National Air Quality Forecast Capability

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NOAA NWS/OST

with contributions from the entire NAQFC Implementation Team

Outline:

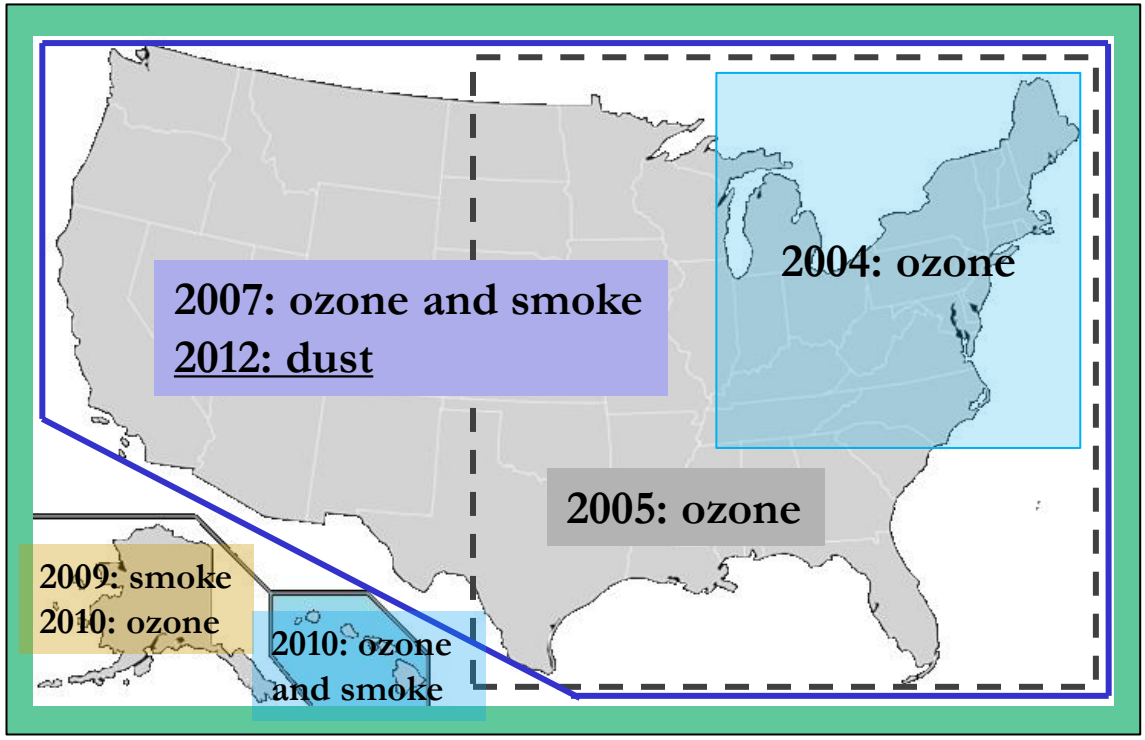
- Background on NAQFC
- Recent progress and updates
  - -Ozone predictions
  - -Smoke predictions
  - -Dust predictions
  - -Prototype PM2.5 predictions
  - -Outreach and feedback
- Summary and plans

National Air Quality Forecast Capability
Capabilities as of 9/2014

- 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
- **Experimental testing:**
  Ozone predictions
- **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

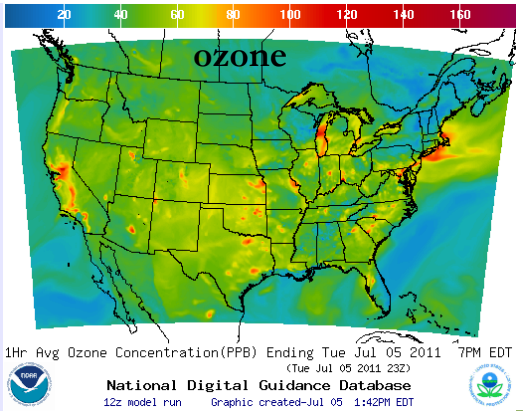
- *On NWS servers: airquality.weather.gov and ftp-servers (12km resolution, hourly for 48 hours)*
- *On EPA servers*
- *Updated 2x daily*

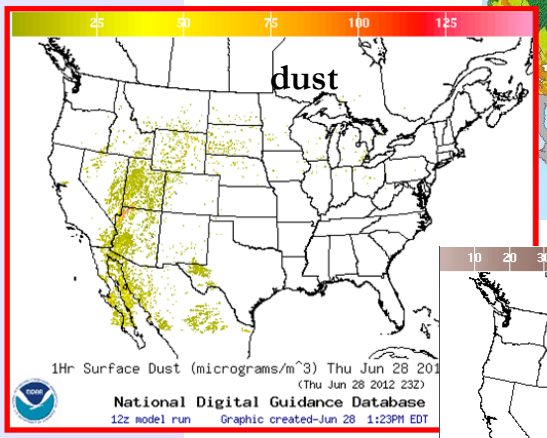
Verification basis, near-real time:

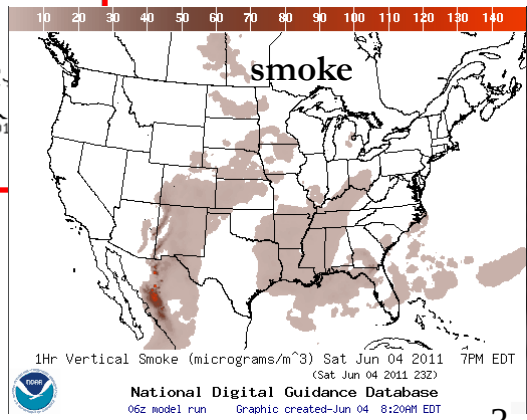
- *Ground-level AIRNow observations of surface ozone*
- *Satellite observations of smoke and dust*

Customer outreach/feedback

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



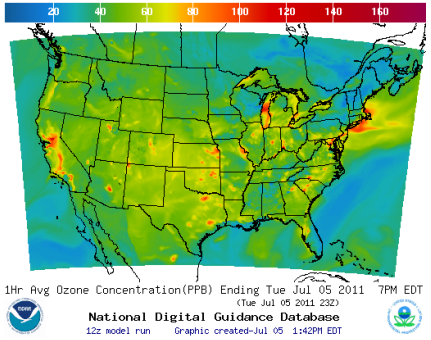




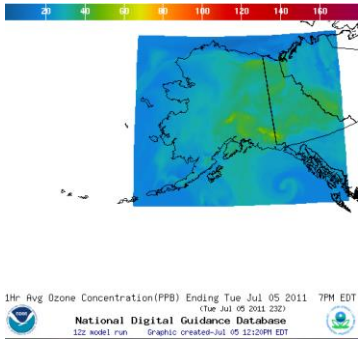
Ozone predictions

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

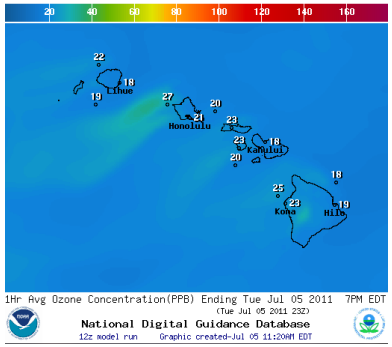
over expanding domains since 2004



1-Hr Average Ozone

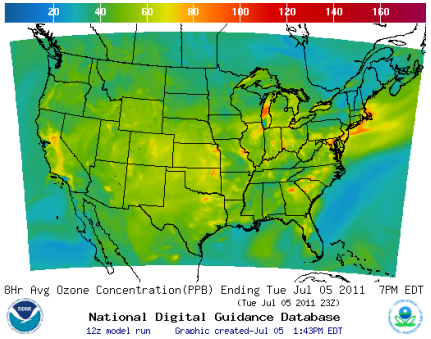


1-Hr Average Ozone

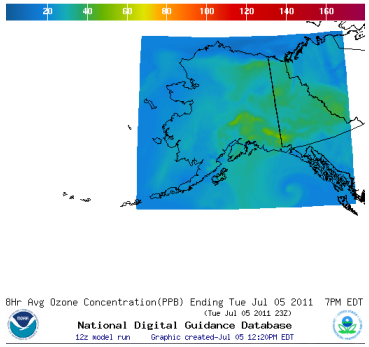


1-Hr Average Ozone

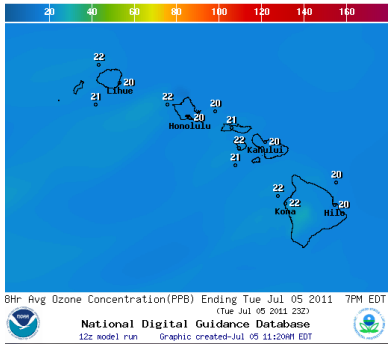
8-Hr Average Ozone

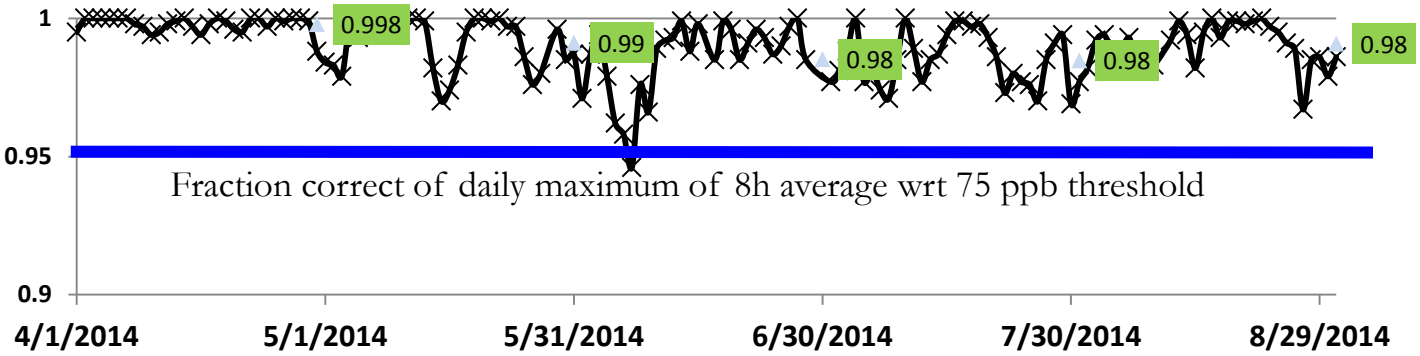


8-Hr Average Ozone



8-Hr Average Ozone



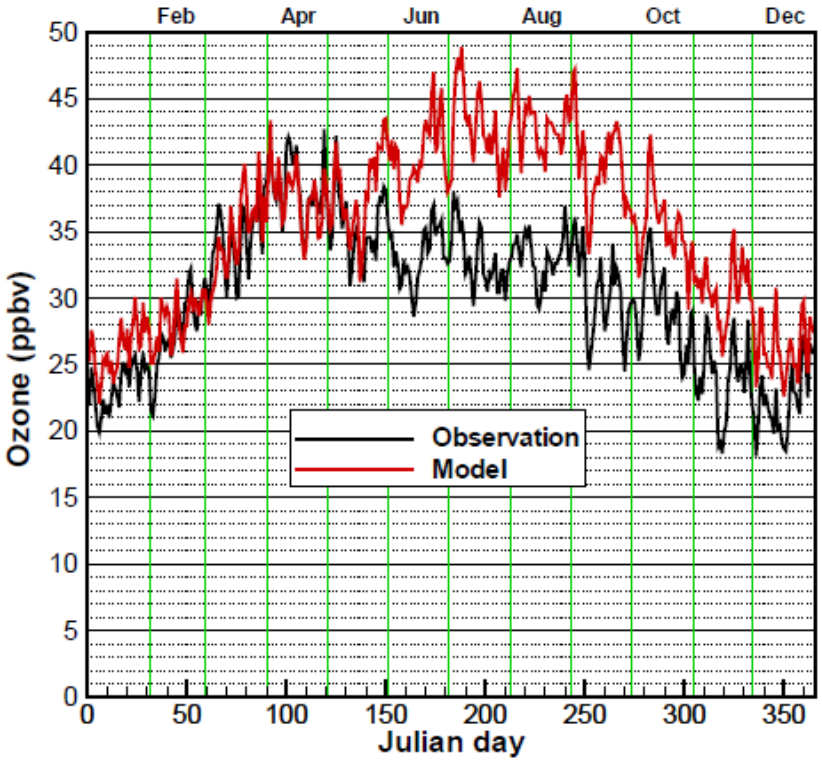


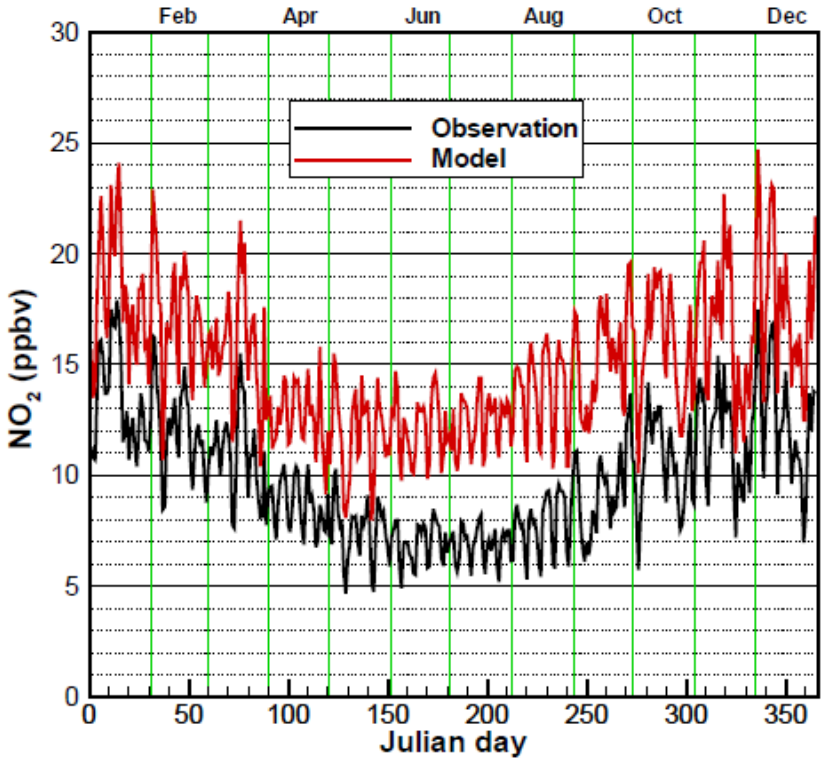
Operational

CONUS, wrt 75 ppb Threshold

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

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



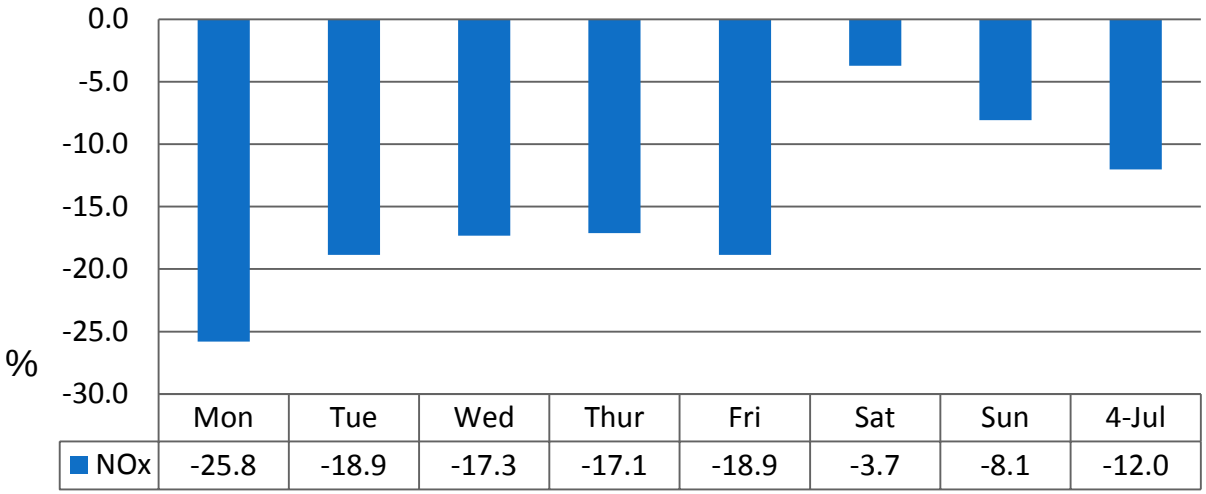


- *T. Chai et al., Geosci. Model Dev., 2013* *(http://www.geosci-model-dev.net/6/1831/2013/gmd-6-1831-2013.html)*
- *Ozone overestimation in August is larger in rural areas, during morning hours, and in the southeast US*
- *NO2 overestimation in August is larger at night time*
- *Ozone biases higher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

Summary of Emission Data Sources

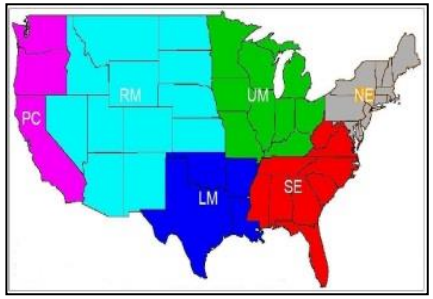
- **Area Sources**
  - US EPA Projected 2012 Nonroad + 2005 NEIs for other sectors;
  - Canada 2006 Emission Inventory;
  - Mexico 1996 EI for six border states;
- **Mobile Sources (onroad)**
  - 2005 NEI with Cross-State Air Pollution Rule (CSAPR) projection for US sources
  - Canada 2006 Emission Inventory;
- **Point Sources (EGUs and non-EGUs)**
  - NEI 2005 for base year;
  - Updated with 2012 Continuous Emission Monitoring (CEM) data for EGUs;
  - Projected into forecast year using DOE Annual Energy Outlook (2014) factors;
- **Natural Sources**
  - *Terrestrial biogenic emission:* BEIS model v3.14
  - *Sea-salt emission:* CMAQ online Sea-salt emission model;

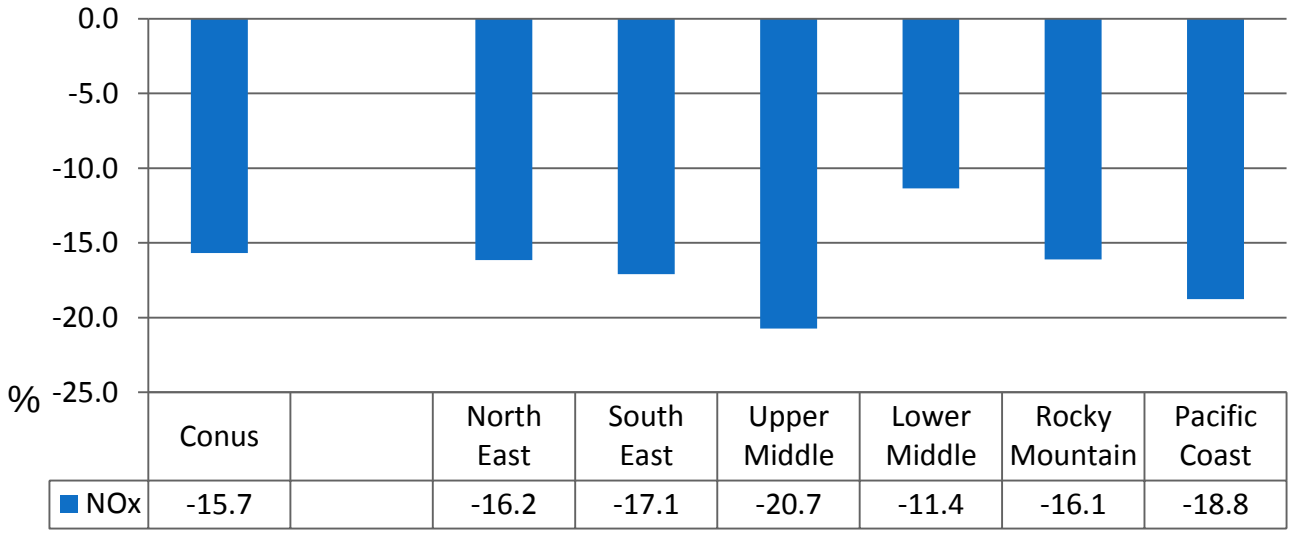
Reduction in NOx emissions implemented in 2012



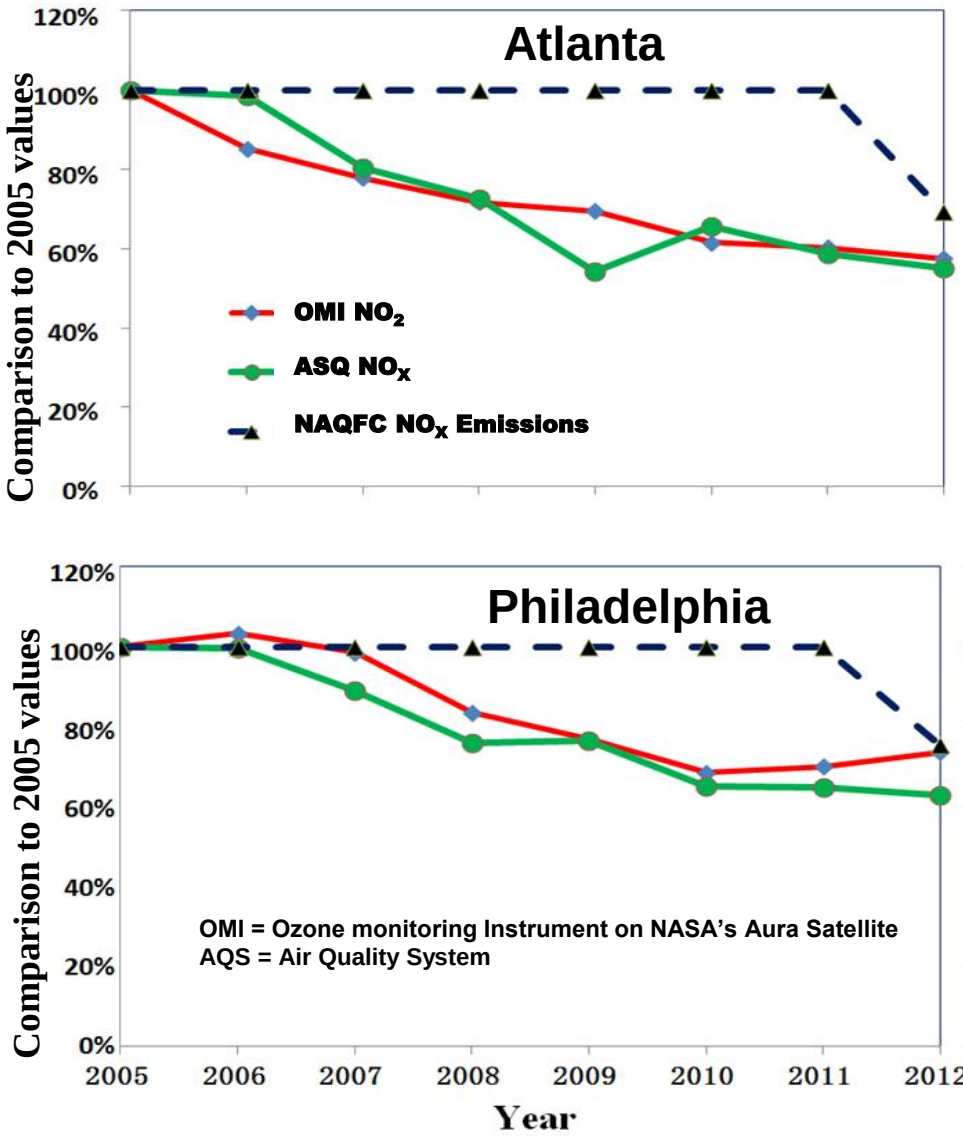
NO_x emission reduction by day of week and holiday for July compared to those used in 2011

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





NOx Emissions



- Relying on projections rather than inventories for mobile sources
- Comparison of projected emission with surface and satellite observations

(Tong et al. Long-term NOx trends over large cities in the United States during the Great Recession: Intercomparison of satellite retrievals, ground observations, and emission inventories, submitted)

Testing of ozone prediction updates

Evaluation of daily maximum of 8h average ozone

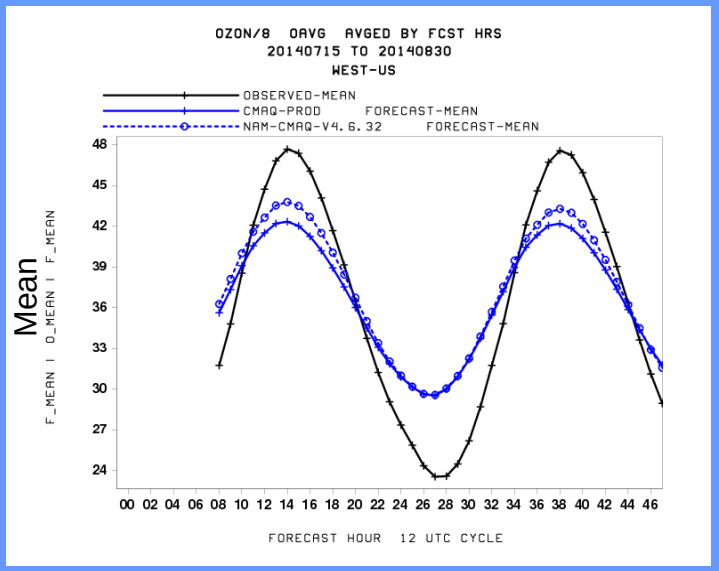
Model updates:

- CB05 chemical mechanism
- Lateral boundary conditions
- Dry deposition
- Minimum PBL height
- Faster removal of organic nitrate

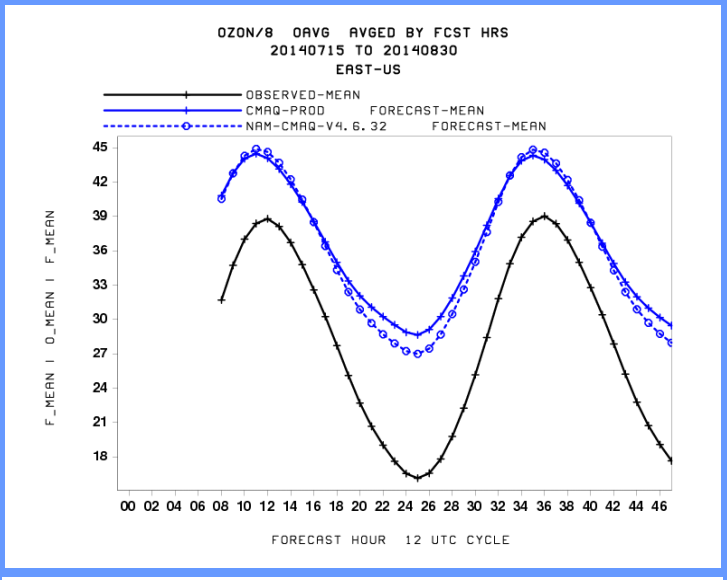
Performance:

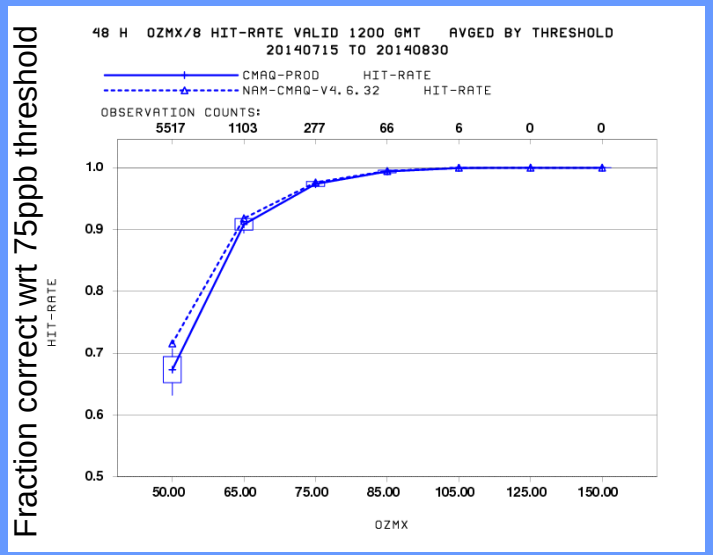
- Increased (better) diurnal variability
- Increased (better) peak ozone in the Western US
- Decreased (better) night-time minimum in the Eastern US
- Slightly increased (worse) peak ozone in the Eastern US
- Small changes in fraction correct for 75ppb threshold

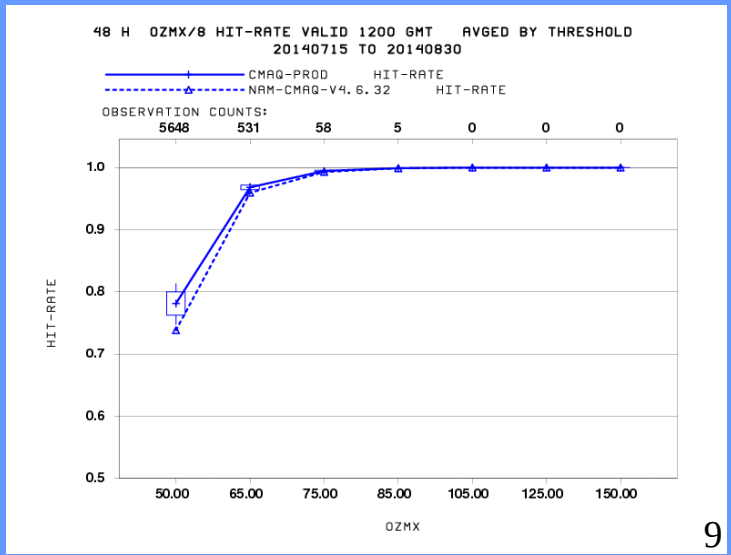
Western US



Eastern US

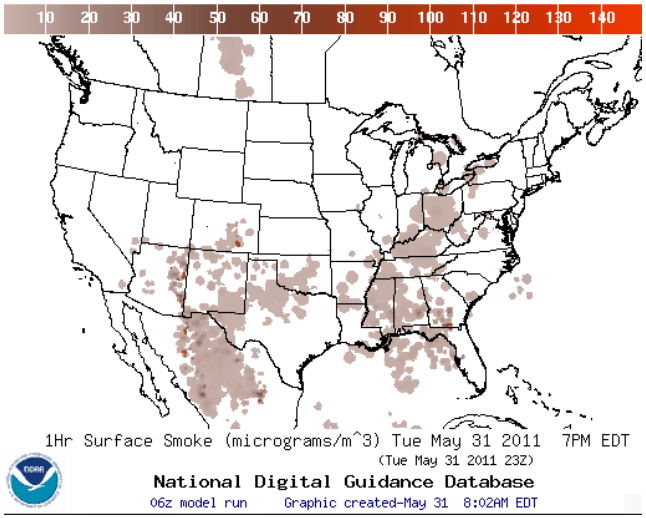




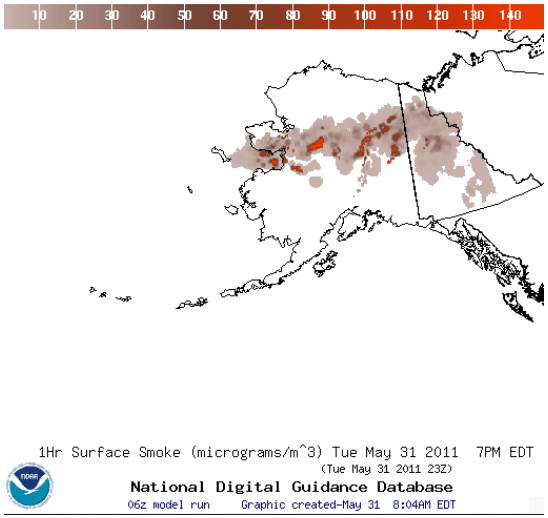


Smoke predictions

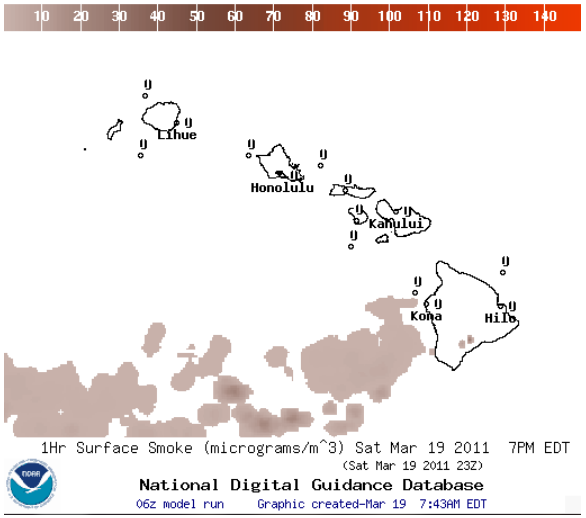
Operational predictions at http://airquality.weather.gov



Surface Smoke

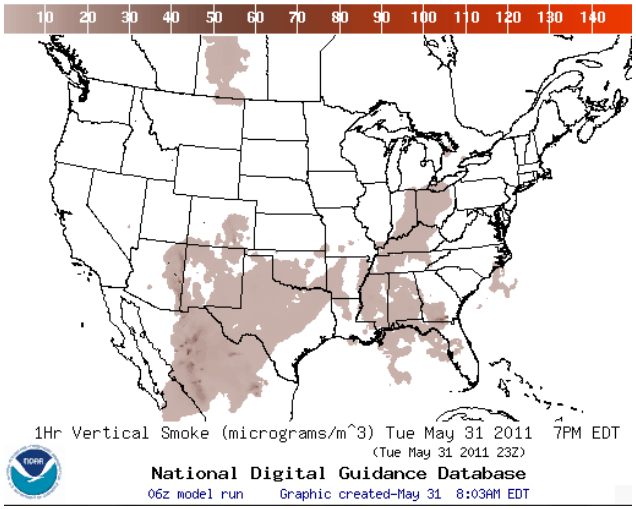


Surface Smoke

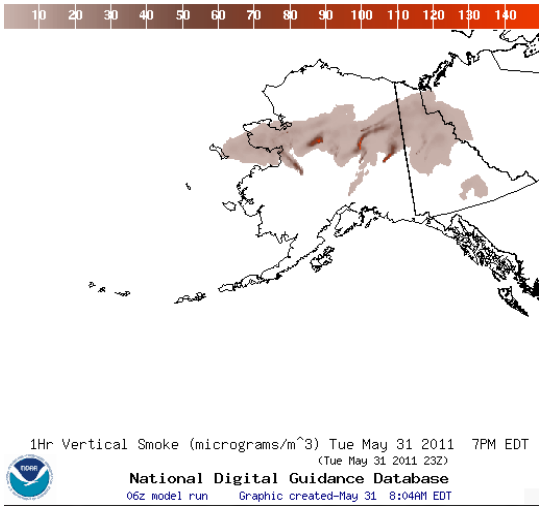


Surface Smoke

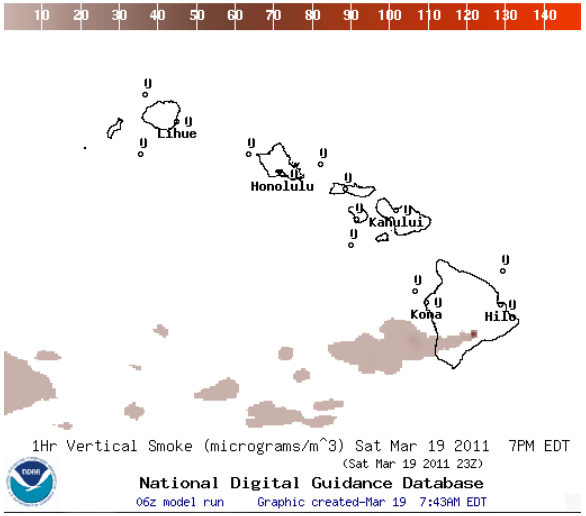
Vertical Smoke



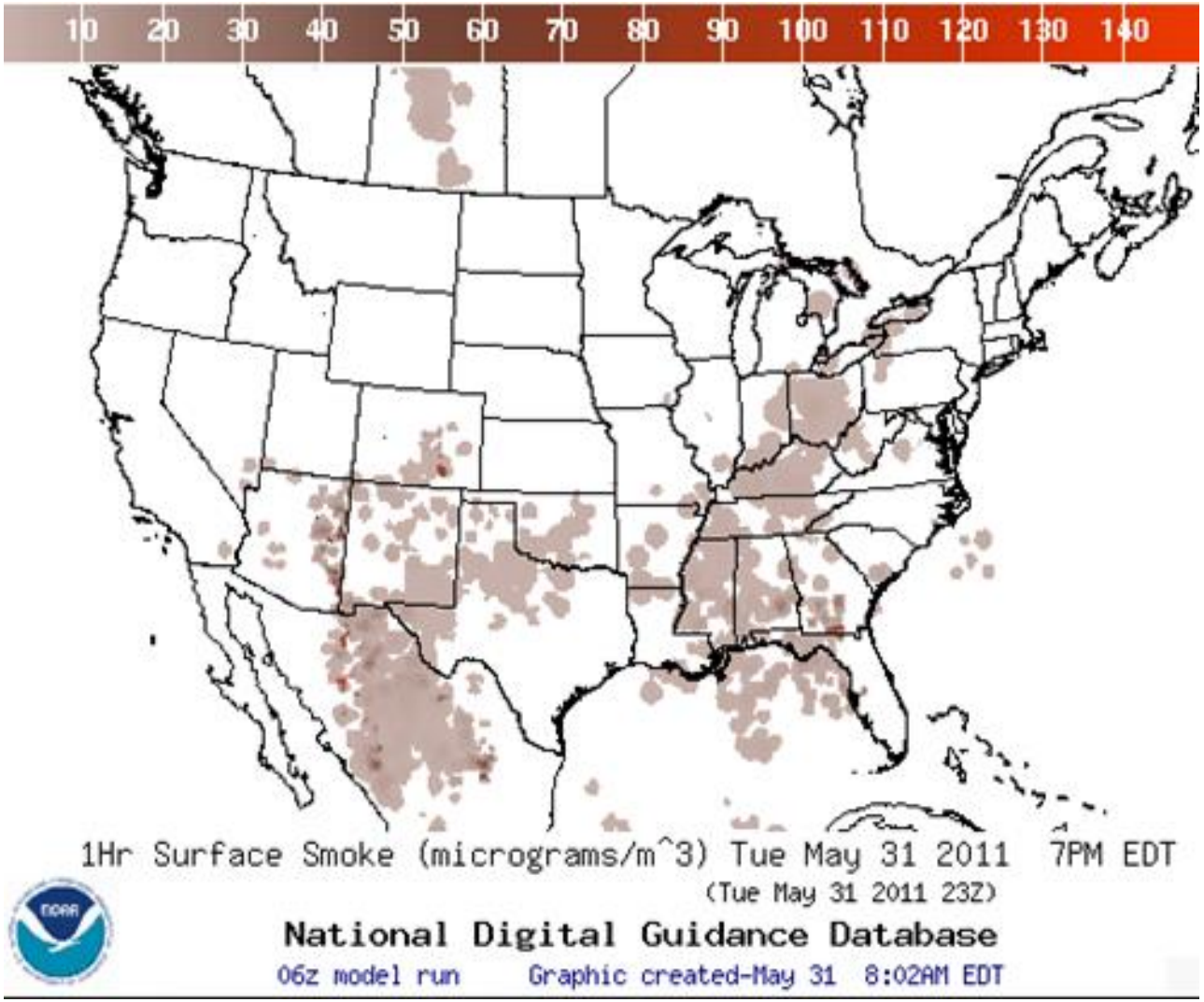
Vertical Smoke



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)
- Last years' updates include increased plume rise, decreased wet deposition, changes in daily emissions cycling
- Developed satellite product for verification (Ciren et.al., JGR 2014)

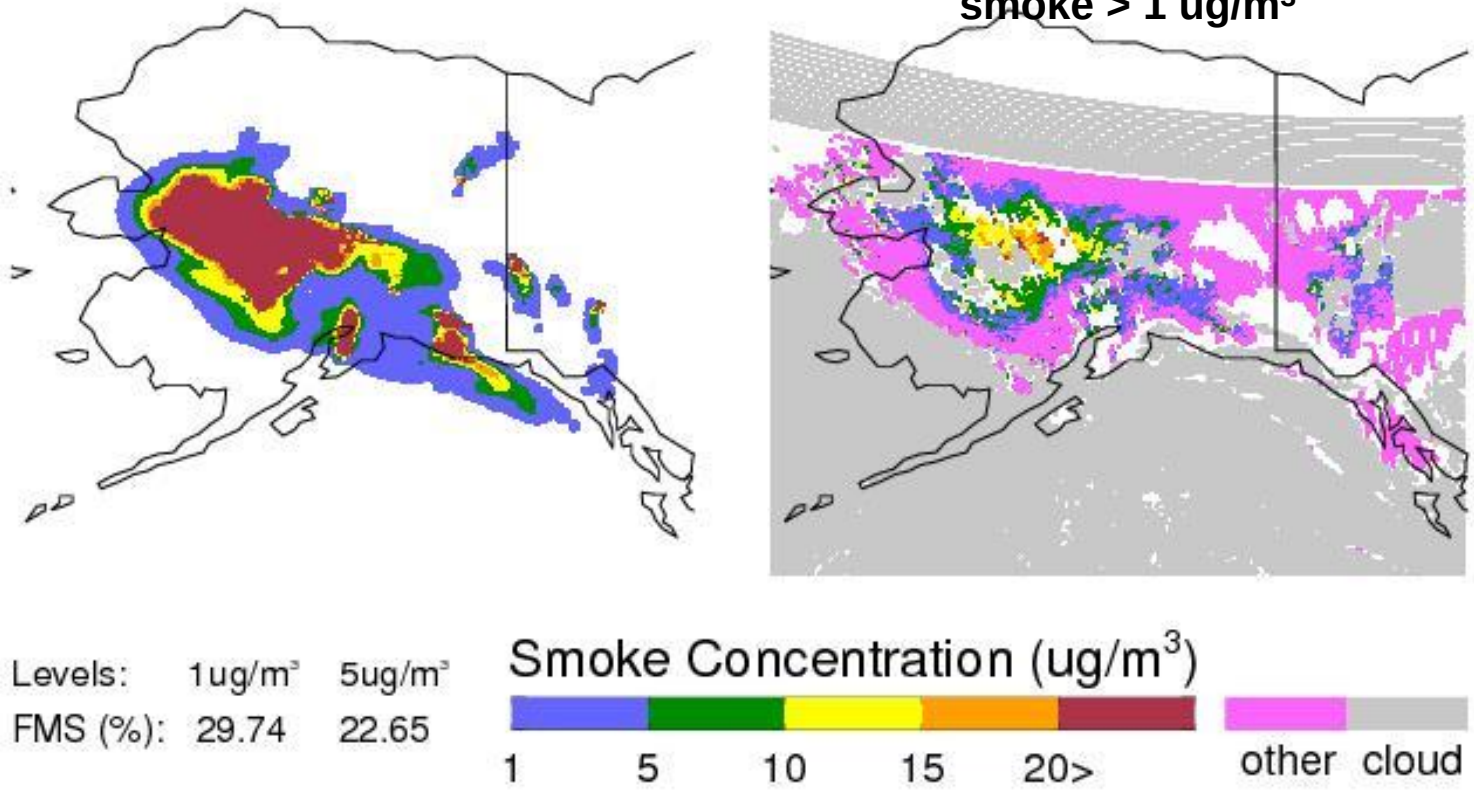
Smoke Verification:
July 13, 2009

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

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

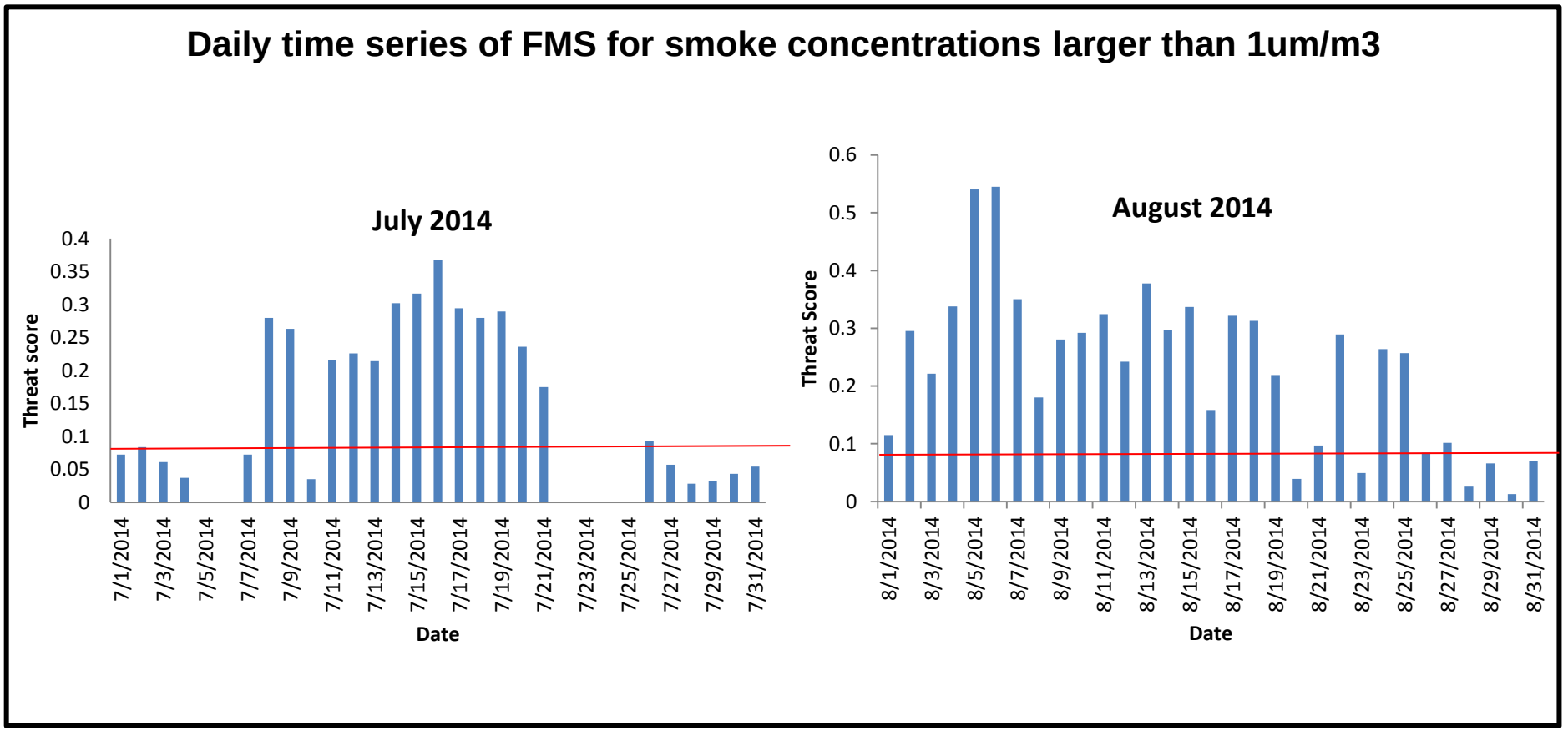
GOES smoke product: Confirms areal extent of peak concentrations

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



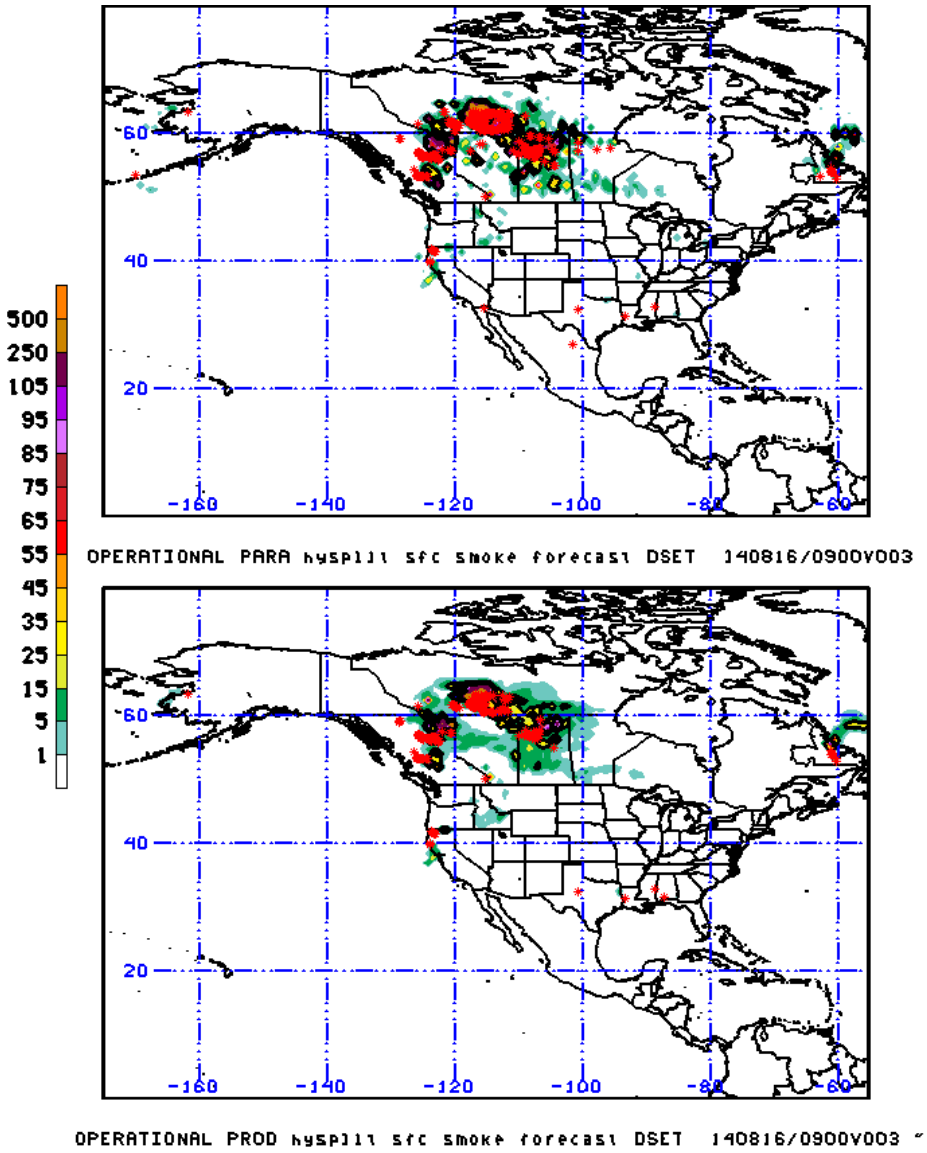
Manuscript about smoke verification product is in preparation

Verification of smoke predictions for CONUS



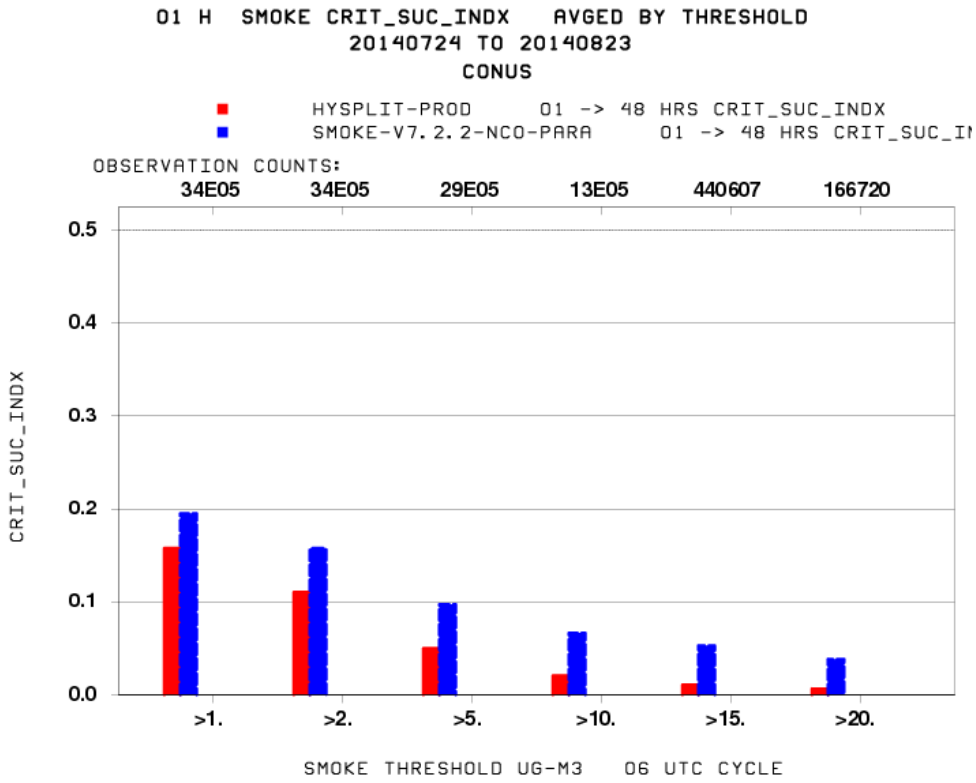
- **Figure of merit in space (FMS), which is a fraction of overlap between predicted and observed smoke plumes, threshold is 0.08 marked by red line**
- **NESDIS GOES Aerosol/Smoke Product is used for verification**

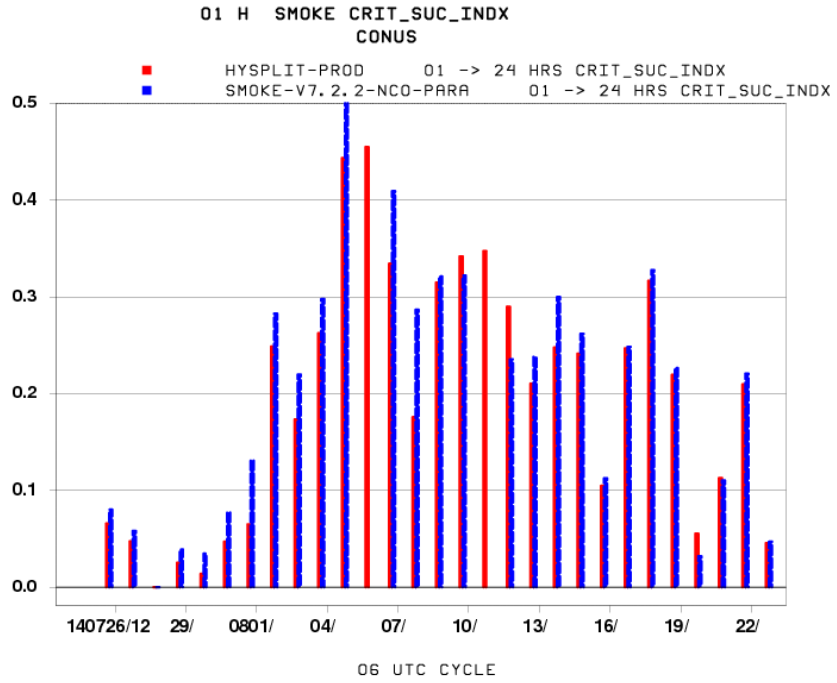
Smoke prediction updates



- Updating to use automated detection of fires in Canada, Mexico and Central America.
- Updating to use 3-D particle model approach (rather than horizontal puffs) to properly represent the additional fires identified with automatic fire detection.
- Multiple modifications were implemented in the North American Mesoscale (NAM) Analysis and Forecast System including updates to radiation, convective parameterization, microphysics, advection, hybrid variational ensemble GSI analysis, satellite bias correction, quality control of observations, satellite radiance assimilation, diabatic digital filter.

Canada/ Mexico Emission impact July –August, 2014 CONUS CSI verification

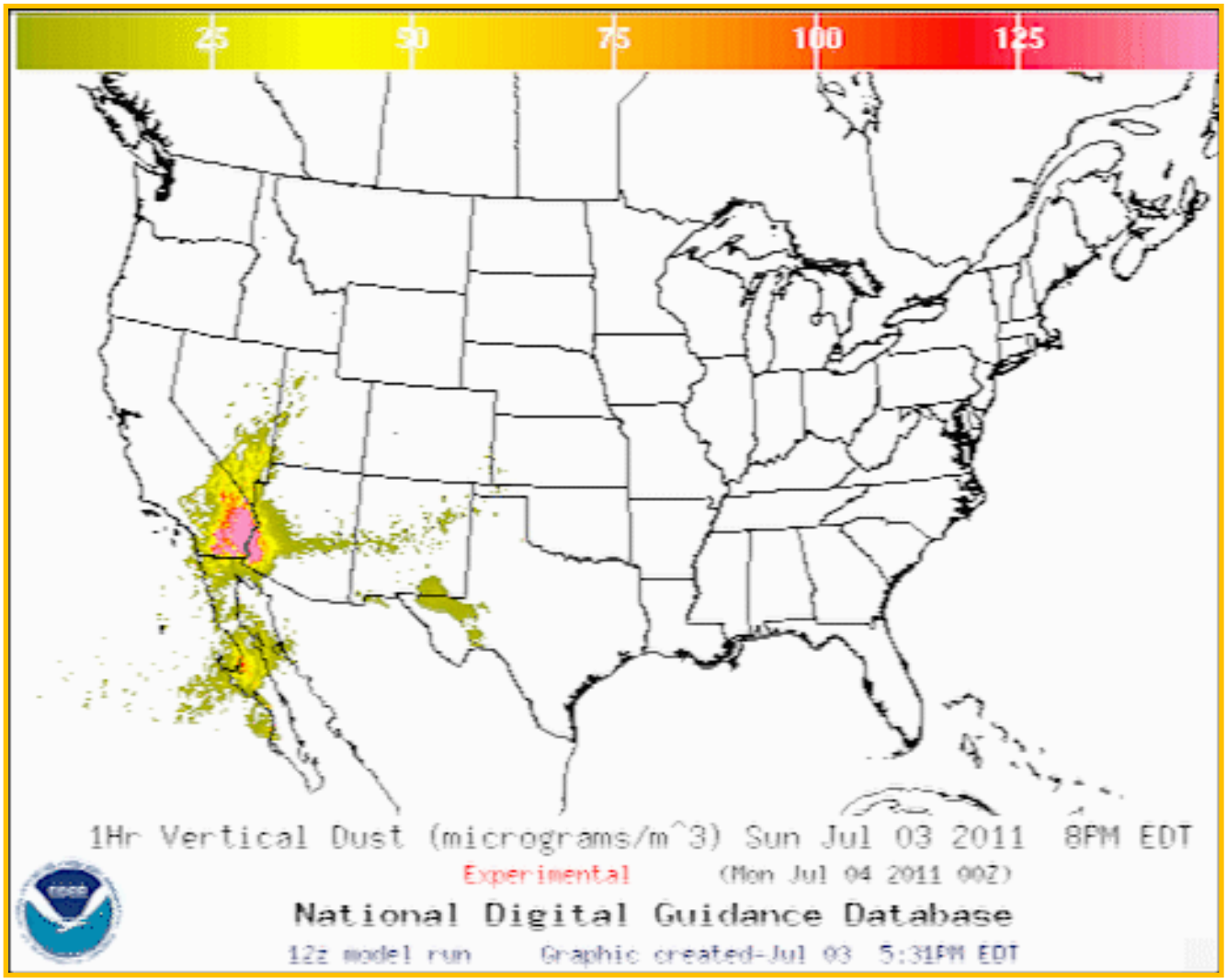




Improved performance with new Canadian and Mexican emissions

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 (2003-2006).

• 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

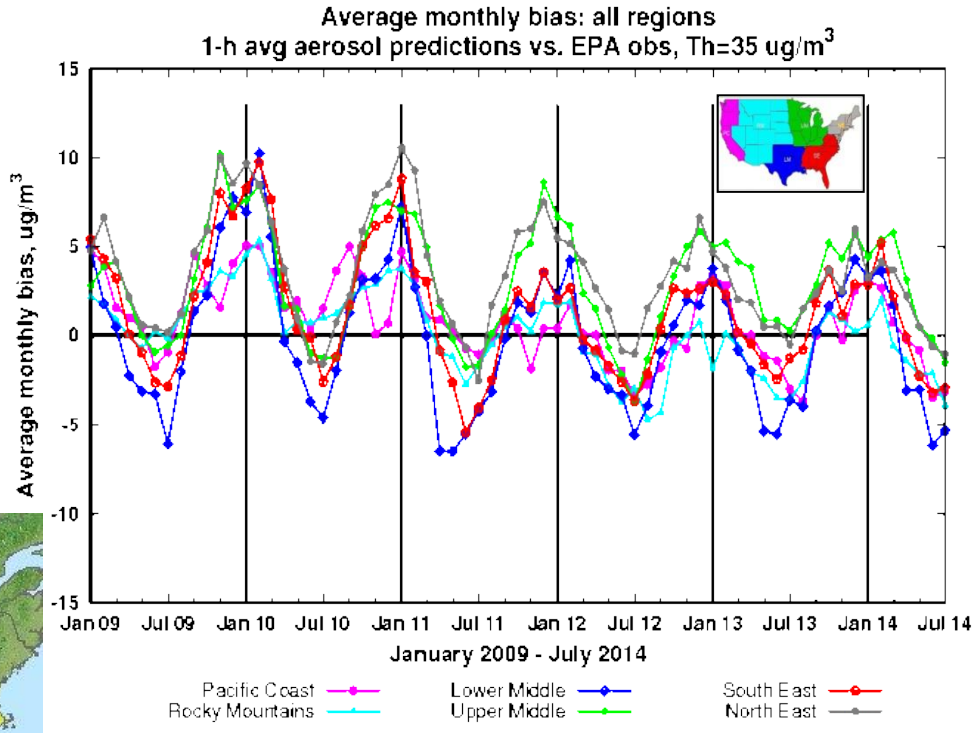
AQ Forecaster Focus group access only, real-time as resources permit

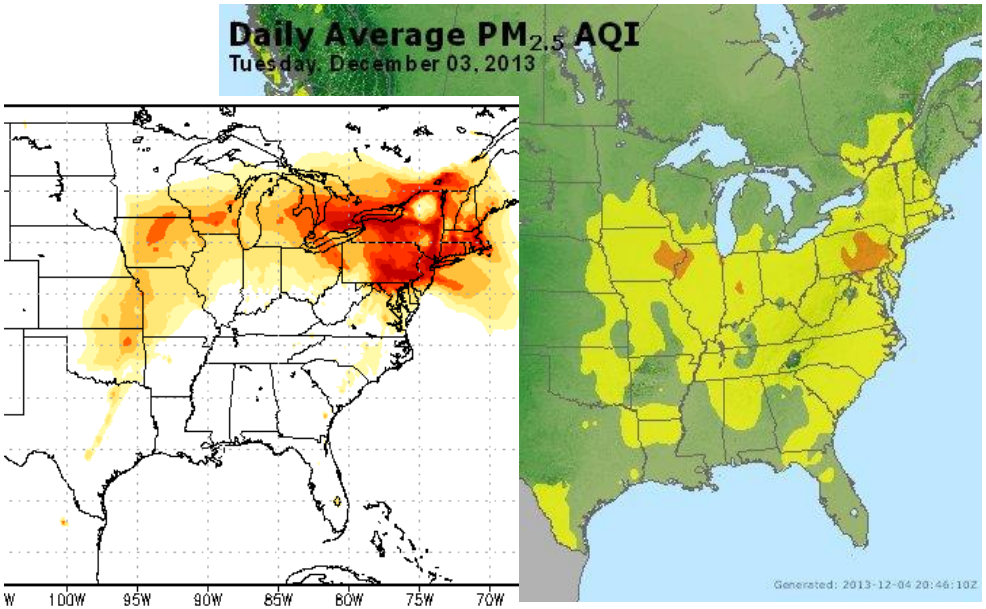
Aerosols over CONUS

From NEI sources only

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

- Show seasonal bias-- winter, overprediction; summer, underprediction



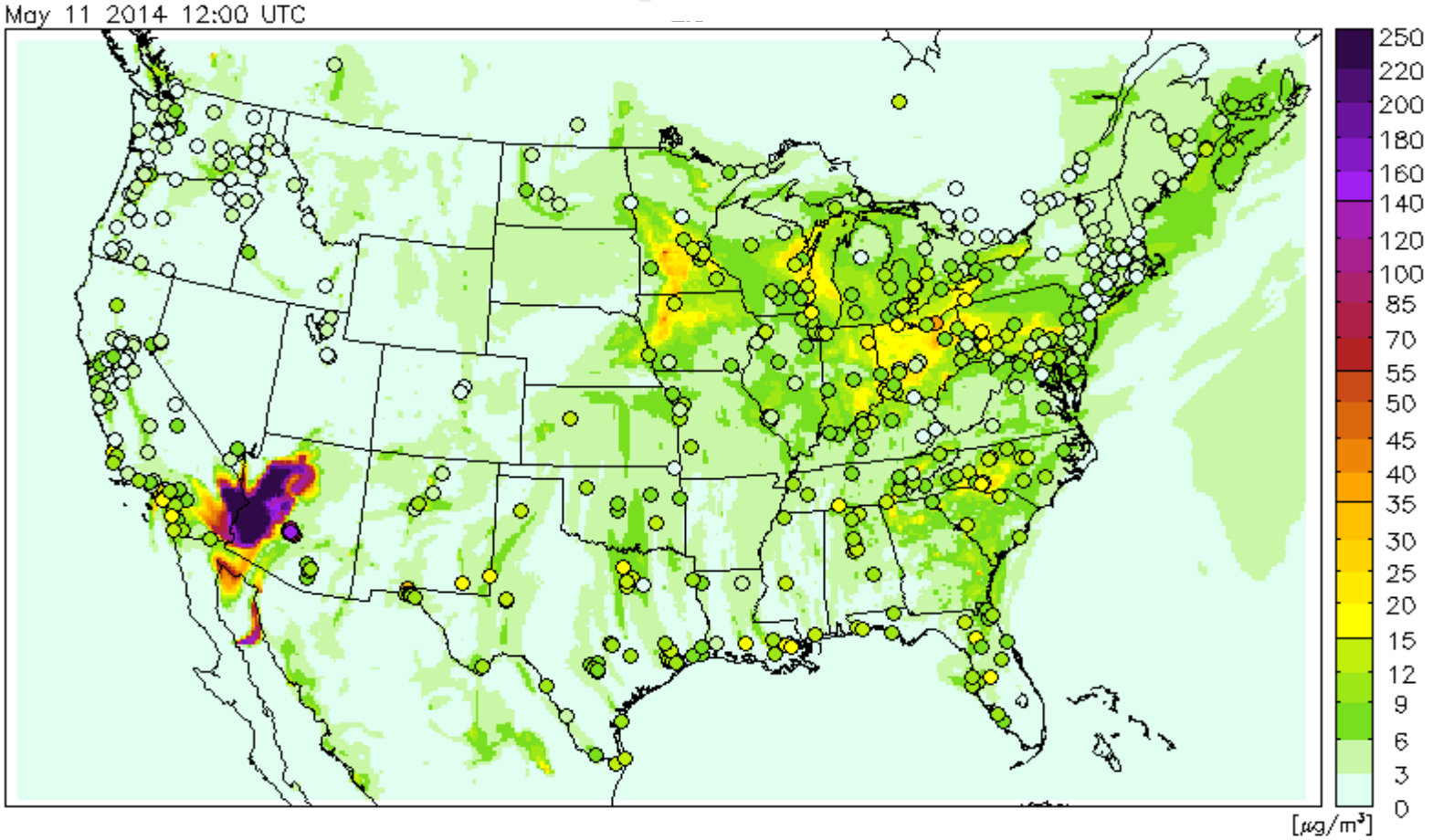


NAQFC PM2.5 test predictions

Forecast challenges

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

Blowing Dust Event in testing of PM2.5 predictions

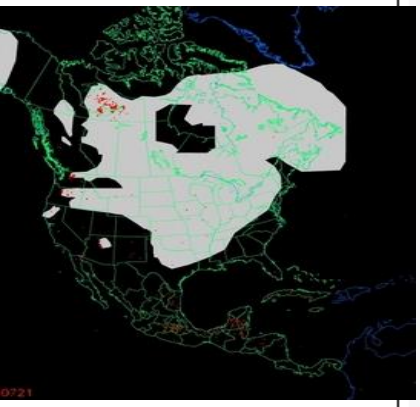


Independent NOAA/NESDIS analysis narrative based on satellite imagery:

BLOWING DUST

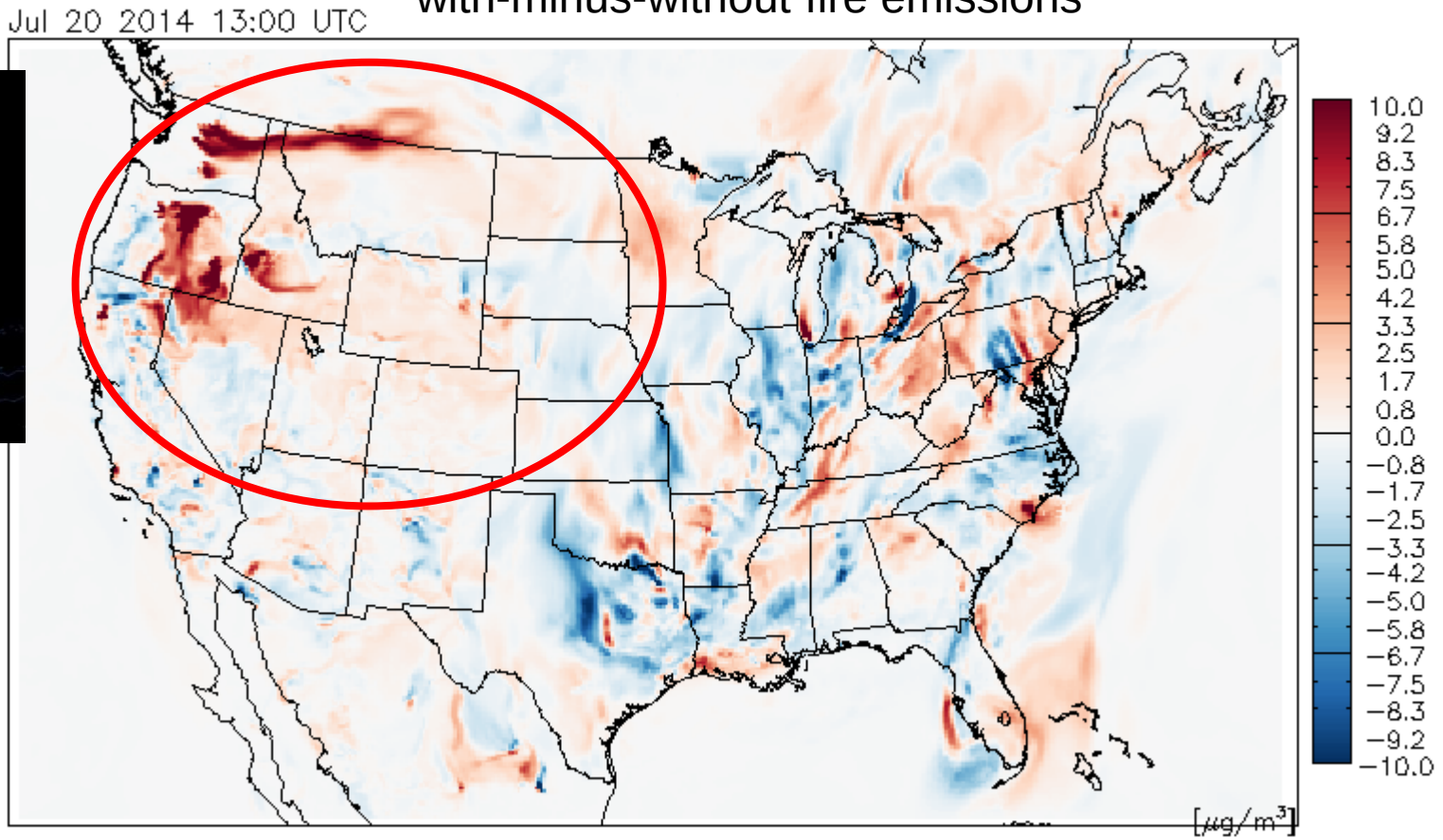
California/Arizona: An area of moderately dense blowing dust was visible sweeping across northern Baja California/Arizona into western New Mexico behind a strong cold frontal boundary. This remnant dust originated from multiple areas in southern California last evening.

Impact of forest fires in testing of PM2.5 predictions

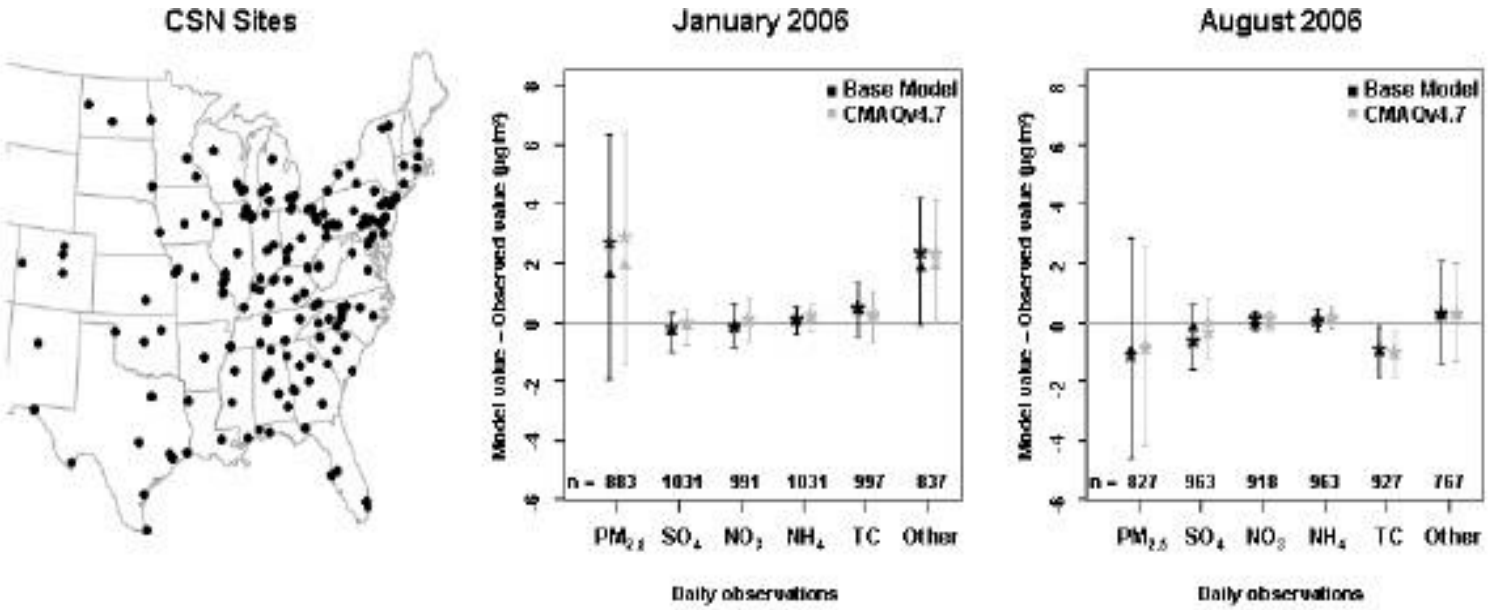


NOAA NESDIS Hazard Mapping System Fire and Smoke Analysis

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



Seasonal Bias in PM2.5 prediction



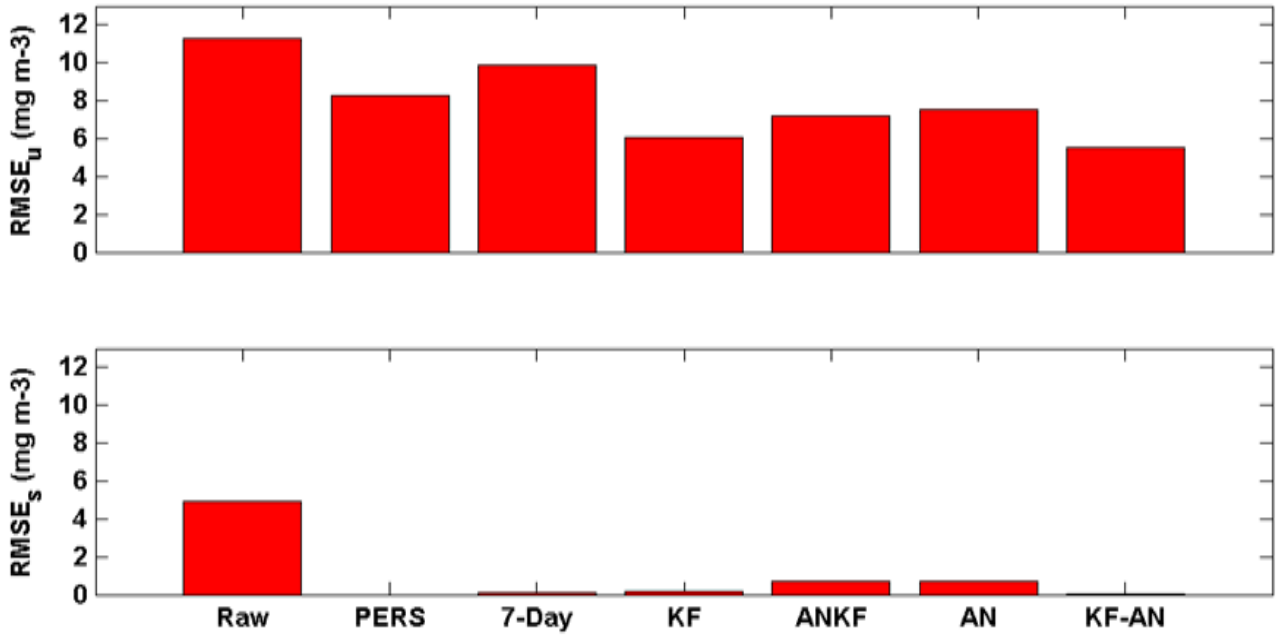
Mean (star), median (triangle), and inter-quartile ranges of model bias (model value – observed value) for multiple fine-particle species measured at CSN sites in the 12km domain. The number of model/observation pairs for each species is shown above the x-axis.

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.

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

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***

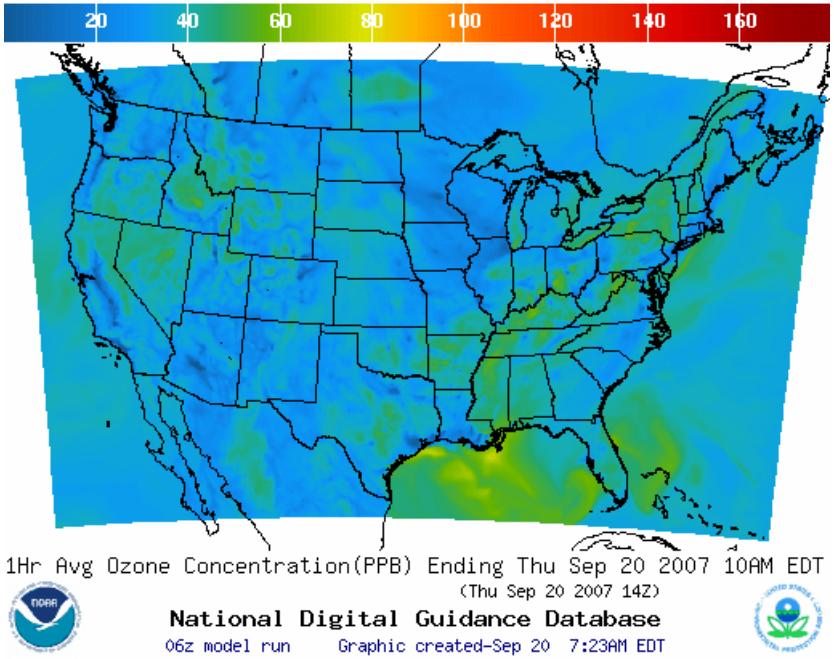
Examples of AQ forecaster feedback after emissions update in 2012:

- Good performance by NAQFC ozone forecast in 2012 in the Philadelphia metropolitan area. *(William Ryan, Penn State)*
- In Connecticut, NOAA model outperformed [human] forecasts- 73% vs. 54%. The NOAA model past record of over-predicting during July-August didn't occur this year. *(Michael Geigert, Connecticut Dept.of Energy and Environmental Protection)*
- 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)*
- *Bias and accuracy statistics for NAQFC ozone predictions improved in 2012 compared to 2011. (Cary Gentry, Forsyth County Office of Environmental Assistance and Protection, Winston-Salem, NC)*

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

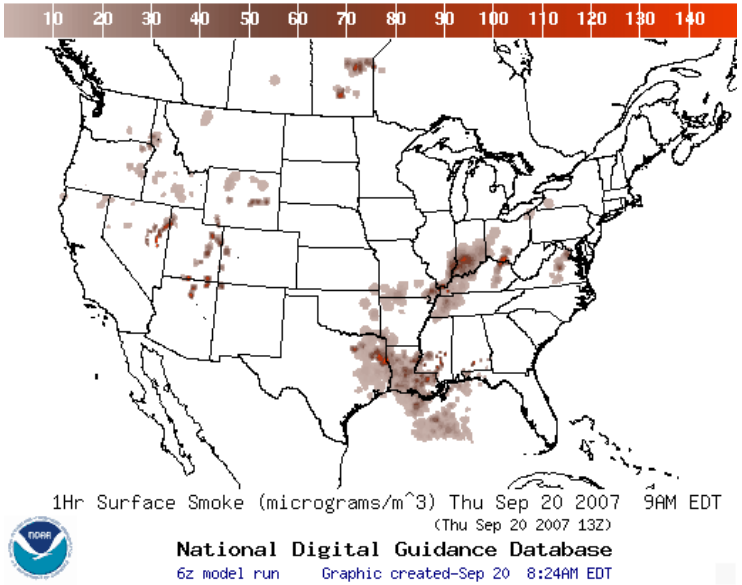
Operational AQ forecast guidance

airquality.weather.gov



Ozone products

Nationwide since 2010



Smoke Products

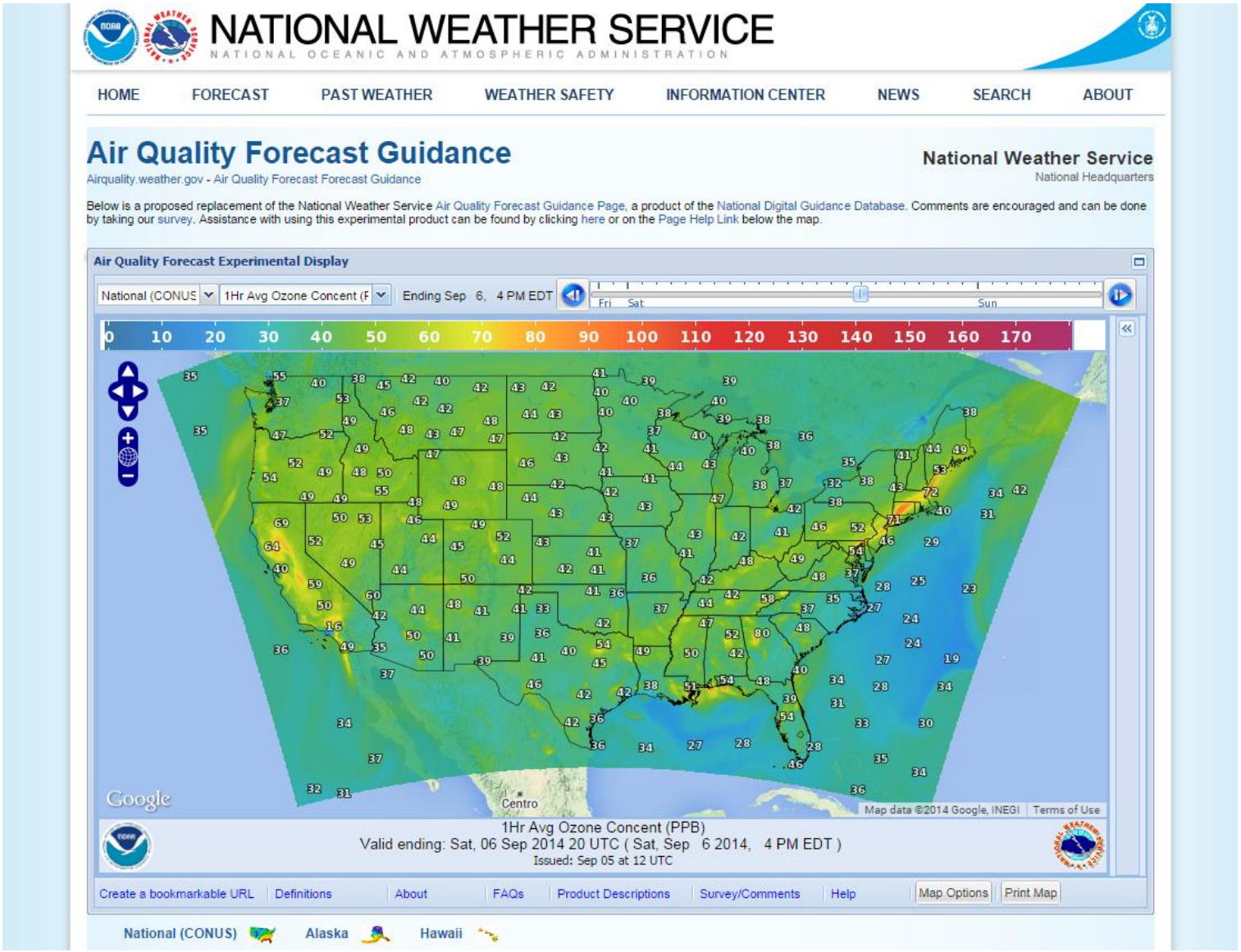
Nationwide since 2010

Dust Products

Implemented 2012

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

Testing new display of AQ predictions



http://preview.weather.gov/graphical/?dataset=aq

Summary and Plans

US national AQ forecasting capability and recent updates:

- Operational **ozone** prediction nationwide; substantial emission update in 2012
- Operational **smoke** prediction nationwide
- Operational **dust** prediction for CONUS sources
- **Experimental ozone** predictions for CONUS; CB05 mechanism, updated emissions, lateral boundary conditions, deposition, NTR
- Prototype CMAQ **PM2.5** predictions with NEI, wildfire and dust emissions

If/when resources allow we plan to:

- Maintain operational AQ predictions
- Transition currently experimental ozone into operations
- Test/implement new display capability
- Use lateral boundary conditions from global dust predictions in prototype PM2.5 predictions
- Test smoke predictions with 4 km meteorology and emission updates

Acknowledgments:
AQF Implementation Team Members

Special thanks to Paula Davidson, OST chief scientist and former NAQFC Manager and to Jim Meager former NOAA AQ Matrix Manager

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NWS/OST/MDL	***Jerry Gorline, Marc Saccucci, Dave Ruth***	***Dev. Verification, NDGD Product Development***
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NESDIS/NCDC	***Alan Hall***	***Product Archiving***
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Dan Starosta, Chris Magee		**NCO transition and systems testing**
Mike Bodner, Andrew Orrison		**HPC coordination and AQF webdrawer**
NOAA/OAR/ARL		
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Roland Draxler, Glenn Rolph, 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

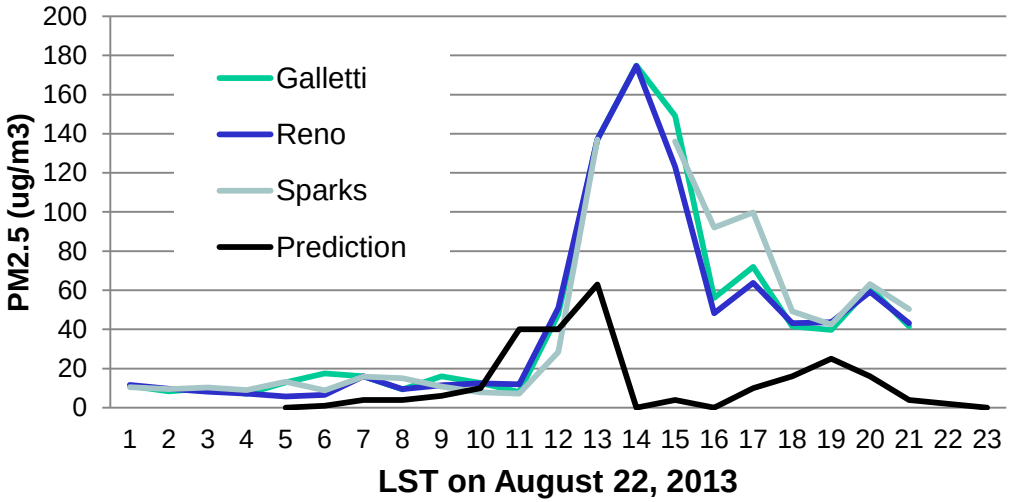
Rim Fire in California

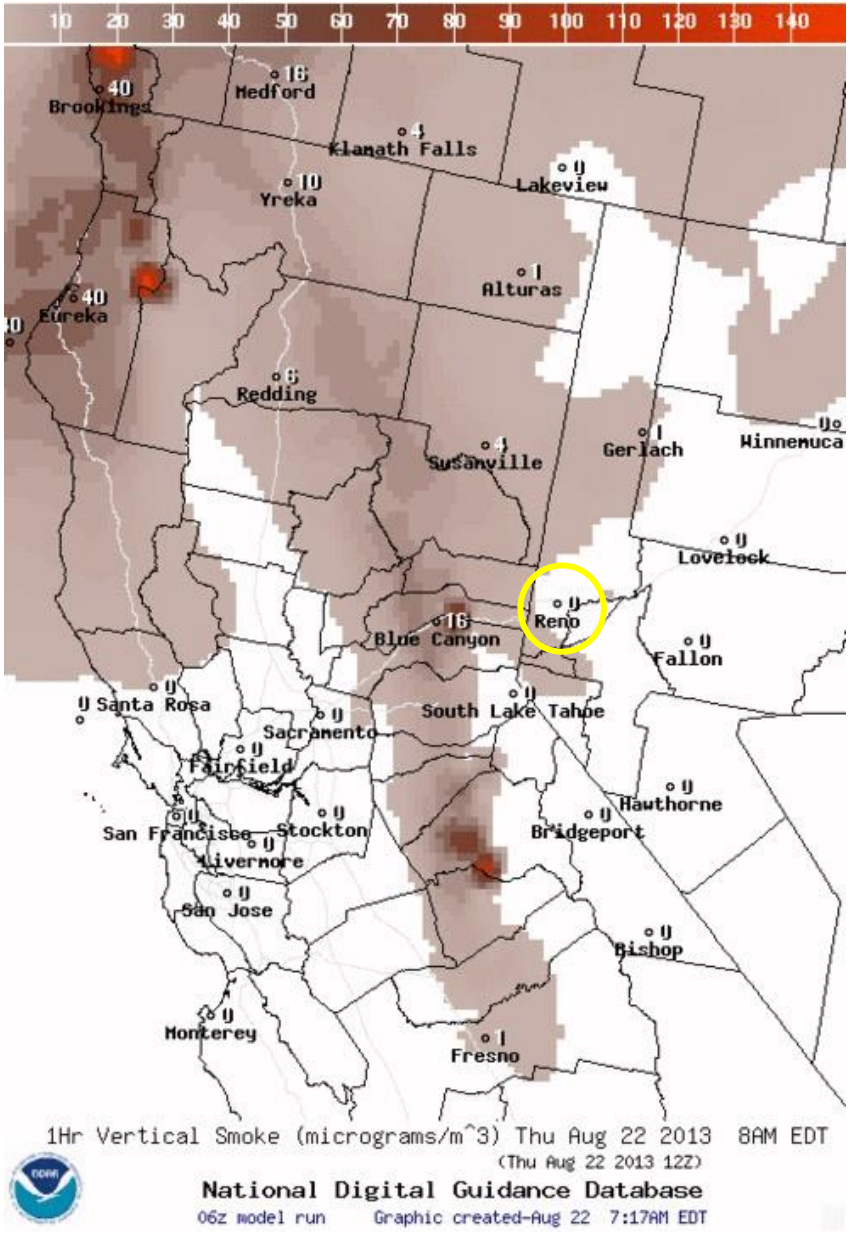
The largest wildfire ever recorded in Yosemite National Park. Fire started on August 17.

Transport of smoke towards Reno, NV on 8/22 was confirmed by GOES-14 satellite imagery.

NWS office in Reno included smoke and haze in their forecast.

Observed PM2.5 concentrations peaked around 2 pm LST, predicted concentrations at the surface peaked at 1 pm, and the highest predicted concentration was lower than observed





http://airquality.weather.gov

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