National Air Quality Forecast Capability in the United States

Ivanka Stajner

NOAA NWS/OST

- Background on NAQFC
- Progress in 2011:
Ozone, Smoke, Dust, PM2.5
- Looking Ahead

IWAQFR

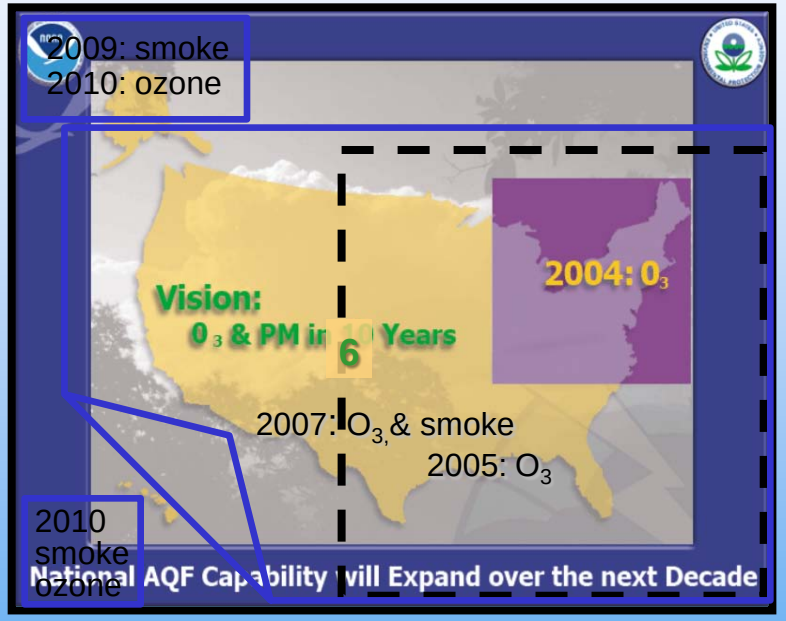
Potomac Maryland *November 29, 2011*

National Air Quality Forecast Capability
Current and Planned Capabilities, 11/11

- Improving the basis for AQ alerts
- Providing AQ information for people at risk

FY11 Prediction Capabilities:

- **Operations:**
  ***Ozone nationwide**: expanded from EUS to CONUS (9/07), AK (9/10) and HI (9/10)*
  ***Smoke nationwide**: implemented over CONUS (3/07), AK (9/09), and HI (2/10)*
- **Experimental testing:**
  Ozone predictions
  Dust predictions over CONUS
- **Developmental testing:**
  Ozone upgrades
  Components for particulate matter (PM) forecasts



Near-term Operational Targets:

- Higher resolution prediction

Longer range:

- Quantitative $PM_{2.5}$ prediction

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

Model Components: Linked numerical prediction system

Operationally integrated on NCEP's supercomputer

- *NCEP mesoscale NWP: NMMB*
- *NOAA/EPA community model for AQ: CMAQ*
- *NOAA HYSPLIT model for smoke prediction*

Observational Input:

- *NWS weather observations; NESDIS fire locations*
- *EPA emissions inventory*

Gridded forecast guidance products

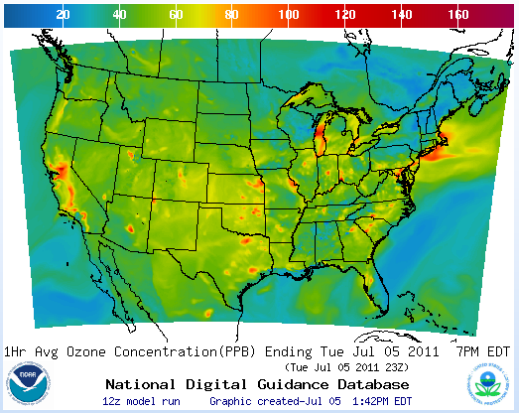
- *On NWS servers: airquality.weather.gov and ftp-servers*
- *On EPA servers*
- *Updated 2x daily*

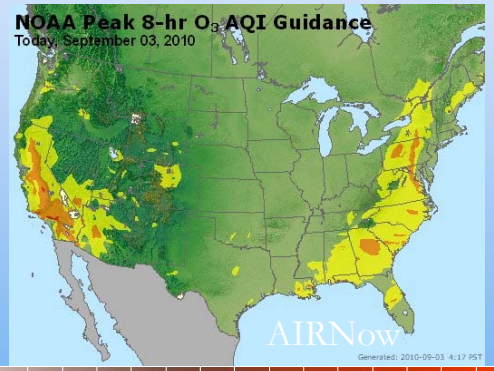
Verification basis, near-real time:

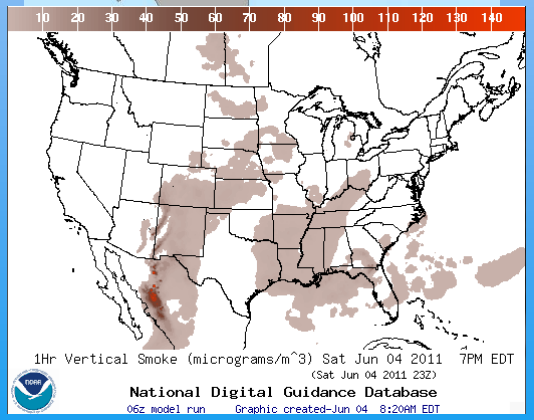
- *Ground-level AIRNow observations*
- *Satellite smoke observations*

Customer outreach/feedback

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







Progress in 2011

Ozone, smoke nationwide; dust testing

Ozone Upgrades: Nationwide predictions since 9/10

- *Operations: Updated emissions for 2011 (CEM point sources, DOE projection factors); Predictions driven by a new NMMB meteorological model (since 10/18/11)*
- *Experimental testing: CB-05 mechanism*
- *Developmental testing: Changing boundary conditions, dry deposition, PBL in CB-05; testing newer CMAQ 4.7.1 driven by NMMB meteorological model*

Smoke: Expanded Forecast Guidance Nationwide

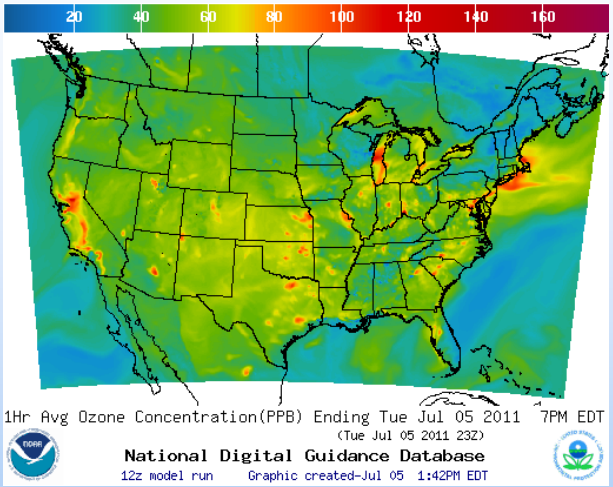
- *Developmental testing: Improvements to verification*

Aerosols: Developmental testing providing comprehensive dataset for diagnostic evaluations. (CONUS)

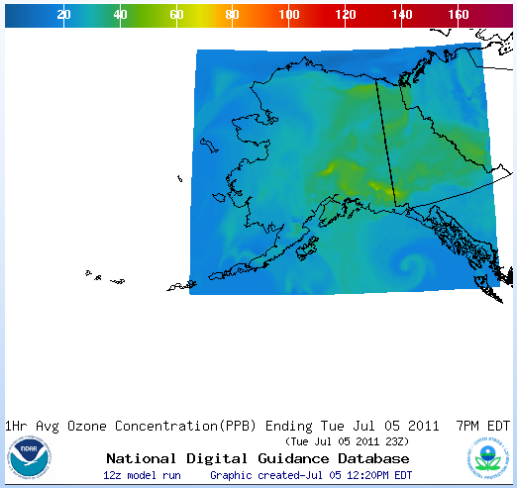
- *Testing CMAQ 4.6 and 4.7.1 with CB-05 chemical mechanism with AERO-4 aerosol modules*
  - Qualitative; summertime underprediction consistent with missing source inputs
- *Dust and smoke inputs: testing dust contributions to PM2.5 from global sources*
  - Real-time testing of combining smoke inputs with CMAQ-aerosol
- ***Experimental testing of dust prediction from CONUS sources***
- ***Real-time testing of assimilation of surface PM2.5 measurements***
- *R&D efforts continuing in chemical data assimilation, real-time emissions sources, advanced chemical mechanisms*

Operational Nationwide Ozone

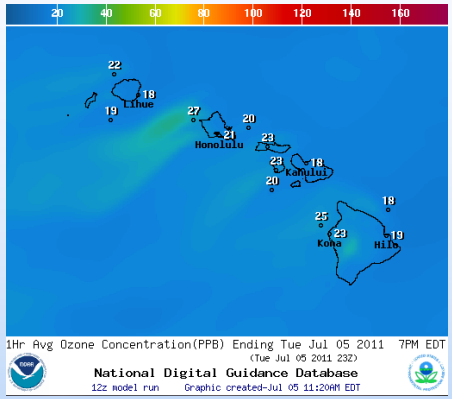
Operational predictions at http://airquality.weather.gov/



1-Hr Average Ozone

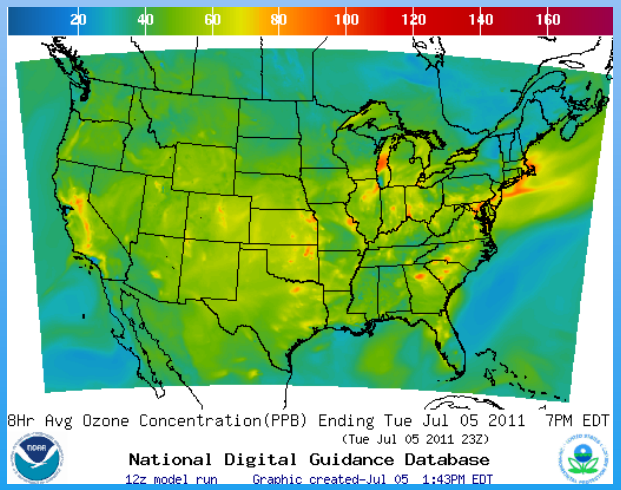


1-Hr Average Ozone

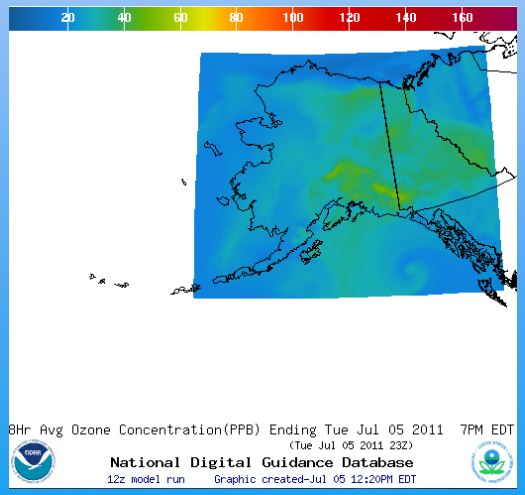


1-Hr Average Ozone

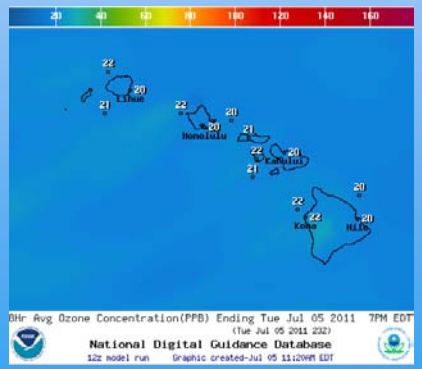
8-Hr Average Ozone



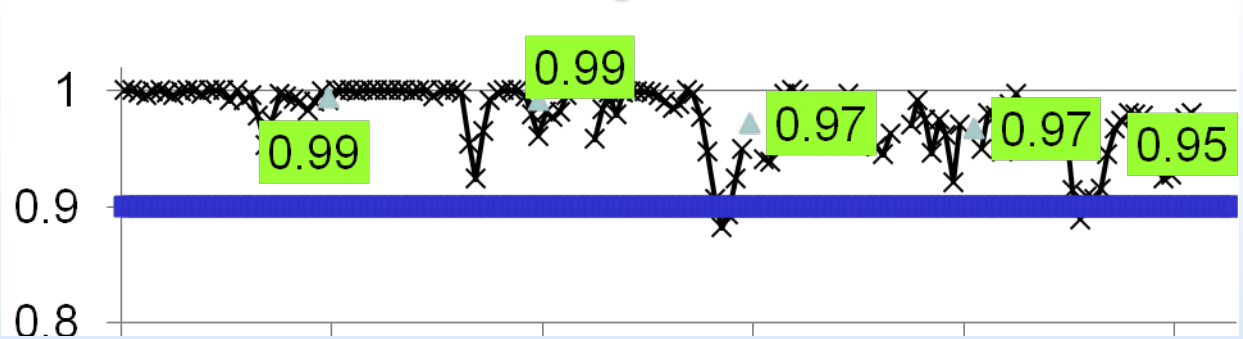
8-Hr Average Ozone



8-Hr Average Ozone

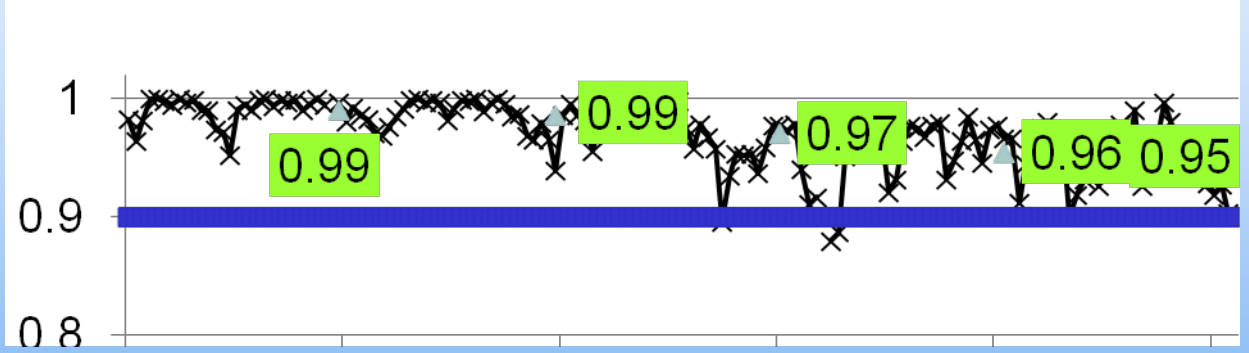


CONUS ozone prediction: Summary verification 2009 to 2011



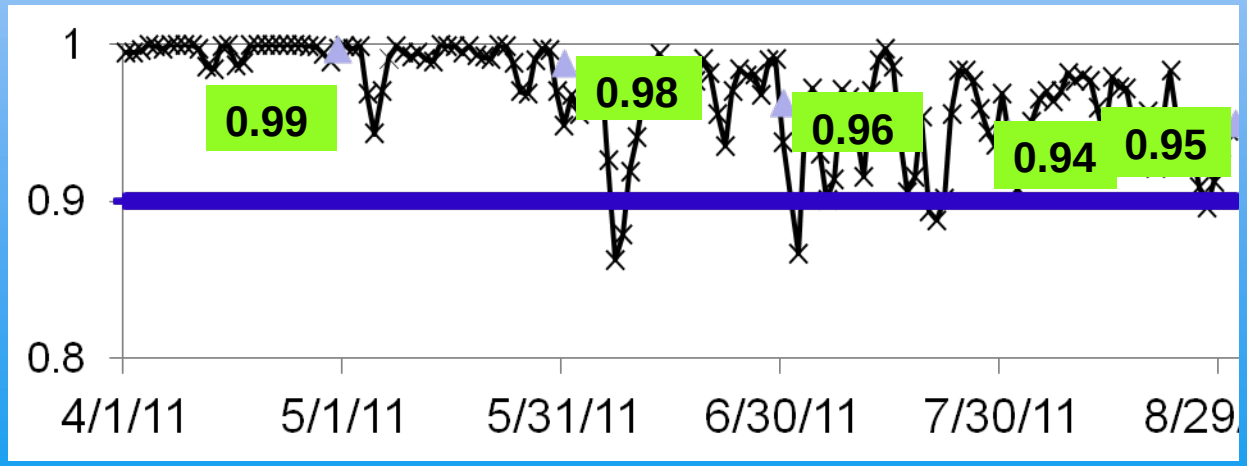
2009 Operational

CONUS, wrt 76ppb Threshold



2010 Operational

CONUS, wrt 76ppb Threshold



2011 Operational

CONUS, wrt 76ppb Threshold

Verification of experimental and developmental predictions: e.g. Youhua Tang with Discover-AQ data, Jerry Gorline for urban/rural, and Yunsoo Choi for weekly cycles

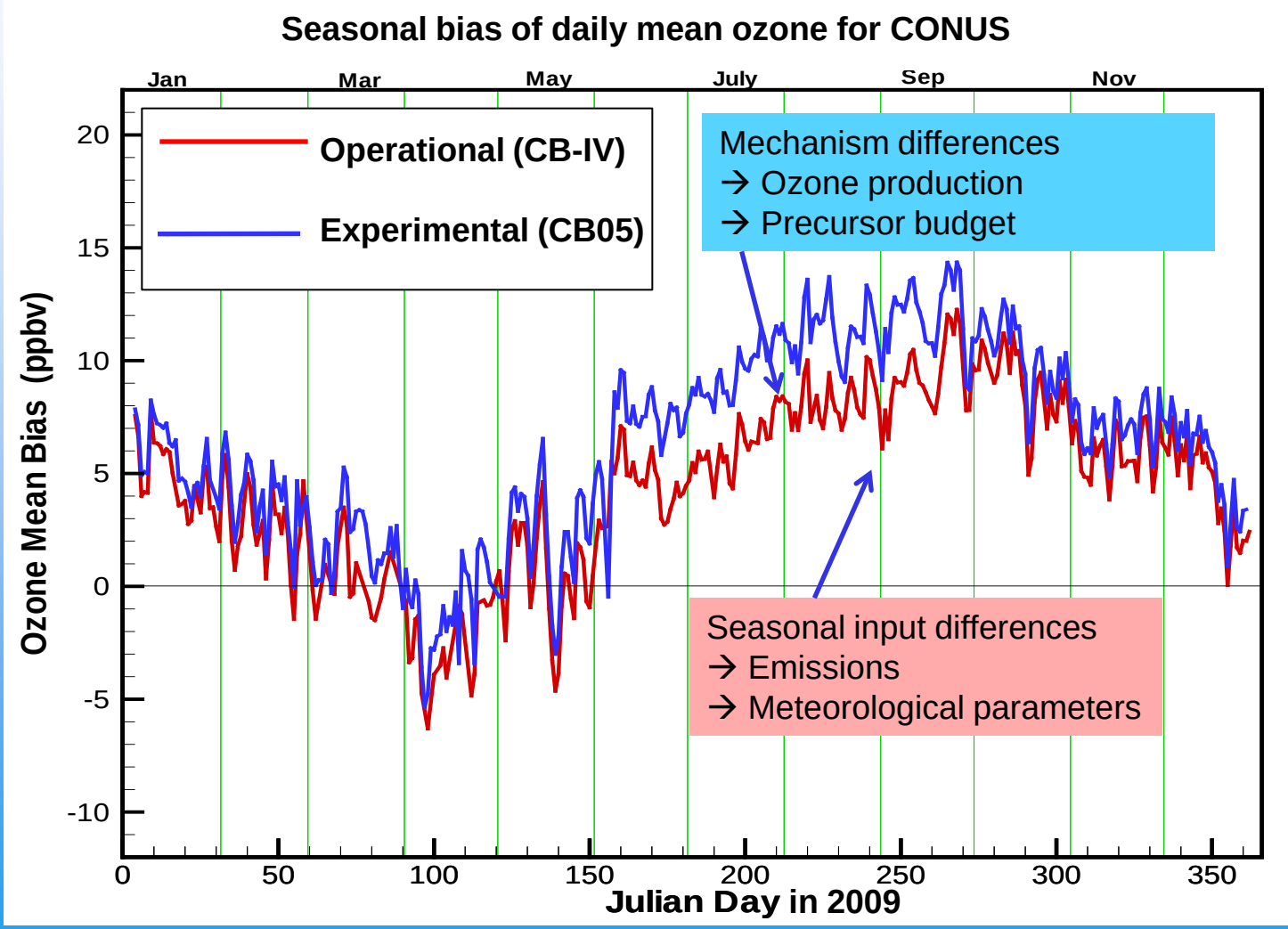
Chemical mechanism sensitivity analysis

Experimental ozone prediction (with CB05 mechanism) shows larger biases than operational ozone prediction (CB-IV mechanism)

- Summertime,
- Eastern US.

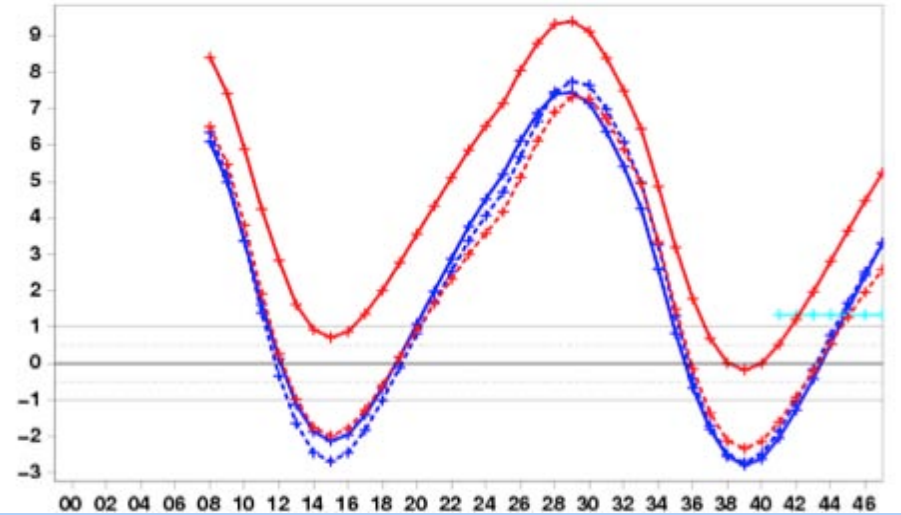
Sensitivity studies:

- Box model studies, e.g. organic nitrate treatment (Saylor and Stein – CB05 has more efficient ozone production for each NOx molecule)
- Emissions (Yunsoo Choi)
- Planning to update emissions

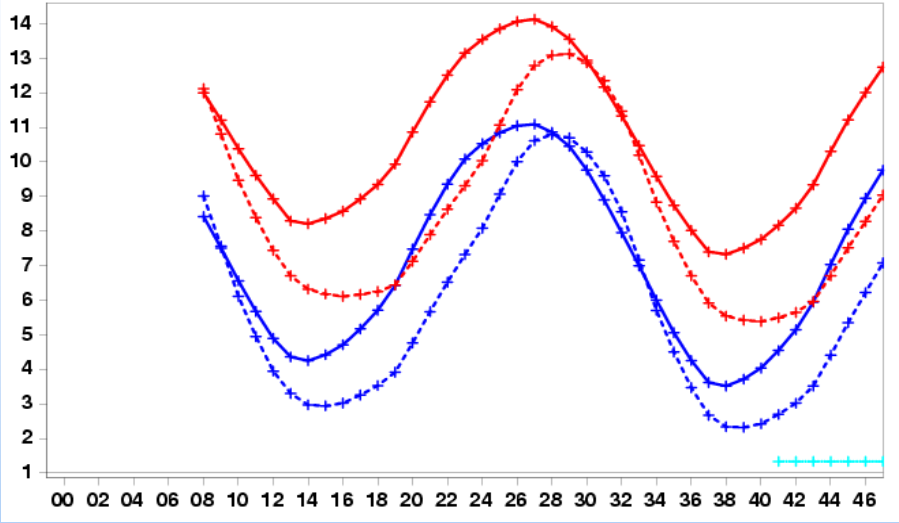


8h average ozone

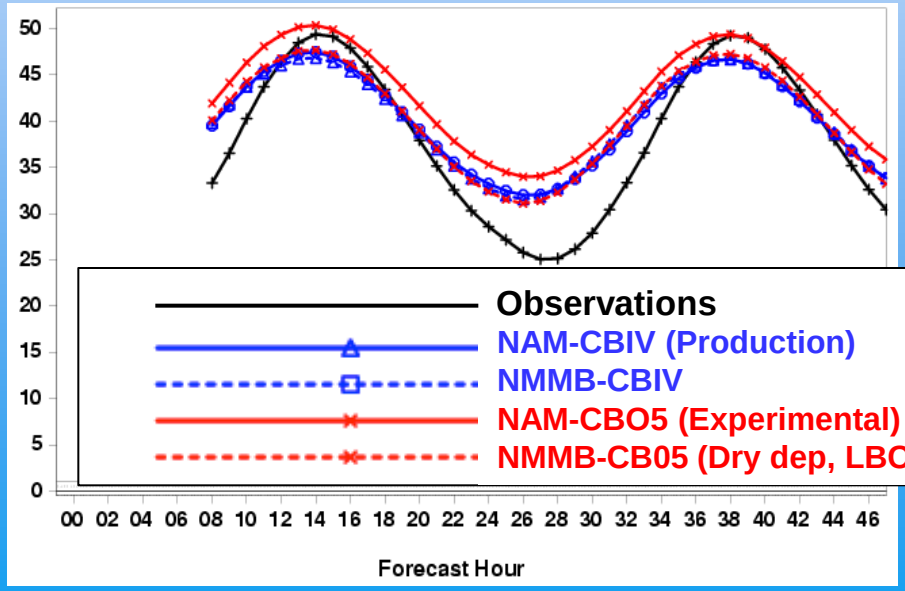
Western US model bias



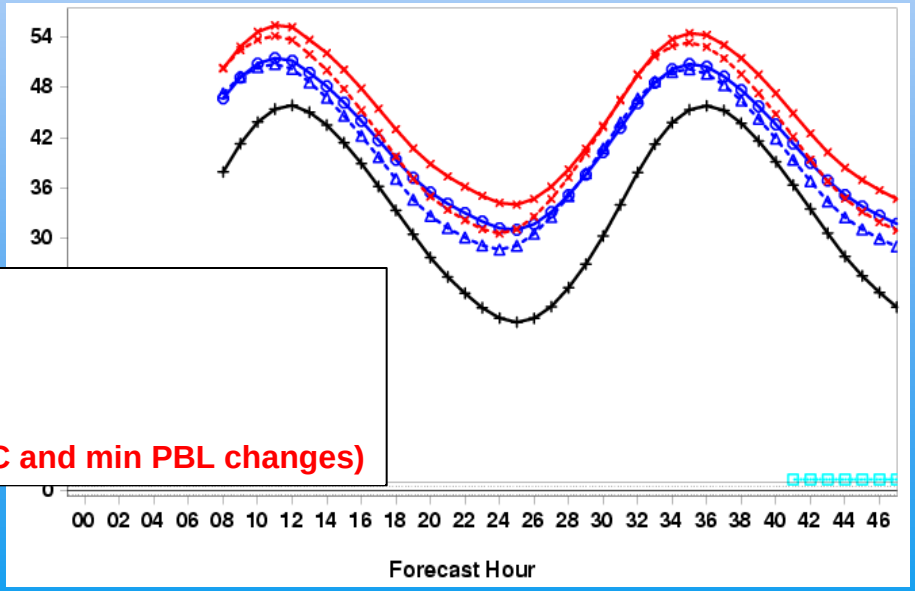
Eastern US model bias



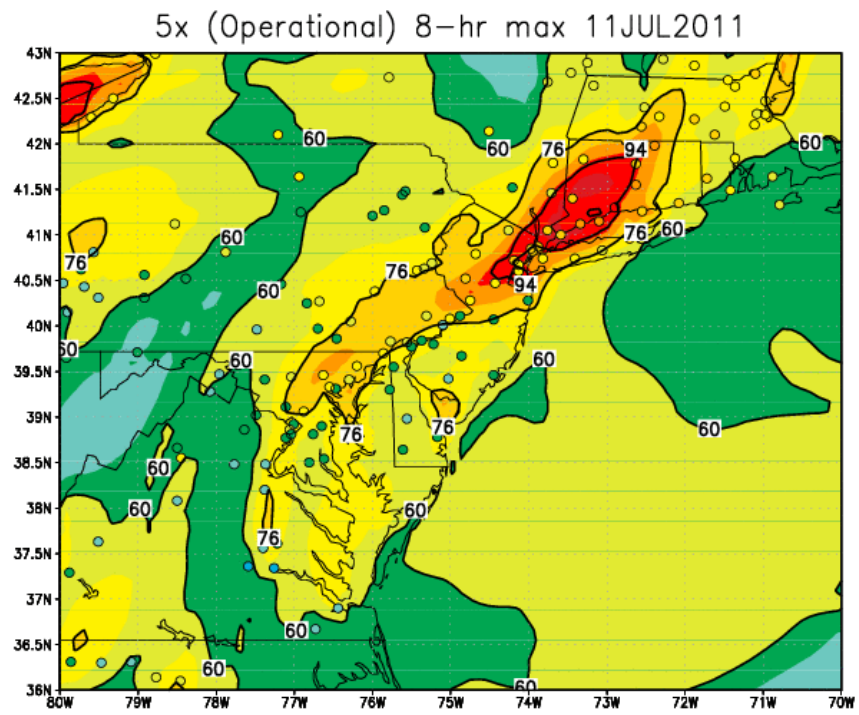
Western US observed and forecast mean



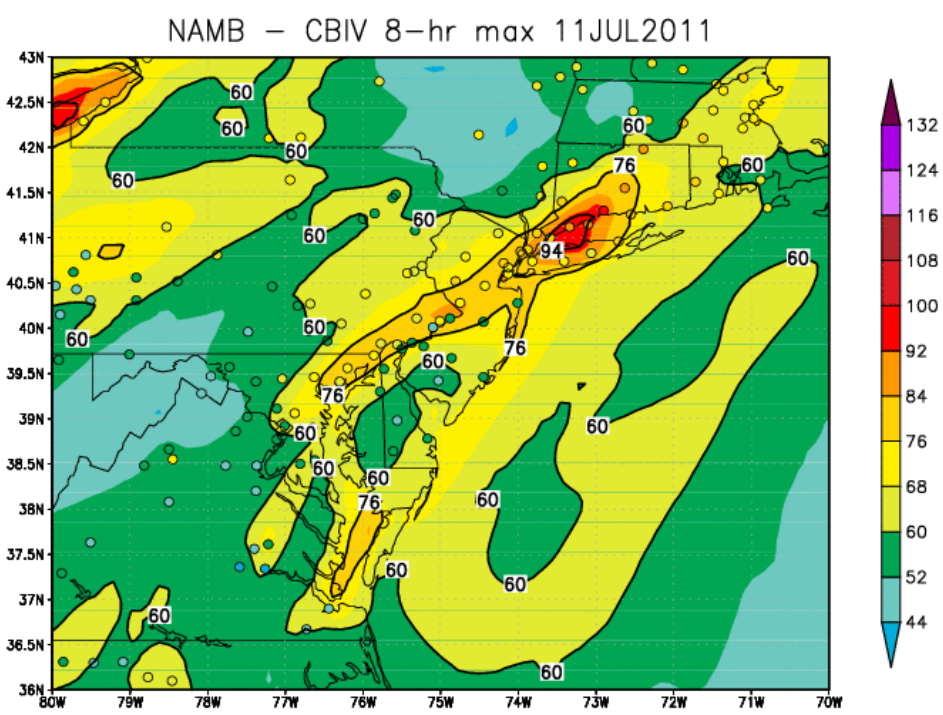
Eastern US observed and forecast mean



Impact of meteorological model



Operational NAM driven ozone predictions



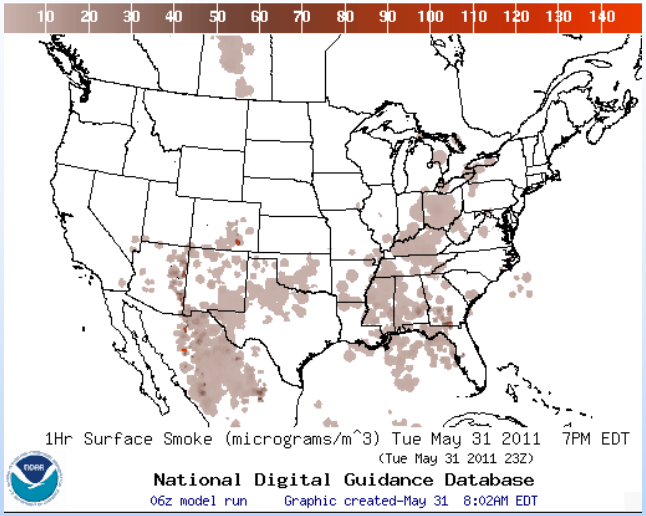
Testing of NMMB driven ozone predictions

Observed monitor values in the circles

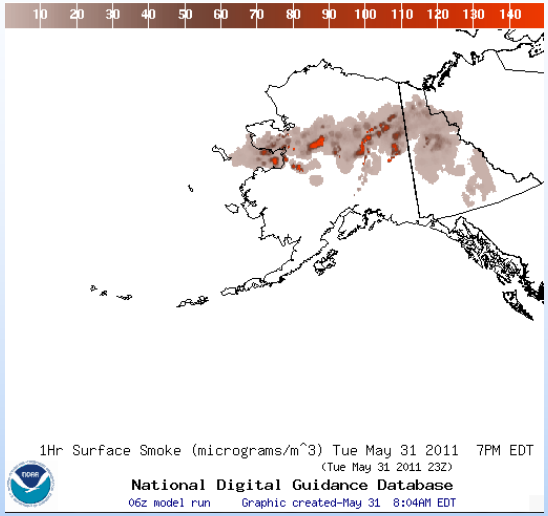
Impacts of NMMB meteorology and land use changes on air quality predictions discussed by Jeff McQueen

Operational Nationwide Smoke

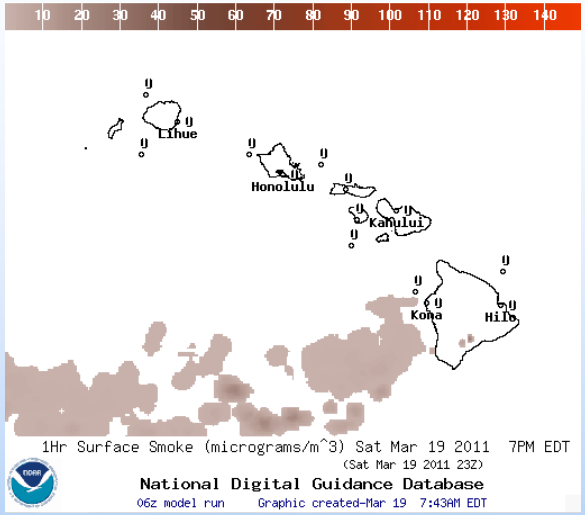
Operational predictions at http://airquality.weather.gov/



Surface Smoke

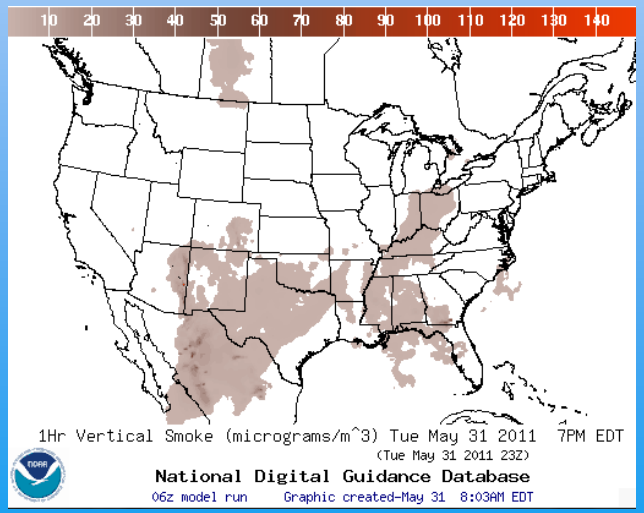


Surface Smoke

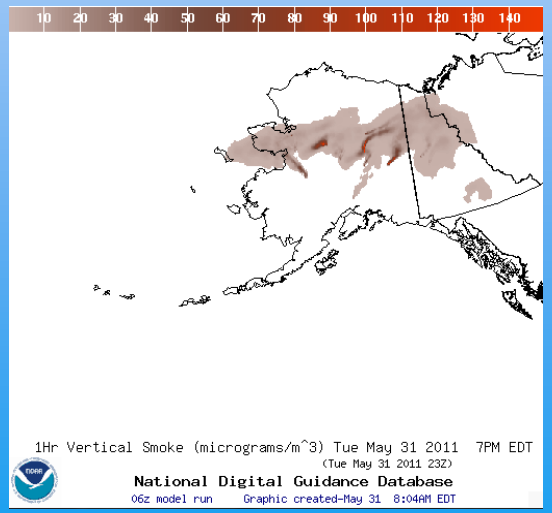


Surface Smoke

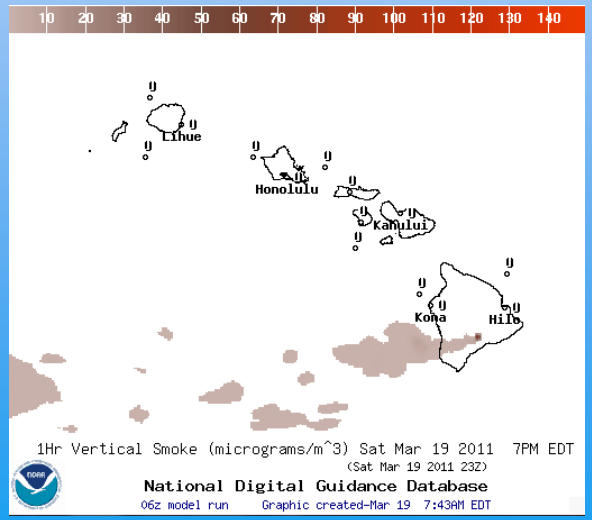
Vertical Smoke



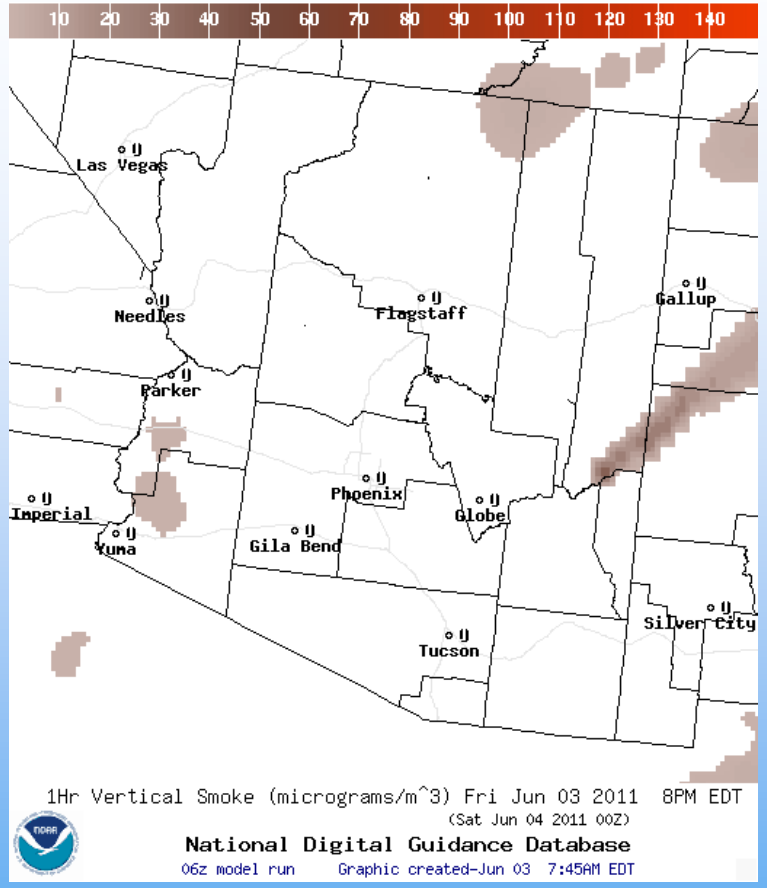
Vertical Smoke



Vertical Smoke



Wallow Wildfire in Arizona



Animation of NOAA's prediction of smoke concentrations in column

Wallow fire, June 3 [1]

June 6 (Luna, NM, AP)

- Fire began May 29, 2011, consumed more then 500,000 acres and 32 homes[3]
- 16 injuries[3]; more then 9000 people evacuated [2]
- 60mph winds contributed to its rapid spread [1]
- Code orange air quality forecast issued for Albuquerque for 4 days (June 6,8,9,13) - NWS prediction included high smoke concentrations
- Hazardous air quality predicted by NAQFC and observed in Springerville, AZ
- NAQFC joined coordination calls with state, local, federal agencies in AZ and NM, and USFS Fire Science Lab in Seattle

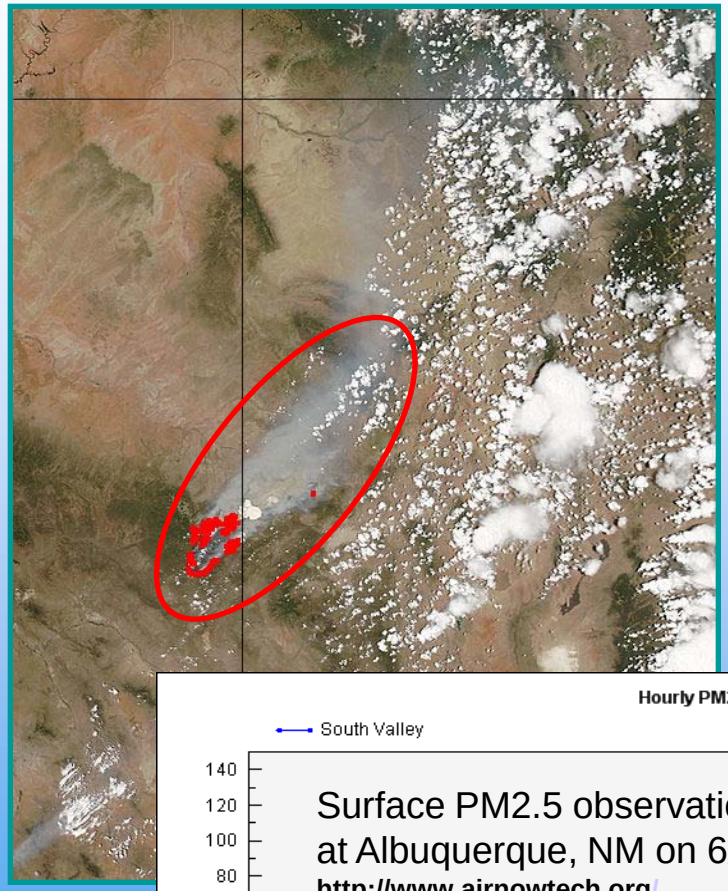
1 Eastern Arizona wildfire still rages, AP, June 5, 2011. http://www.latimes.com/news/la-na-arizona-wildfires-20110606-pictures,0,6897558.photogallery

2 As Arizona wildfire rages, officials allow some to return home, CNN, June 12, 2011 http://www.cnn.com/2011/US/06/12/arizona.wildfires/

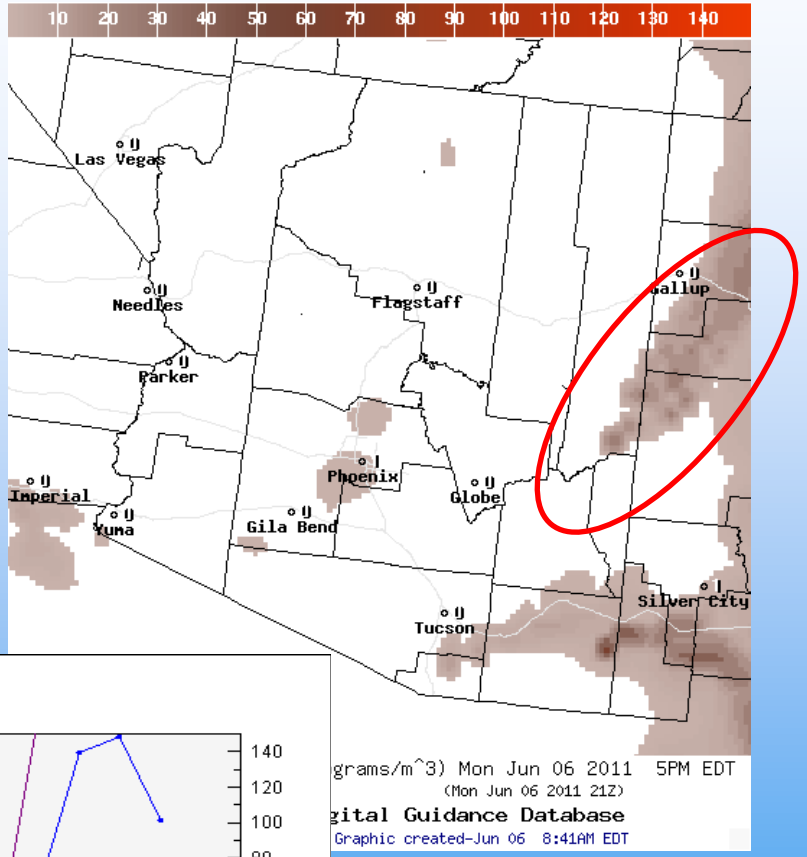
3 InciWeb, Incident information system, accessed on Oct. 23, 2011 http://www.inciweb.org/incident/article/2262/

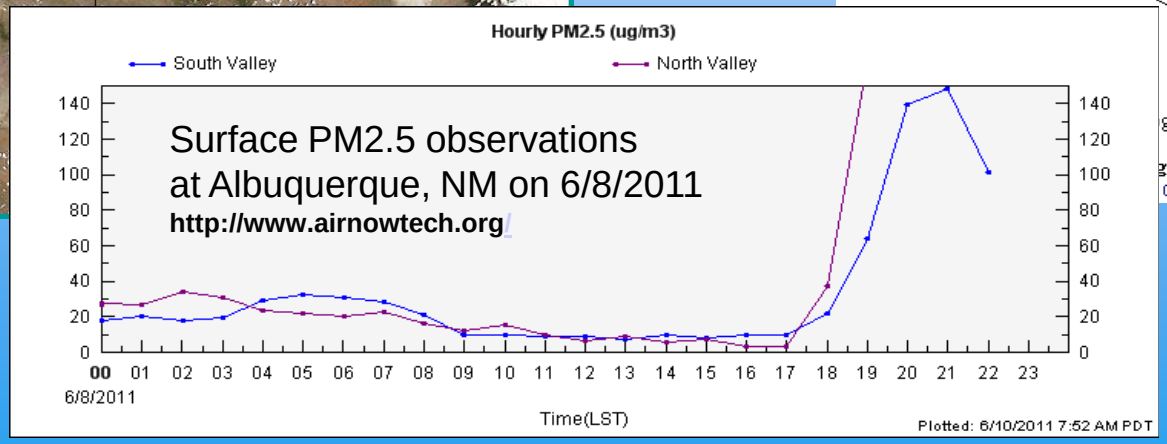
Smoke from Wallow wildfire

MODIS Aqua: June 6, 2001 20:40 UTC



NWS column smoke prediction: June 6, 2011, 21 UTC



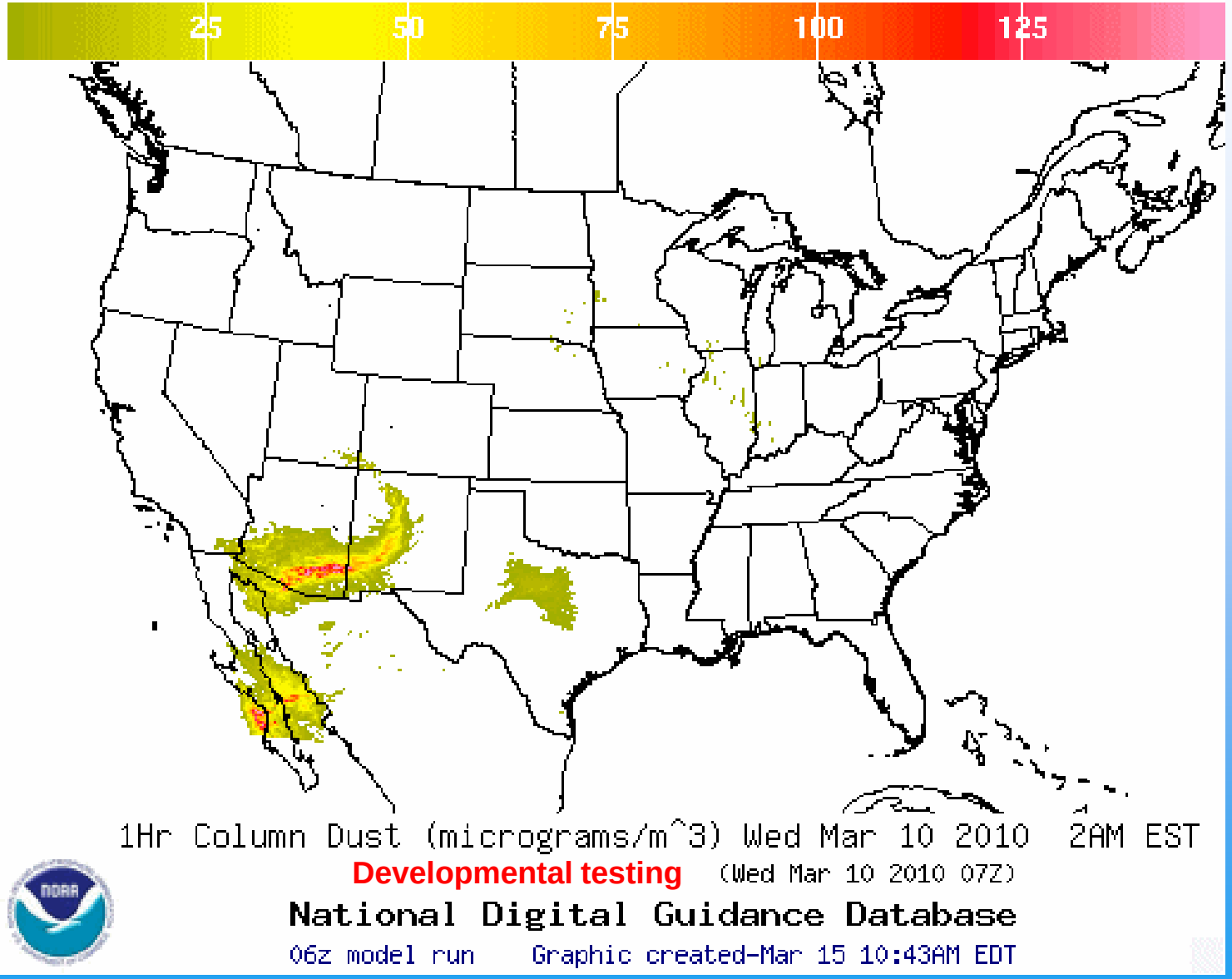


airquality.weather.gov

Example of impact on air quality downwind

CONUS Dust Predictions: Experimental Testing

Experimental predictions at http://airquality.weather.gov/expr/



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 monthly MODIS deep blue climatology (2003-2006).
- HYSPLIT model for transport, dispersion and deposition (Draxler et al., JGR, 2010)
- Emissions modulated by soil moisture in experimental testing.
- Developing satellite product for verification (Zeng and Kondragunta)

Phoenix, AZ Haboob July 5, 2011

- Massive dust storm hit Phoenix, AZ in the evening on July 5, 2011[2]
- 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
- Originated from 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[1]
- Storm moved through Phoenix at 30-40 mph[1]

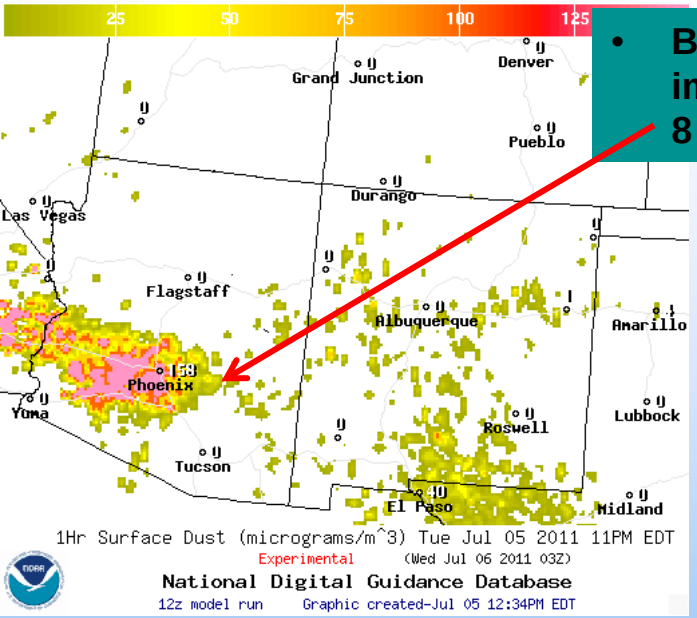
Source: http://www.wrh.noaa.gov/psr/pns/2011/July/DustStorm.php

1. "More Phoenix storms forecast after huge evening dust storm," http://www.azcentral.com/community/phoenix/articles/2011/07/06/20110706phoenix-dust-storm-weather-abrk.html
2. Phoenix Dust Storm: Arizona Hit with Monstrous 'Haboob', http://www.huffingtonpost.com/2011/07/06/phoenix-dust-storm-photos-video_n_891157.html

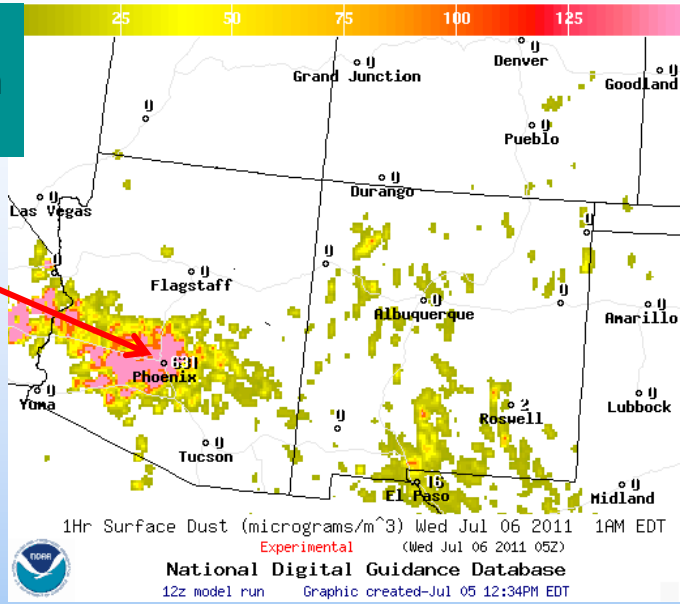
Source: http://www.huffingtonpost.com/2011/07/06/phoenix-dust-storm-photos-video_n_891157.html

Phoenix on July 5

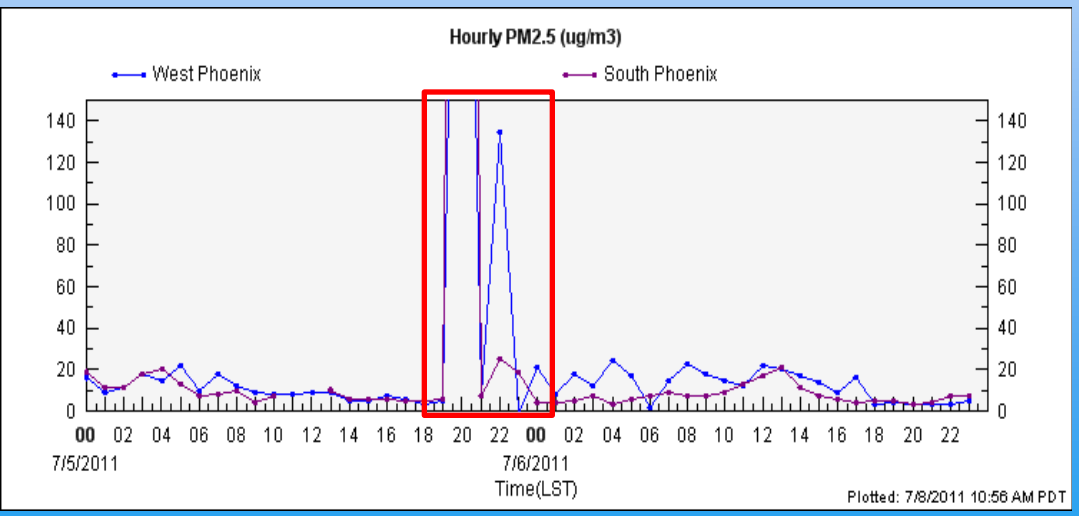
- **Based on observations, largest impact on Phoenix was between 8 PM and 10 PM LST**



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



Note AZ three hours behind EDT in summer



Peak values: 996 ug/m^3 at South Phoenix station at 8PM and 506 ug/m^3 at West Phoenix station at 8 PM (AIRNow Tech)

- Timing of **July 5 storm**: beginning time of predicted storm is correct, but predicted storm extends past observed ending
- For **dust storm on October 4 near Picacho, AZ** developmental predictions (with more sources and emissions modulated by real time soil moisture performed better). This configuration is in experimental testing since November 22.

Developmental PM2.5 predictions for Summer 2011

Focus group access only, real-time as resources permit

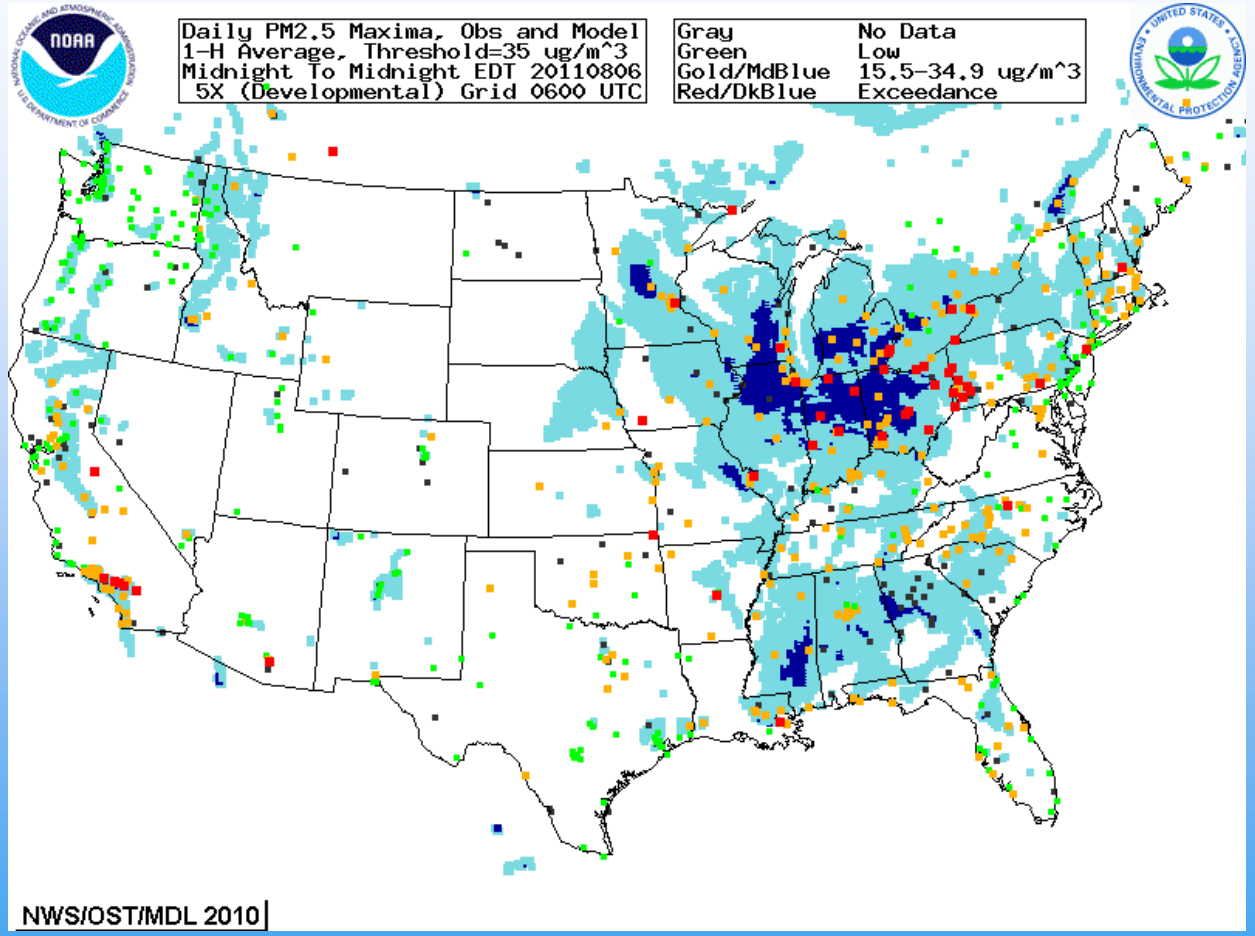
Aerosols over CONUS

From NEI sources only

- CMAQ:
  CB05 gases,
  AERO-4 aerosols
- Sea salt emissions and reactions
- No climatological wildfire emissions

Testing of real-time wildfire smoke emissions in CMAQ

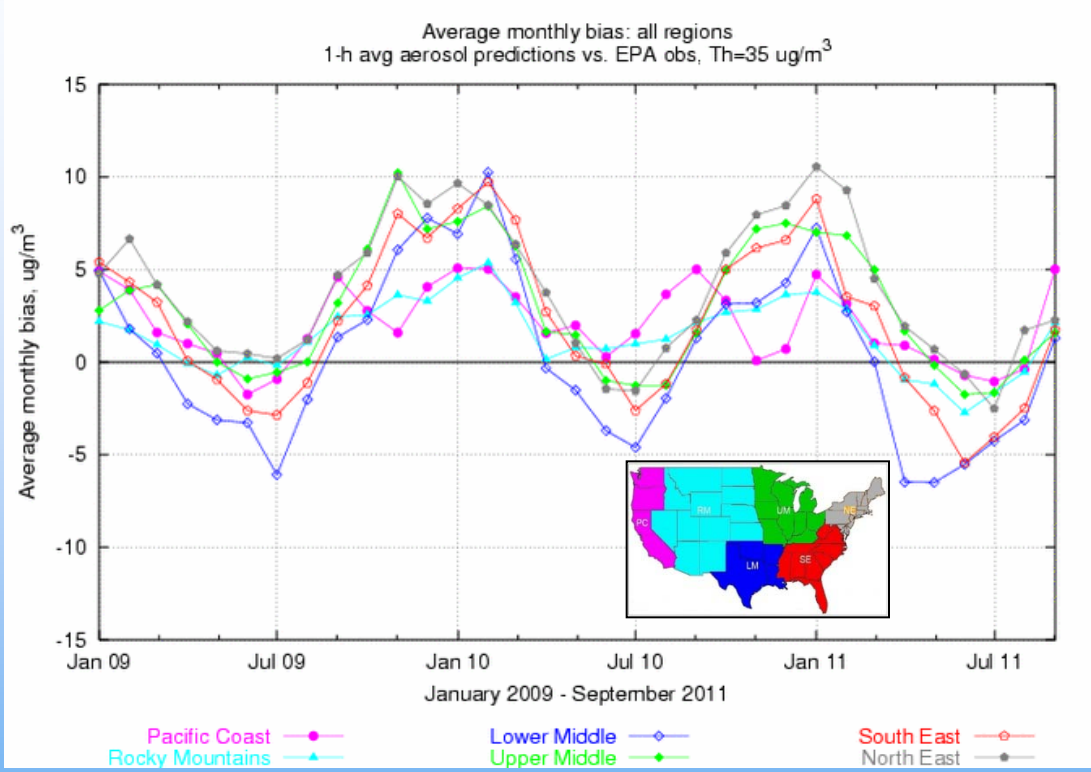
Developing dust emissions
(e.g. poster by Daniel Tong)

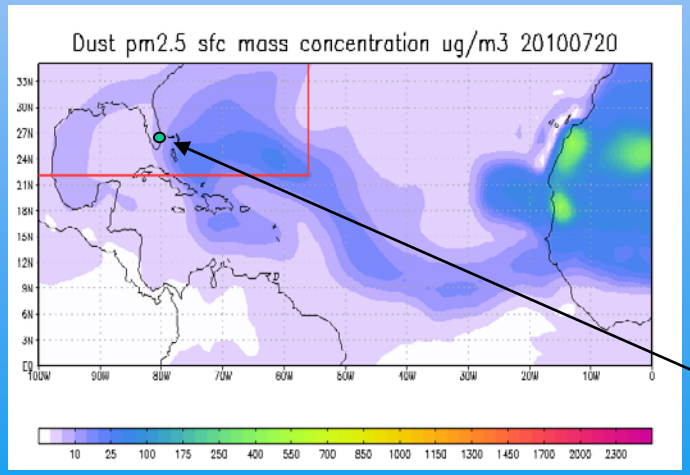


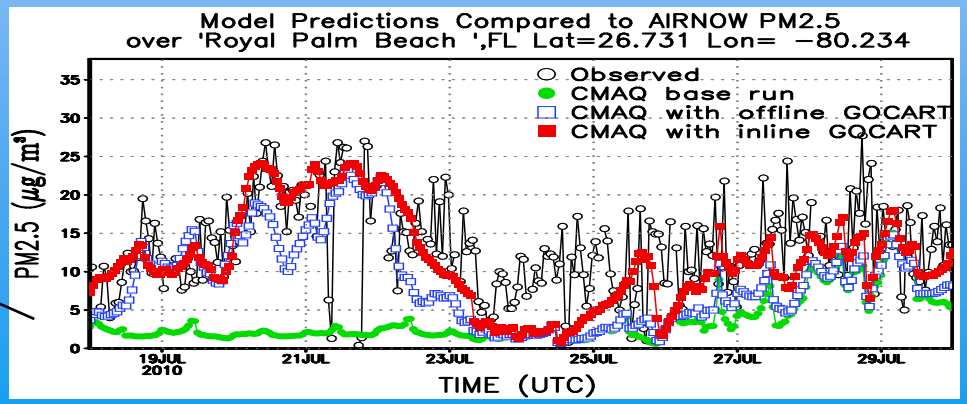
Quantitative PM performance

Forecast challenges

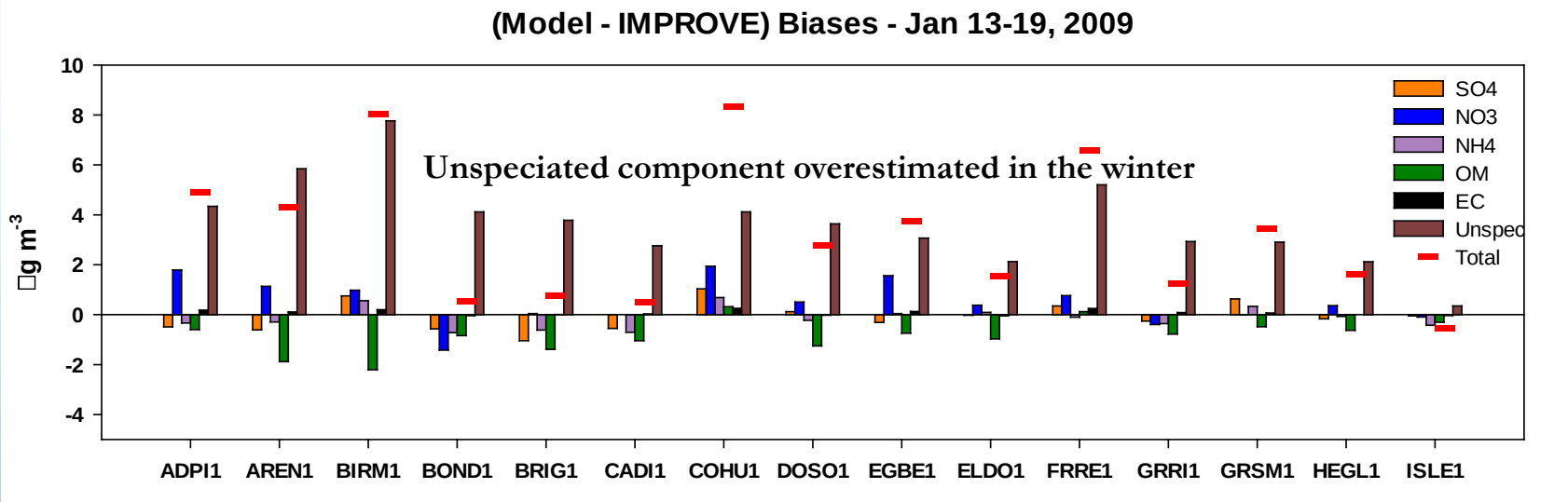
- *Aerosol simulation using emission inventories:*
- **Seasonal bias**:
  - winter – overprediction, summer – underprediction
- ***Intermittent sources*** *(contributions from wildfire smoke are in real time testing)*
- ***Chemical boundary conditions/trans-boundary inputs*** *(poster by Sarah Lu)*

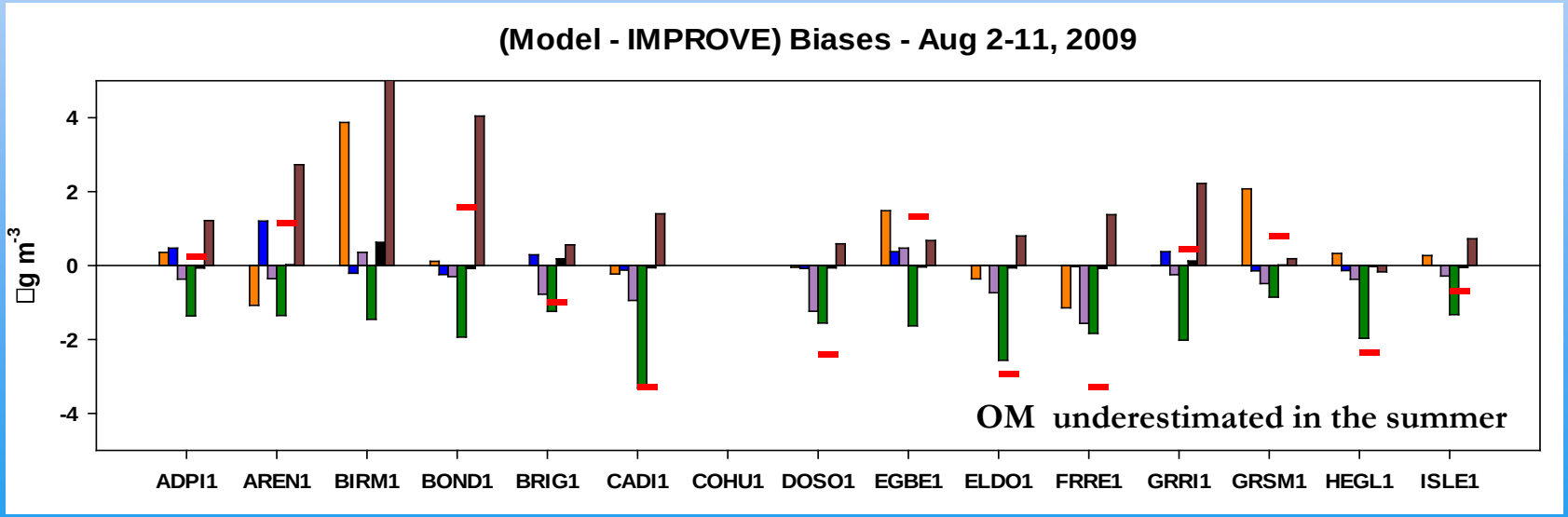






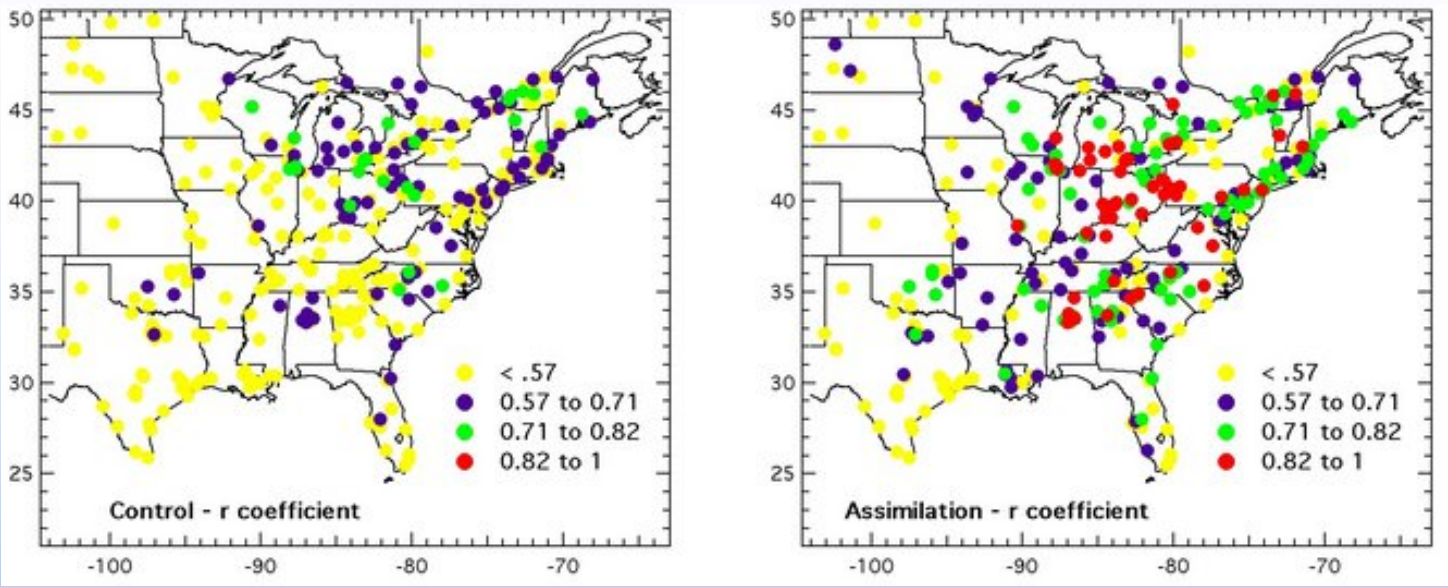
Speciated evaluation



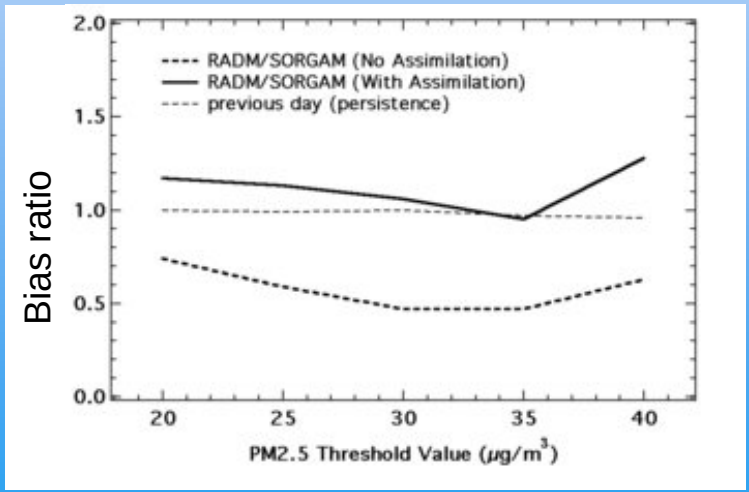


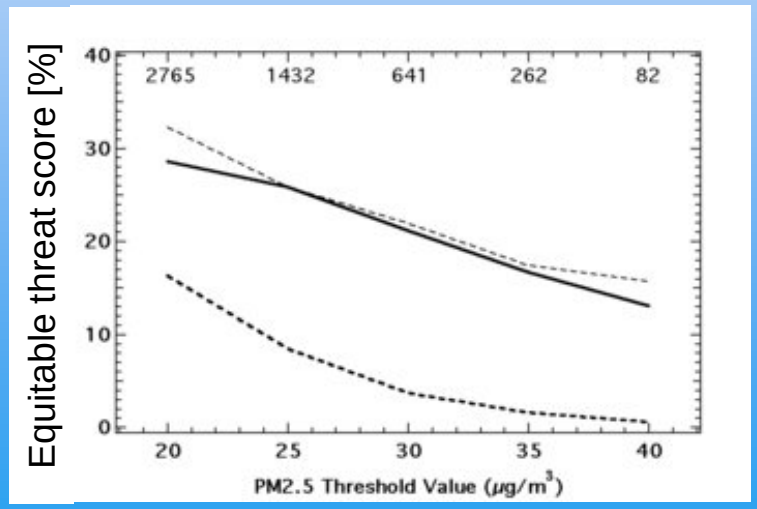
Examples of biases at several IMPROVE stations in the Eastern US (Rick Saylor, Yunhee Kim et al)

Assimilation of surface PM data



- Assimilation increases correlation between forecast and observed PM2.5
- Control is forecast without assimilation





Assimilation reduces bias and increases equitable threat score

Pagowski et al QJRMS, 2010
(also talk and poster)

- Exploring bias correction approaches, *e.g. Djalalova et al., Atmospheric Env., 2010*

Summary

US national AQ forecasting capability status:

- **Ozone** and **smoke** prediction nationwide
- Experimental testing of **dust** prediction from CONUS sources
- Developmental testing of CMAQ **aerosol** predictions with NEI sources

Near-term plans for improvements and testing:

- Operational dust predictions over CONUS
- Development of satellite product for verification of dust predictions
- Understanding/reduction of summertime ozone biases in the CB05 system
- Development of higher resolution predictions (optimization of prediction code; faster preparation of emission inputs – poster by Hyun Cheol Kim)

Development and integration of components for quantitative PM predictions:

- Integration of NEI, smoke and dust sources; inventory updates
- Data assimilation, bias correction; starting with surface PM monitor data
- Inclusion of lateral boundaries from global model predictions
- Testing advanced chemical mechanisms; evaluation of PM speciation
- Closer coupling of meteorological and chemical models

Acknowledgments:
AQF Implementation Team Members

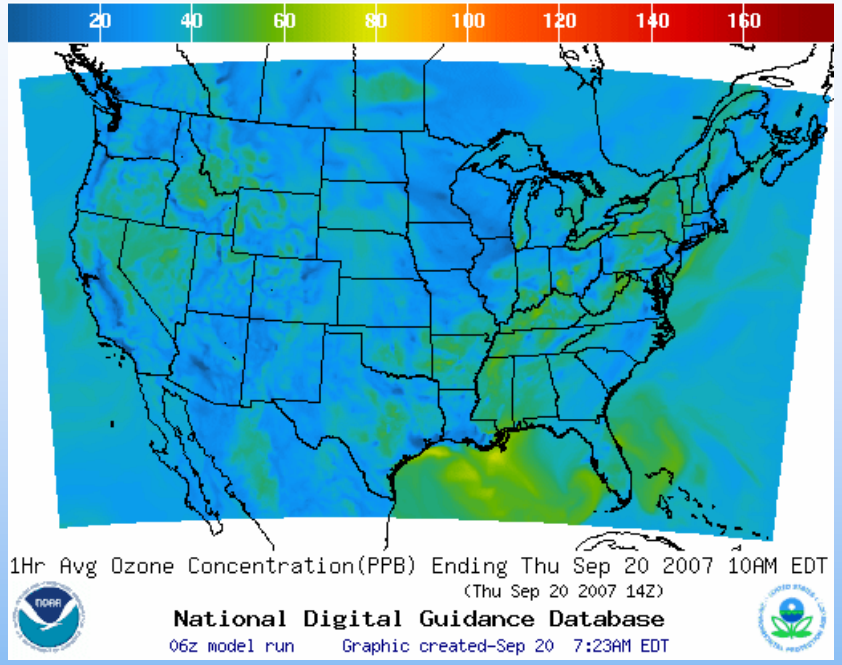
Special thanks to Paula Davidson, OST chief scientist and former NAQFC Manager

NOAA/NWS/OST	***Ivanka Stajner***	***NAQFC Manager***
NOAA/OAR	***Jim Meagher***	***NOAA AQ Matrix Manager***
NWS/OCWWS	***Jannie Ferrell***	***Outreach, Feedback***
NWS/OPS/TOC	***Cindy Cromwell, Bob Bunge***	***Data Communications***
NWS/OST/MDL	***Jerry Gorline, Marc Saccucci, Tim Boyer, Dave Ruth***	***Dev. Verification, NDGD Product Development***
NWS/OST	***Kyle Wedmark, Ken Carey***	***Program Support***
NESDIS/NCDC	***Alan Hall***	***Product Archiving***
NWS/NCEP		
Jeff McQueen, Youhua Tang, Marina Tsidulko, Jianping Huang		**AQF model interface development, testing, & integration**
***Sarah Lu , Ho-Chun Huang**		**Global data assimilation and feedback testing**
***Brad Ferrier, *Dan Johnson, *Eric Rogers, *Hui-Ya Chuang**		**WRF/NAM coordination**
Geoff Manikin		**Smoke Product testing and integration**
Dan Starosta, Chris Magee		**NCO transition and systems testing**
Robert Kelly, Bob Bodner, Andrew Orrison		**HPC coordination and AQF webdrawer**
NOAA/OAR/ARL		
Pius Lee, Rick Saylor, Daniel Tong , Tianfeng Chai, Fantine Ngan, Yunsoo Choi, Hyun-Cheol Kim, Yunhee Kim, Mo Dan		**CMAQ development, adaptation of AQ simulations for AQF**
Roland Draxler, Glenn Rolph, Ariel Stein		**HYSPLIT adaptations**
NESDIS/STAR	***Shobha Kondragunta, Jian Zeng***	***Smoke Verification product development***
NESDIS/OSDPD	***Liqun Ma, Mark Ruminski***	***HMS product integration with smoke forecast tool***
EPA/OAQPS partners:		
Chet Wayland, Phil Dickerson, Brad Johns		***AIRNow development, coordination with NAQFC***

* Guest Contributors

Operational AQ forecast guidance

airquality.weather.gov

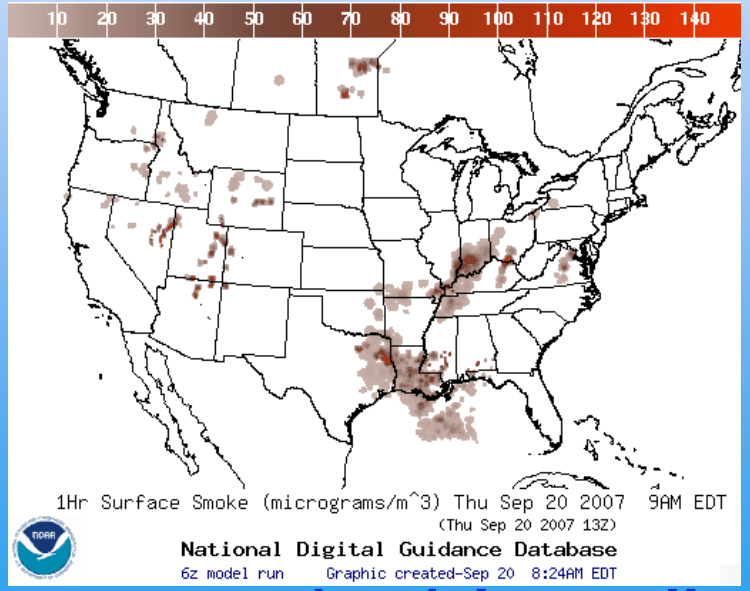


CONUS Ozone

Expansion Implemented September, 2007

Smoke Products

Implemented March, 2007

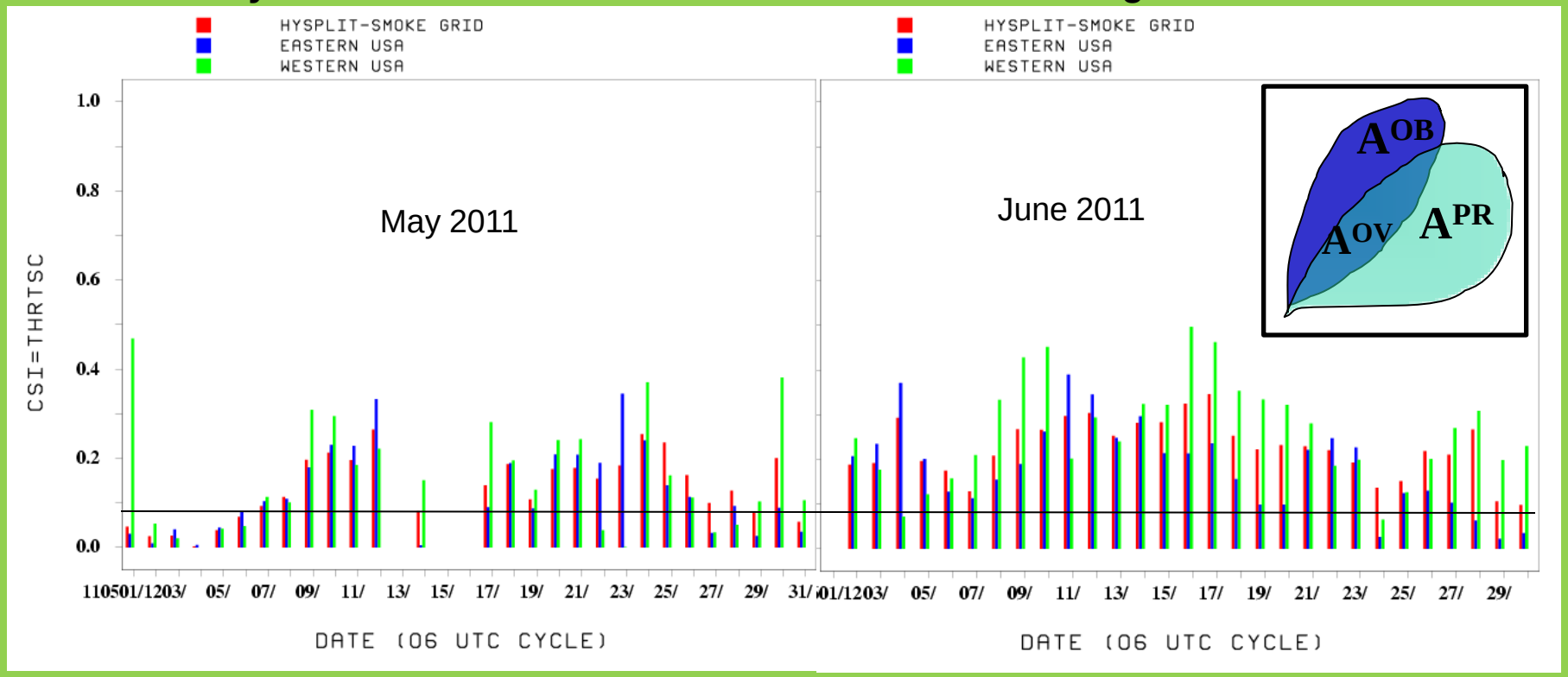


Further information: www.nws.noaa.gov/ost/air_quality

Backup

Verification of smoke predictions

Daily time series of FMS for smoke concentrations larger than 1um/m3

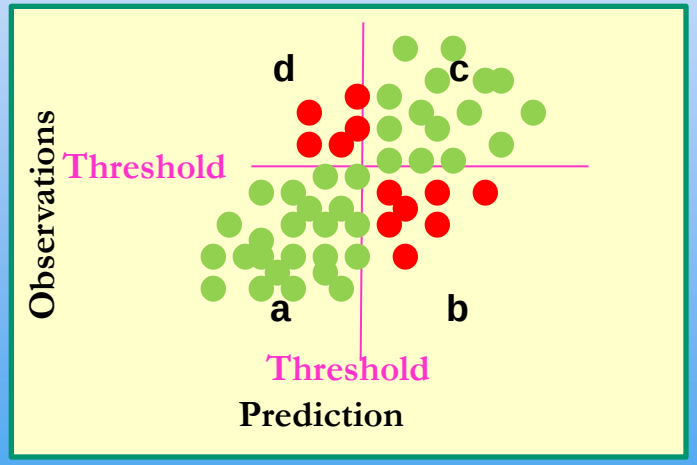


- **Figure of merit in space (FMS), which is a fraction of overlap between predicted and observed smoke plumes, exceeds 0.08 in the western US since May 29 when Wallow wildfire began.**
- **NESDIS GOES Aerosol/Smoke Product is used for verification**

Real-time Verification Approach for Ozone

- **Real-time verification of data**
  - *Comparing model with observed values from AIRNow ground level observations*

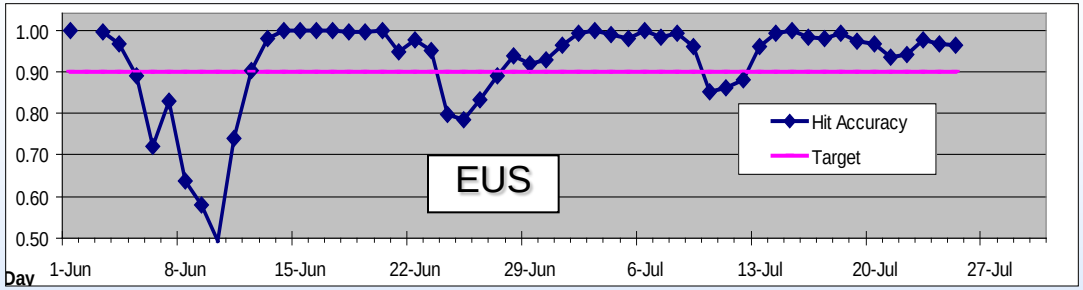
- **Daily maximum of 8-hour ozone**
  - *Metric is the fraction correct with respect to threshold commonly used for "code orange" AQ alerts in the US (currently 75 ppb)*



Fraction Correct = (a+c)/(a+b+c+d)

Skill target for fraction correct ≥ 0.9

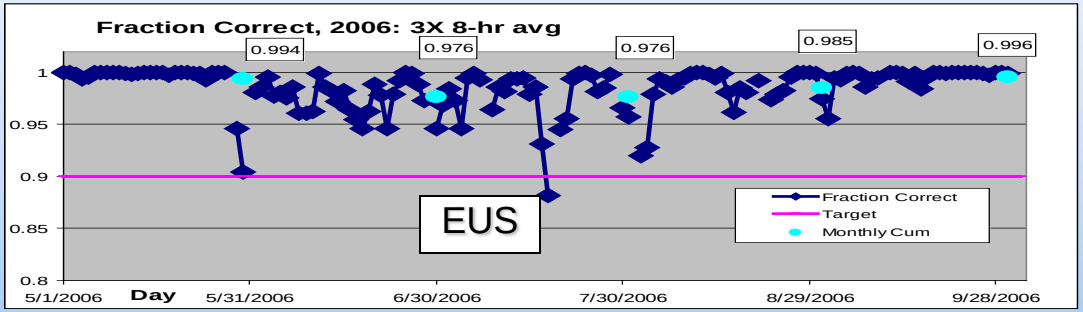
Progress from 2005 to 2008:
Ozone Prediction Summary Verification



2005

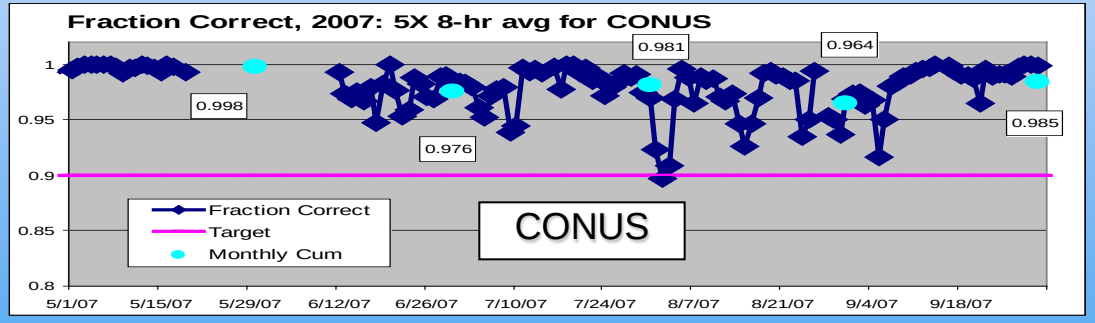
Initial Operational Capability (IOC)

Operational, NE US Domain



2006 Operational

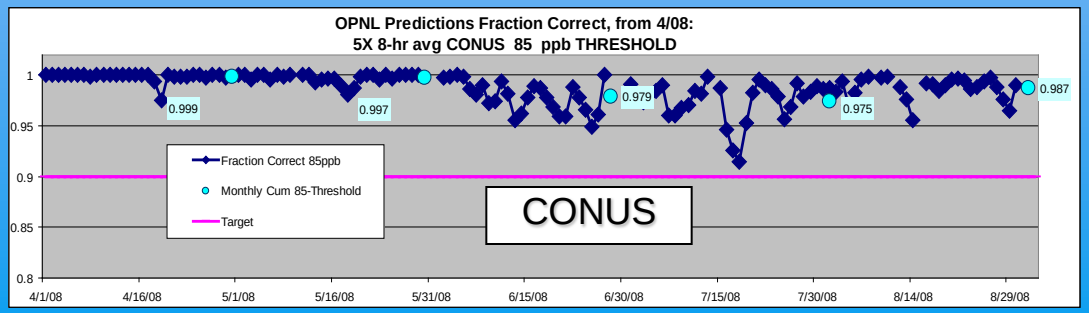
Operational, Eastern US



2007 Experimental

Experimental, Contiguous US

Approved 9/07 to replace Eastern US config in operations

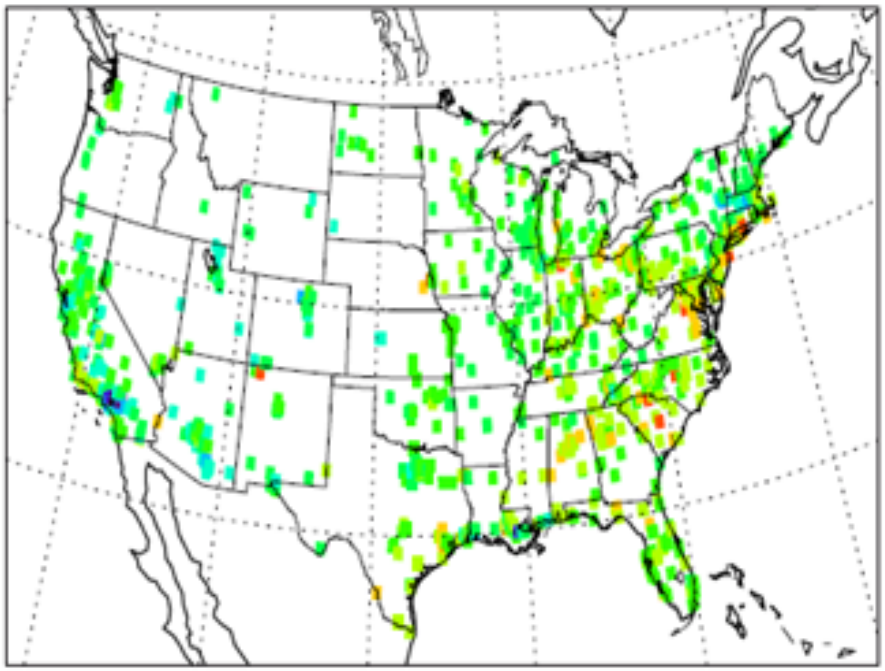


2008 Operational

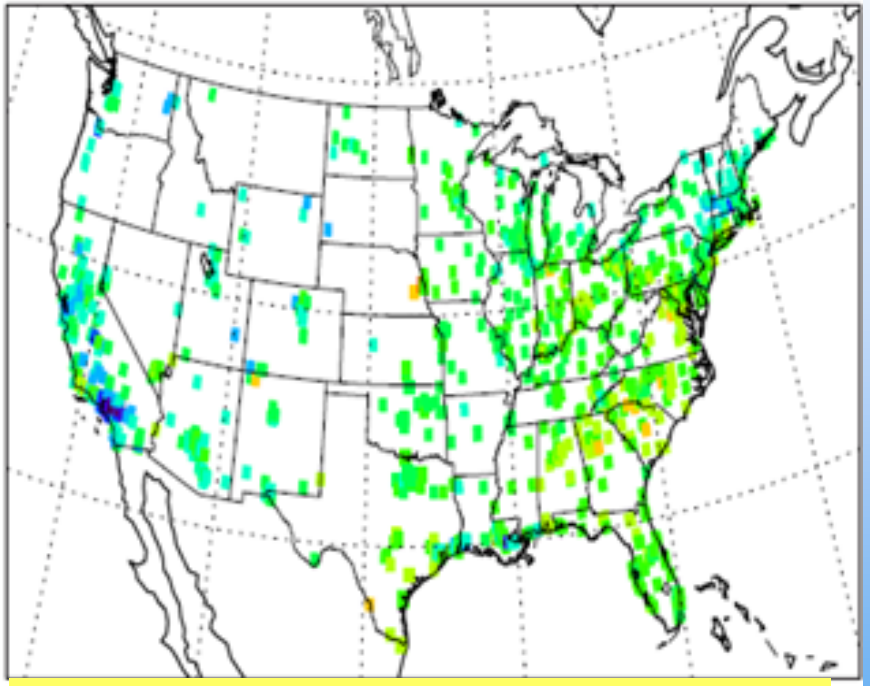
CONUS, wrt 85ppb Threshold

Ozone sensitivity in the CB05 system:
Experimental and developmental configuration

Model-minus-AIRNow observations: mean for daytime in August 2009



Experimental test configuration



Developmental test configuration with modified:
- Lateral boundary conditions,
- Minimum PBL height,
- Aerodynamic resistance, forest canopy height

In depth: Byun et al. in the Processes session

Smoke Forecast Tool:
What is it?

Overview

- Passive transport/dispersion computed with HYSPLIT & WRF-NAM (or GFS, OCONUS). 24-hr spin-up, 48-hour prediction made daily with 6Z cycle

Fire Locations

- NESDIS/HMS: Filtered ABBA product (only fires with observed associated smoke)

Emissions

- USFS' BlueSky algorithm for emitted PM2.5

Smoke Transport/dispersion

- HYSPLIT (Lagrangian); plume rise based on combustion heat and meteorology

Verification

- Based on satellite imagery for footprint of extent of observed smoke in atmospheric column exceeding threshold of detection

Smoke Forecast Tool
Major Components

NWP Model

NAM / WRF-NMM

NOAA / NWS

Weather Observations

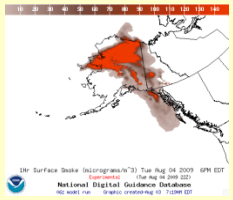
NESDIS HMS Fire Locations

HYSPLIT Module:

NOAA / OAR

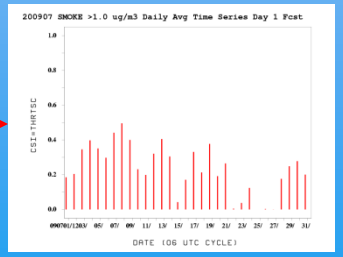
USFS's BlueSky Emissions Inventory:

USFS

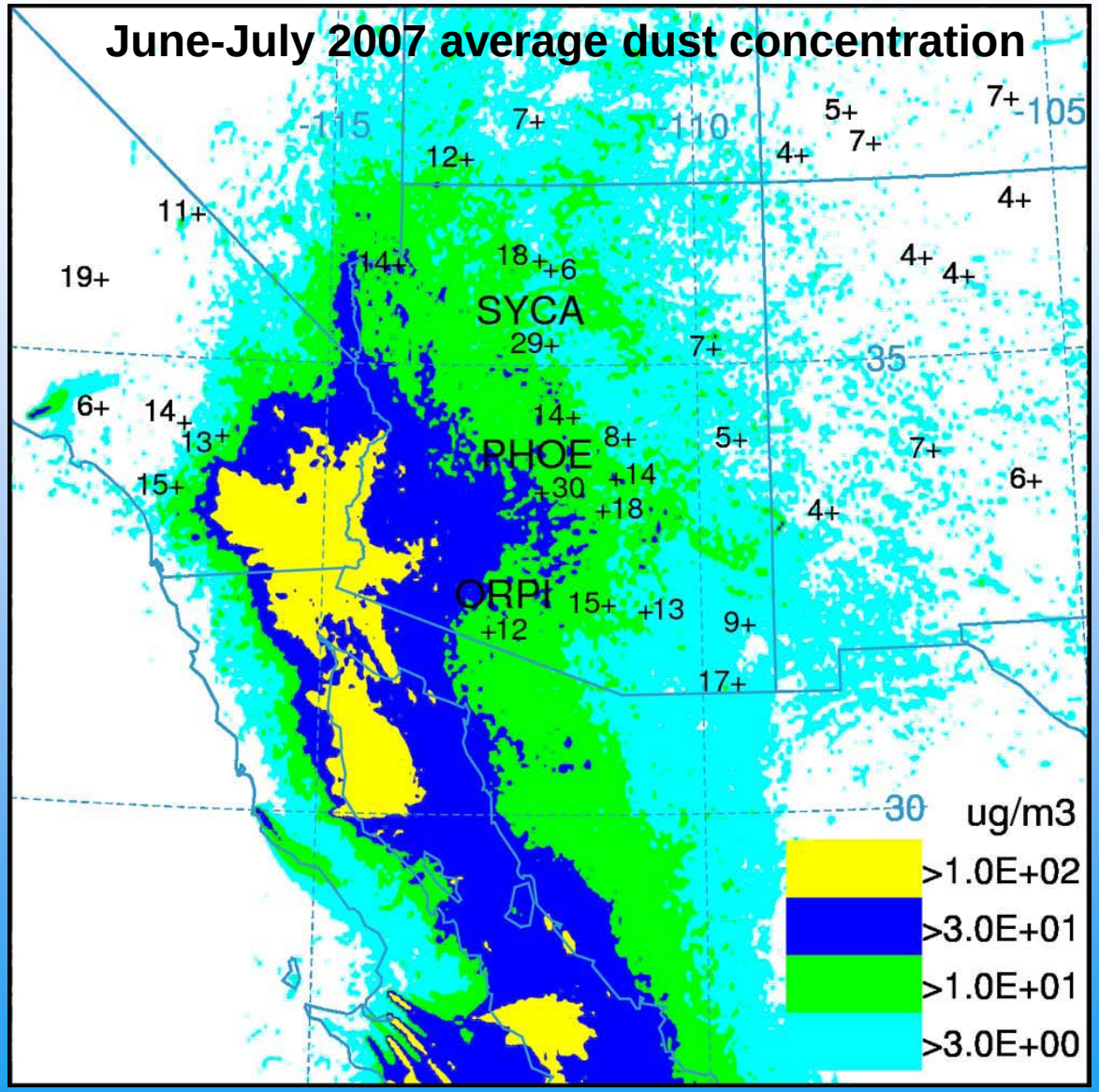


Verification:

NESDIS/GASP Smoke



Dust simulation compared with IMPROVE data



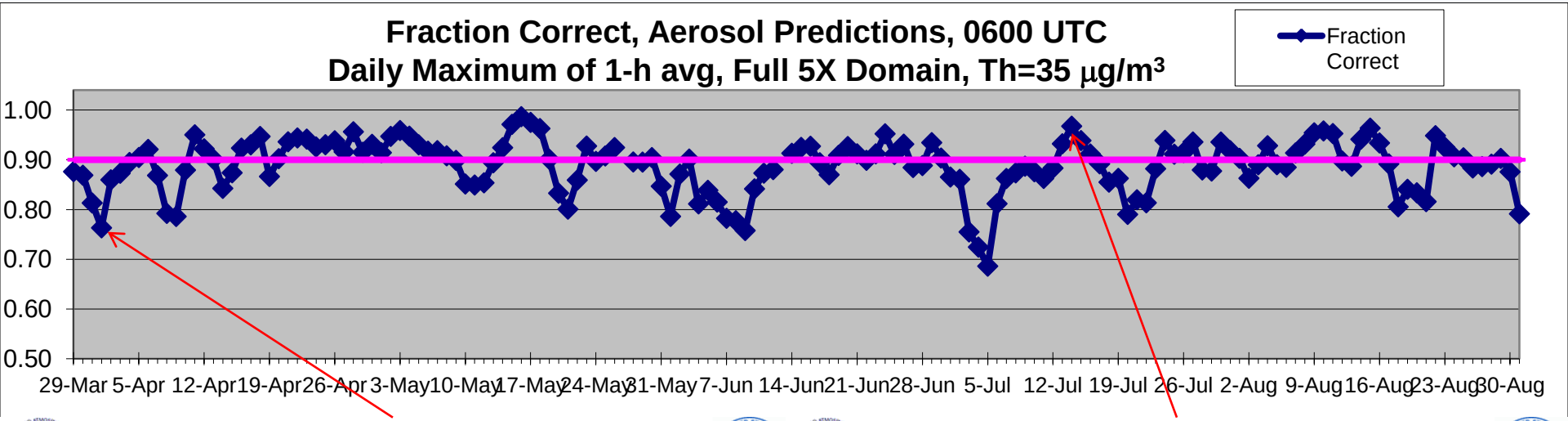
HYSPLIT simulated air concentrations are compared with IMPROVE data in southern California and western Arizona:

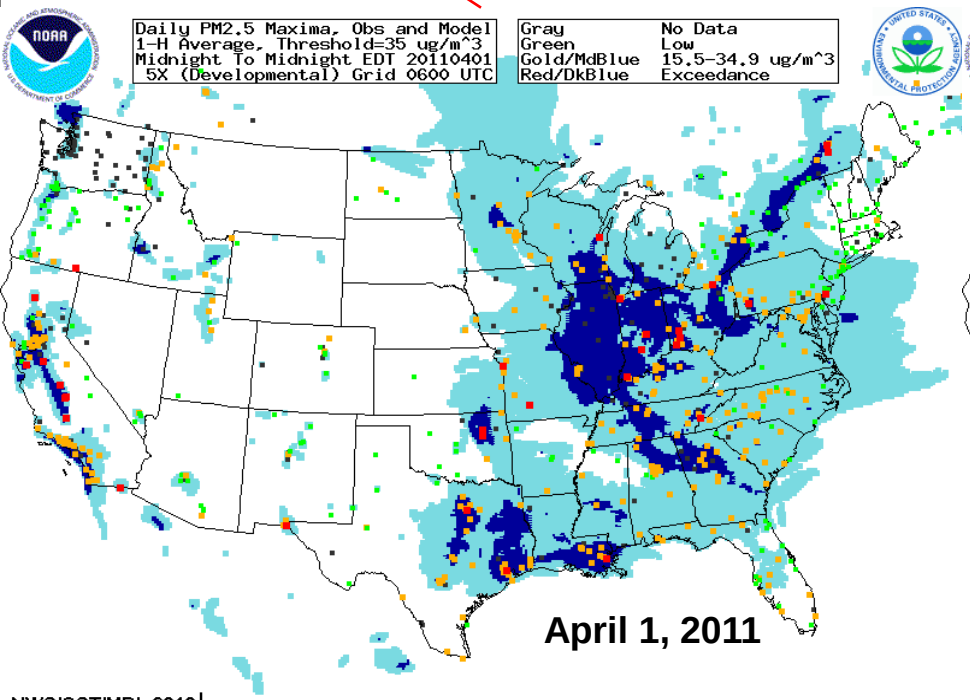
- **Model simulations: contours**
- **IMPROVE dust concentration: numbers next to "+"**
- **Variability in model simulation**
- **Highest measured value in Phoenix**
- **Model and IMPROVE comparable in 3-10 ug/m^3 range**
- **Spotty pattern indicates under-prediction. Considering ways for improving representation of smaller dust emission sources.**

(Draxler et al., JGR, 2010)

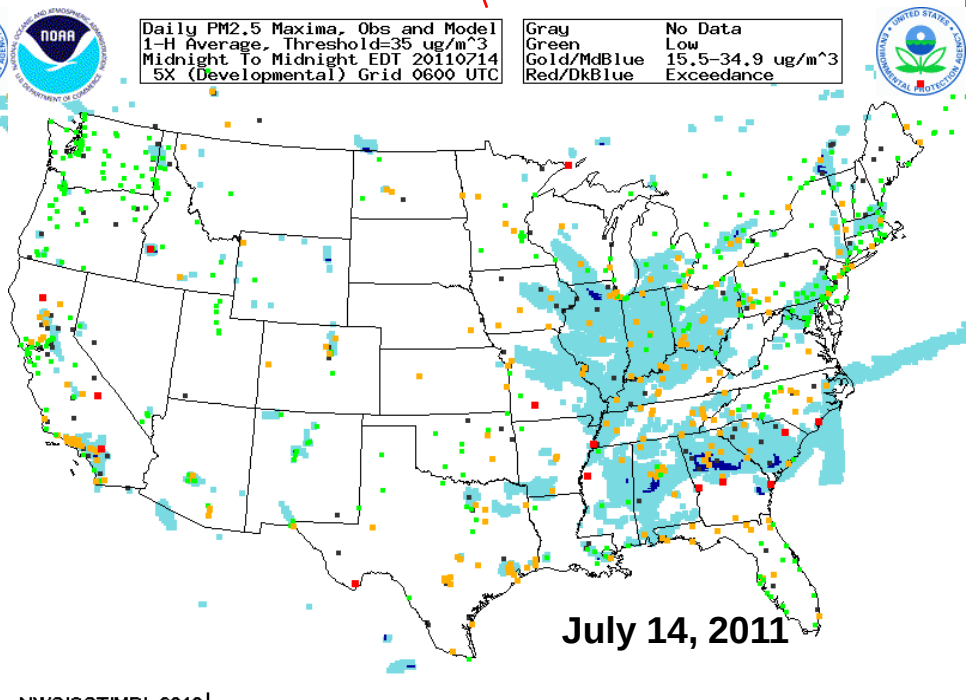
Developmental Aerosol Predictions:

Summary Verification, 2011





April 1, 2011



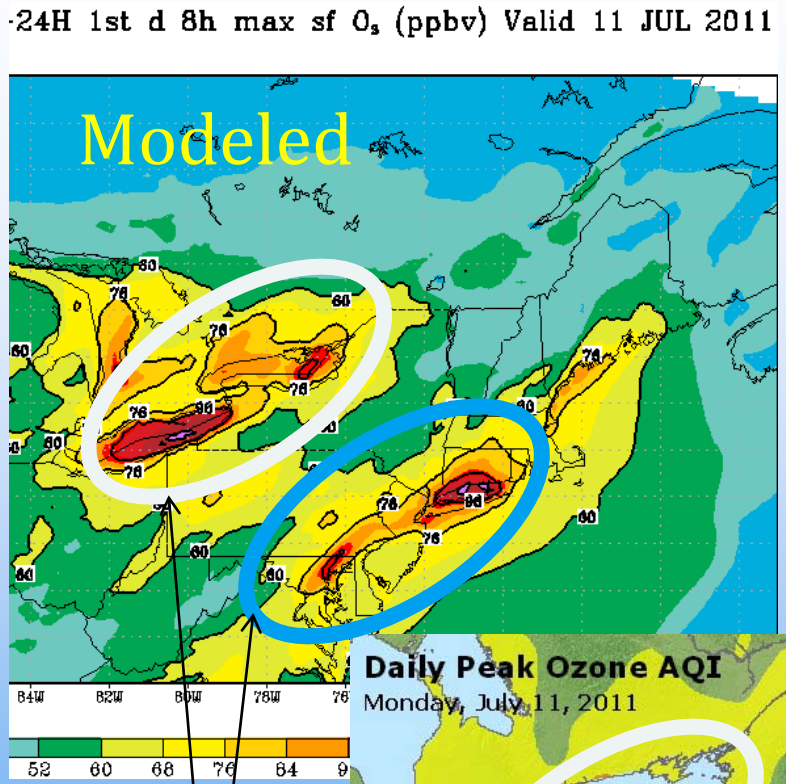
July 14, 2011

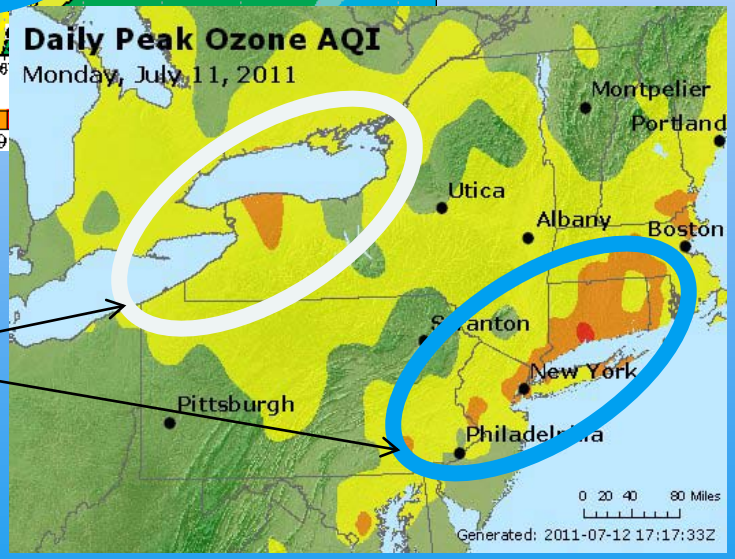
NWS/OST/MDL 2010

AQ Forecaster Feedback Examples

Michael Geigert, CT Department of Environmental Protection:

- Analyzed case on July 11 AIRNow data vs 12Z operational ozone model run
- Model still over-predicting in most cases, however not unreasonable
- Model does not yet have the resolution to pick up hourly fluctuations of plume location and intensity
- Still most problematic at coastal sites, but it still performed very well overall





Examples of model overprediction