National Air Quality Forecast Capability

Ivanka Stajner
NOAA NWS/OST

with contributions from the entire NAQFC Implementation Team

Outline:

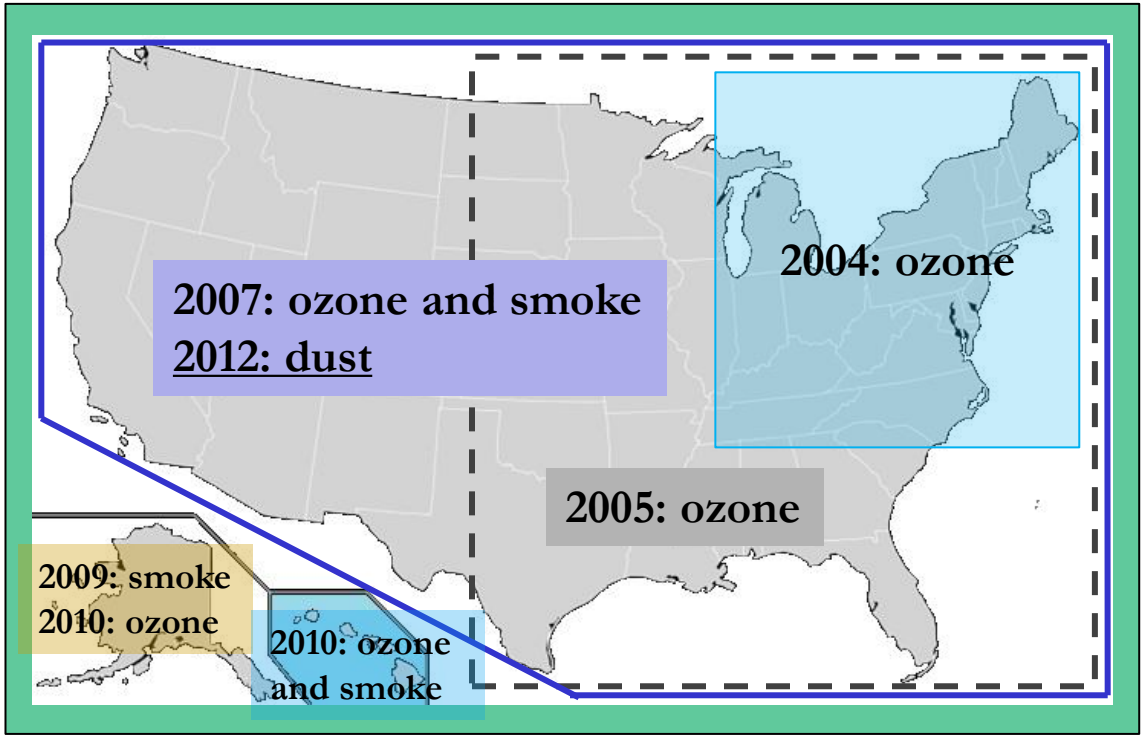
- Background on NAQFC
- Recent progress and updates
  - -Ozone predictions
  - -Smoke predictions
  - -Dust predictions
  - -Prototype PM2.5 predictions
  - -Outreach and feedback
- Summary and plans

National Air Quality Forecast Capability
Capabilities as of 9/2013

- 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



In October 2012 NWS requested comments on proposed termination of ozone and testing of PM2.5 predictions. Comments were collected and analyzed. Per NWS management direction all AQ predictions have been migrated to new NCEP supercomputers and are currently being produced.

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

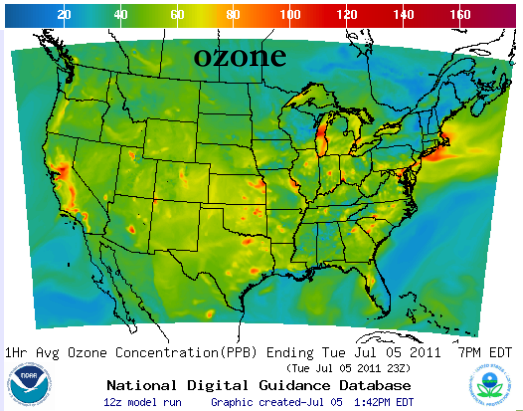
- *On NWS servers: airquality.weather.gov and ftp-servers*
- *On EPA servers*
- *Updated 2x daily*

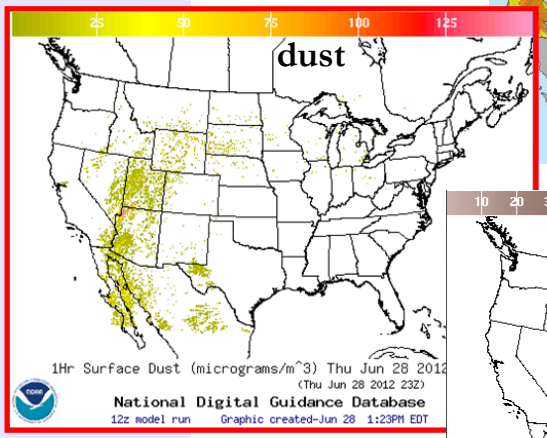
Verification basis, near-real time:

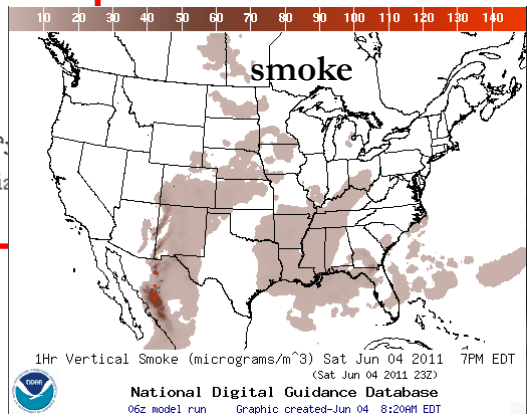
- *Ground-level AIRNow observations of surface ozone*
- *Satellite observations of smoke and dust*

Customer outreach/feedback

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







Recent progress and updates

North American Meteorological model, currently Non-hydrostatic Multi-scale Model (NMMB) was updated and migrated to new supercomputers

- *These meteorological predictions are used for all air quality predictions (July 2013)*

Ozone - *Substantial emission updates for 2012; reuse these emissions in 2013:*

- *Mobile6 used for mobile emissions, but with emissions scaled by growth/reduction rate from 2005 to 2012*
- *Non-road area sources use Cross State Rule Inventory*
- *Canadian emissions use 2006 inventory*

Dust predictions implemented operationally in March 2012:

- *Dust emissions are modulated by real-time soil moisture*
- *Longer time step to speed up dust predictions implemented in October 2012*

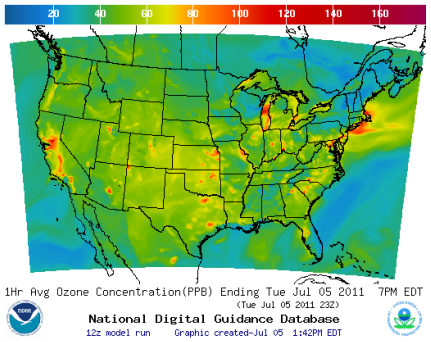
Smoke updates implemented in July 2013:

- *Increased maximum plume rise limit from 0.75 to 1.25 of the PBL depth; decreased wet removal, changed in daily emissions cycling; made horizontal puff dispersion rate more consistent with particle dispersion*

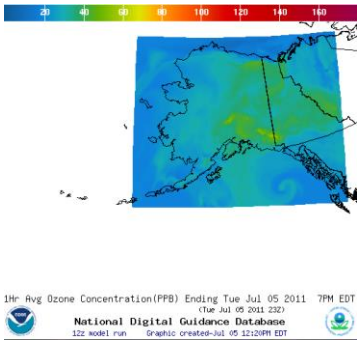
<u>All AQ predictions have migrated to new NCEP computers</u>

Ozone predictions

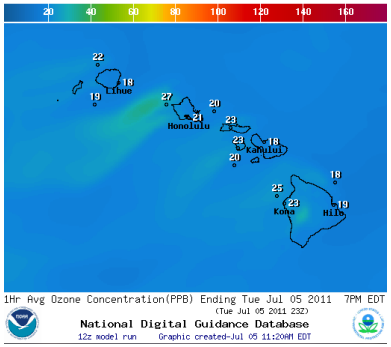
Operational predictions at http://airquality.weather.gov over expanding domains since 2004



1-Hr Average Ozone

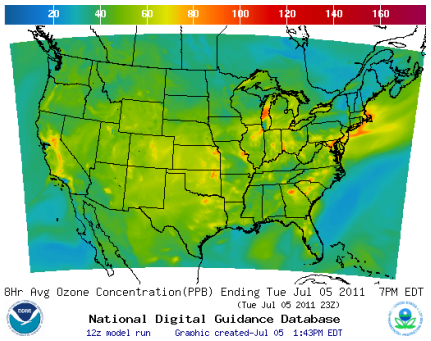


1-Hr Average Ozone

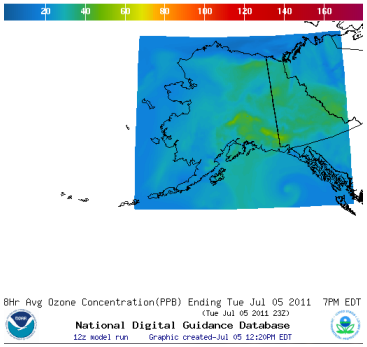


1-Hr Average Ozone

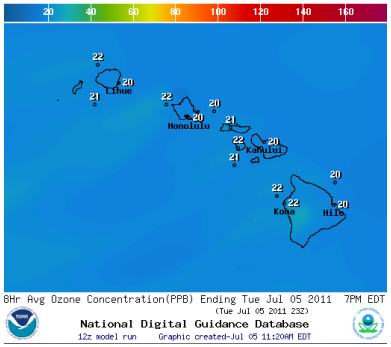
8-Hr Average Ozone

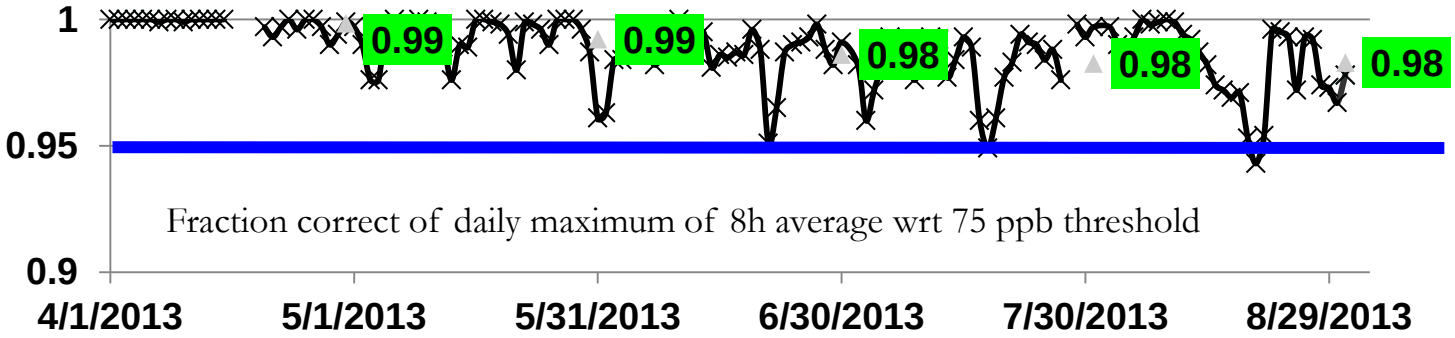


8-Hr Average Ozone



8-Hr Average Ozone



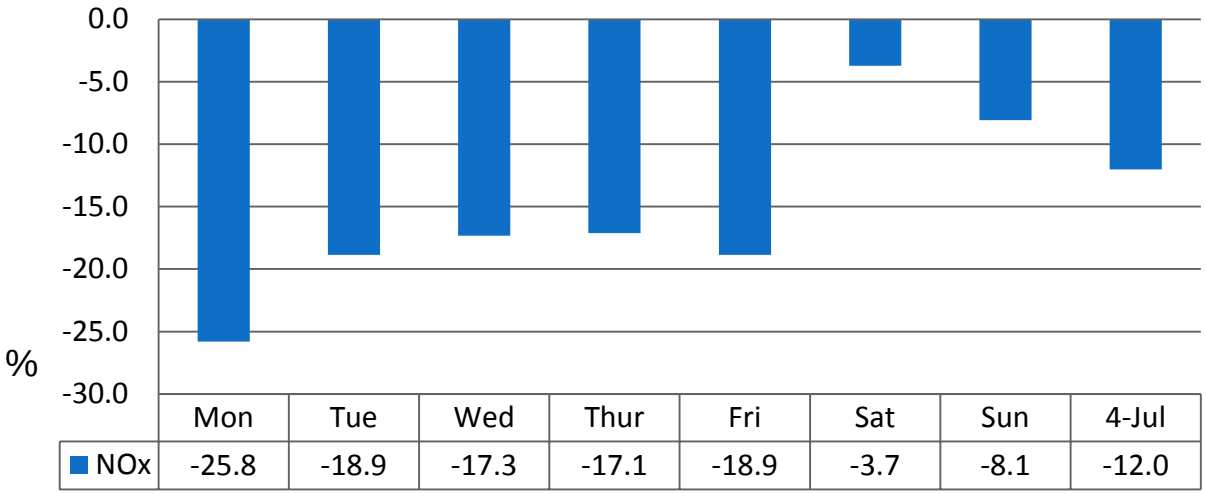


Operational

CONUS, wrt 75 ppb Threshold

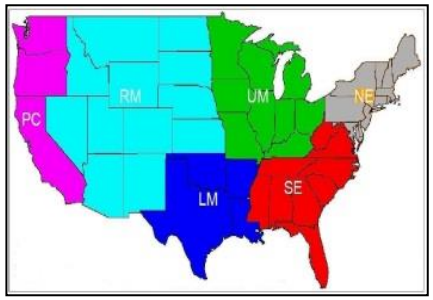
Maintaining prediction accuracy as the warning threshold was lowered and emissions of pollutants are changing

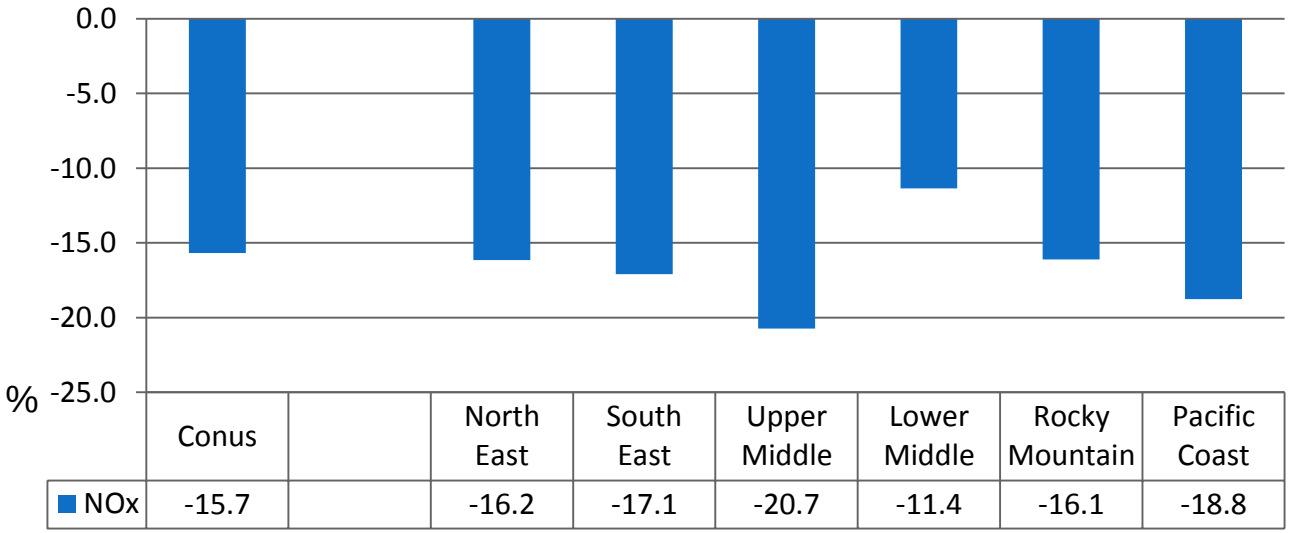
NOx emission change



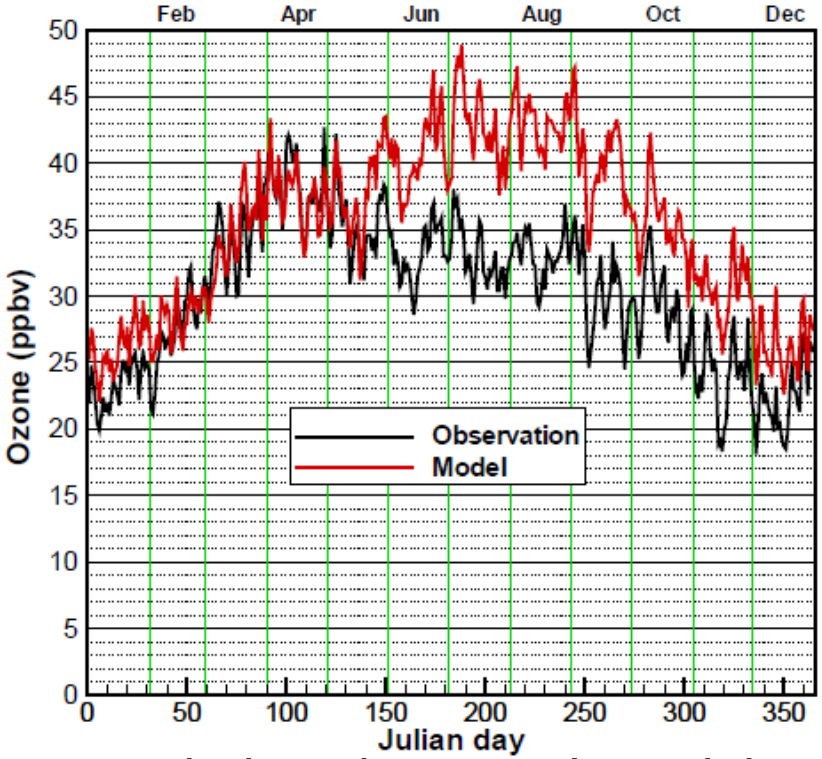
NO_x emission change by day of week and holiday for July compared to those used in 2011

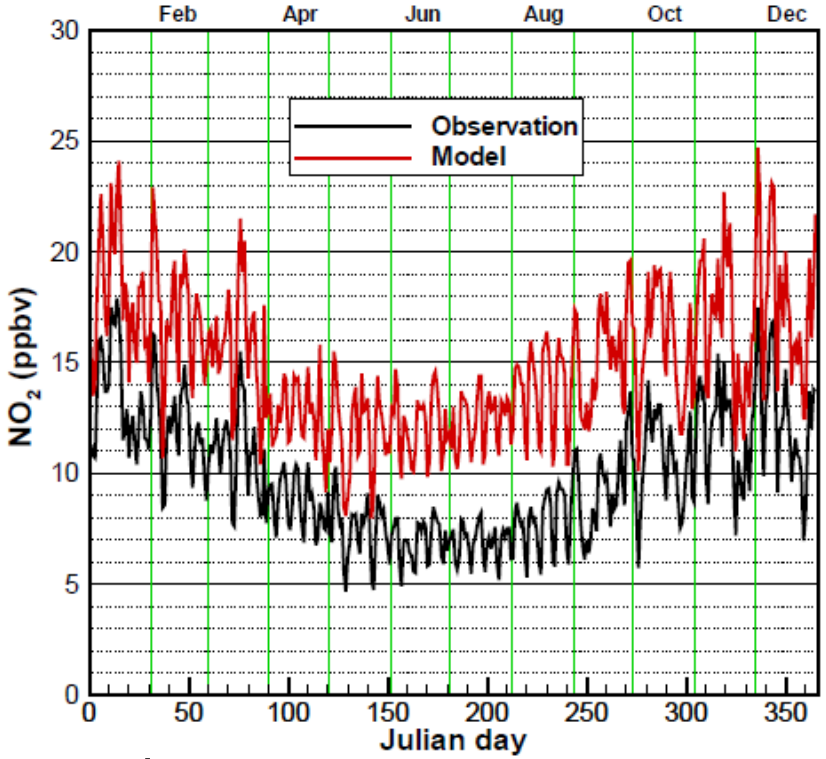
NO_x emission change by region for July compared to those used in 2011





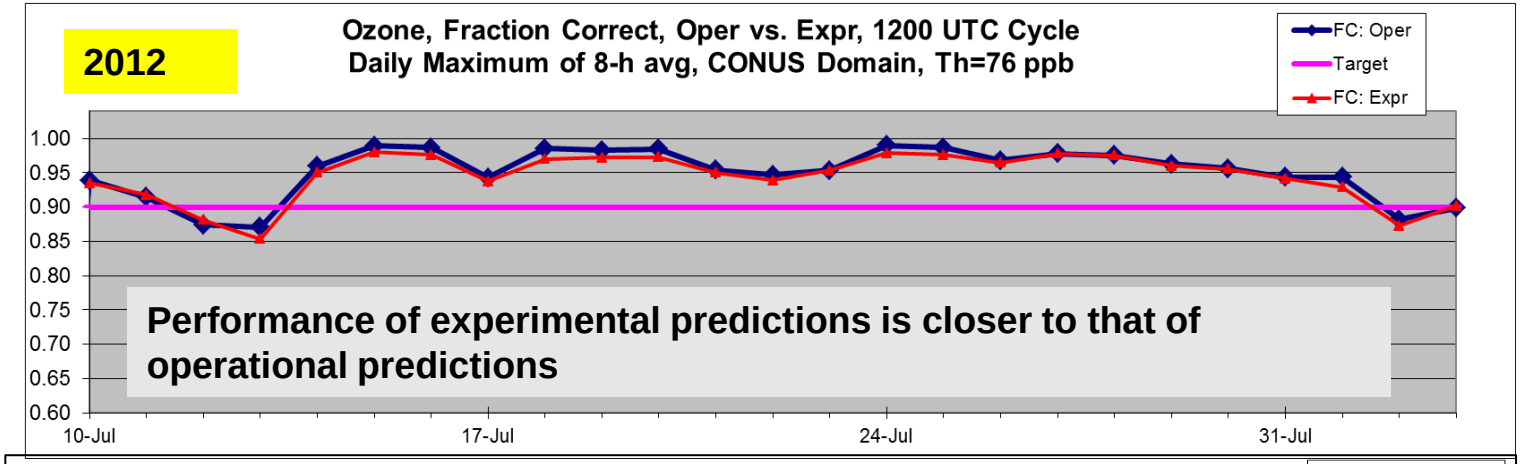
Evaluation of experimental NAQFC ozone predictions for 2010 using ozone and NO2 observations

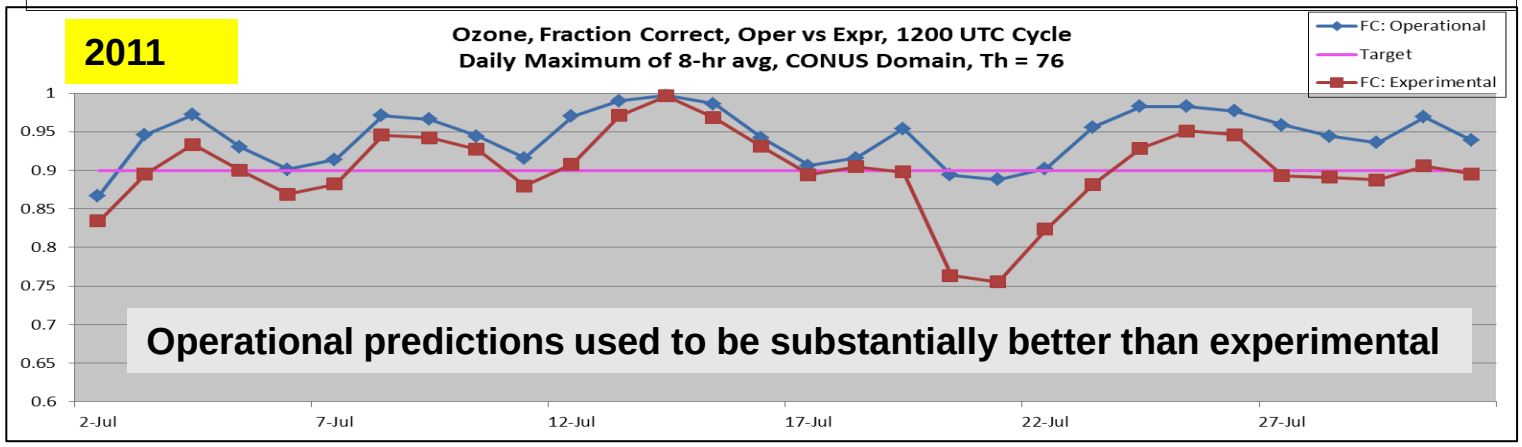




- *T. Chai et al., Geosci. Model Dev. Discuss., in press*
- *Ozone overestimation in August is larger in rural areas, during morning hours, and in the southeast US*
- *NO2 overestimation in August is larger at night time*
- *Ozone biases higher on weekends, but NO2 biases higher on weekdays*

Operational and experimental predictions: fraction correct

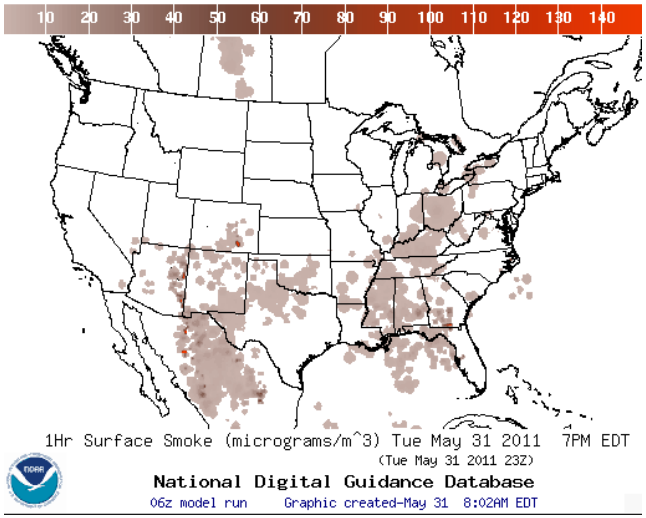




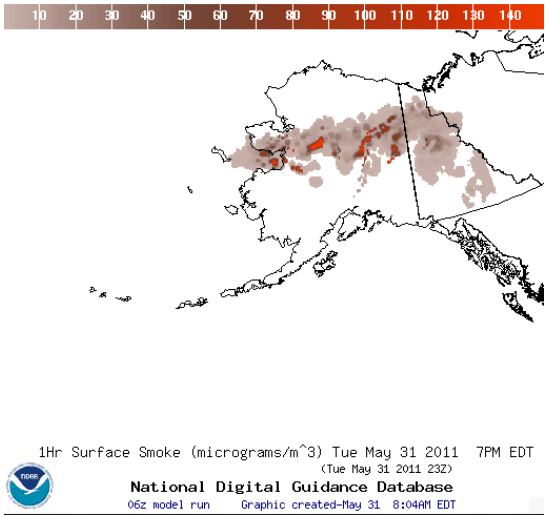
	2011	2012 changes		2013 changes
Operational **CB-IV**	WRF-NMM, 2005 NEI	NMM-B, 2012 emission projections		Reusing 2012 emissions
Experimental **CB05**	WRF-NMM, 2005 NEI	NMM-B, 2012 emission projections	LBC, dry deposition, minimum PBL height	Reusing 2012 emissions

Smoke predictions

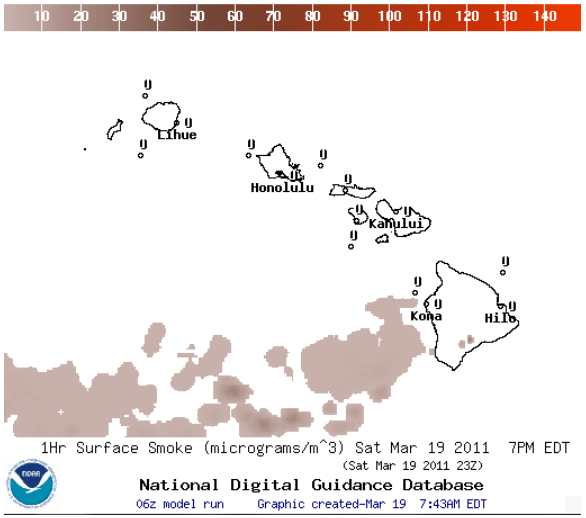
Operational predictions at http://airquality.weather.gov



Surface Smoke

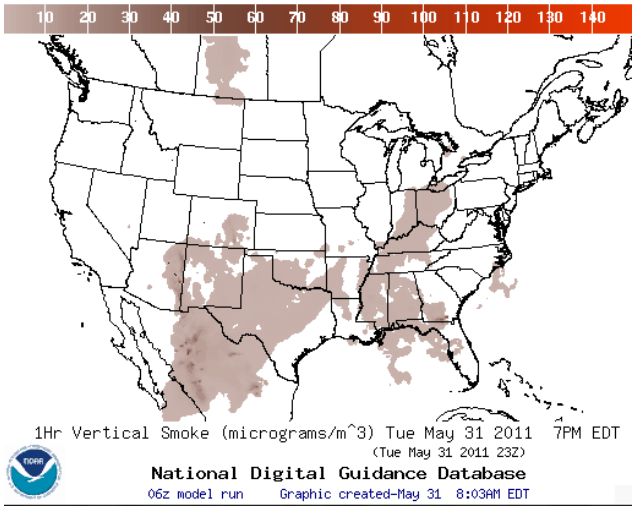


Surface Smoke

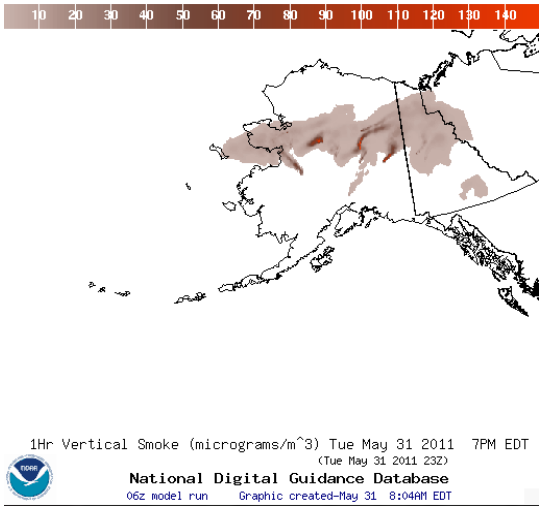


Surface Smoke

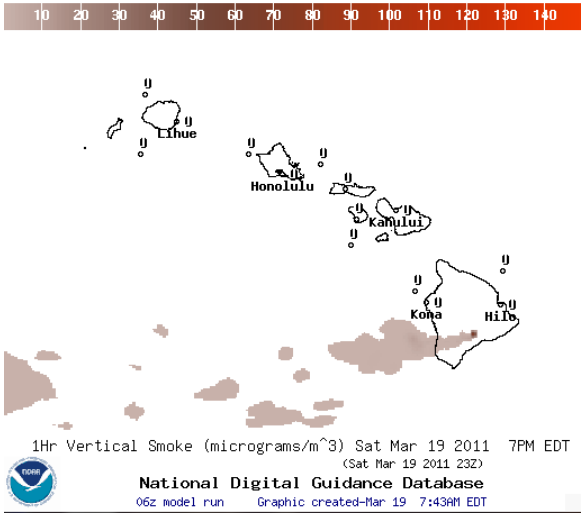
Vertical Smoke



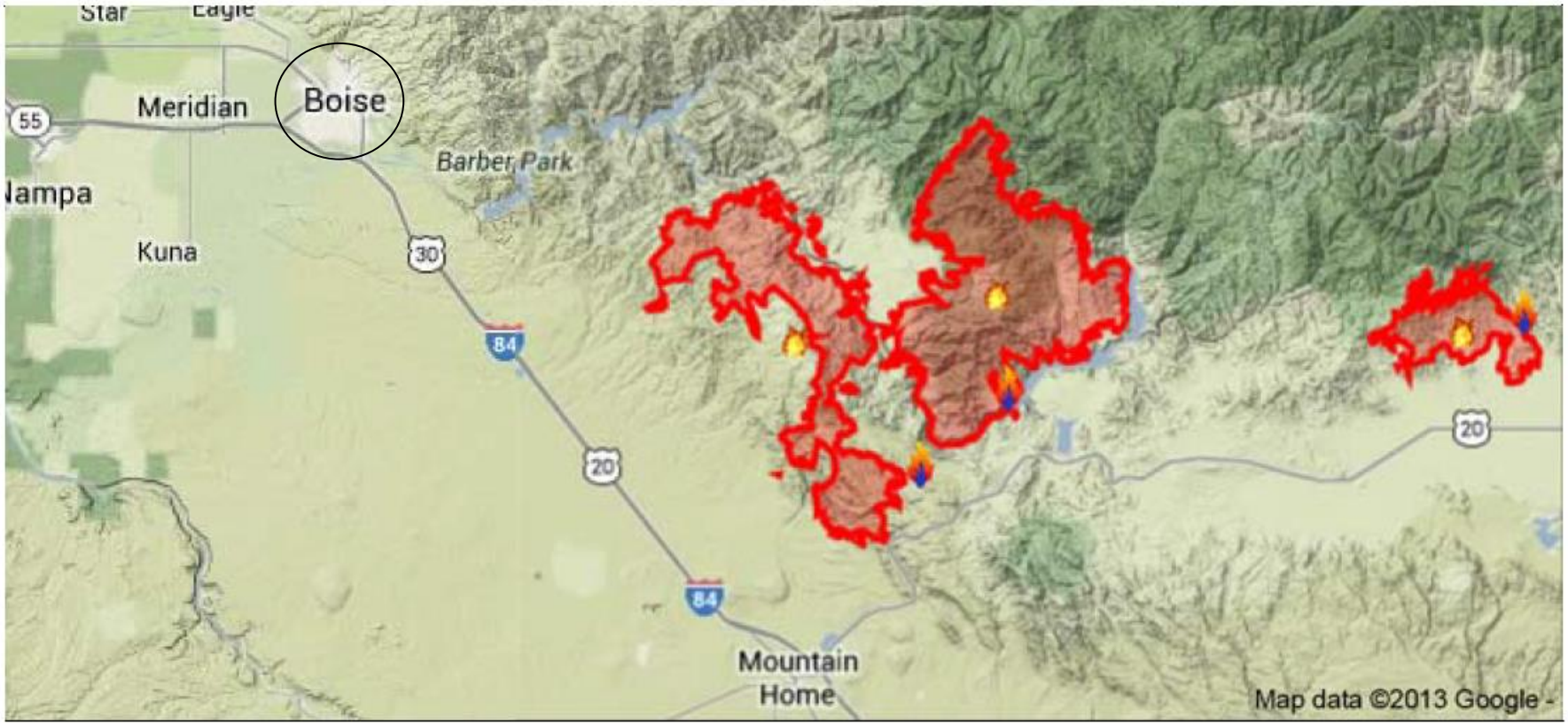
Vertical Smoke



Vertical Smoke



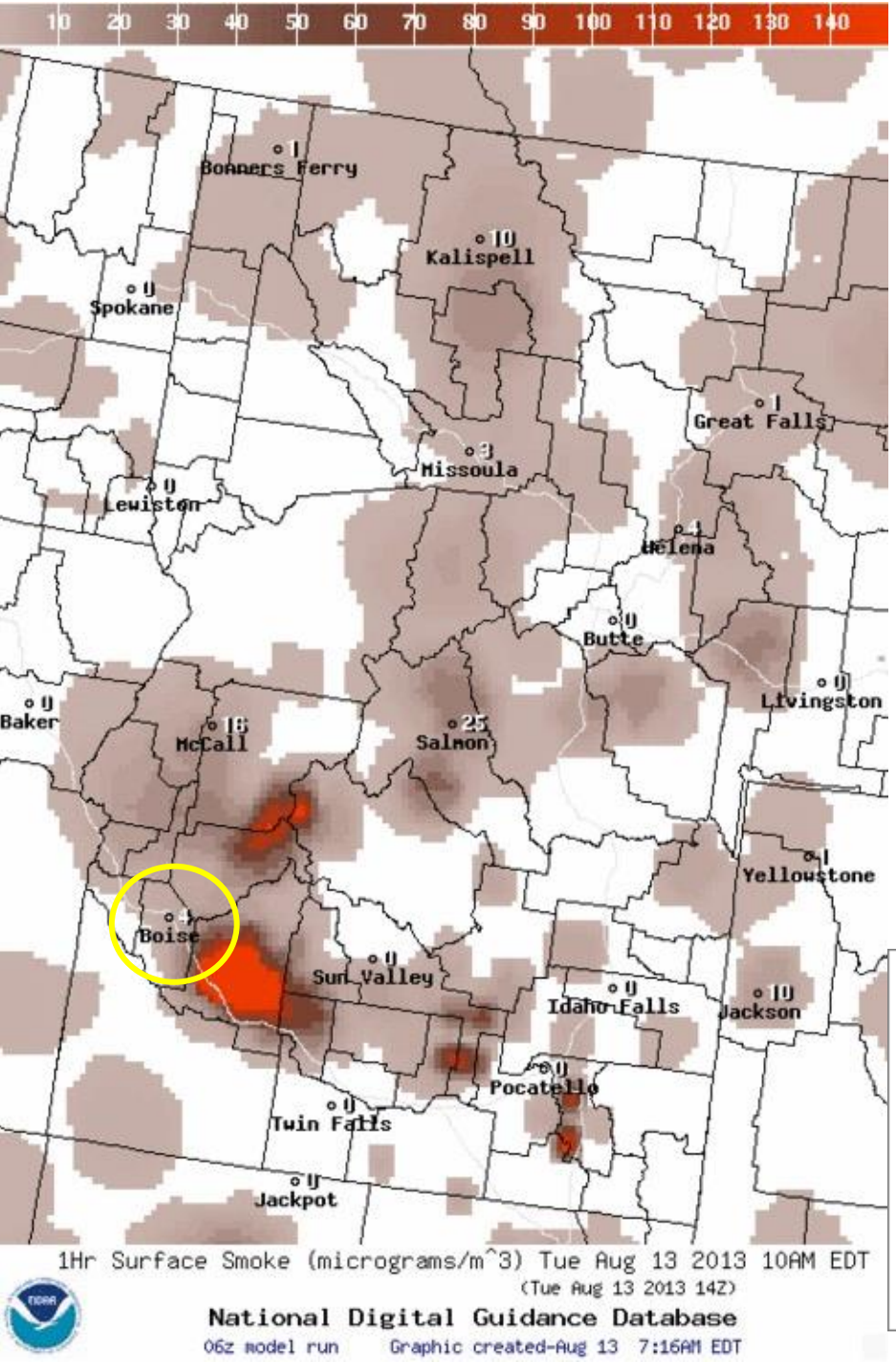
Example: Pony Complex Fire

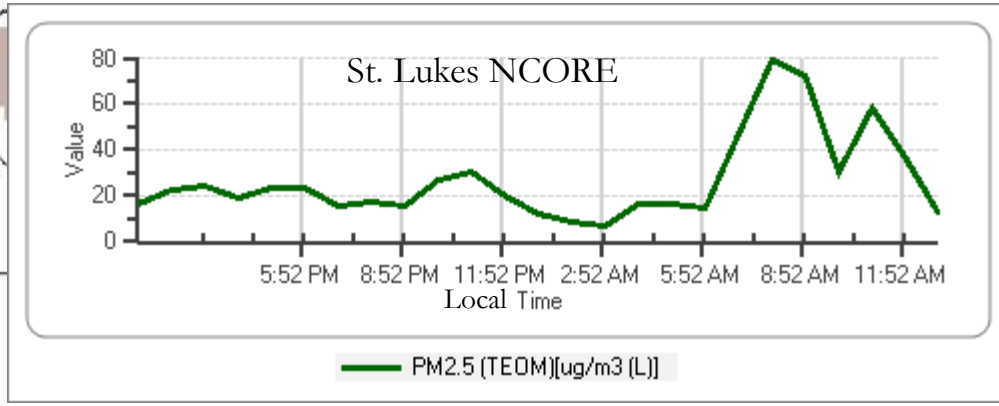


Wildfire near Mountain Home, ID caused by lightning on August 8, 2013
August 13, 2013: 143,900 acres burned and 30% contained

NAQFC smoke predictions

Predictions from the morning of August 13 show smoke impacting Boise in the morning on August 14.





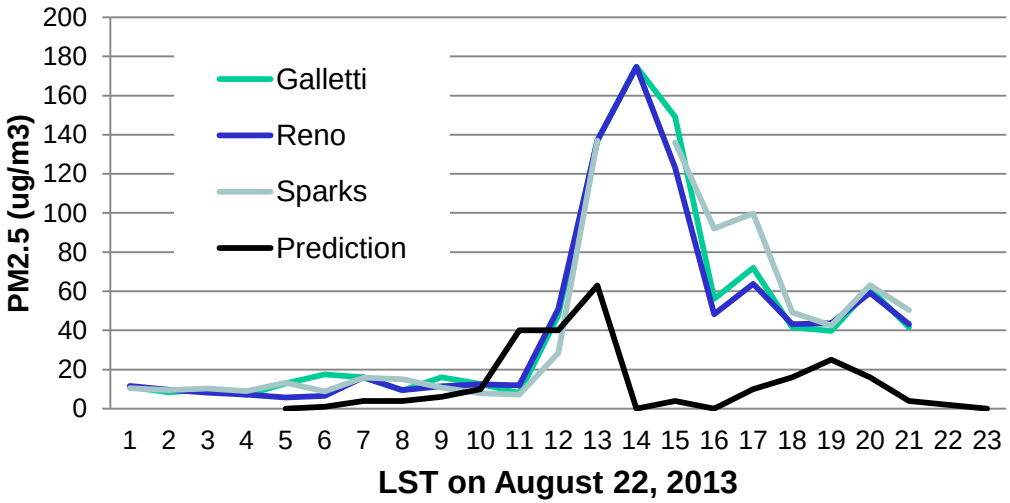
Rim Fire in California

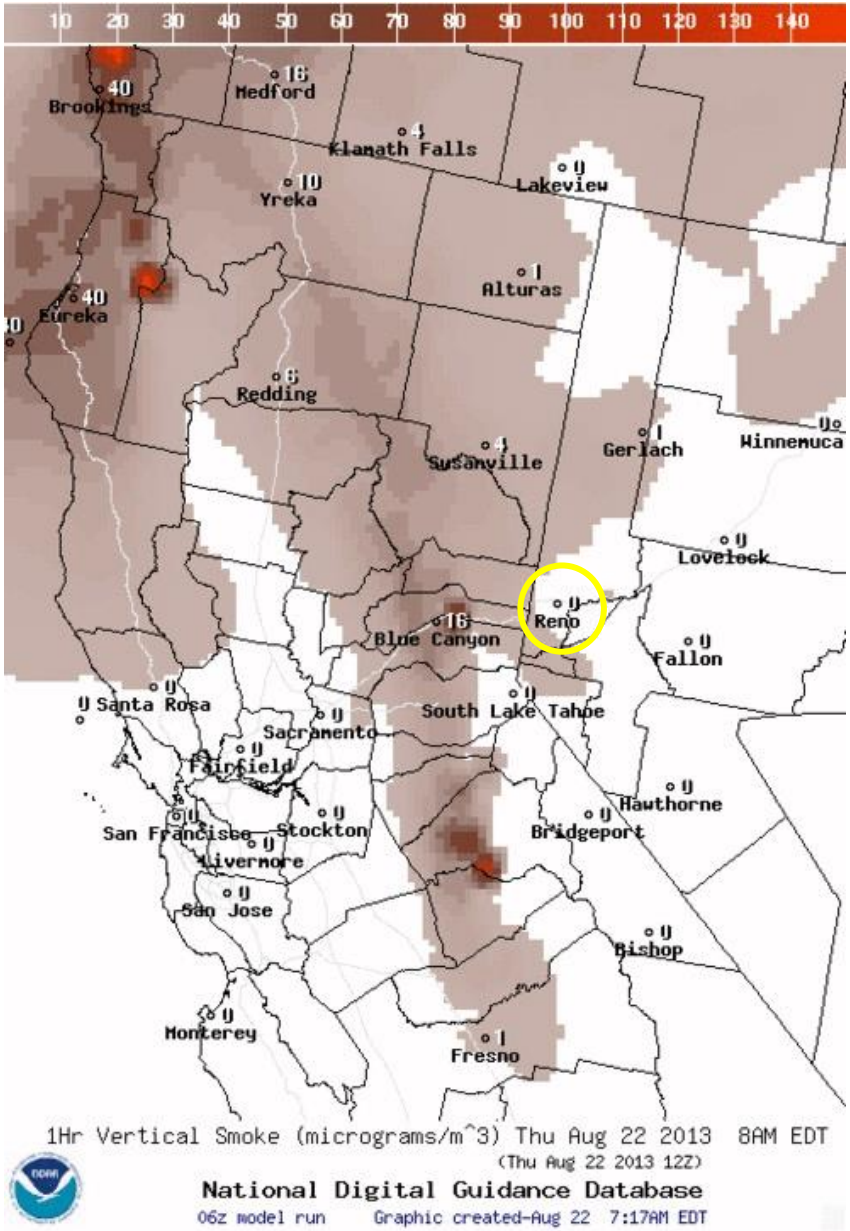
The largest wildfire ever recorded in Yosemite National Park. Fire started on August 17. As of 9/25/2013 it was 85% contained.

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.

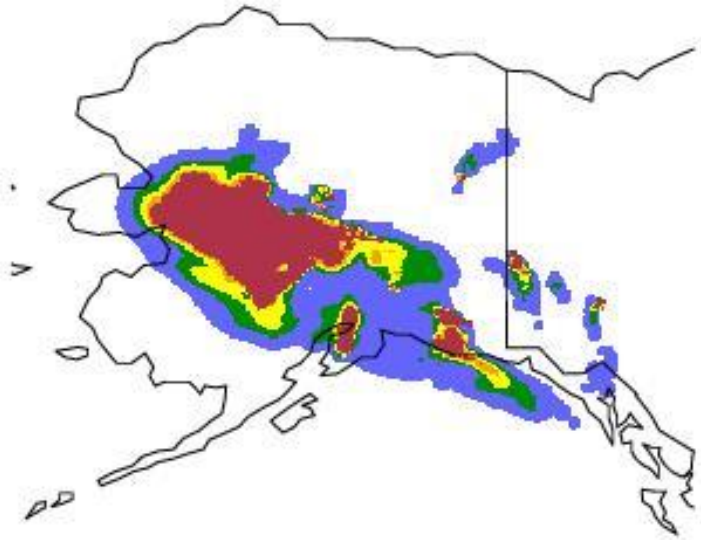
Observed PM2.5 concentrations peaked around 2 pm LST, predicted concentrations at the surface peaked at 1 pm, and the highest predicted concentration was lower than observed





Smoke Verification:
July 13, 2009

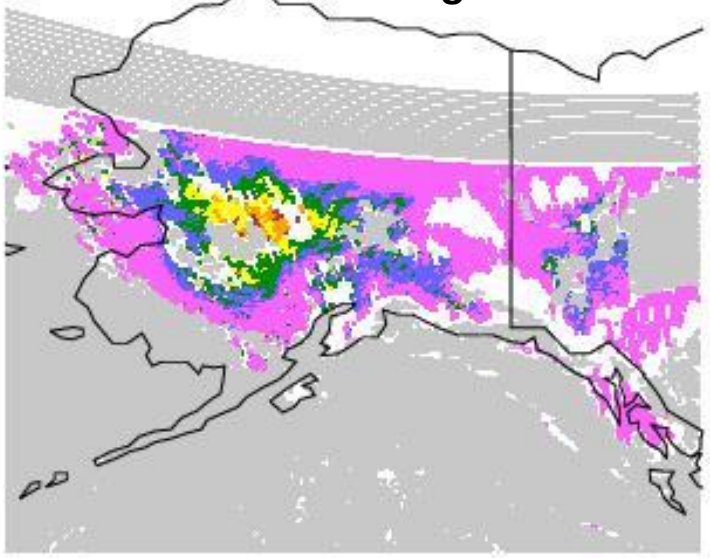
7/13/09, 17-18Z, Prediction:

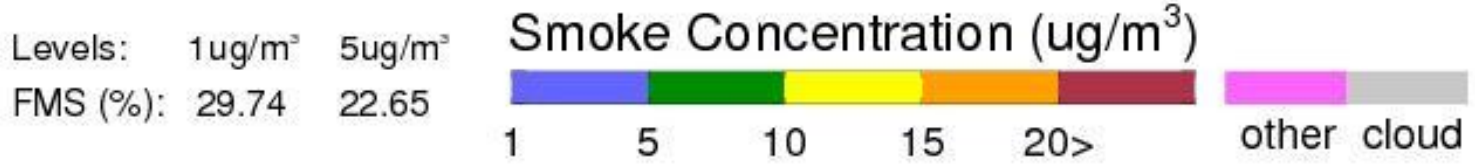


7/13/09, 17-18Z, Observation:

GOES smoke product: Confirms areal extent of peak concentrations

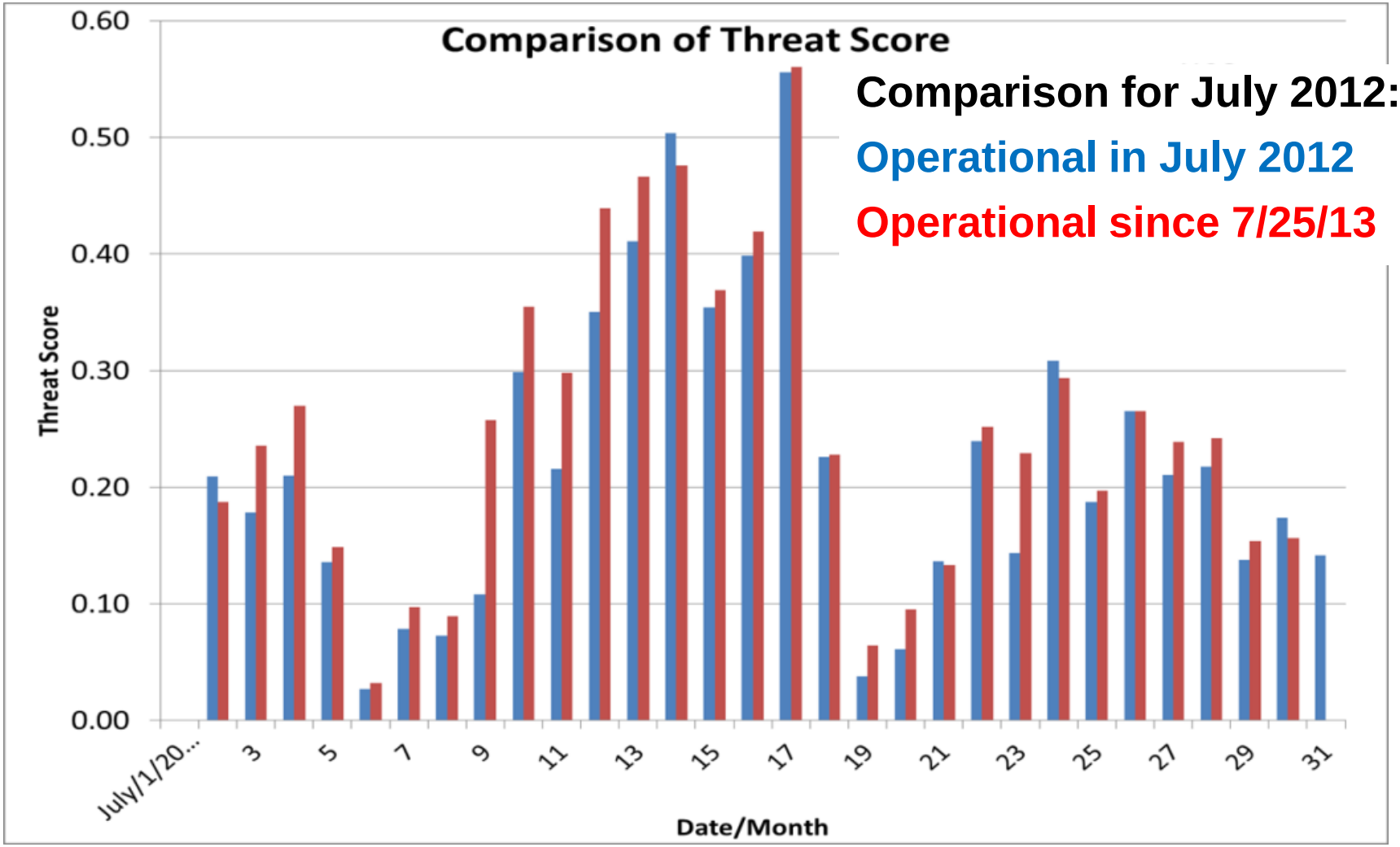
FMS = 30%, for column-averaged smoke > 1 ug/m^3





Manuscript about smoke verification product is in preparation

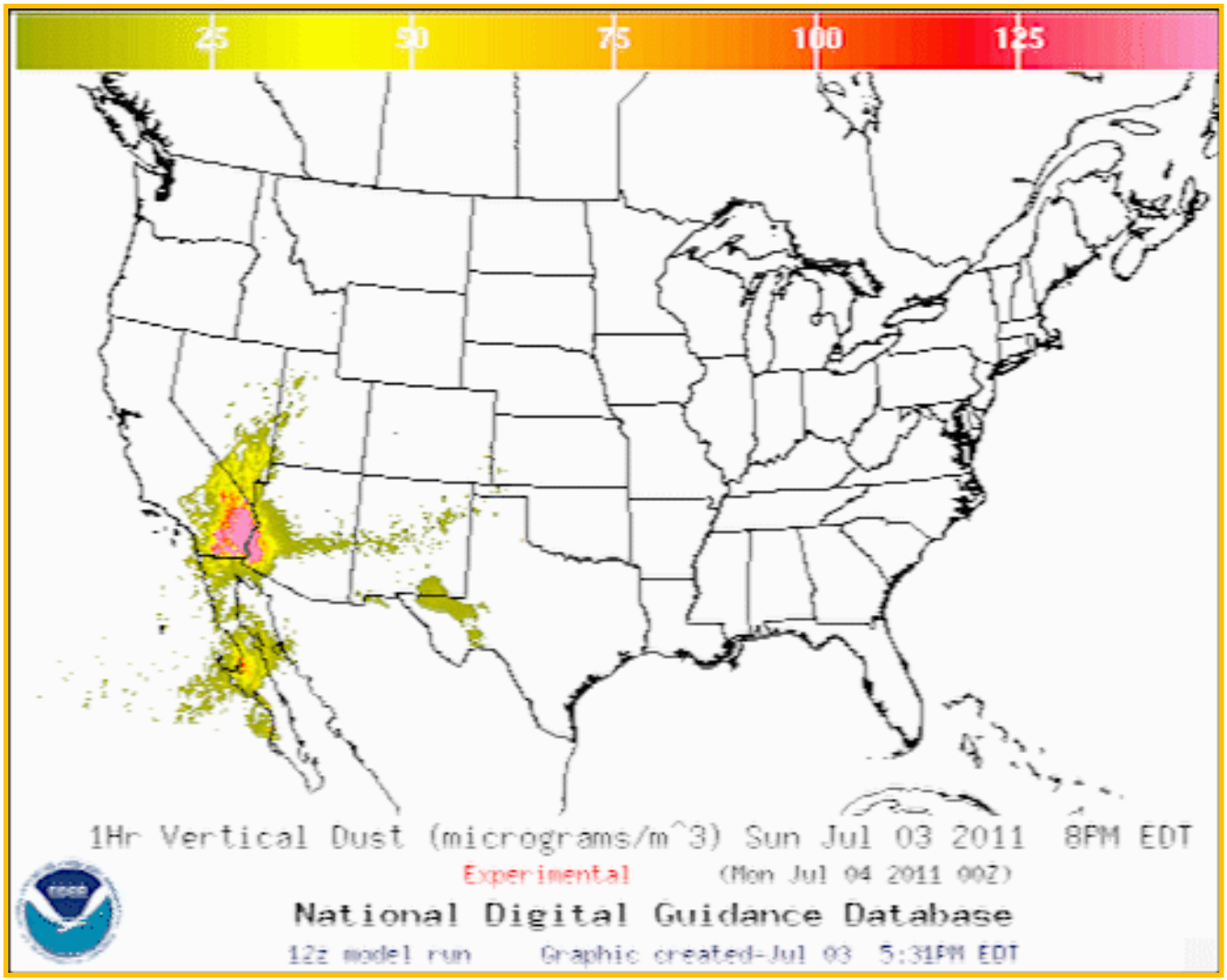
Verification of smoke predictions against GOES smoke retrievals



Testing of updates: increased plume rise, decreased wet deposition, changes in daily emissions cycling

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 (Zeng and Kondragunta)

Phoenix, AZ dust event on July 5, 2011

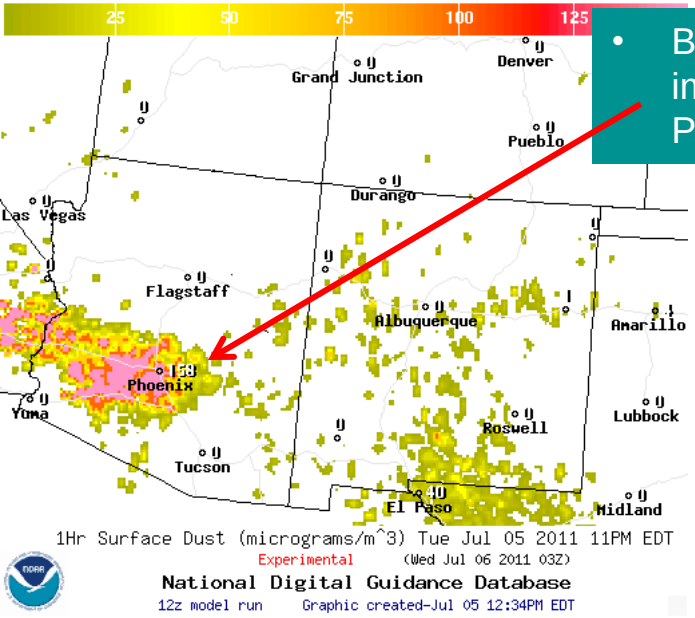
- Massive dust storm hit Phoenix, AZ in the evening on July 5, 2011
- Cloud was reported to be 5,000 feet when it hit, radar shows heights from 8,000-10,000 feet tall and 50 miles wide

Source: http://www.wrh.noaa.gov/psr/pns/2011/July/DustStorm.php

Source: http://www.huffingtonpost.com/2011/07/06/phoenix-dust-storm-photos-video_n_891157.html

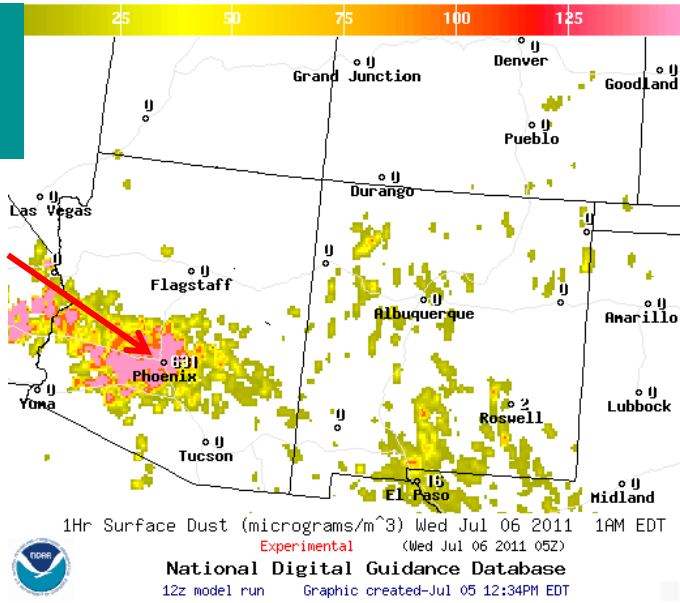
- Originated from convection near Tucson
- Stopped air traffic for over an hour
- Arizona DEQ reported a PM10 concentration of 6,348 ug/m^3 during peak of storm at site in downtown Phoenix
- Storm moved through Phoenix at 30-40 mph

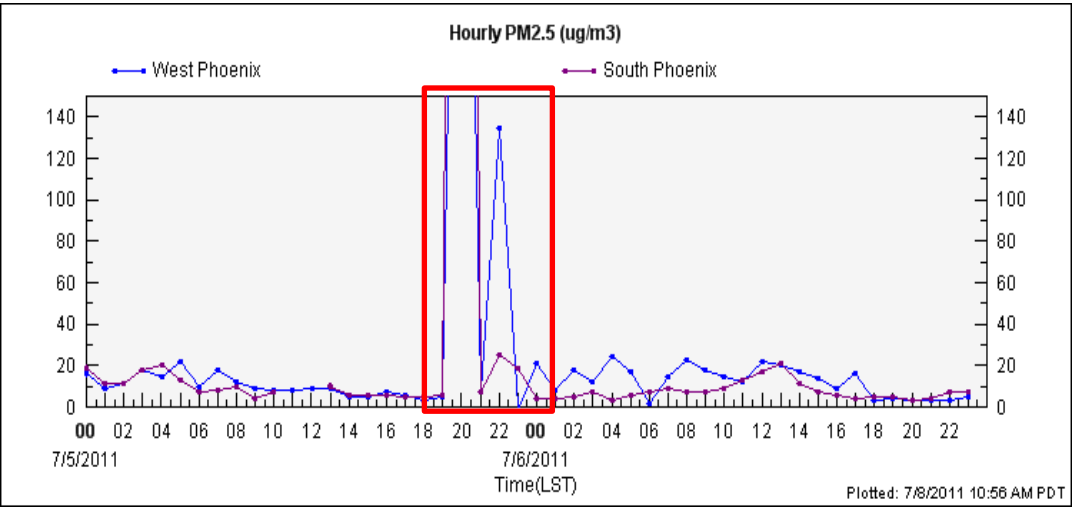
PM 2.5 observations in Phoenix



- Based on observations, height of impact on Phoenix was between 8 PM and 10 PM LST

Predicted surface dust concentrations:
- 8PM 158 ug/m^3
- 10PM 631 ug/m^3



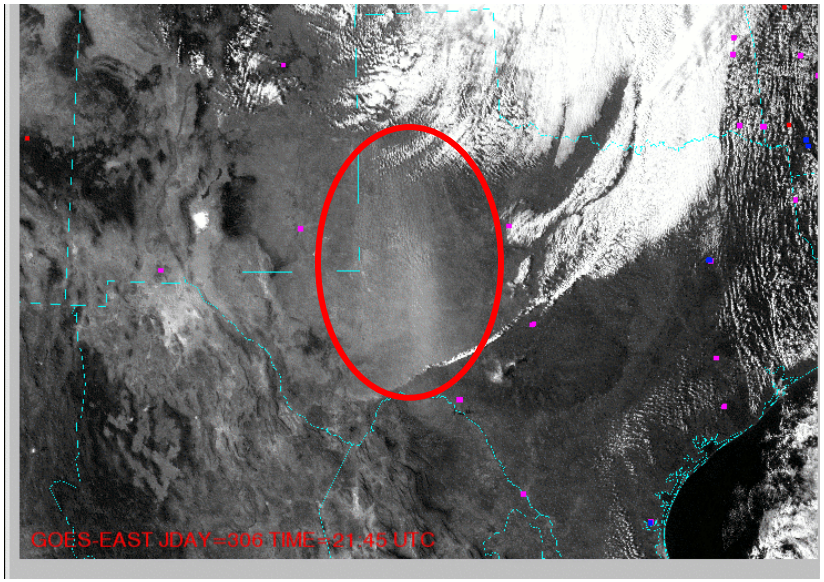


- Timing of storm based on comparing predictions to observations looks accurate (albeit perhaps early – 63 ug/m^3 predicted at 7 PM for Phoenix), however, the predictions keep the high levels seen at 10 PM LST for the next four to five hours, not seen in the observations

Dust prediction updates

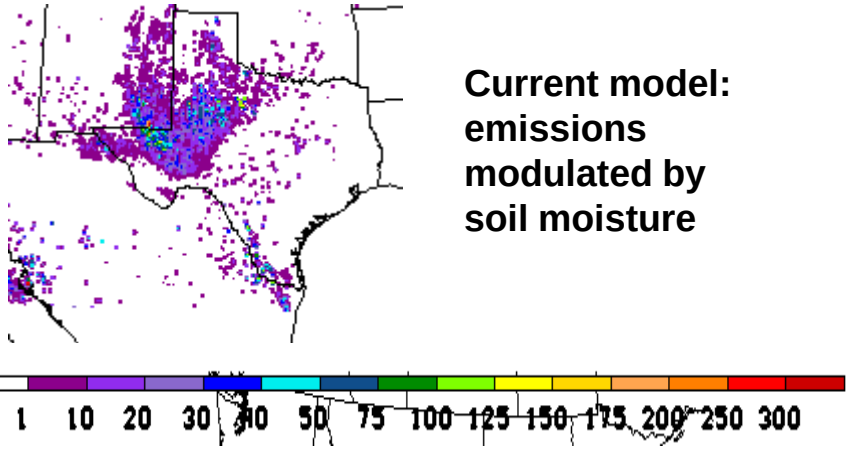
- **Modulating dust emissions using real-time soil moisture information**

Texas dust event on November 2, 2011



A widespread dust event occurred on Nov 2 beginning around 18Z in west central Texas. This event was the result of ~25kt synoptic scale winds ahead of a cold front. Through 0Z (Nov 3) the dust blew south covering all of west Texas and parts of southeast New Mexico.

Predicted dust concentration (ug/m3) at the surface

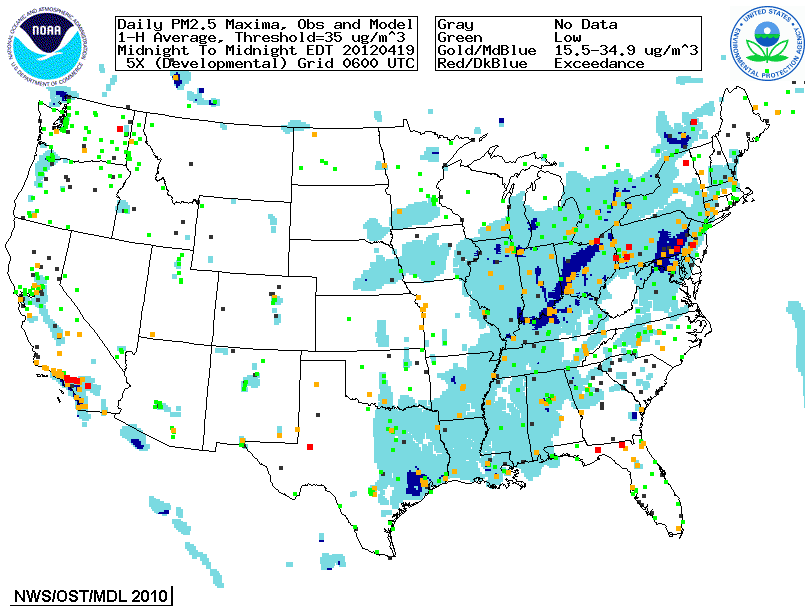


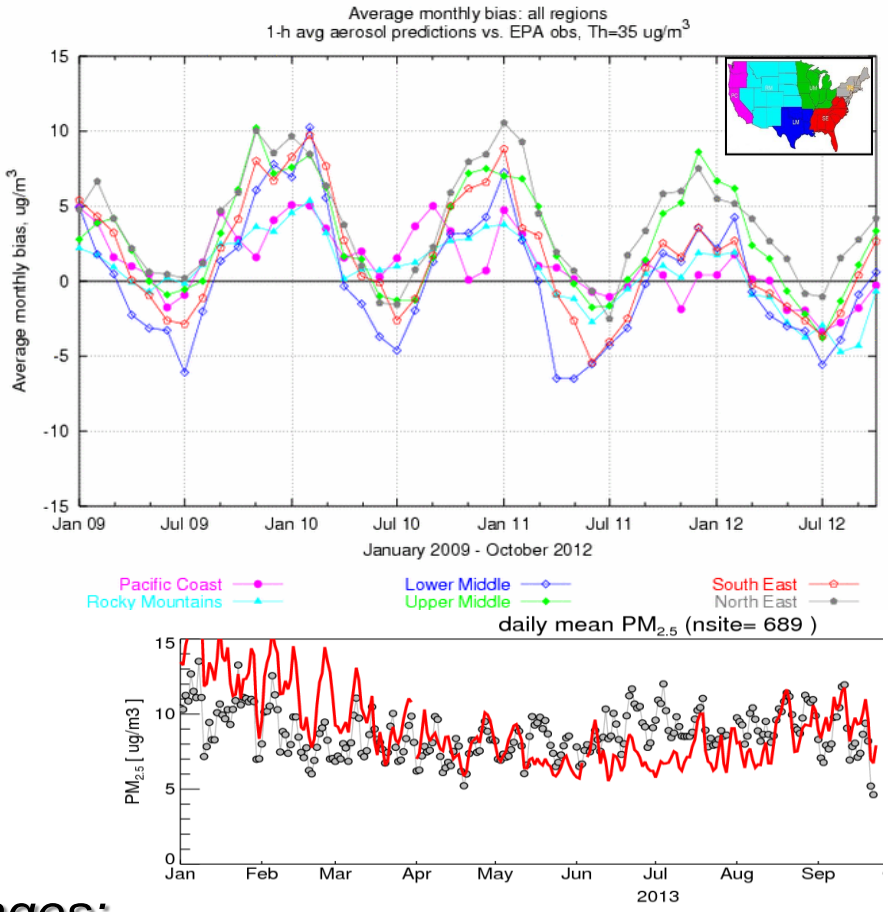
Current model: emissions modulated by soil moisture

Previous model: emissions not modulated by soil moisture

- **Longer time step** (10 min vs. 6 min) provides comparable predictions, but 30% faster
- **Reduced wet deposition**

Quantitative PM performance





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

Wildfire smoke emissions not included

Challenges:

- *Aerosol simulation using emission inventories* show seasonal bias: winter, overprediction; summer, underprediction
- *Intermittent sources*
- *Chemical boundary conditions/trans-boundary inputs*

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 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)*

Summary

US national AQ forecasting capability:

- Operational **ozone** prediction nationwide
- Operational **smoke** prediction nationwide
- Operational **dust** prediction for CONUS sources
- **Experimental ozone** predictions for CONUS
- **Developmental PM2.5** predictions with NEI sources

If/when resources allow we plan to:

- Maintain operational AQ predictions
- Improve and transition currently experimental ozone into operations
- Use lateral boundary conditions from global dust predictions in testing of PM2.5 predictions
- Include intermittent smoke and dust emissions into testing of PM2.5 predictions

Acknowledgments:
AQF Implementation Team Members

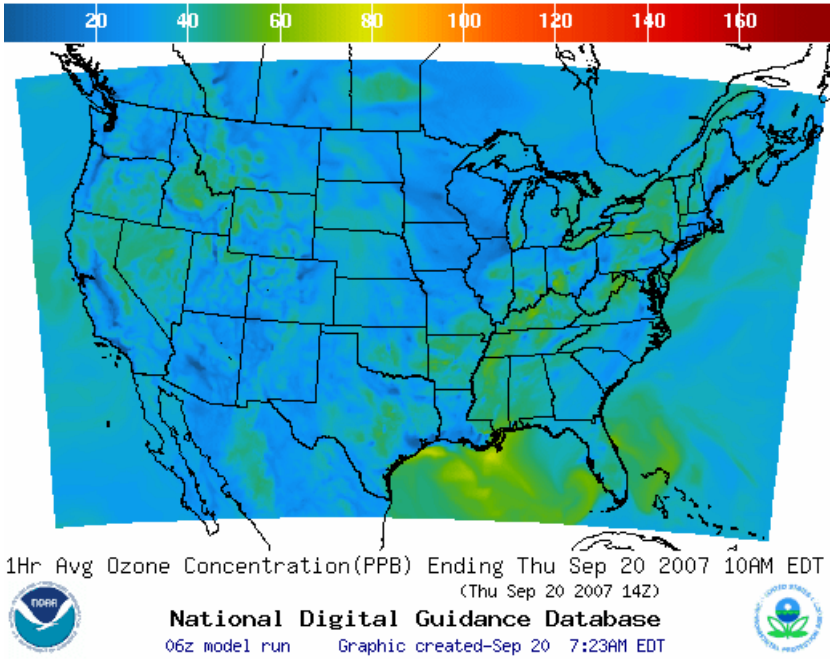
Special thanks to Paula Davidson, OST chief scientist and former NAQFC Manager and to Jim Meager former NOAA AQ Matrix Manager

NOAA/NWS/OST	***Ivanka Stajner***	***NAQFC Manager***
NWS/OCWWS	***Jannie Ferrell***	***Outreach, Feedback***
NWS/OPS/TOC	***Cynthia Jones***	***Data Communications***
NWS/OST/MDL	***Jerry Gorline, Marc Saccucci, Dave Ruth***	***Dev. Verification, NDGD Product Development***
NWS/OST	***Sikchya Upadhayay***	***Program Support***
NESDIS/NCDC	***Alan Hall***	***Product Archiving***
NWS/NCEP		
Jeff McQueen, Jianping Huang		**AQF model interface development, testing, & integration**
***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**
Dan Starosta, 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**
Hyun-Cheol Kim		
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

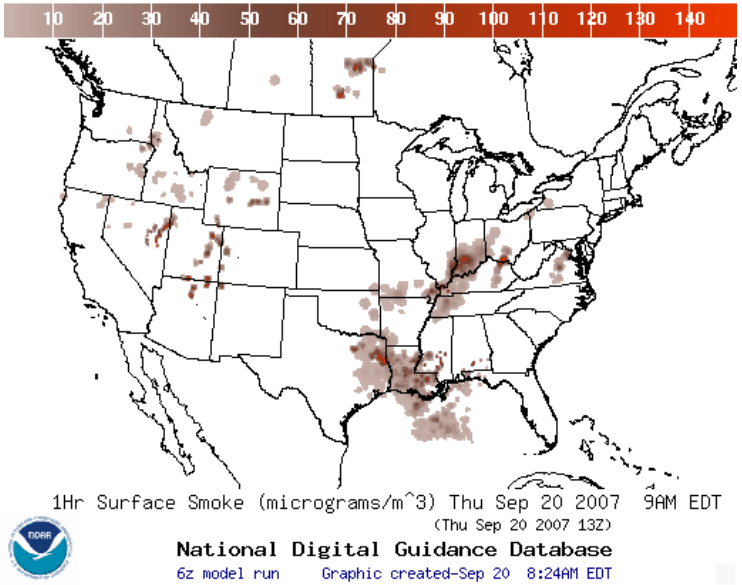
Operational AQ forecast guidance

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

Backup

Smoke Forecast Tool
Major Components

NWP Model

NAM/NMMB

NOAA/NWS

Weather Observations

NWP Post-processors for AQ Modules

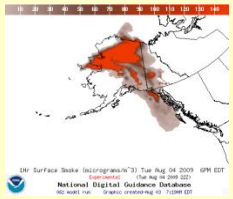
NESDIS HMS Fire Locations

HYSPLIT Module:

NOAA/OAR

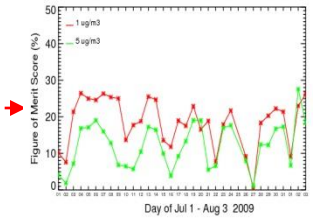
USFS's BlueSky Emissions Inventory:

USFS



Verification:

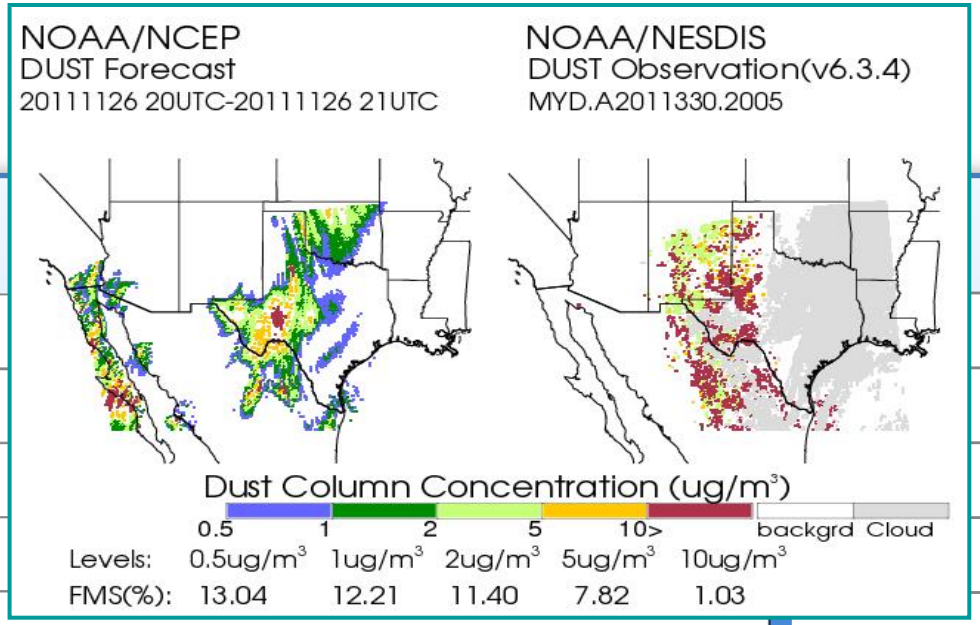
NESDIS/GASP Smoke



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



Verification of dust predictions

with 10 min and 6 min time step