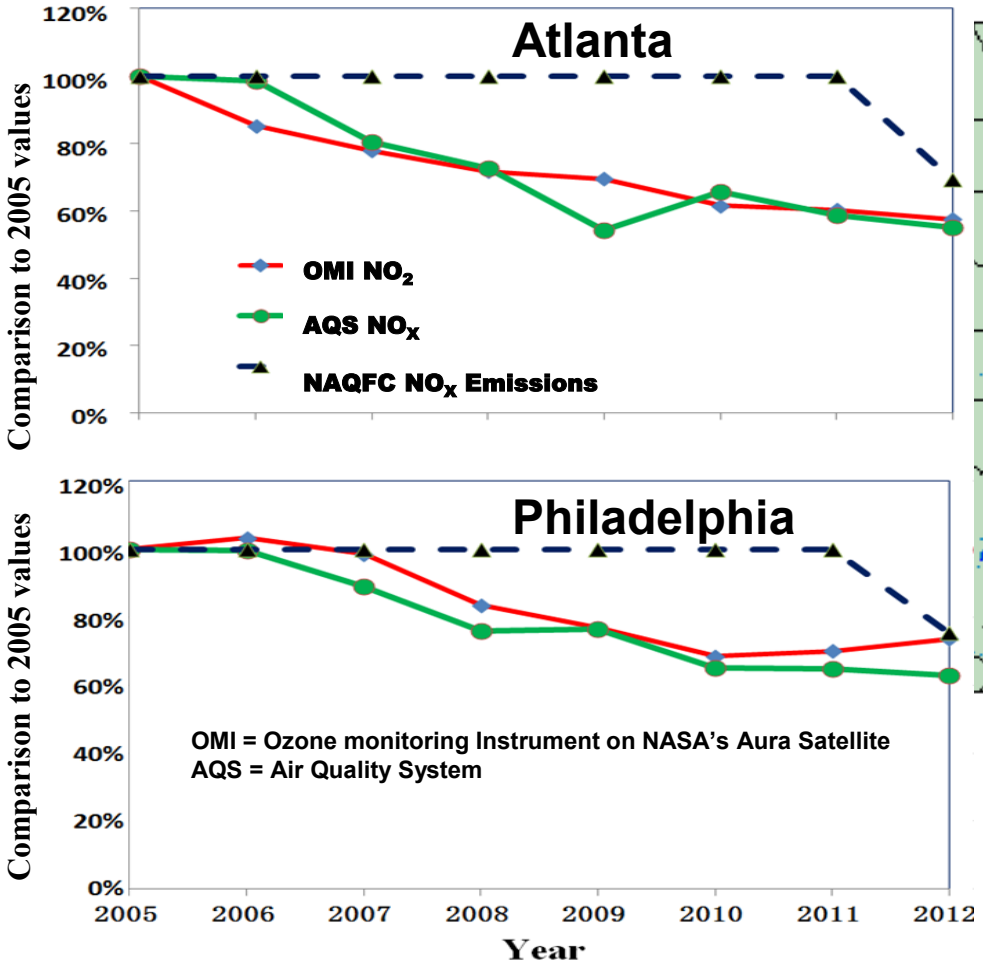
Evaluation of experimental CB05 NAQFC ozone predictions for 2010, prior to emissions update





- *T. Chai et al., Geosci. Model Dev., 2013* *(http://www.geosci-model-dev.net/6/1831/2013/gmd-6-1831-2013.html)*
- *Ozone overestimation in August is larger in rural areas, during morning hours, and in the southeast US*
- *NO2 overestimation in August is larger at night time*
- *Ozone biases higher on weekends, but NO2 biases higher on weekdays*

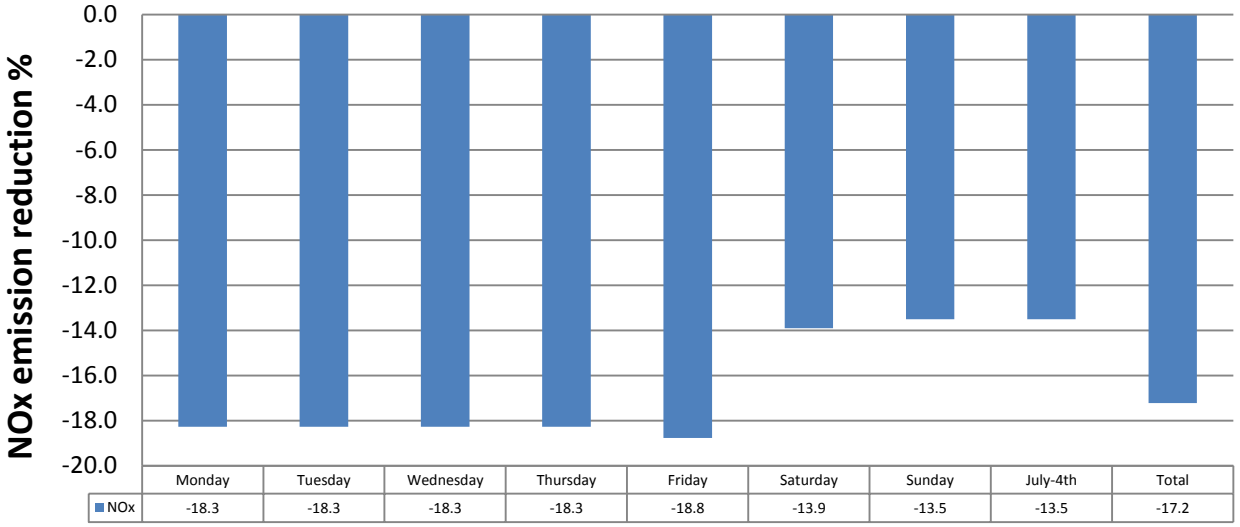
NOx changes



- Difference between NOx emissions used in 2012 and 2011 (blue indicates decrease in 2012).
- Mobile and nonroad emissions were updated based on projections for 2012.

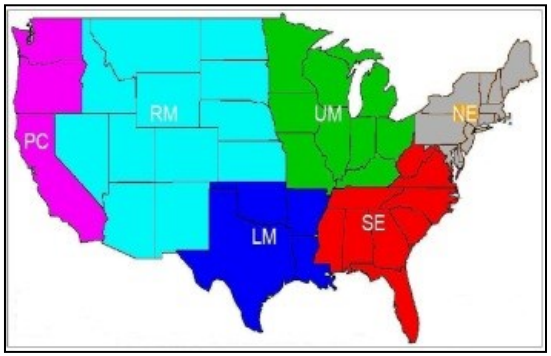
Comparison of projected emissions with surface and satellite observations shows that projected reductions from 2005 to 2012 are similar to observed *(Tong et. al. Long-term NOx trends over large cities in US, Atm. Env. 2015)*.

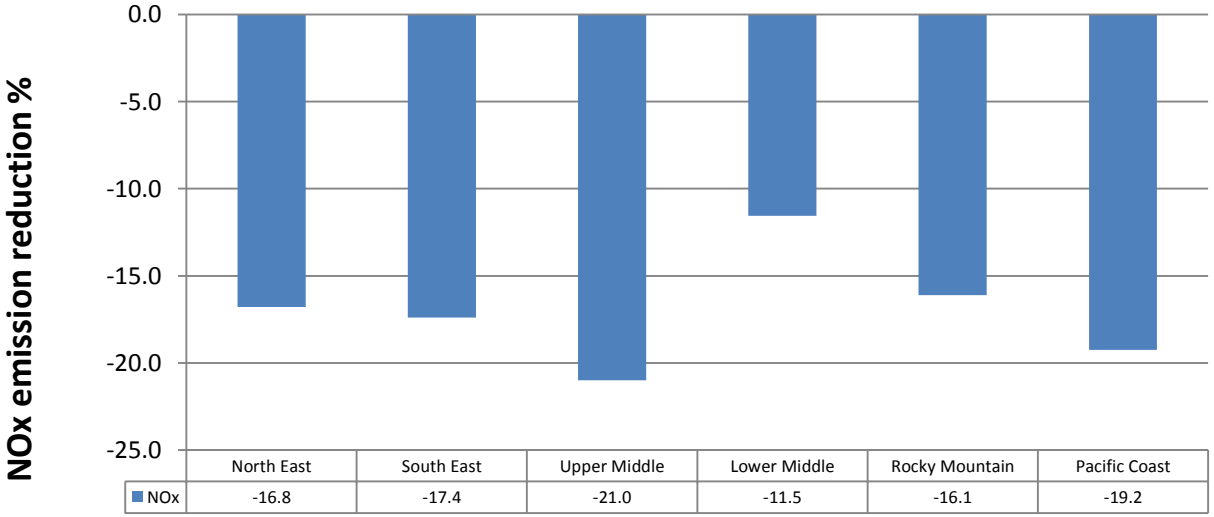
Reduction in NOx emissions implemented in 2012



NO_x emission reduction by day of week and holiday for July compared to those used in 2011

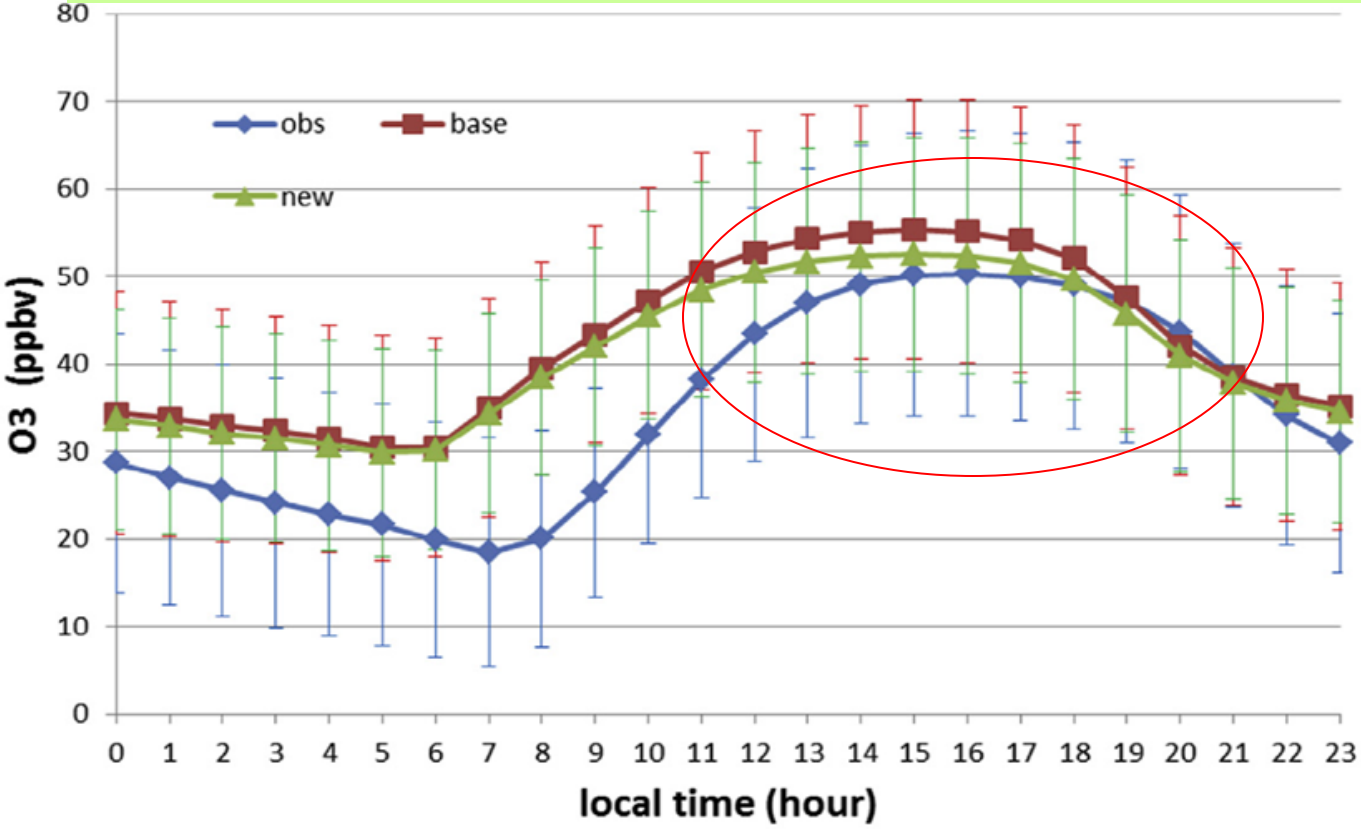
NO_x emission reduction by region for July compared to those used in 2011





Impact of NOx emissions update on ozone predictions

NOx emission used in July 2012 are 17.2% lower than those used in July 2011



Peak Ozone bias in summertime is reduced with updated emissions

(Pan et. al., Assessment of NOx and Ozone forecasting performance in the US NAQFC before and after the 2012 major emissions updates, Atmospheric Environment, 2014).

NOx and Ozone biases over CONUS (*in July 2011*)

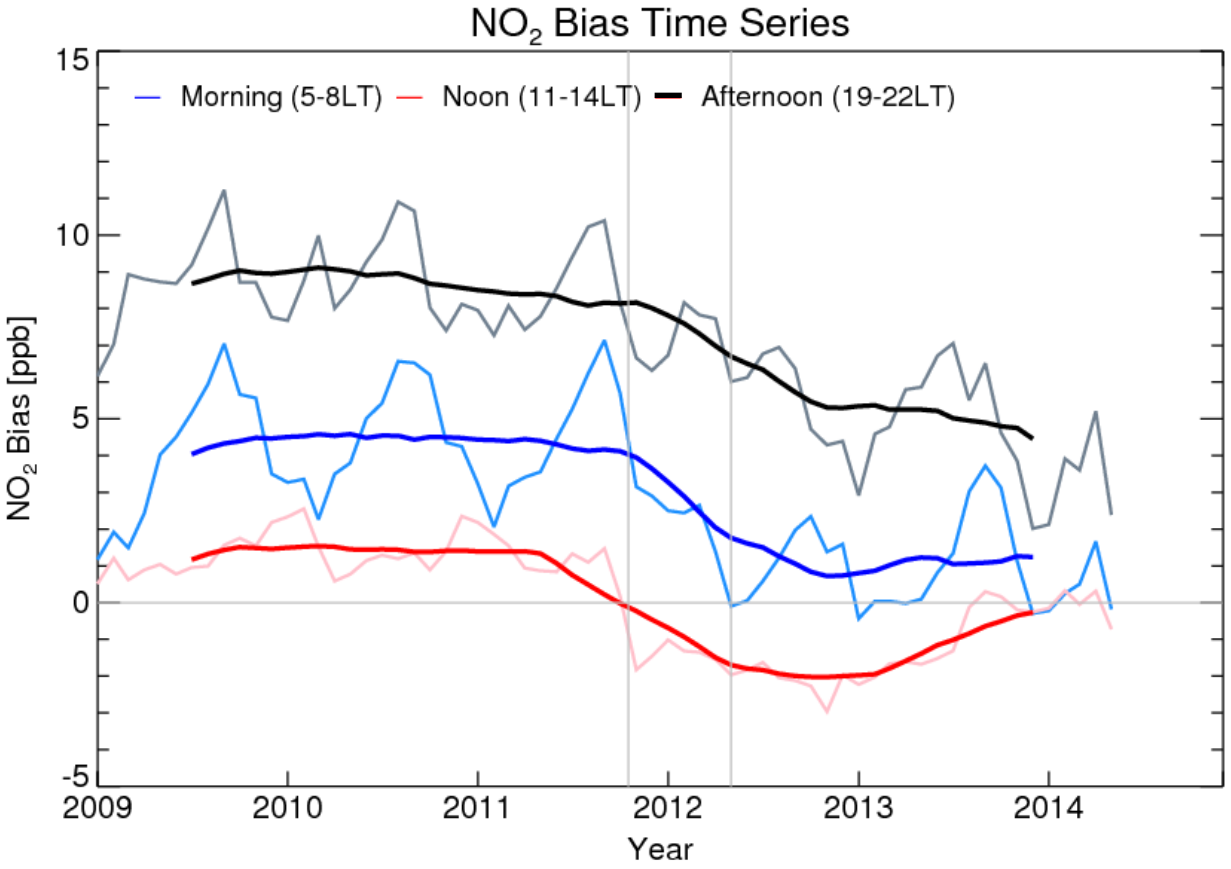
Land use	NO_x_Bias[a] (ppbv)		ΔNOx (New-base)	O3_Bias[b] (ppbv)		ΔO3 (New-base)
	Base	New		Base	New	
Urban	2.8	0.46	-2.34	7.08	6.16	-0.92
Suburban	4.62	2.53	-2.09	7.48	6.22	-1.26
Rural	0.75	0.18	-0.57	7.8	5.93	-1.87

a The total number of NO_x AQS sites is 295 including urban (101), suburban (111) and rural (83).

b The total number of ozone AQS sites is 1144 including urban (201), suburban (438) and rural (505).

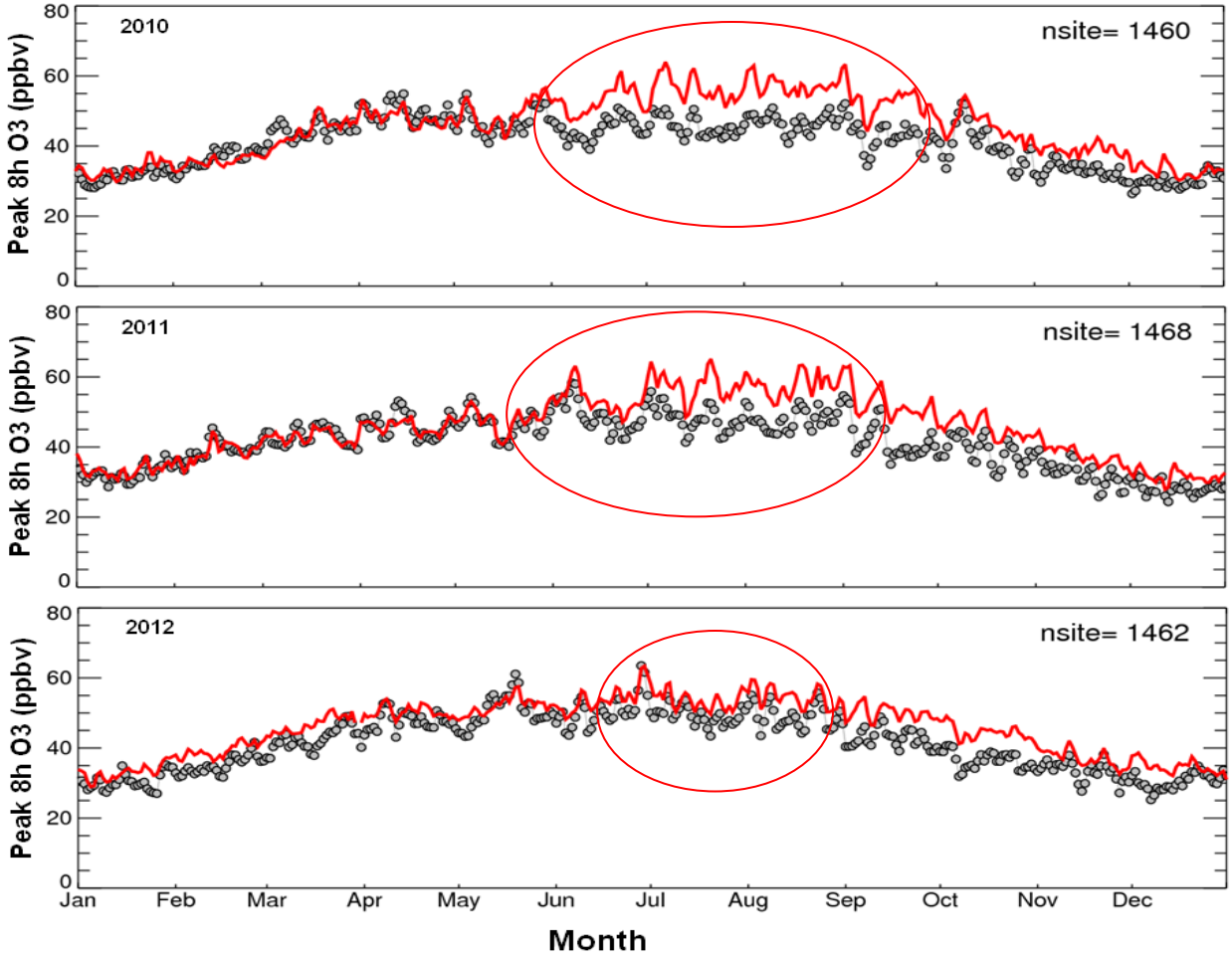
- **Positive biases reduced for all urbanization types for NOx and ozone.**
- **Largest improvements for NOx are in urban areas.**
- **Largest improvements for ozone in rural areas.**

Impacts of model and emission updates on other species



NO_2 bias by time of the day was reduced following experimental model update in 2011 and emission update in 2012 *(Courtesy: Hyun-Cheol Kim)*

Impact of emission update on ozone



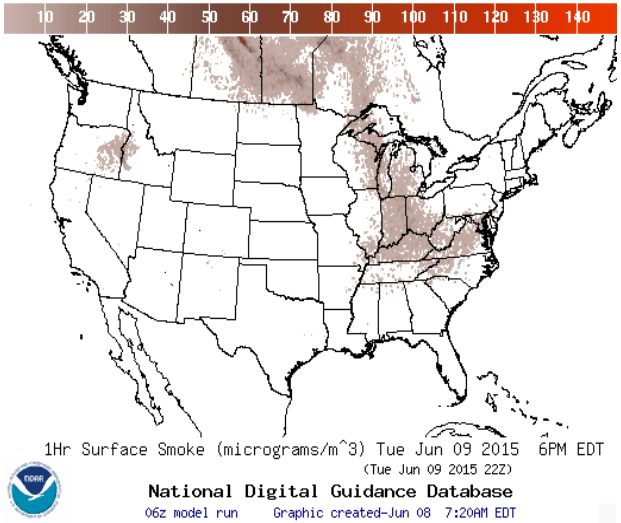
Comparison of mean values over the continental US of daily maximum 8-hr Ozone concentrations from surface monitor observations (circles) and collocated NAQFC predictions (red line) for years 2010, 2011 and 2012.

Summary of Emission Data Sources for 2015

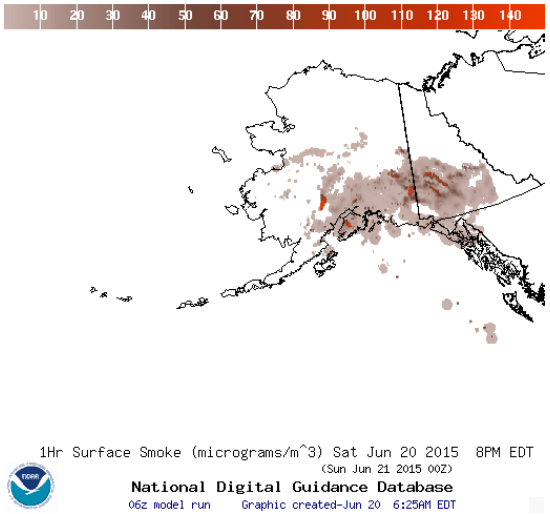
- **Area Sources**
  - US EPA 2011 NEIs;
  - Canada 2010 Emission Inventory;
  - Mexico 2012 EI for six border states;
  - New US residential wood combustion and oil and gas sectors;
  - Snow/Ice effect on fugitive dust emissions;
- **Mobile Sources (onroad)**
  - 2005 NEI with Cross-State Air Pollution Rule (CSAPR) projection for US sources
  - Canada 2010 Emission Inventory;
  - Mexico 2012 EI for six border states;
- **Point Sources (EGUs and non-EGUs)**
  - NEI 2005 for base year;
  - Updated with 2013 Continuous Emission Monitoring (CEM) data for EGUs;
  - Projected into forecast year using DOE Annual Energy Outlook (2015) factors;
- **Natural Sources**
  - *Terrestrial biogenic emission:* BEIS model v3.14
  - *Sea-salt emission:* CMAQ online Sea-salt emission model;
  - Fire emissions based on HMS fire detection and BlueSky emission model;
  - Windblown dust emission: Standalone version of the FENGSHA model;

Smoke predictions

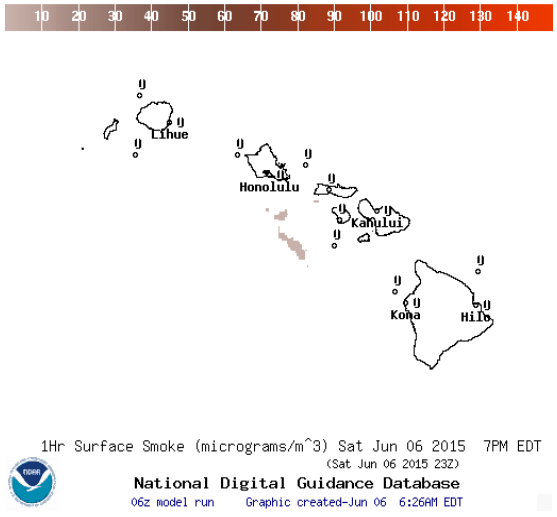
Operational predictions at http://airquality.weather.gov



Surface Smoke

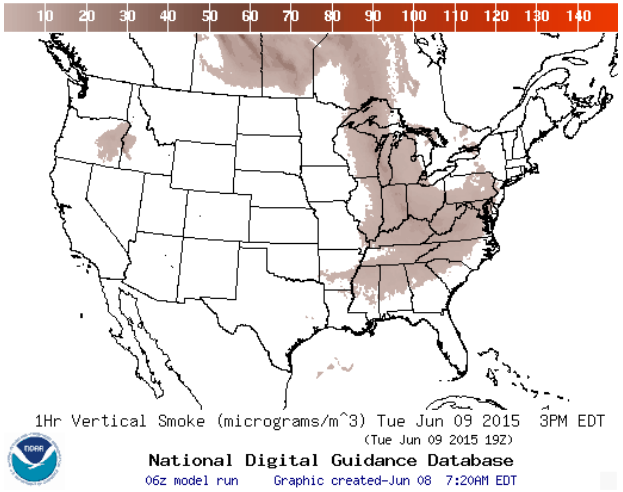


Surface Smoke

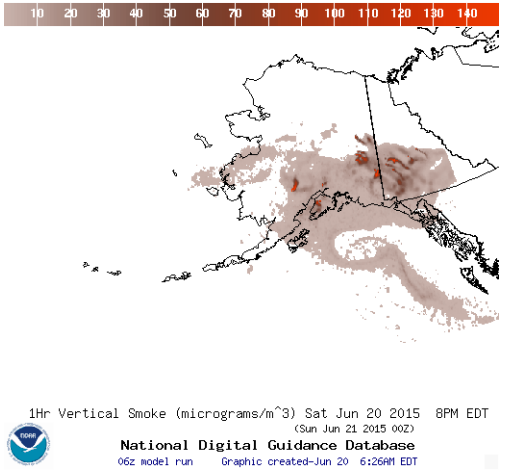


Surface Smoke

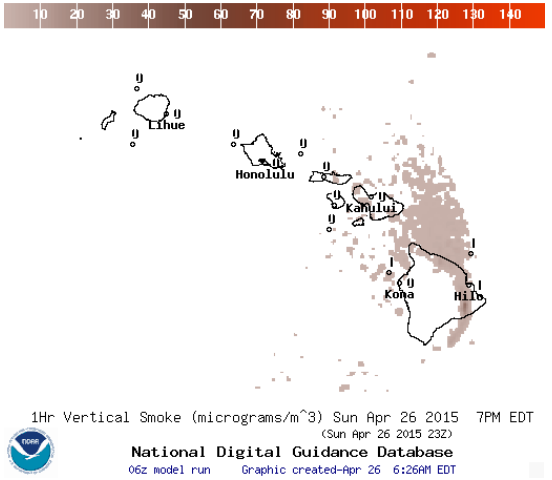
Vertical Smoke



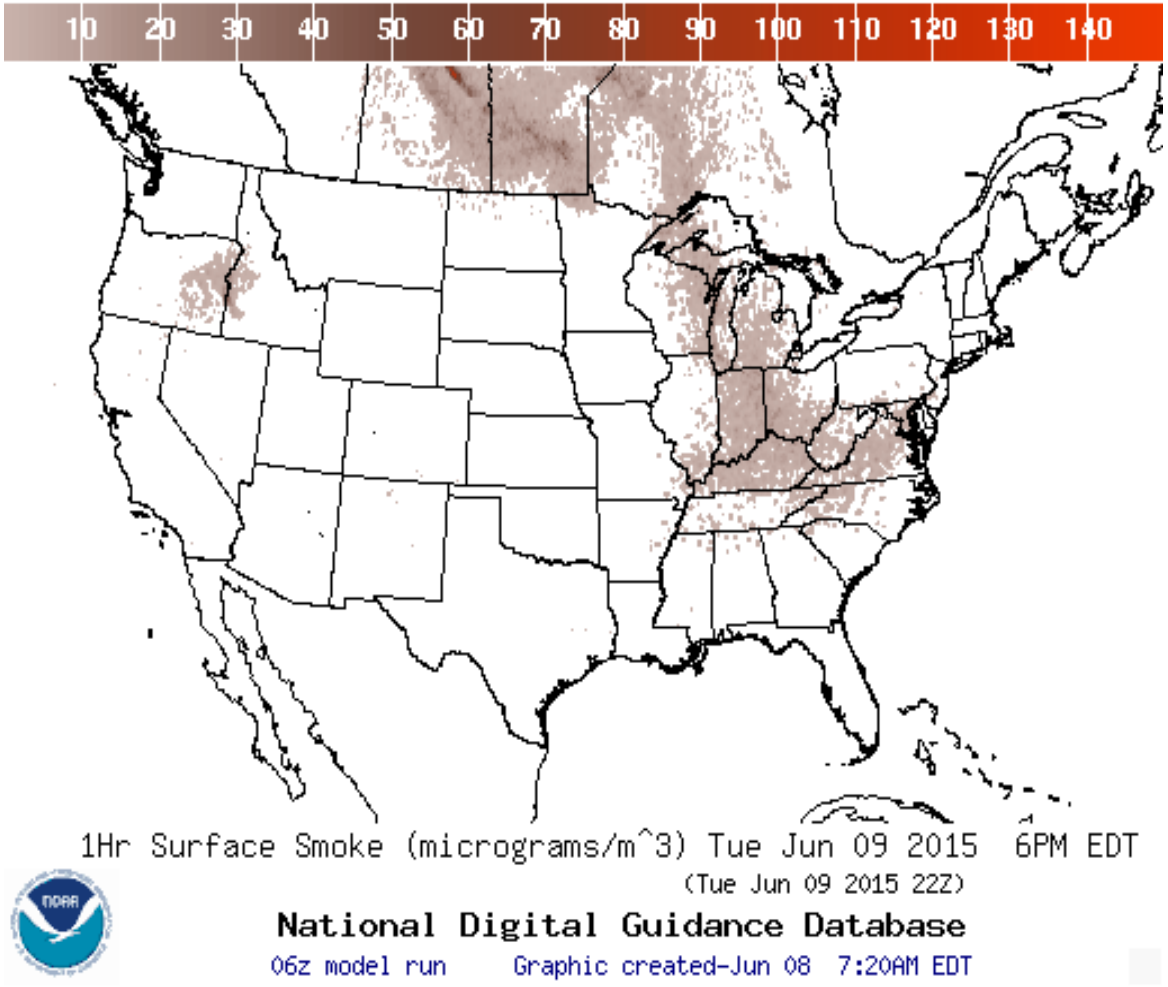
Vertical Smoke



Vertical Smoke



Smoke predictions



- Smoke predictions for CONUS (continental US), Alaska and Hawaii
- NESDIS provides wildfire locations
- Bluesky provides emissions estimates
- HYSPLIT model for transport, dispersion and deposition (Rolph et. al., W&F, 2009)
- Increased plume rise, decreased wet deposition, changes in daily emissions cycling
- Developed satellite product for verification ((Kondragunta et.al. AMS 2008)

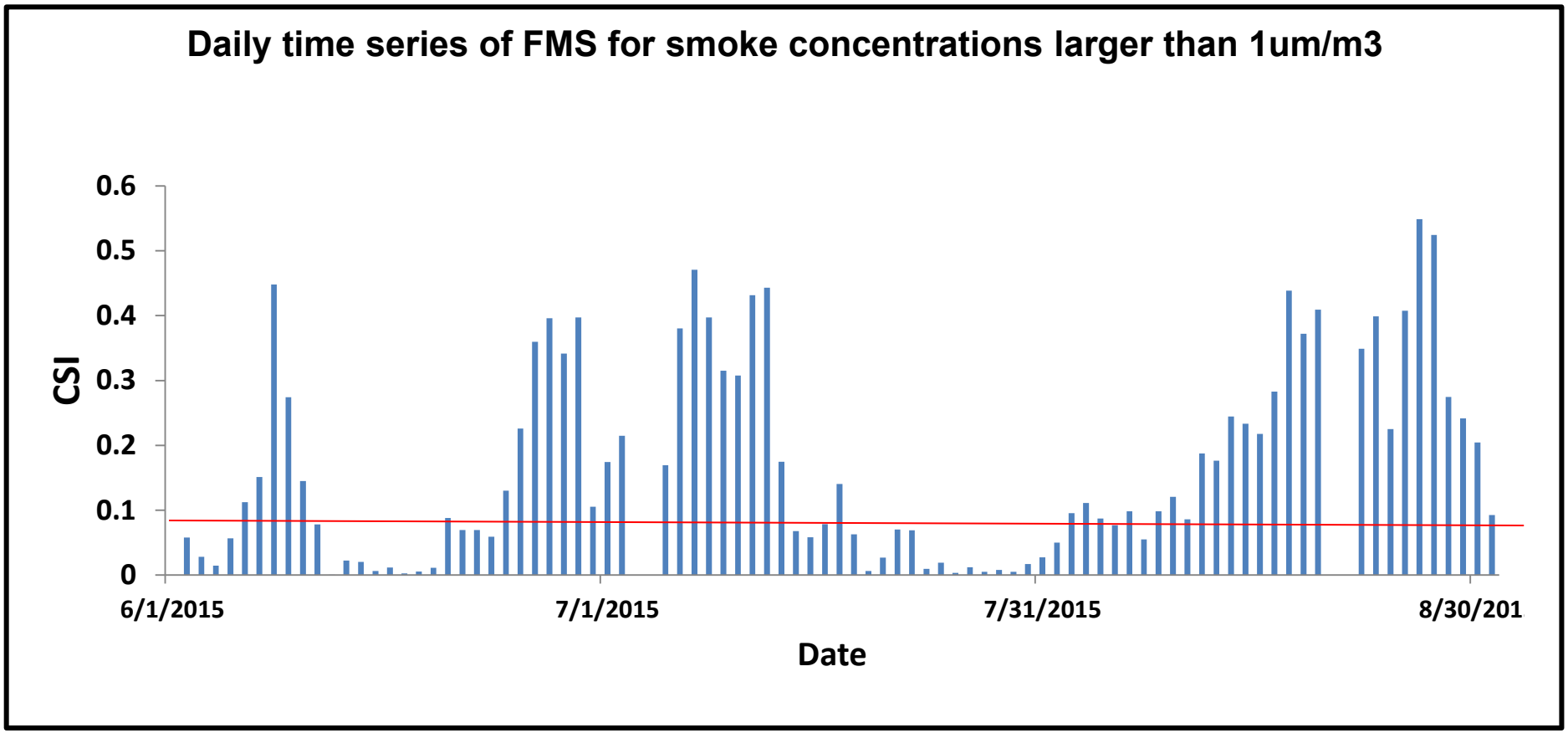
Recent updates includes

- Automated detection of fires in Canada, Mexico and Central America
- 3-D particle model approach (rather than horizontal puffs) to properly represent the additional fires identified with automatic fire detection

Current testing includes

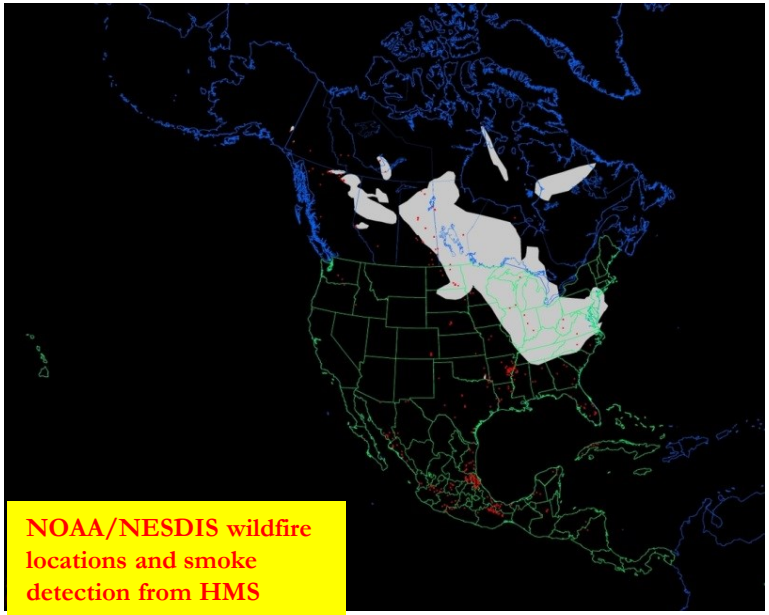
- Updated BlueSky System for smoke emissions

Verification of smoke predictions for CONUS

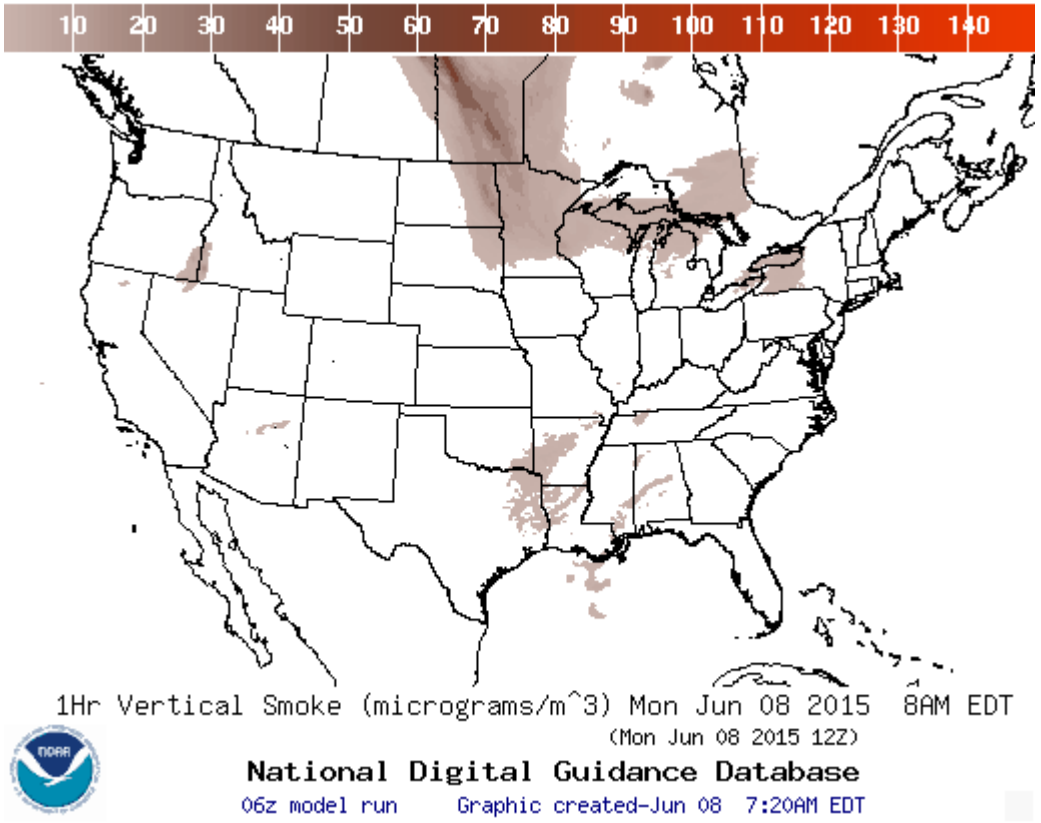


- Figure of merit in space (FMS), which is a fraction of overlap between predicted and observed smoke plumes, threshold is 0.08 marked by red line
- NESDIS GOES Aerosol/Smoke Product is used for verification

Canadian wildfire smoke 6/9/2015



NOAA/NESDIS wildfire locations and smoke detection from HMS

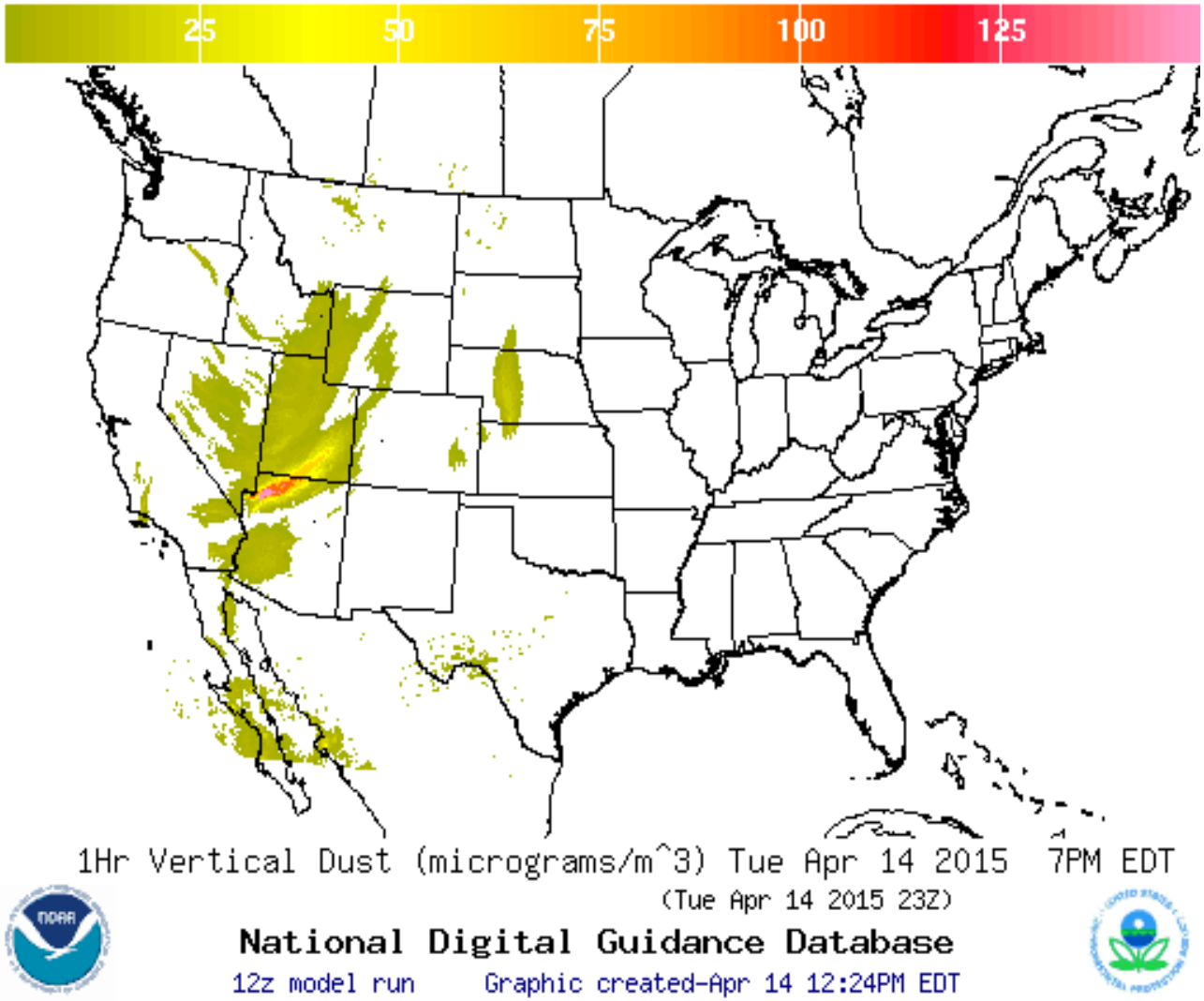


Fairfax, Virginia on June 9, 2015

Canadian wildfire smoke intrusion into CONUS was captured well in NOAA's smoke predictions

CONUS dust predictions

Operational Predictions at http://airquality.weather.gov/



Standalone prediction of airborne dust from dust storms:

•Wind-driven dust emitted where surface winds exceed thresholds over source regions

• Source regions with emission potential estimated from MODIS deep blue climatology for 2003-2006 (Ginoux et. al. 2010).

• Emissions modulated by real-time soil moisture.

• HYSPLIT model for transport, dispersion and deposition (Draxler et al., JGR, 2010)

• Wet deposition updates in July 2013

• Developed satellite product for verification (Ciren et.al., JGR 2014)

Testing of PM2.5 predictions

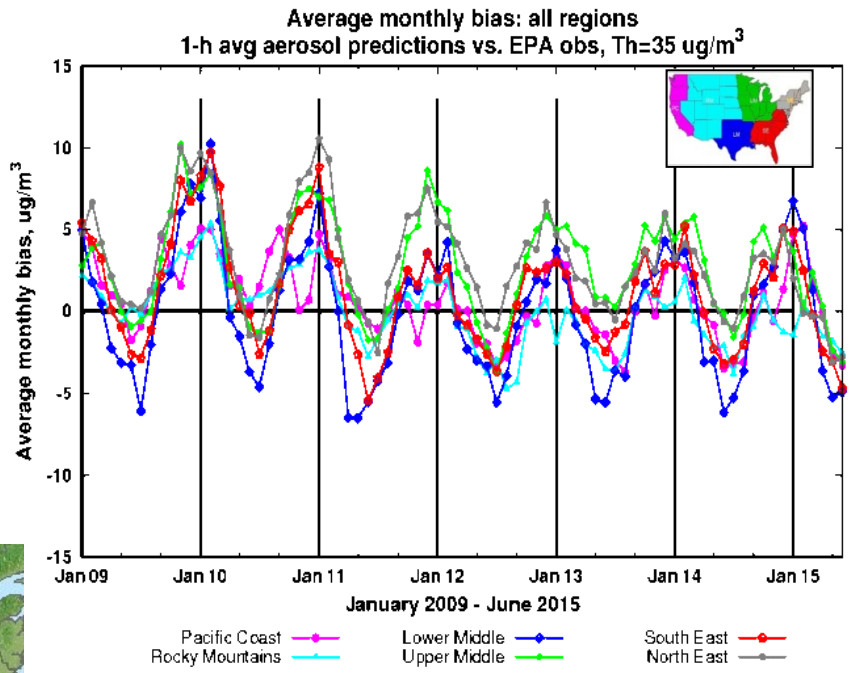
AQ Forecaster Focus group access only. Test predictions produced by operational air quality system since January 2015

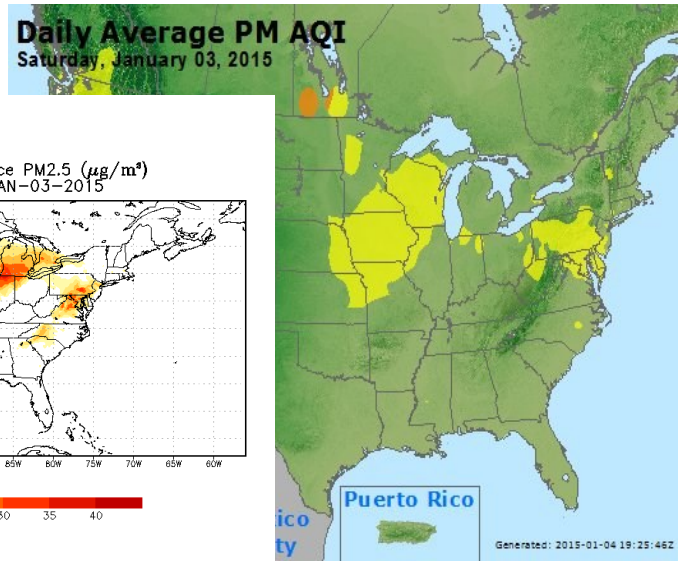
Aerosols over CONUS

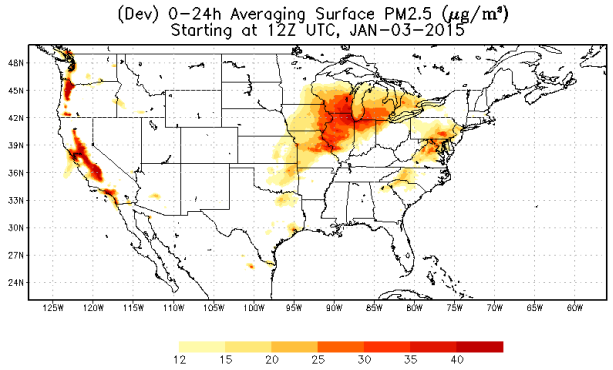
From NEI sources only before summer 2014

- 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

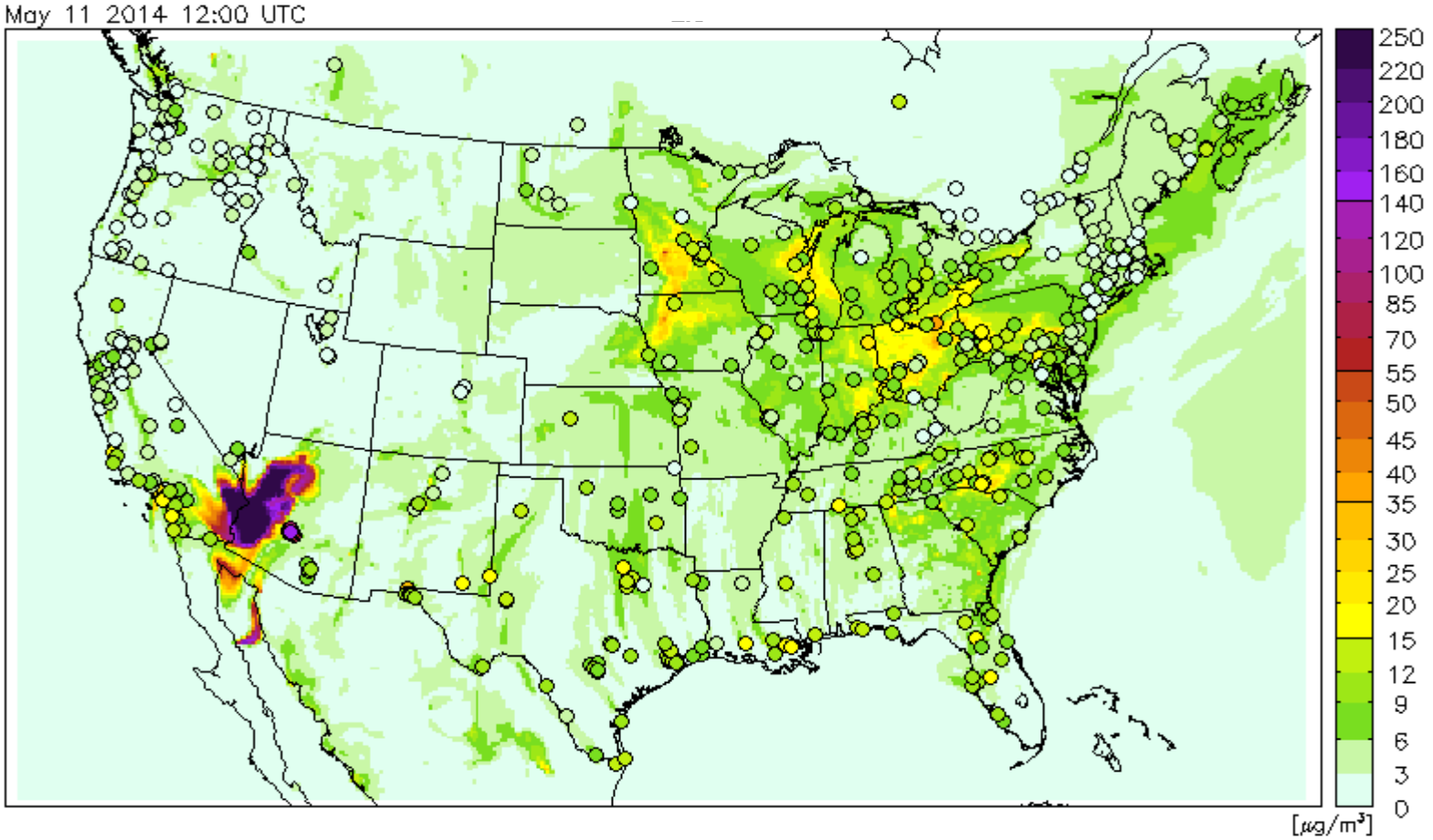
- *Improving sources for **wildfire smoke and dust** – in testing since summer 2014*
- *Chemical mechanisms eg. SOA*
- *Meteorology eg. PBL height*
- *Chemical boundary conditions/trans-boundary inputs*

Updates to CMAQ system for CONUS domain in January 2015

- Carbon Bond gas-phase Mechanisms (CB05) with updated rate constants and linkage with the particulate phase through heterogeneous reactions,
- Monthly varying lateral boundary conditions for 36 gaseous and aerosol species below 7 km altitude,
- Modified dry deposition velocity calculation,
- Planetary boundary layer height in the model constrained to be at least 50 m,
- Faster removal of organic nitrate from the atmosphere,
- Inclusion of particulate emissions from wild fires based on wildfire locations observed over the previous day,
- Suppression of soil emissions when terrain is covered by ice or snow,
- Windblown dust emissions are included using threshold friction velocity and soil wetness fraction with climatological source composition and locations.

Simplify maintenance of AQ predictions by unifying prediction code for CONUS, AK and HI.

Blowing dust event in testing of PM2.5 predictions

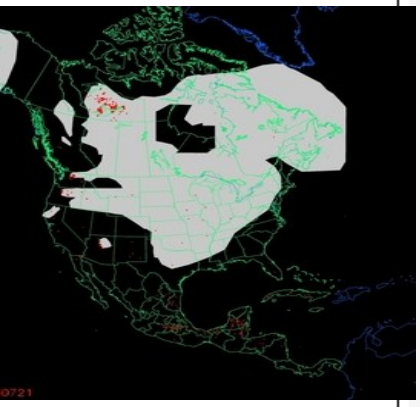


Independent NOAA/NESDIS analysis narrative based on satellite imagery:

BLOWING DUST

California/Arizona: An area of moderately dense blowing dust was visible sweeping across northern Baja California/Arizona into western New Mexico behind a strong cold frontal boundary. This remnant dust originated from multiple areas in southern California last evening.

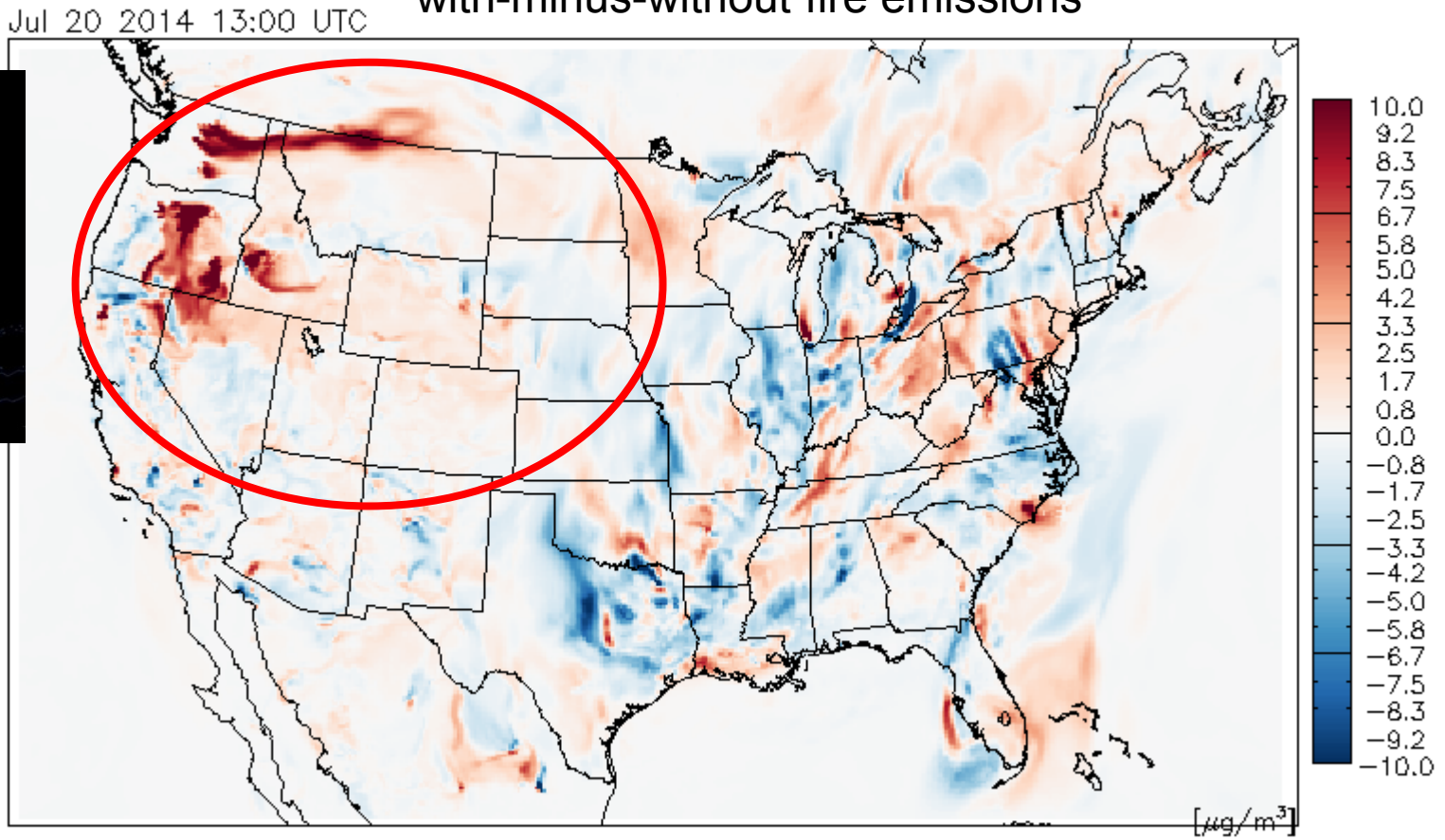
Impact of forest fires in testing of PM2.5 predictions



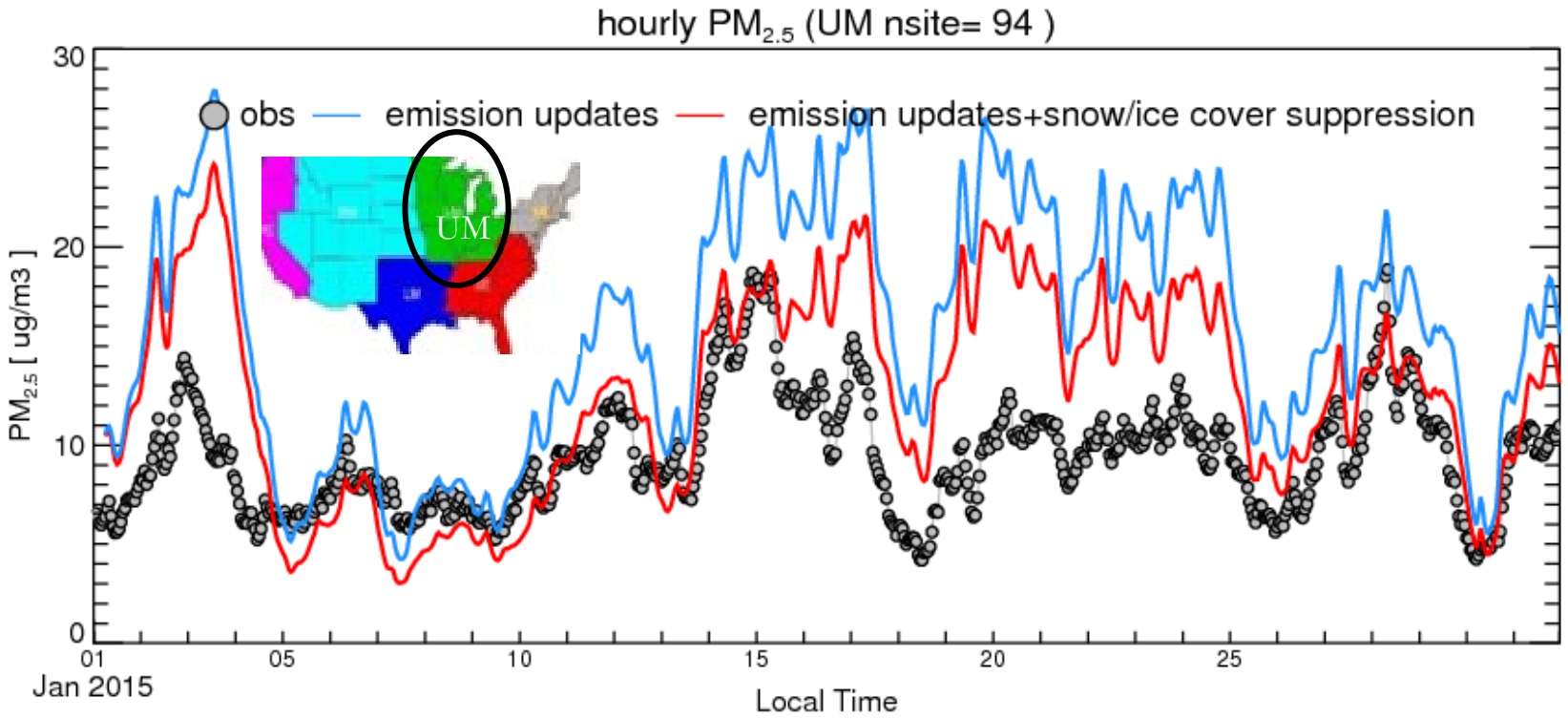
NOAA NESDIS Hazard Mapping System Fire and Smoke Analysis

Detection of wildfire locations from satellite imagery

Difference between two PM2.5 predictions: with-minus-without fire emissions

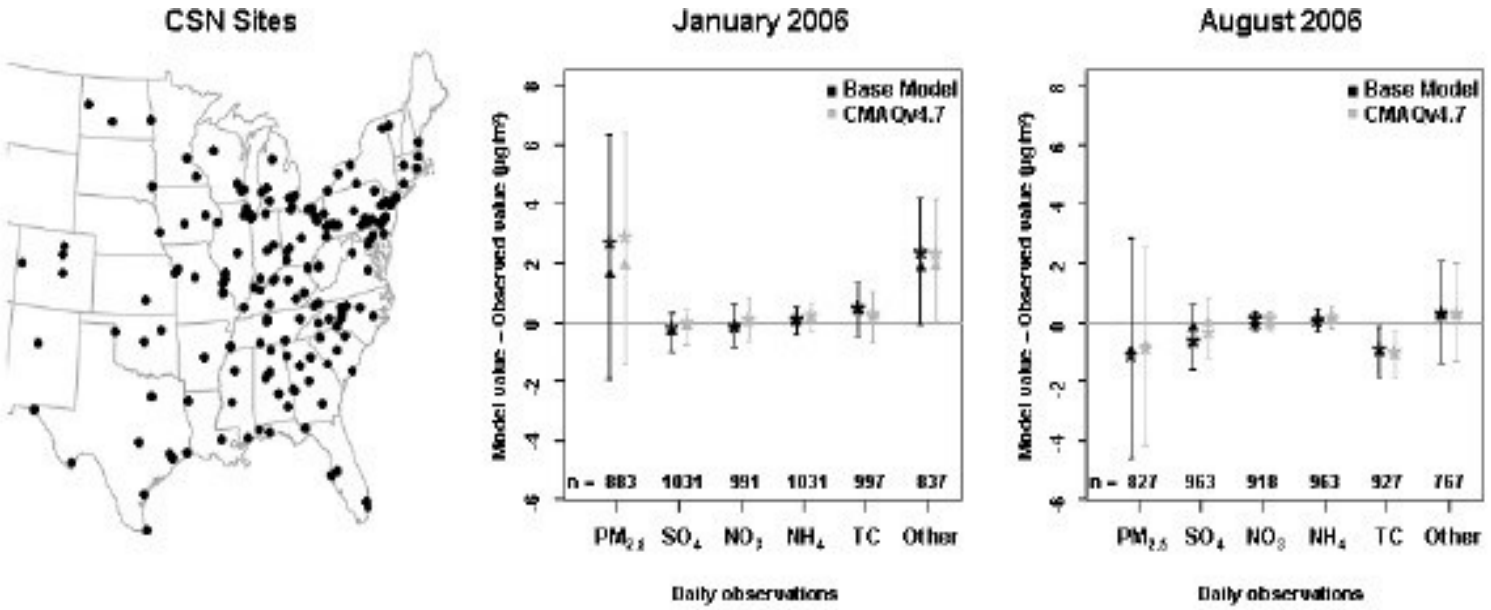


Snow/Ice dust modulation



	Case		mean	bias	NME (%)	RMSE	Corr. coef., r
UM	Jan 2015 (data-size=650)	obs	9.42	0	0	0	1
		emission updates	15.93	6.51	69	11.7	0.48
		emission updates + snow/ice cover suppression	12.52	3.1	33	8.94	0.46

Seasonal Bias in PM2.5 prediction



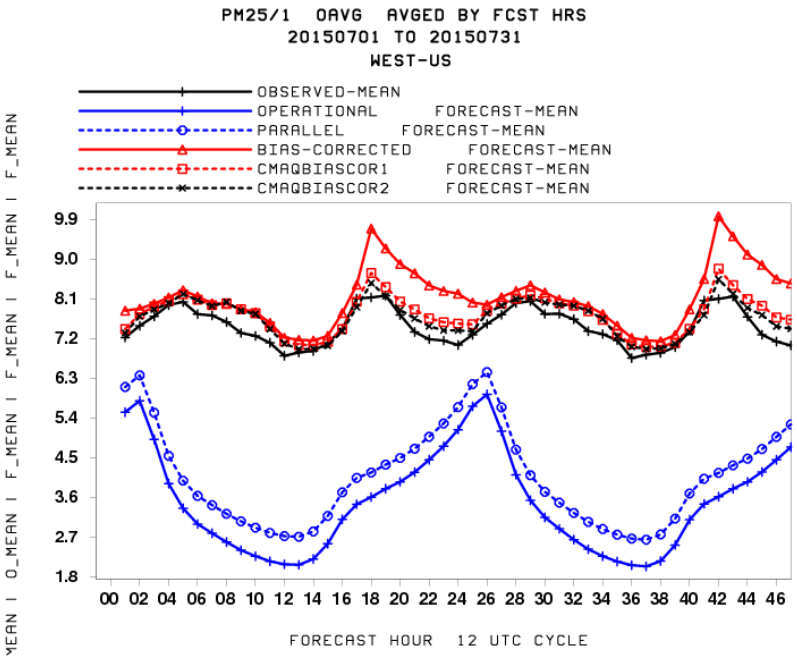
Mean (star), median (triangle), and inter-quartile ranges of model bias (model value – observed value) for multiple fine-particle species measured at CSN sites in the 12km domain. The number of model/observation pairs for each species is shown above the x-axis.

The bias in the total mass of PM2.5 is dominated by overpredictions of unspecified PM in the winter and by underpredictions of carbon aerosols in the summer. (*Foley et. al., Incremental testing of the Community Multiscale Air Quality (CMAQ) modeling system version 4.7, Geosci. Model Dev., 3, 205-226, 2010)*

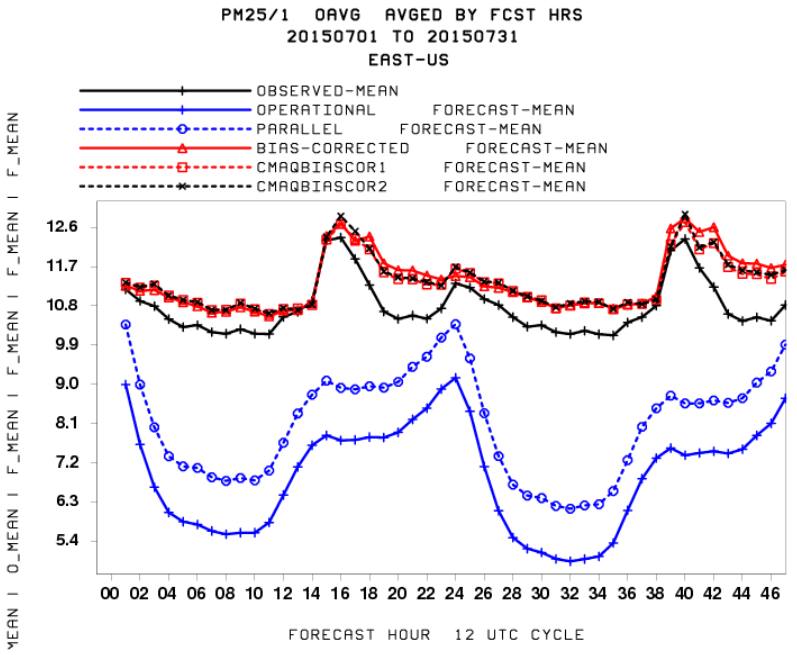
Saylor et. al. found same type of seasonal speciation biases in the CMAQ v4.6 for IMPROVE sites.

Bias Correction for developmental PM2.5 predictions

Western US



Eastern US



Using 4 week training period and analog ensemble with 10 members (solid red), 5 members (dashed red) and 3 members (dashed black)

Current testing of CMAQ updates and near-term plans

- Partial update of emissions using NEI 2011 (since May 2015)
- Including lateral boundary conditions from global dust predictions
- Increased vertical resolution from 22 to 35 layers
- Testing analog forecast technique for PM2.5 bias correction (*Djalalova I, Delle Monache L, Wilczak: PM2.5 analog forecast and Kalman filter post-processing for the Community Multiscale Air Quality (CMAQ) model, Atmospheric Environment, 2015)*
- Update to a newer version of BlueSky smoke emission system *(further testing needed)*

Partnering with AQ Forecasters

Focus group, State/local AQ forecasters:

- Participate in real-time developmental testing of new capabilities, e.g. aerosol predictions
- Provide feedback on reliability, utility of test products
- Local episodes/case studies emphasis
- Regular meetings; working together with EPA's AIRNow and NOAA
- ***Feedback is essential for refining/improving coordination***

Examples of AQ forecaster feedback after emissions update in 2012:

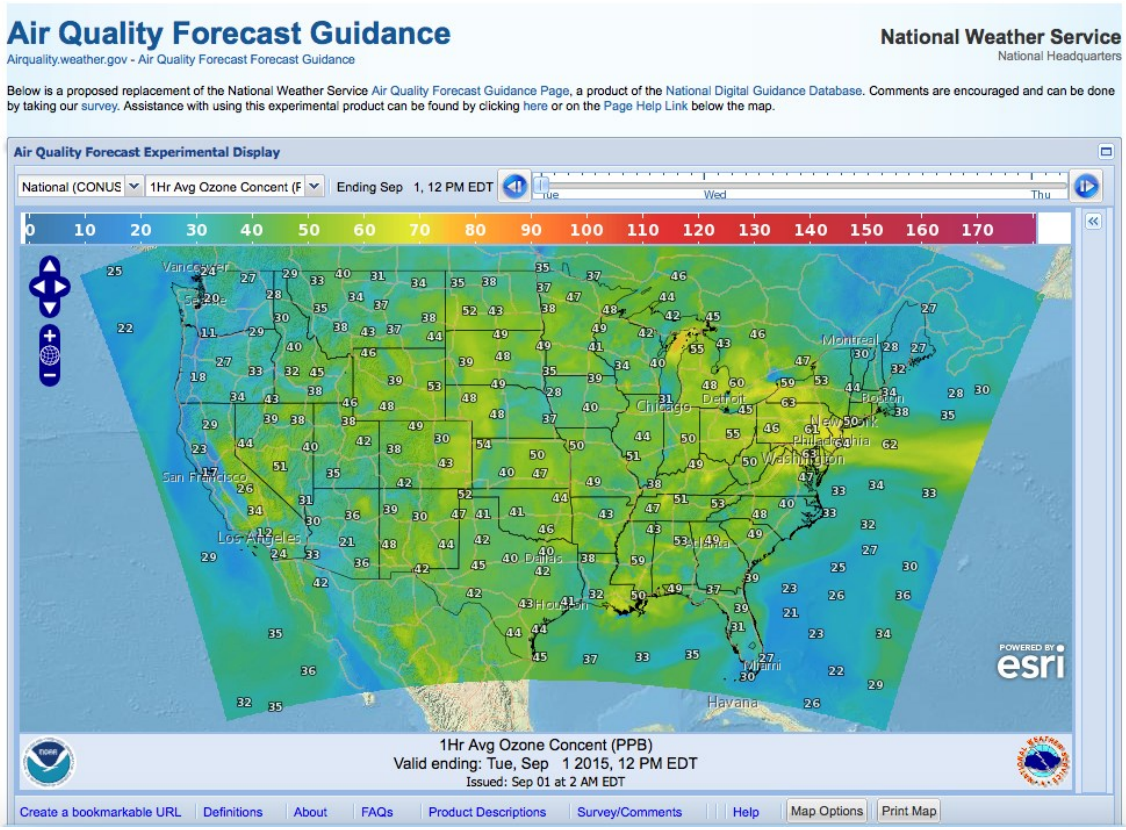
- In Maryland, NOAA ozone predictions have improved since 2011: significant improvement in false alarm ratio (FAR) with some decrease in probability of detection (POD). *(Laura Landry, Maryland Department of the Environment)*

Updates in 2014:

- In Connecticut, *The late summer over-prediction has been nearly eliminated. The CB05/AERO-4 model looks good for production. (Michael Geigert, Connecticut Department of Energy and Environmental Protection)*

Currently evaluating updates in ozone and testing of PM2.5 predictions

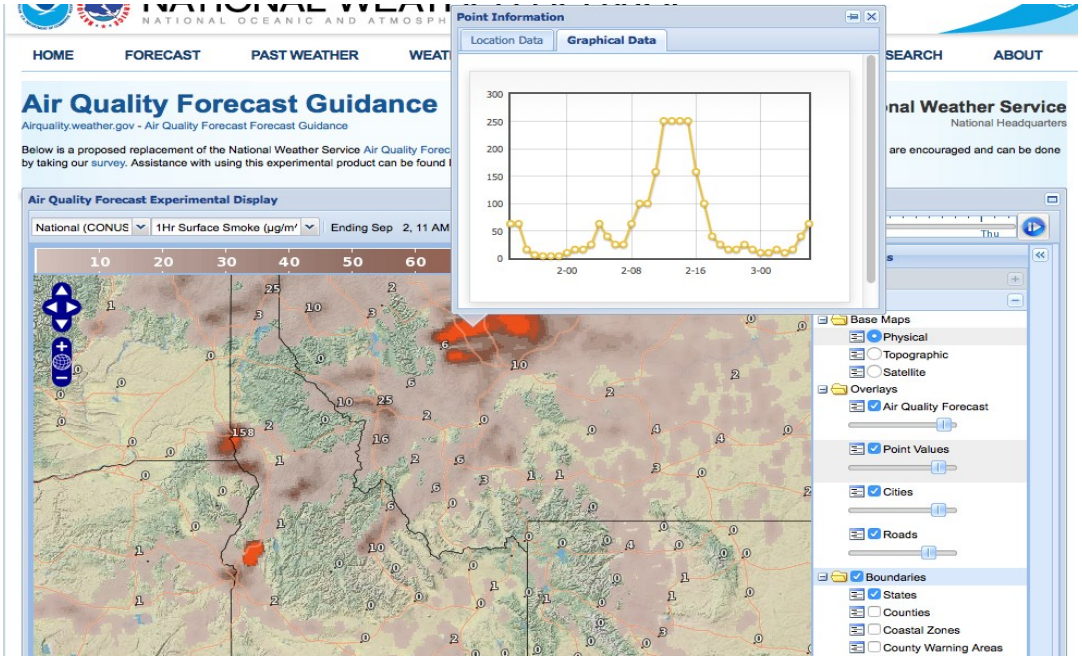
Next Generation of AQ display/distribution on the Web



- Uses a PostgreSQL Database with PostGIS extensions to manage data
- Open Geospatial Consortium (OGC) Web Mapping Service (WMS)
- Possible expansion of NWS XML/SOAP Services to include Air Quality Data
- Uses Open Layers with a ESRI Map Background
- Very Interactive – zoom and roam/data interrogation
- Faster data refresh
- Mobile device support

Next Generation of AQ on the Web: Progress

- Work continues on improving system performance - current version is not responsive enough to release to the public
- Integrating functionality from old viewer, including mouseover navigation
- Once final touches are in place, this will be posted in parallel to old site and opened for user comments
- After comment period, a transition plan will be executed to replace old interface



Air Quality Guidance:
Data access from weather.gov

- **Graphical Ozone & Smoke Guidance Displays:**

  http://airquality.weather.gov/

  http://airquality.weather.gov/expr/

- **GRIB2 Data Download:**

  ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/DF.gr2/DC.ndgd/GT.aq/AR.conus
  ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/DF.gr2/DC.ndgd/GT.aq/AR.alaska
  ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/DF.gr2/DC.ndgd/GT.aq/AR.hawaii
  ftp://tgftp.nws.noaa.gov/SL.us008001/ST.expr/DF.gr2/DC.ndgd/GT.aq/AR.conus

- **Web Questions, Suggestions:**

  Email Marc.Saccucci@noaa.gov

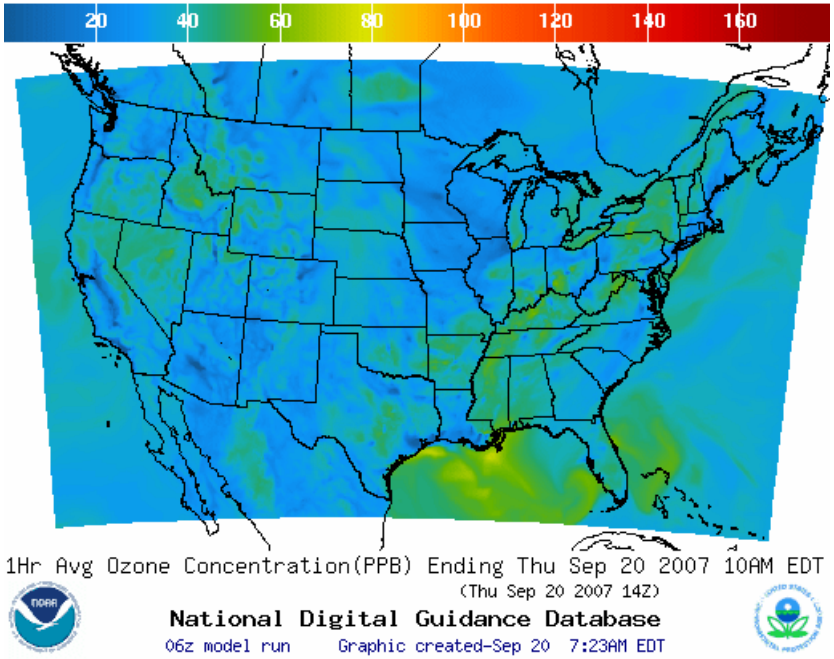
Summary and plans

US national AQ forecasting capability:

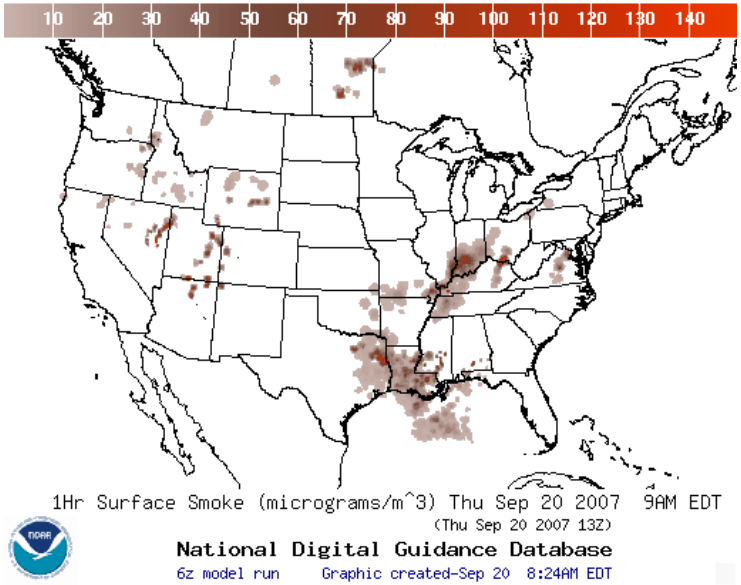
- Operational **ozone** prediction nationwide; CMAQ with CB05 mechanism
- Operational **smoke** prediction nationwide
- Operational **dust** prediction from CONUS sources
- Prototype CMAQ **PM2.5** predictions with NEI, wildfire and dust emissions:
  - Bias correction and linkages with global dust predictions in testing
  - Evaluation for potential experimental (public) release.

Operational AQ forecast guidance

airquality.weather.gov



Ozone products
Nationwide since 2010



Smoke Products
Nationwide since 2010
Dust Products
Implemented 2012

Further information: www.nws.noaa.gov/ost/air_quality

Acknowledgments:
AQF implementation team members

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

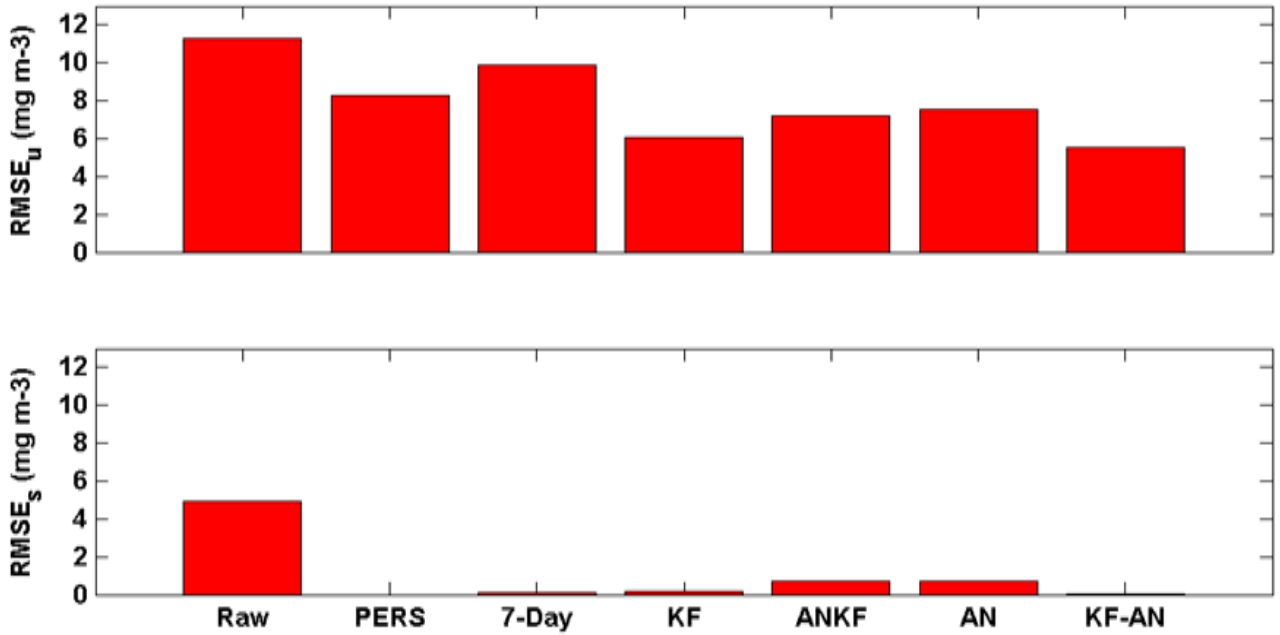
NOAA/NWS/OSTI	***Ivanka Stajner***	***NAQFC Manager***
NWS/AFSO	***Jannie Ferrell***	***Outreach, Feedback***
NWS/OD	***Cynthia Jones***	***Data Communications***
NWS/OSTI/MDL	***Jerry Gorline, Marc Saccucci, Dave Ruth***	***Dev. Verification, NDGD Product Development***
NWS/OSTI	***Sikchya Upadhayay***	***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, Chris Magee		**NCO transition and systems testing**
Mike Bodner, Andrew Orrison		**HPC coordination and AQF webdrawer**
NOAA/OAR/ARL		
Pius Lee, Daniel Tong, Tianfeng Chai		**CMAQ development, adaptation of AQ simulations for AQF**
Li Pan, 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

Backup

Removal of Bias in PM2.5 predictions

- Quality control of the observations is essential
- Five different post-processing techniques were tested



Raw: Hourly AIRNow data available in real-time

PERS: Persistence forecast

7-day: 7-day running mean subtraction

KF: Kalman-filter approach

ANKF: Analog forecast technique followed by Kalman filter approach

AN: Analog Forecast technique

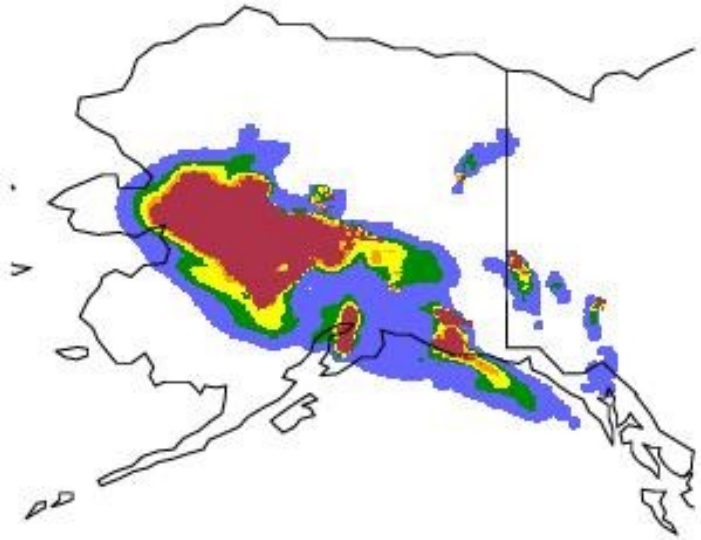
KF-AN: Kalman-filter approach followed by Analog forecast technique

Unsystematic component of the RMSE (top panel) and systematic component of RMSE (bottom panel) using hourly values for the month of November evaluated at the 518 AIRNow PM2.5 sites.

I. Djalalova, L. Delle Monache, and J. Wilczak: PM2.5 analog forecast and Kalman filter post-processing for the Community Multiscale Air Quality (CMAQ) model, manuscript in preparation

Smoke Verification:
July 13, 2009

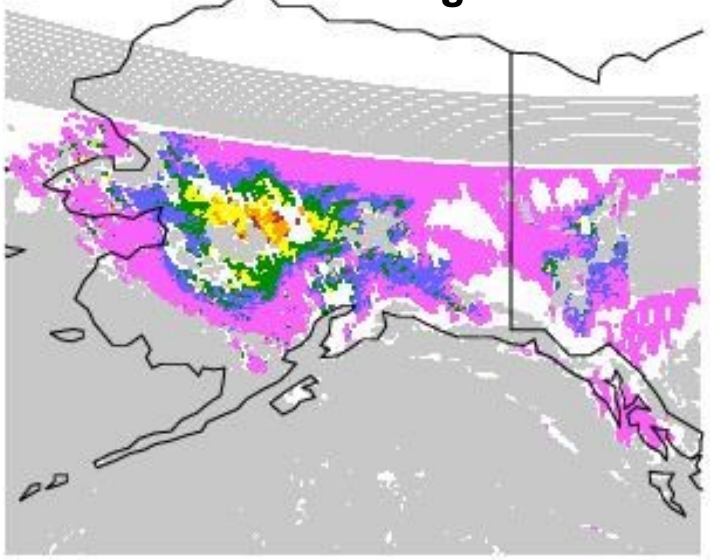
7/13/09, 17-18Z, Prediction:

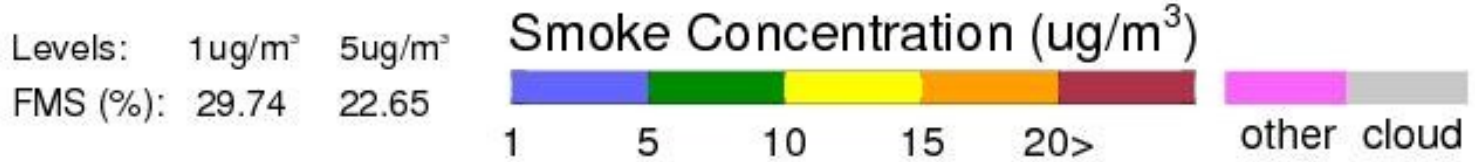


7/13/09, 17-18Z, Observation:

GOES smoke product: Confirms areal extent of peak concentrations

FMS = 30%, for column-averaged smoke > 1 ug/m^3





Manuscript about smoke verification product is in preparation

Real time verification examples

Using MODIS Dust Mask Algorithm from NOAA/NESDIS satellite imagery
"Footprint" comparison:

- Threshold concentration > 1 μg/m^3, for average dust in the column
- Tracking threat scores, or figure-of-merit statistics:
  (Area Pred ∩ Area Obs) / (Area Pred U Area Obs)
- Initial skill target 0.05