

# Applications of GOES and MODIS Aerosol Products in NOAA's Operational Air Quality Predictions

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NOAA/NWS



# Outline



## ***Background on NAQFC***

### ***Progress in 2012***

- *Ozone predictions*
- *Smoke predictions*
- *Dust predictions*
- *Prototype PM2.5 predictions*
- *Outreach and feedback*

### ***Summary***

# National Air Quality Forecast Capability

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

## 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)

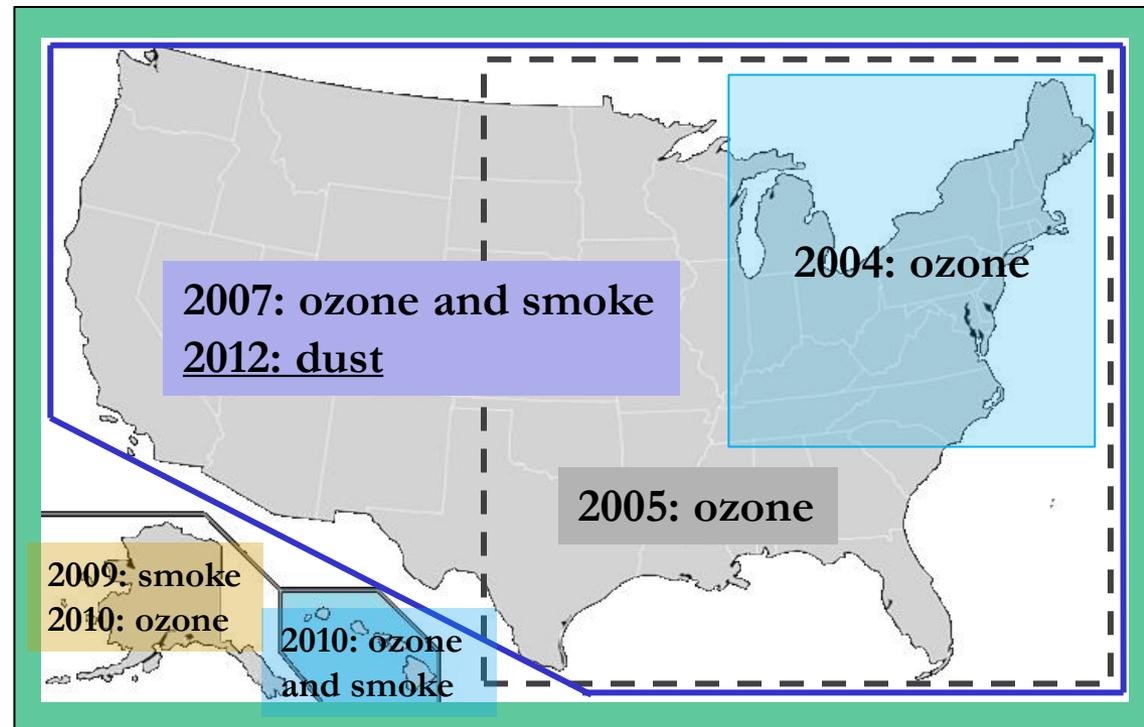
**Dust over CONUS:** (3/12)

- **Experimental testing:**

Ozone predictions

- **Developmental testing:**

Components for particulate matter (PM) forecasts



# National Air Quality Forecast Capability

## End-to-End Operational Capability

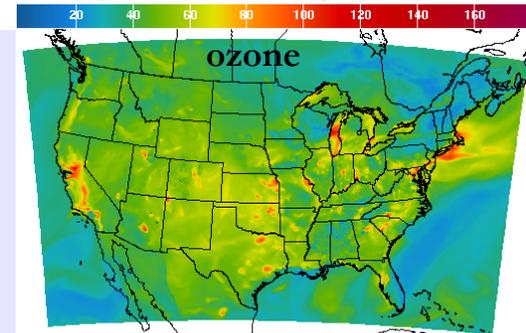
### Model: Linked numerical prediction system

Operationally integrated on NCEP's supercomputer

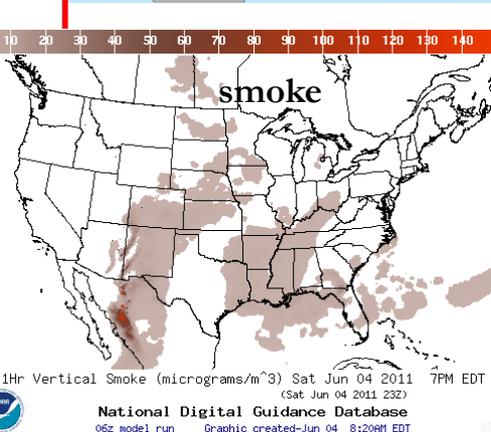
- NOAA NCEP mesoscale numerical weather prediction
- NOAA/EPA community model for air quality: CMAQ
- NOAA HYSPLIT model for smoke and dust prediction

### Observational Input:

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



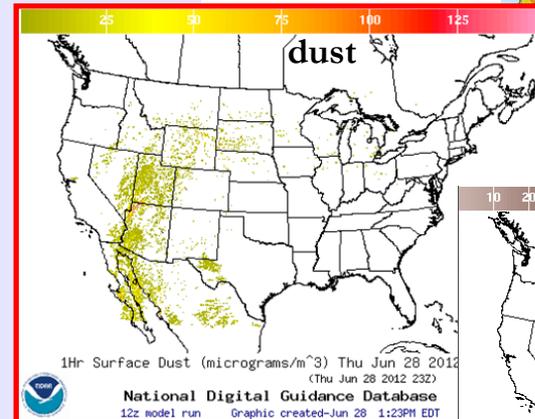
1Hr Avg Ozone Concentration (PPB) Ending Tue Jul 05 2011 7PM EDT  
(Tue Jul 05 2011 23Z)  
National Digital Guidance Database  
12z model run Graphic created-Jul 05 1:42PM EDT



1Hr Vertical Smoke (micrograms/m<sup>3</sup>) Sat Jun 04 2011 7PM EDT  
(Sat Jun 04 2011 23Z)  
National Digital Guidance Database  
06z model run Graphic created-Jun 04 8:20AM EDT

### Gridded forecast guidance products

- On NWS servers: [airquality.weather.gov](http://airquality.weather.gov) and ftp-servers
- On EPA servers
- Updated 2x daily



1Hr Surface Dust (micrograms/m<sup>3</sup>) Thu Jun 28 2012 1:23PM EDT  
(Thu Jun 28 2012 23Z)  
National Digital Guidance Database  
12z model run Graphic created-Jun 28 1:23PM EDT

### 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



# Progress in 2012



## ***North American Meteorological model was upgraded to Non-hydrostatic Multi-scale Model (NMMB)***

- *These meteorological predictions are used for all air quality predictions (October 2011)*

## ***Ozone Updates:***

- *Substantial emission updates:*
  - *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 updates:***

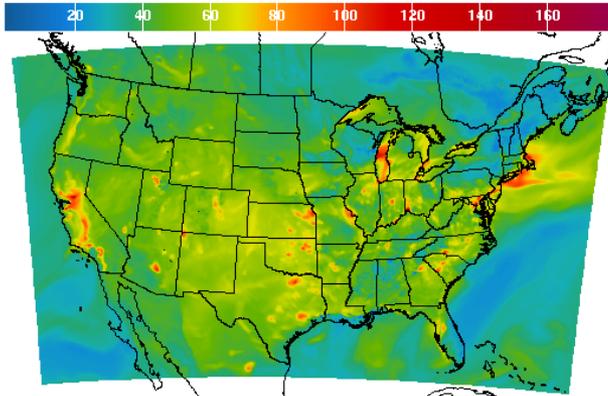
- ***Dust predictions implemented operationally in March 2012***
- *Dust emissions are modulated by real-time soil moisture*
- *Testing use of a longer time step to speed up dust predictions*

## ***Smoke updates:***

- *Finer resolution for Hawaii domain*
- *Testing of updates to plume rise and deposition parameters*

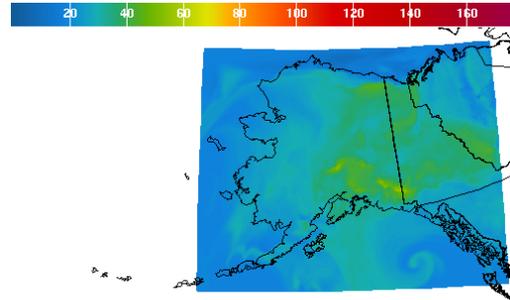
# Ozone predictions

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



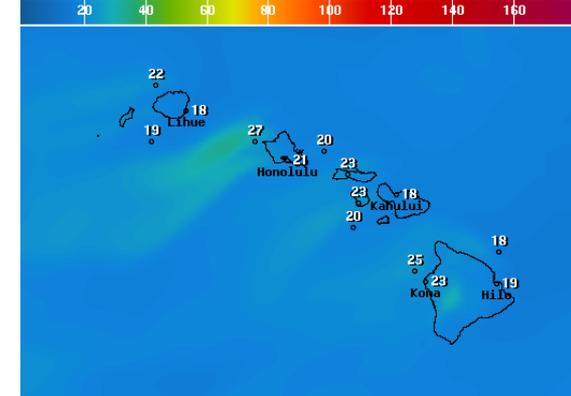
1Hr Avg Ozone Concentration(PPB) Ending Tue Jul 05 2011 7PM EDT  
 (Tue Jul 05 2011 23Z)  
**National Digital Guidance Database**  
 12z model run Graphic created-Jul 05 1:42PM EDT

**1-Hr Average Ozone**  
**8-Hr Average Ozone**



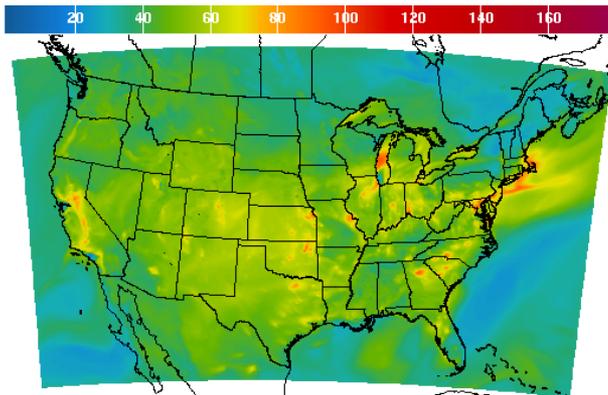
1Hr Avg Ozone Concentration(PPB) Ending Tue Jul 05 2011 7PM EDT  
 (Tue Jul 05 2011 23Z)  
**National Digital Guidance Database**  
 12z model run Graphic created-Jul 05 12:20PM EDT

**1-Hr Average Ozone**  
**8-Hr Average Ozone**

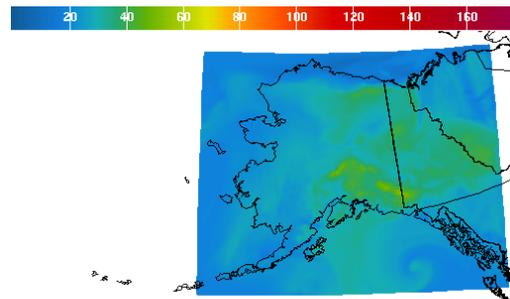


1Hr Avg Ozone Concentration(PPB) Ending Tue Jul 05 2011 7PM EDT  
 (Tue Jul 05 2011 23Z)  
**National Digital Guidance Database**  
 12z model run Graphic created-Jul 05 11:20AM EDT

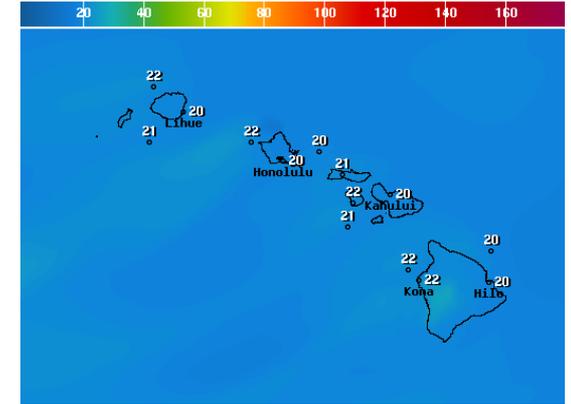
**1-Hr Average Ozone**  
**8-Hr Average Ozone**



8Hr Avg Ozone Concentration(PPB) Ending Tue Jul 05 2011 7PM EDT  
 (Tue Jul 05 2011 23Z)  
**National Digital Guidance Database**  
 12z model run Graphic created-Jul 05 1:43PM EDT



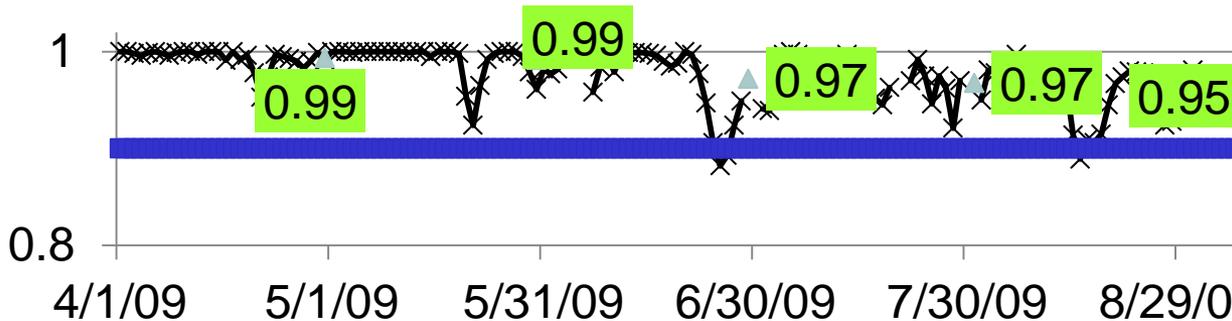
8Hr Avg Ozone Concentration(PPB) Ending Tue Jul 05 2011 7PM EDT  
 (Tue Jul 05 2011 23Z)  
**National Digital Guidance Database**  
 12z model run Graphic created-Jul 05 12:20PM EDT



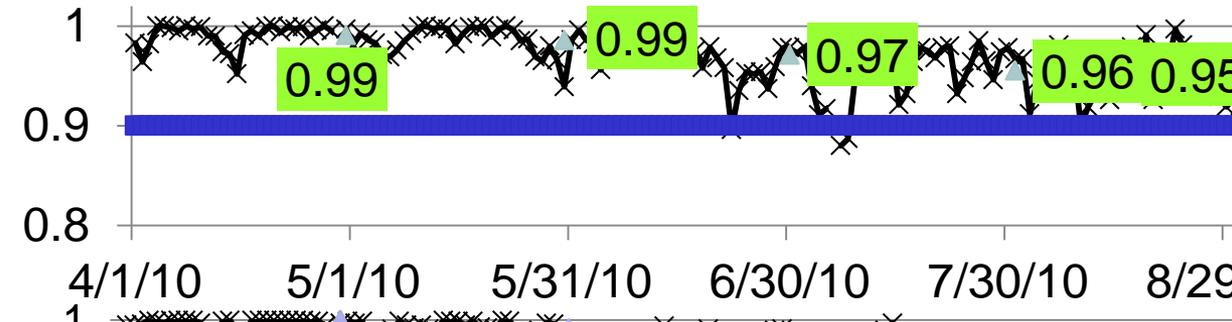
8Hr Avg Ozone Concentration(PPB) Ending Tue Jul 05 2011 7PM EDT  
 (Tue Jul 05 2011 23Z)  
**National Digital Guidance Database**  
 12z model run Graphic created-Jul 05 11:20AM EDT



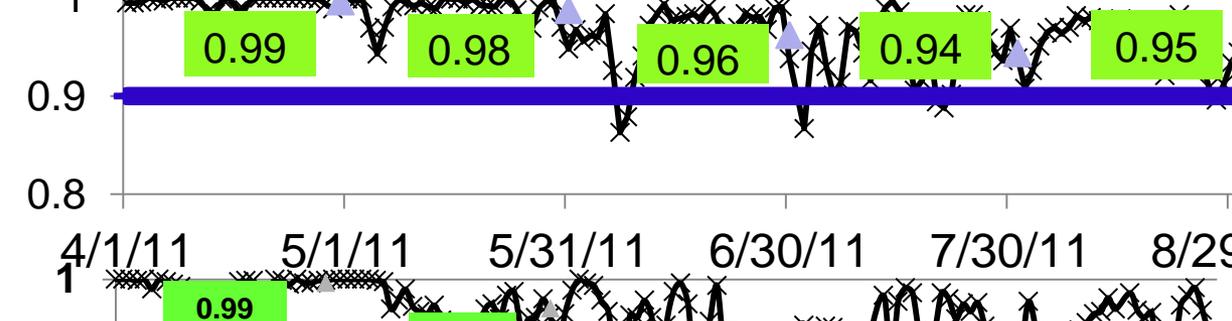
# Summary of ozone Verification over CONUS



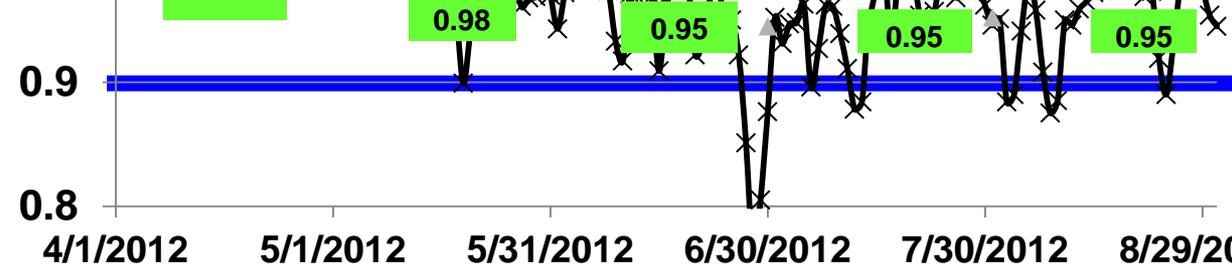
2009 **Operational**  
CONUS, wrt 76ppb Threshold



2010 **Operational**  
CONUS, wrt 76ppb Threshold



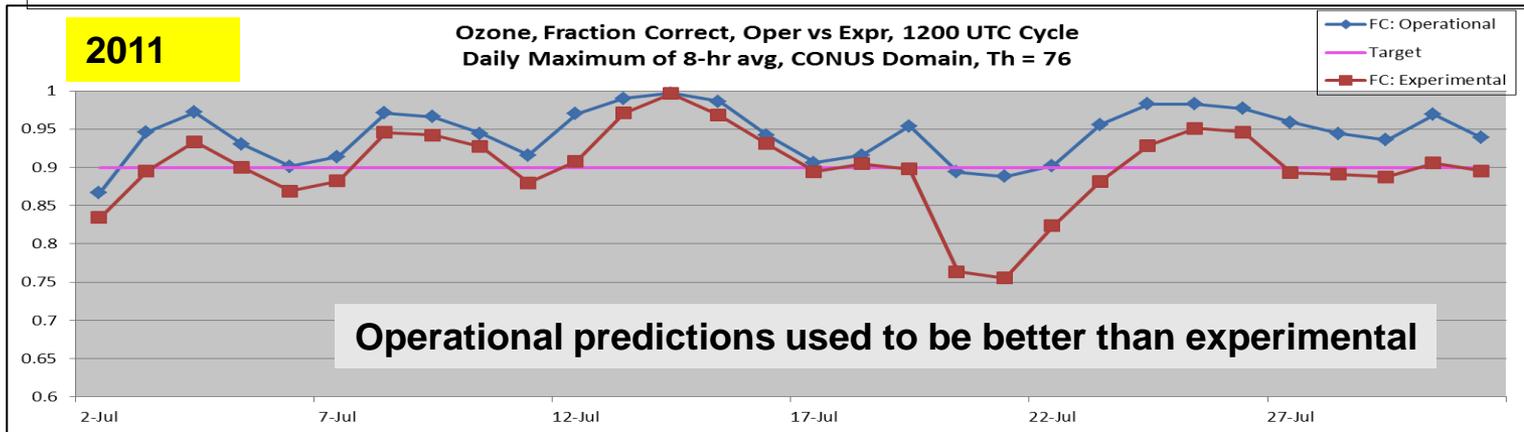
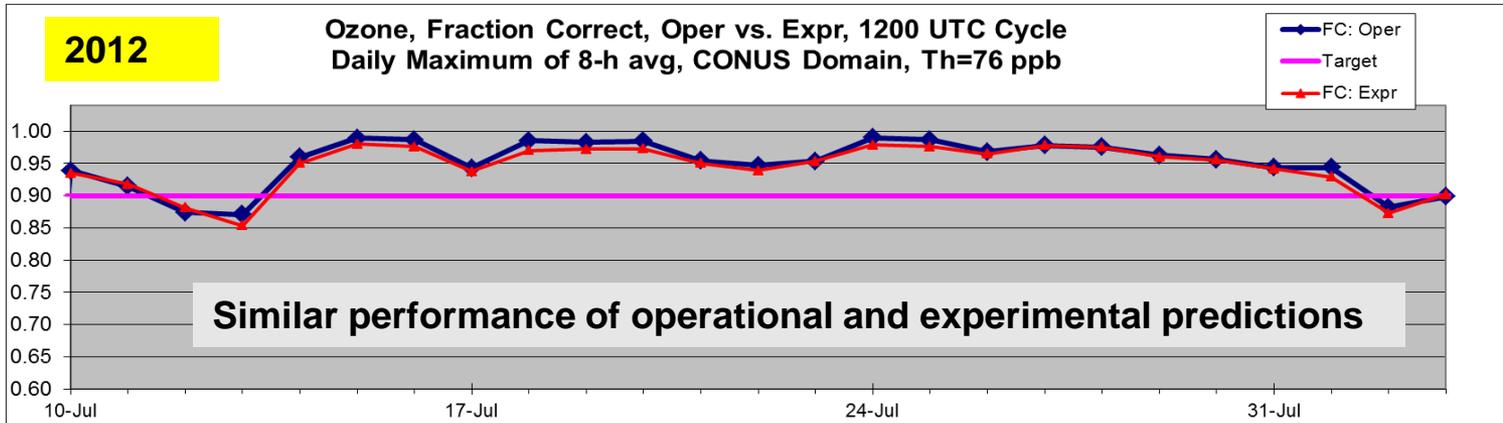
2011 **Operational**  
CONUS, wrt 76 ppb Threshold



2012 **Operational**  
CONUS, wrt 76 ppb Threshold

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

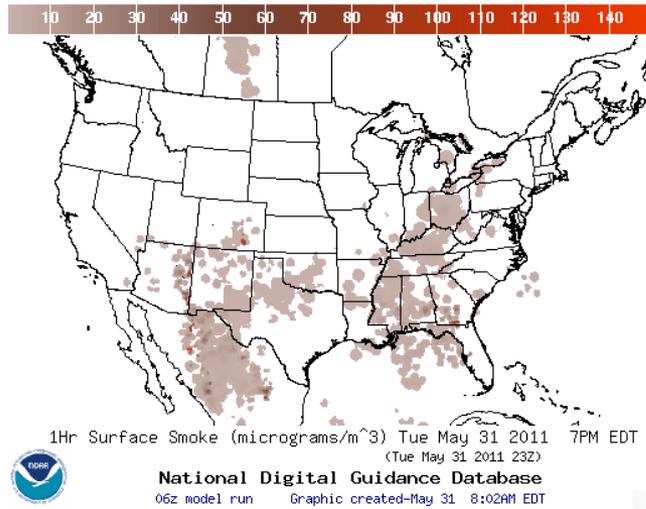
# Operational and experimental predictions: fraction correct



	2011	2012 updates	
<b>Operational</b> <b>CB-IV</b>	WRF-NMM, 2005 NEI	NMM-B, 2012 emission projections	
<b>Experimental</b> <b>CB05</b>	WRF-NMM, 2005 NEI	NMM-B, 2012 emission projections	LBC, dry deposition, minimum PBL height

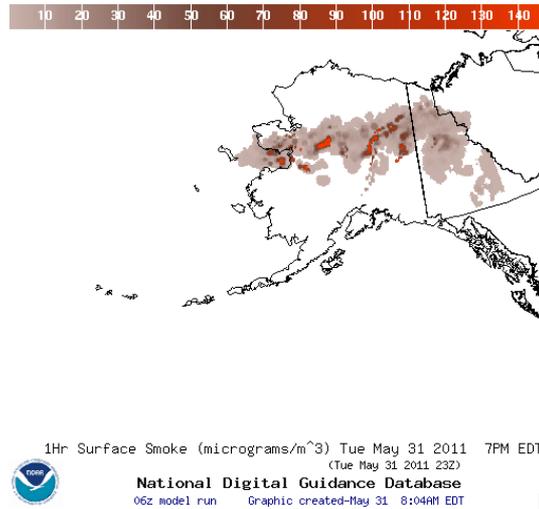
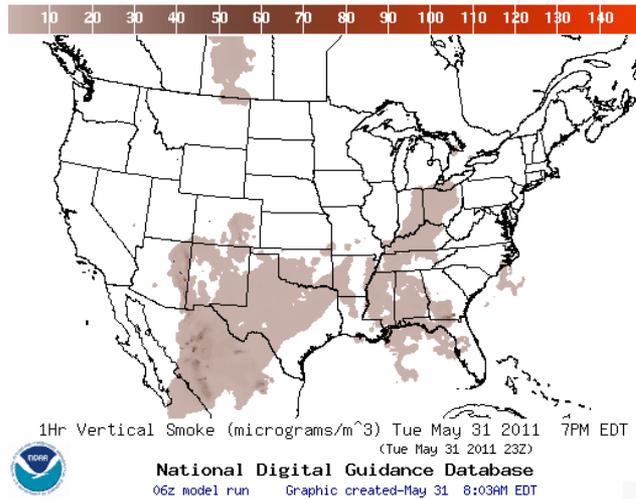
# Smoke predictions

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



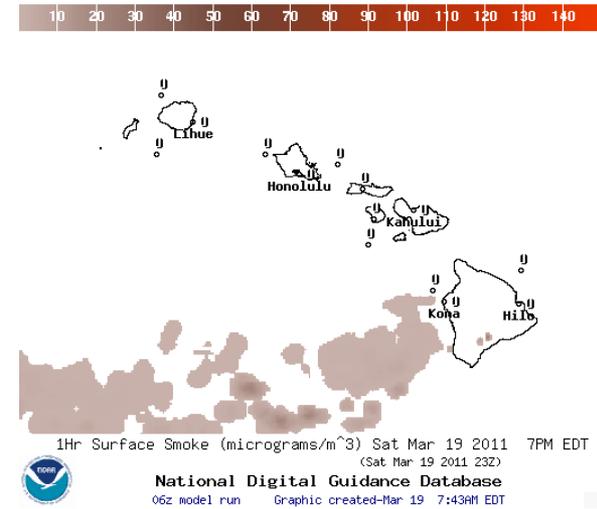
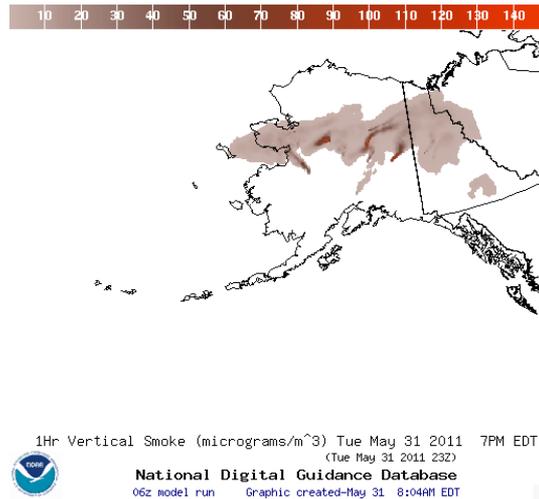
Surface Smoke

Vertical Smoke



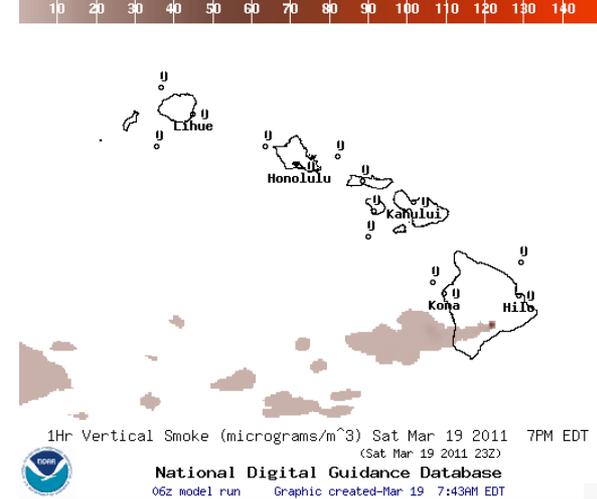
Surface Smoke

Vertical Smoke



Surface Smoke

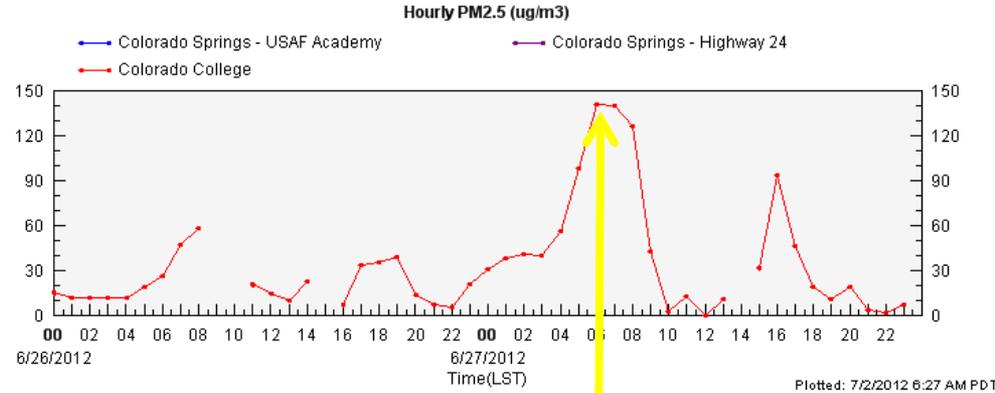
Vertical Smoke



# Colorado Springs – Waldo Canyon Fire

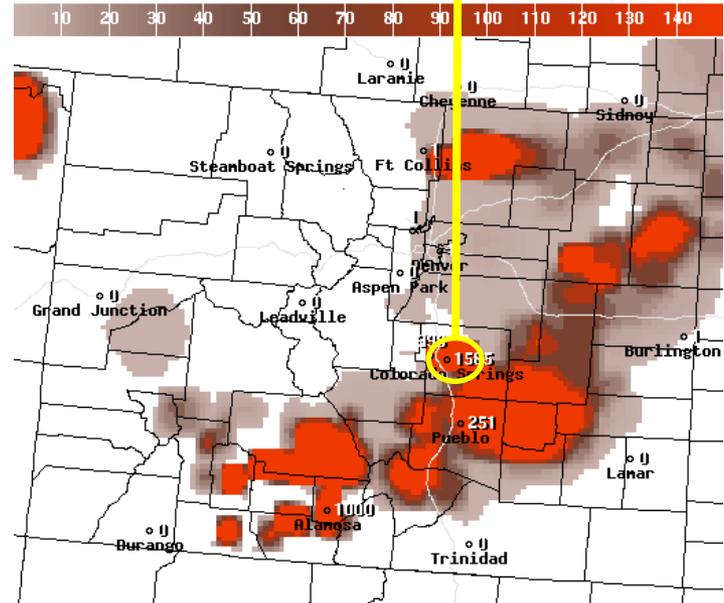


Waldo Canyon fire on June 26 in Colorado Springs<sup>2</sup>



Plotted: 7/2/2012 6:27 AM PDT

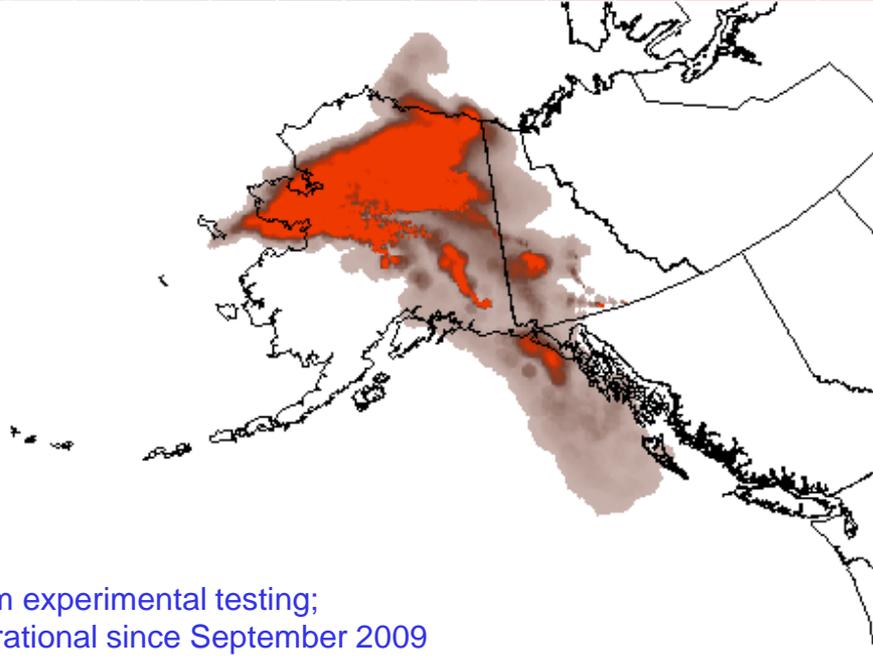
- Began on June 23, west of Colorado Springs<sup>1</sup>
- Moved eastward, burning over 18,000 acres and destroying 346 homes
- Peak of fire June 26-27
- Evacuations reached 32,000 on June 27
- The cause is under investigation
- Smoke plume reached 20,000 feet<sup>2</sup>
- High winds in region have fueled rapid spread of fire; dry conditions persistent; consecutive Red Flag Warning days



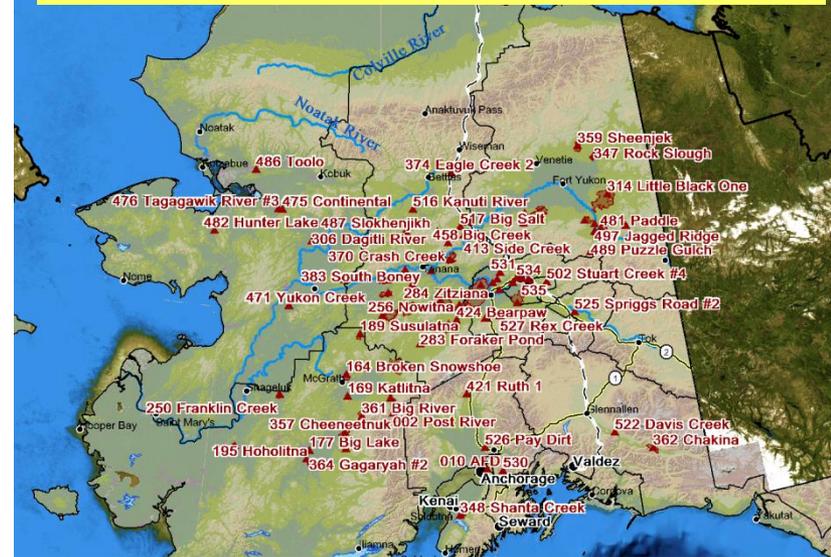
1Hr Surface Smoke (micrograms/m<sup>3</sup>) Wed Jun 27 2012 8AM EDT (Wed Jun 27 2012 12Z)

1. Inciweb Reports, <http://www.inciweb.org/incident/2929/>  
 2. Waldo Canyon fire reaches 'epic proportions', <http://www.csmonitor.com/USA/Latest-News-Wires/2012/0627/Waldo-Canyon-fire-reaches-epic-proportions-video>

# Smoke from wildfires in Alaska



86 active wildfires on August 4, 2009  
 4 temporary flight restrictions  
 ~3 million acres burned in 2009



From experimental testing;  
 operational since September 2009

1Hr Surface Smoke (micrograms/m<sup>3</sup>) Tue Aug 04 2009 6PM EDT

Experimental (Tue Aug 04 2009 22Z)

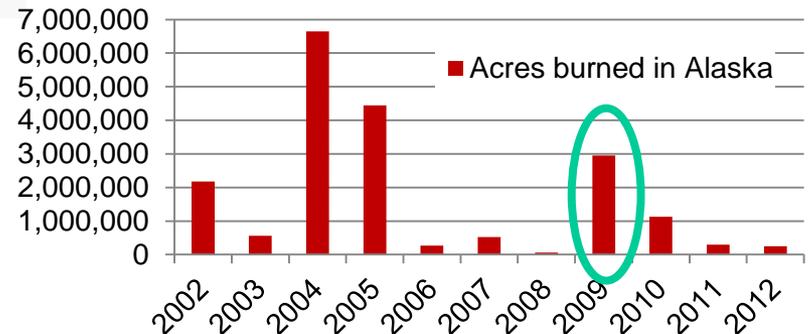
National Digital Guidance Database

06z model run Graphic created-Aug 03 7:19AM EDT



In year 2009:

- Large Alaskan fires began in early July
- Driest July ever recorded in Fairbanks and second warmest July ever (avg 66.5°).



# Smoke Verification:

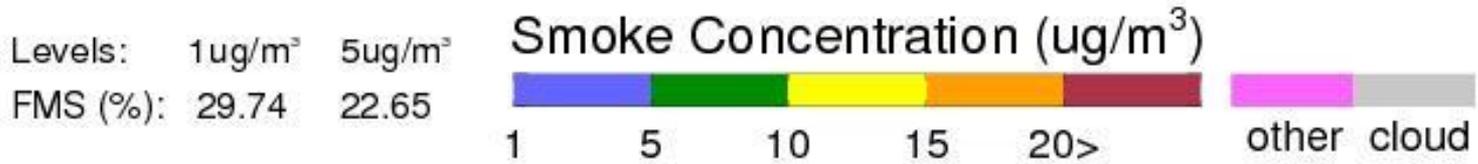
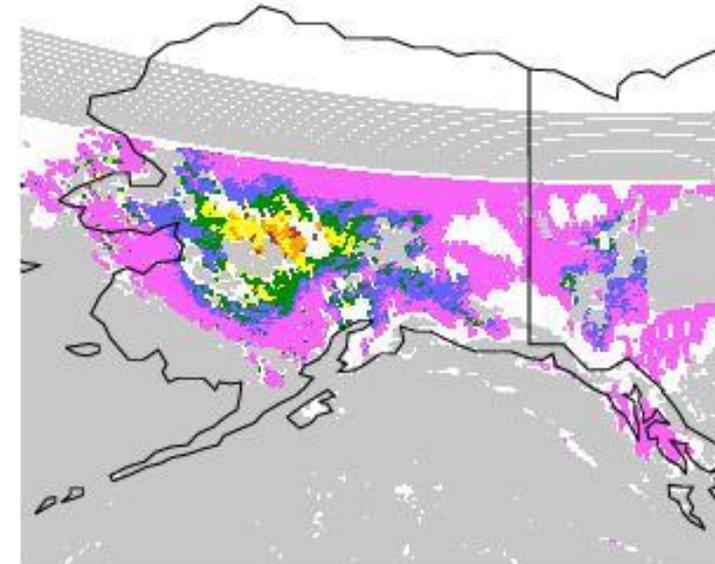
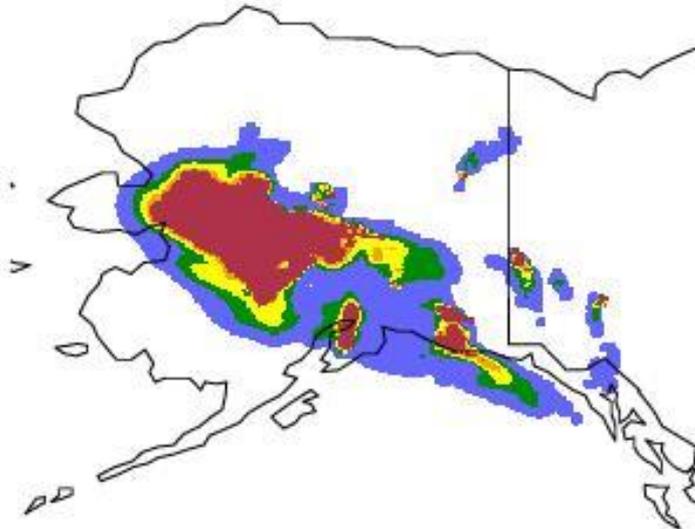
## July 13, 2009

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

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

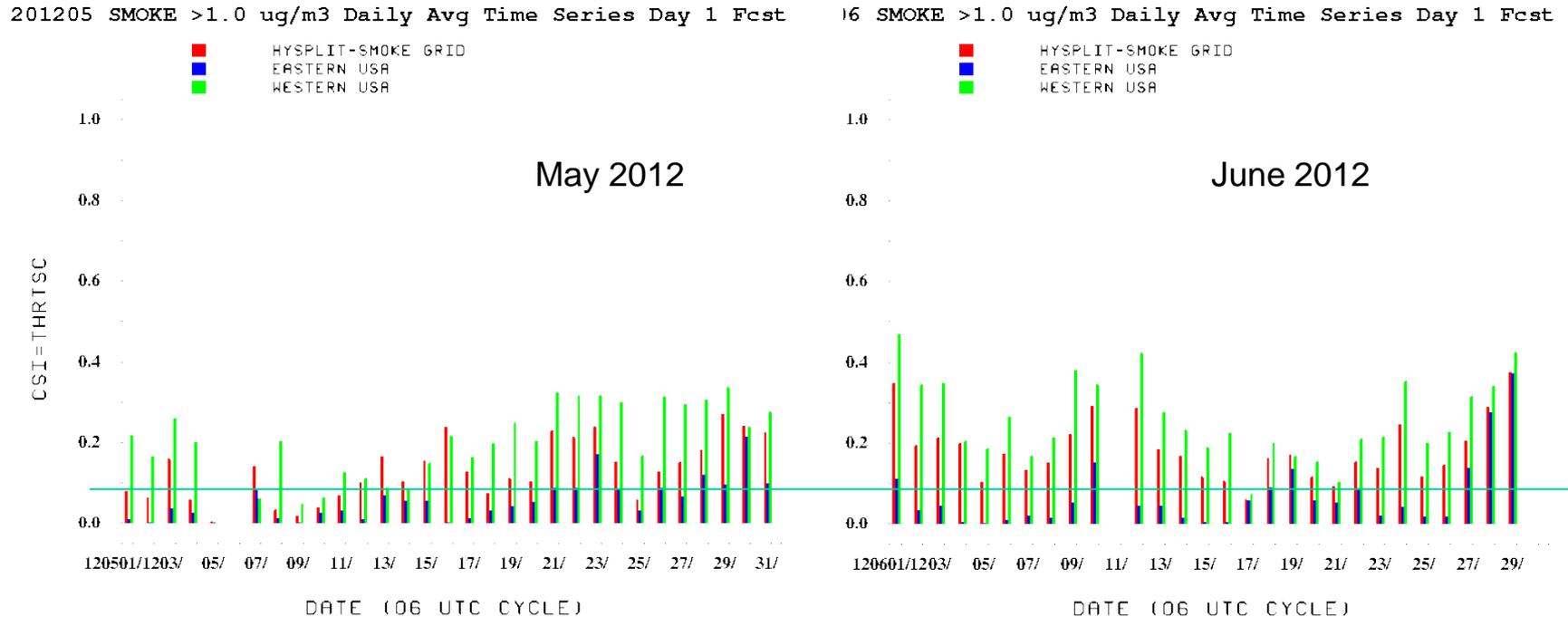
**GOES smoke product: Confirms areal extent of peak concentrations**

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



# Verification of smoke predictions for CONUS

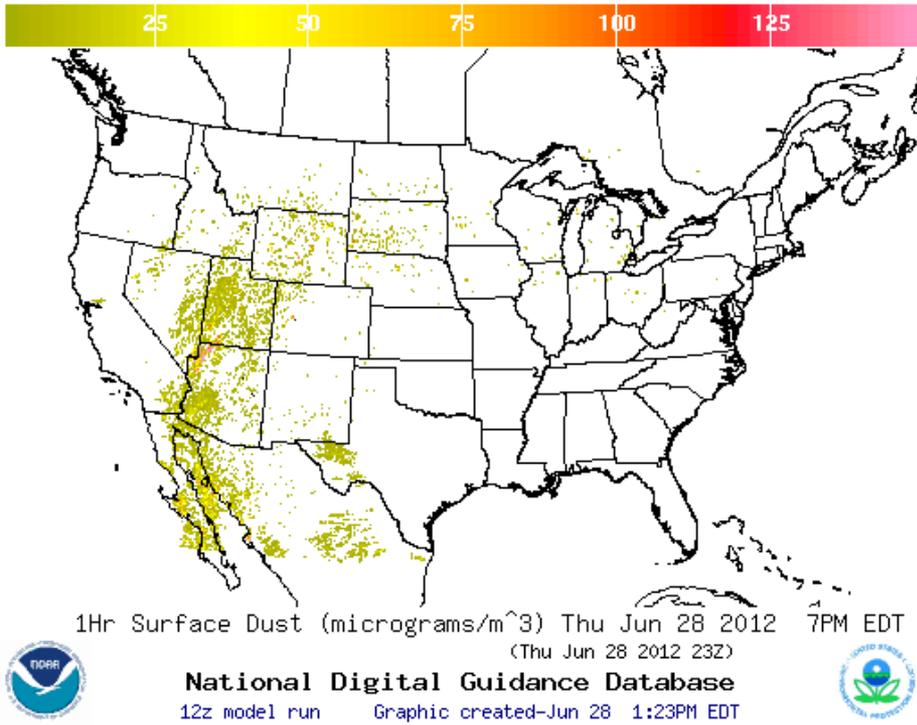
## Daily time series of FMS for smoke concentrations larger than 1 $\mu$ m/m<sup>3</sup>



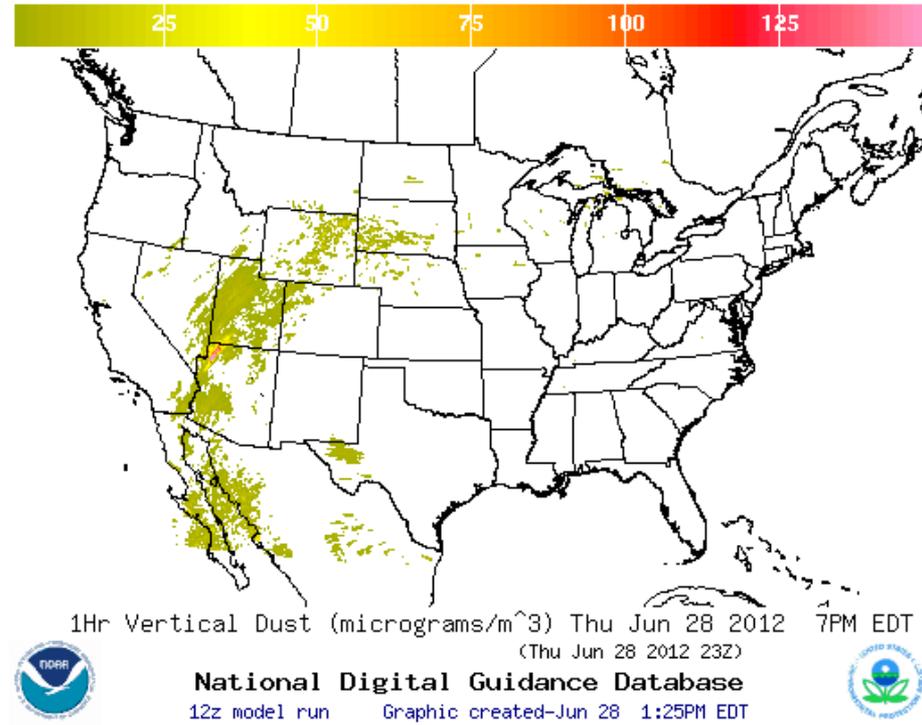
- **Figure of merit in space (FMS), which is a fraction of overlap between predicted and observed smoke plumes, threshold is 0.08 marked by green line**
- **NESDIS GOES Aerosol/Smoke Product is used for verification**



# Dust Predictions



**Surface Dust**

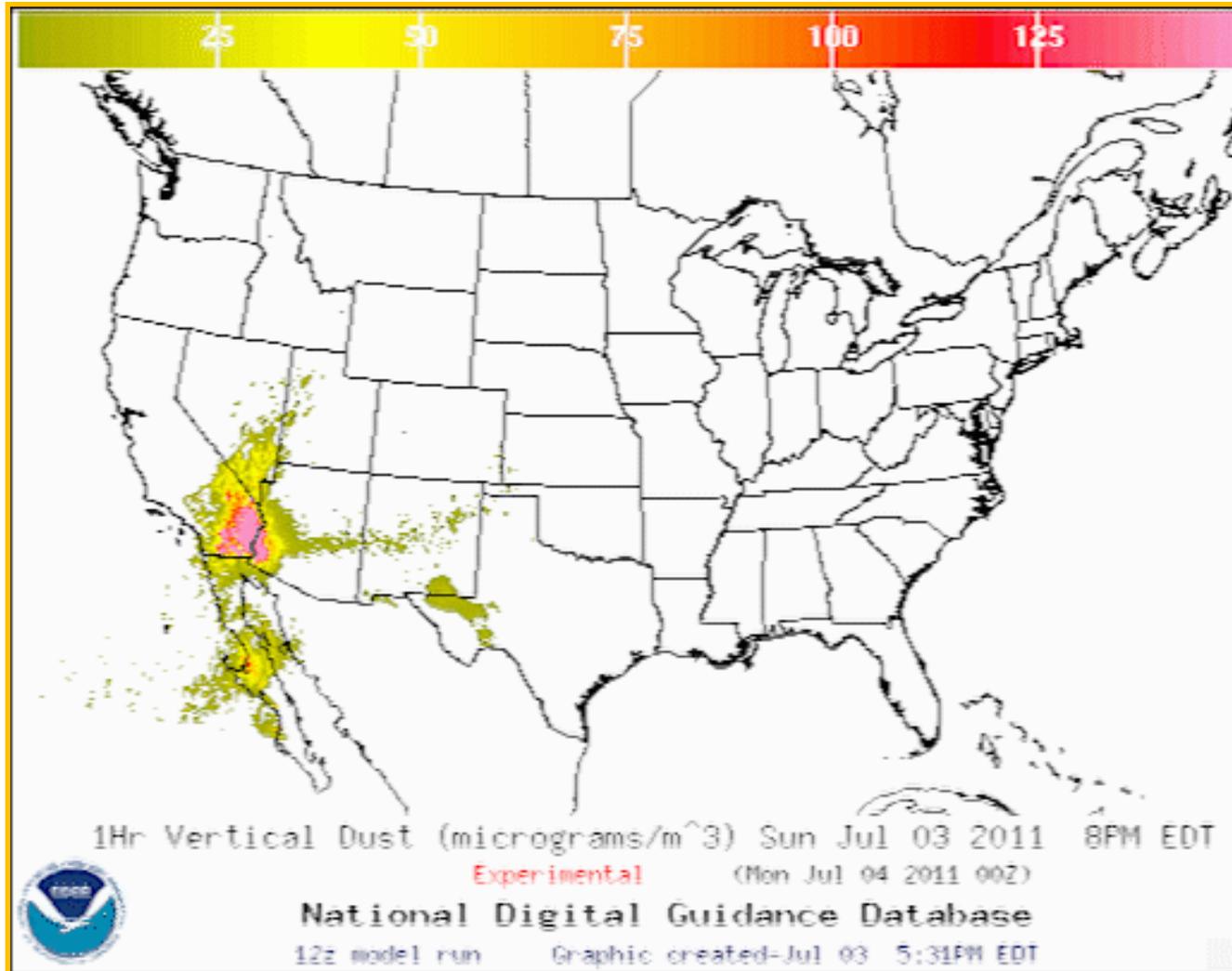


**Vertical Dust**

***Operational predictions at <http://airquality.weather.gov>***

# 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).
  - HYSPLIT model for transport, dispersion and deposition (Draxler et al., JGR, 2010)
  - Emissions modulated by real-time soil moisture.
  - 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

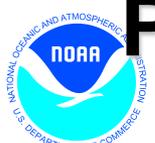


Source: <http://www.wrh.noaa.gov/psr/pns/2011/July/DustStorm.php>

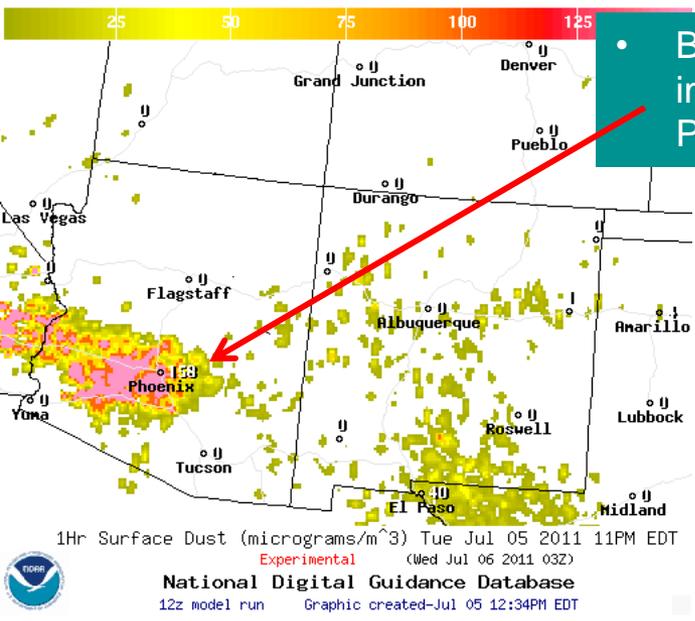
- Originated from convection near Tucson
- Stopped air traffic for over an hour
- Arizona DEQ reported a PM10 concentration of  $6,348 \text{ ug/m}^3$  during peak of storm at site in downtown Phoenix
- Storm moved through Phoenix at 30-40 mph



Source: [http://www.huffingtonpost.com/2011/07/06/phoenix-dust-storm-photos-video\\_n\\_891157.html](http://www.huffingtonpost.com/2011/07/06/phoenix-dust-storm-photos-video_n_891157.html)

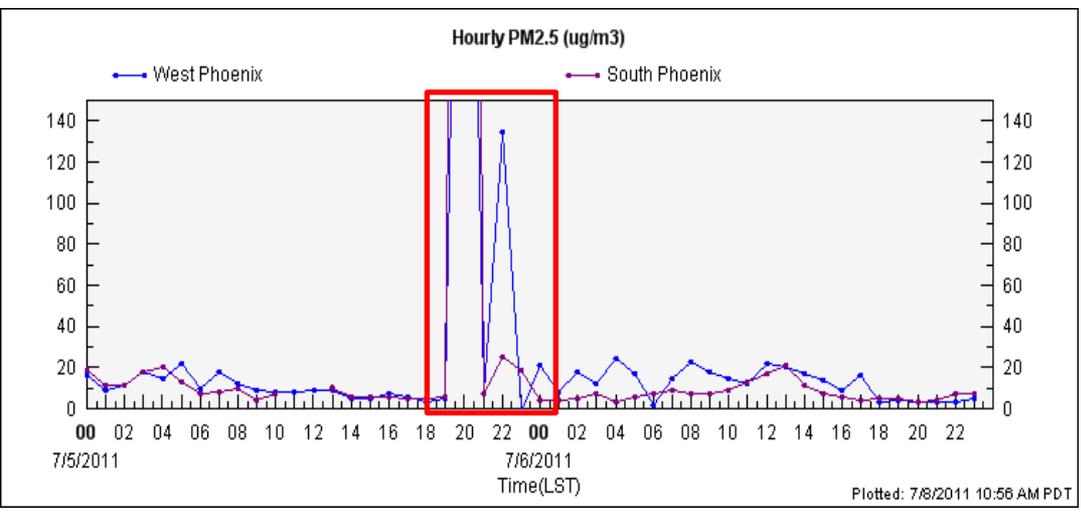
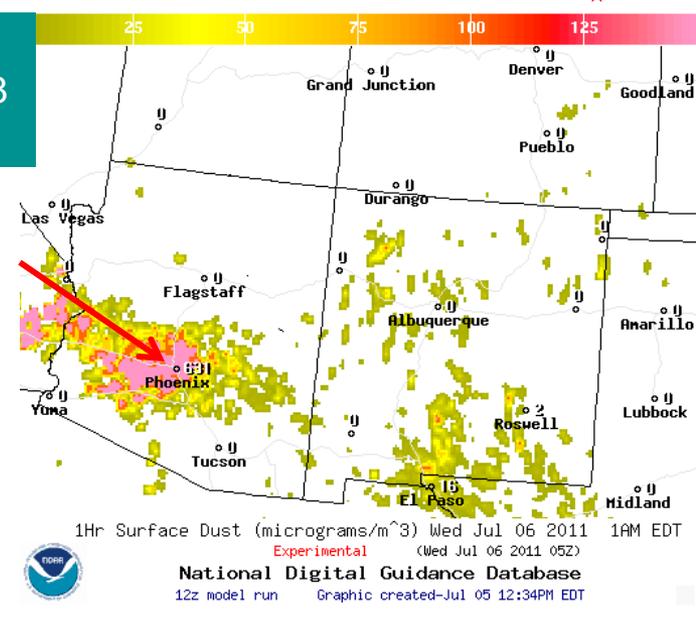


# Phoenix Observed PM 2.5 Observations



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

Predicted surface dust concentrations:  
 - 8PM 158 ug/m<sup>3</sup>  
 - 10PM 631 ug/m<sup>3</sup>

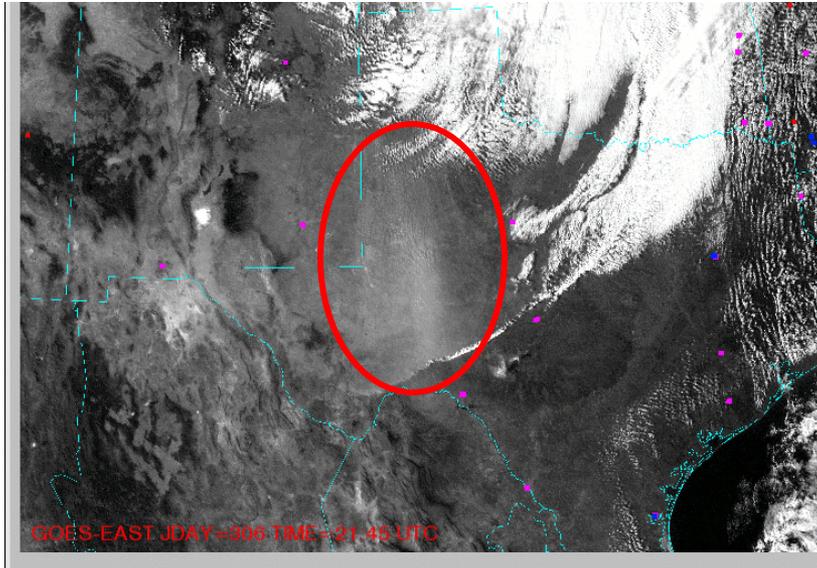


- Timing of storm based on comparing predictions to observations looks accurate (albeit perhaps early – 63 ug/m<sup>3</sup> predicted at 7 PM for Phoenix), however, the predictions keep the high levels seen at 10 PM LST for the next four to five hours, not seen in the observations

# Dust prediction updates

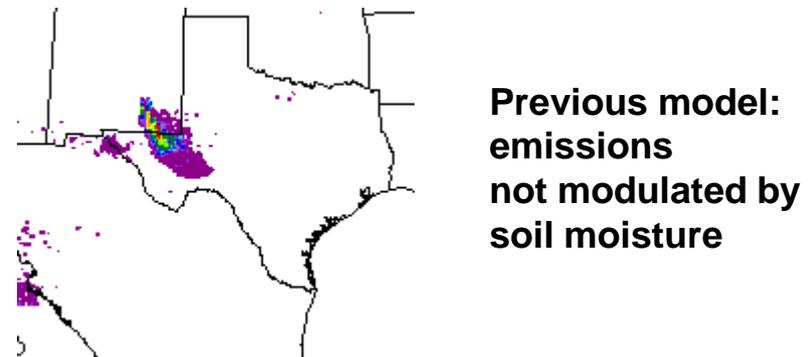
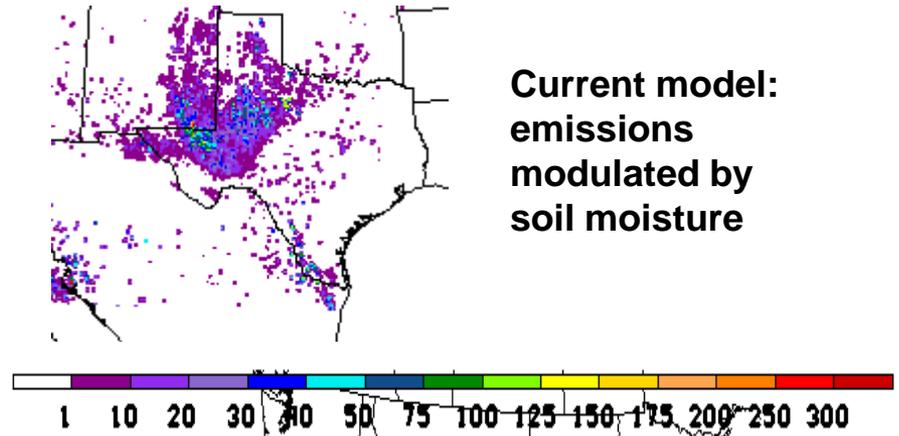
- **Modulating dust emissions using real-time soil moisture information** (now operational)

## 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/m<sup>3</sup>) at the surface



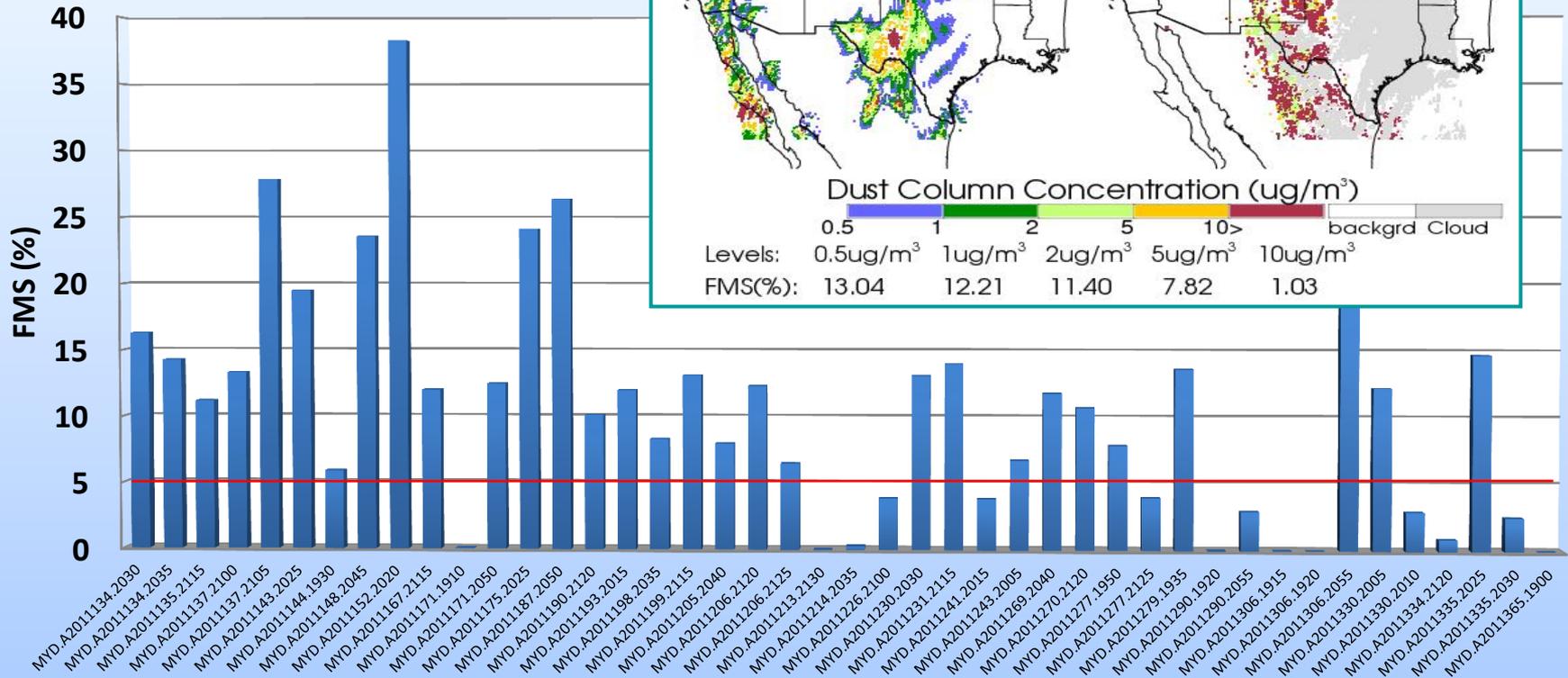
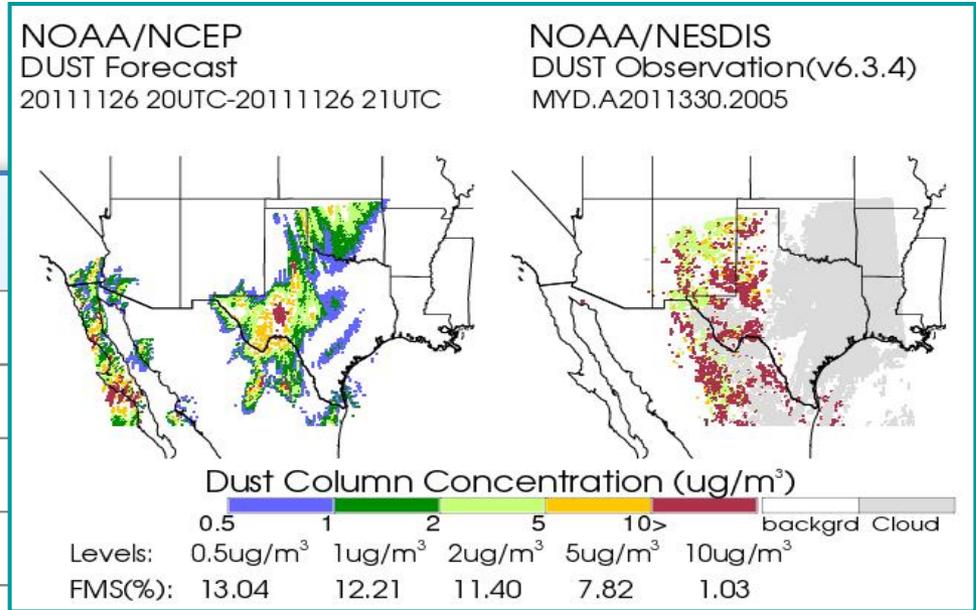
- **Longer time step** (10 min vs. 6 min) provides comparable predictions, but reduces prediction run time by over 30% (currently in testing)

# Real time verification examples

Using MODIS Dust Mask Algorithm from NOAA/NESDIS satellite imagery

“Footprint” comparison:

- Threshold concentration  $> 1 \mu\text{g}/\text{m}^3$ , for average dust in the column
- Tracking threat scores, or figure-of-merit statistics:  
 $(\text{Area Pred} \cap \text{Area Obs}) / (\text{Area Pred} \cup \text{Area Obs})$
- Initial skill target 0.05



**Focus group access only, real-time as resources permit**

## Fine particulate matter over CONUS

*From NEI sources only*

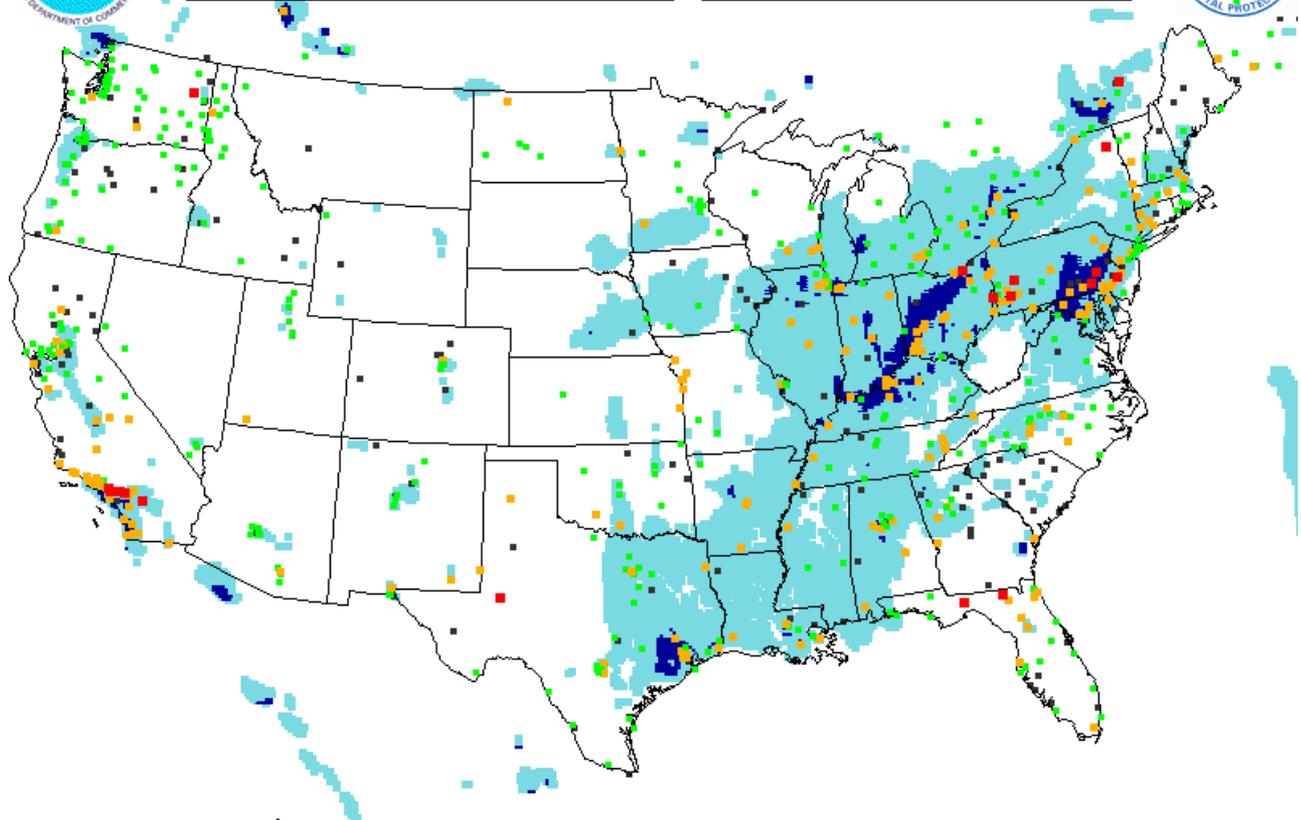
- CMAQ: CB05 gases, AERO-4 aerosols
- Sea salt emissions

**Wildfire smoke emissions not included**



Daily PM2.5 Maxima, Obs and Model  
 1-H Average, Threshold=35 ug/m<sup>3</sup>  
 Midnight To Midnight EDT 20120419  
 5X (Developmental) Grid 0600 UTC

Gray	No Data
Green	Low
Gold/MdBlue	15.5–34.9 ug/m <sup>3</sup>
Red/DkBlue	Exceedance

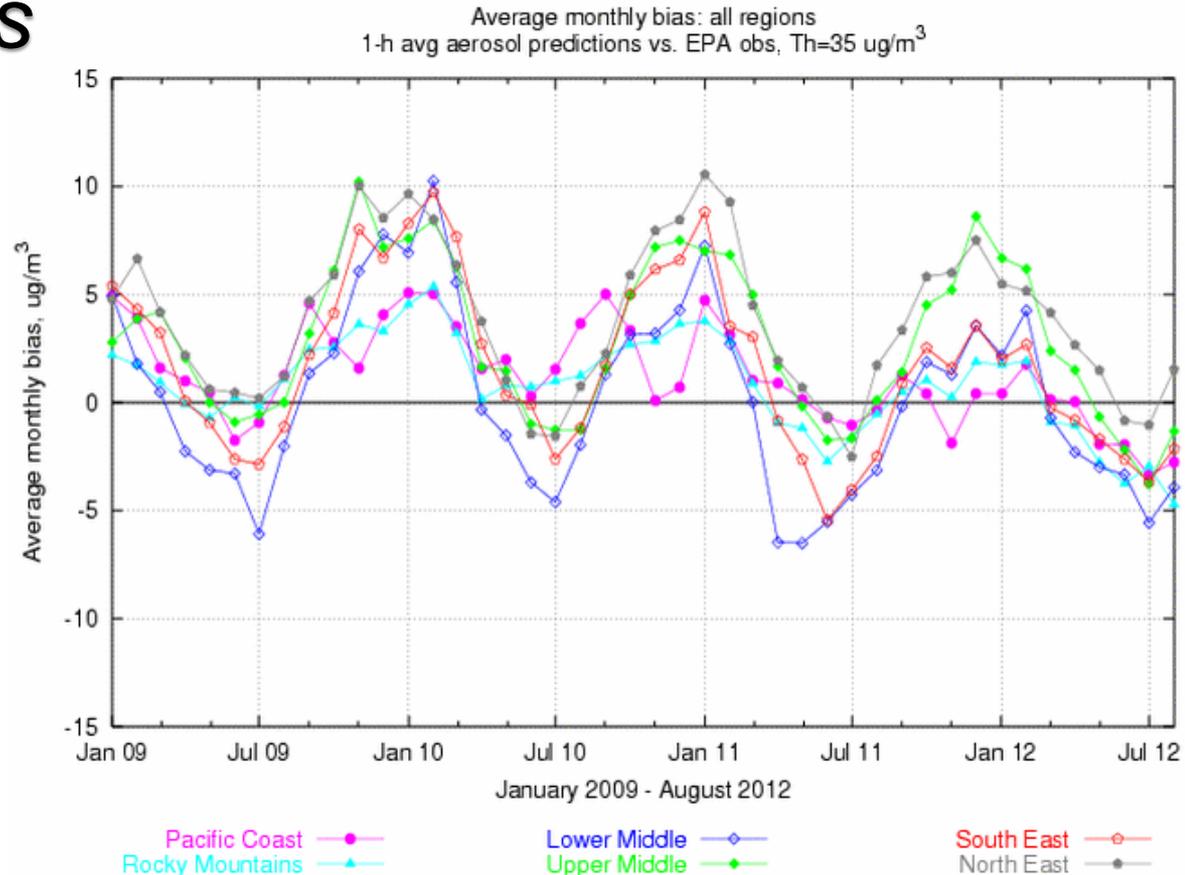


NWS/OST/MDL 2010

# Quantitative PM performance

## Forecast 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

<http://www.epa.gov/airnow/airaware/>

## 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**

**Air Quality Awareness Week**

Learn more about the AQI  
Learn more about the School Flag Program

[AirNow.gov](#) | [Tools for Teachers](#) | [Tools for Weathercasters](#) | [State & Local Activities](#) | [State & Local Resources](#)

Sign-up for EnviroFlash | Facebook | Twitter

**Healthy Air. Healthy You.**  
Learn how air quality affects your health during Air Quality Awareness Week, April 30-May 4.

**Monday: It's Not Just Ozone. Particulate Pollution Matters, Too**

You probably heard that ground-level ozone is bad for you. But did you know that there's another common pollutant that can harm your lungs and your heart? [More](#)

**Tuesday: Know When You Can Breathe Easy**

Today is World Asthma Day. If you have asthma, you're among the millions of people more at risk from both particle pollution and ozone. Here's why: particle pollution can penetrate deep into the lungs, aggravating lung disease, triggering asthma attacks and bronchitis, and increasing susceptibility to respiratory infections. Ozone can inflame the airways, reduce lung function and make people more sensitive to allergens – all of which can be problems for people with asthma. [More](#)

**Wednesday: Heads Up: Particulate Pollution Can Harm Your Heart**

You're doing a lot of things to keep your heart healthy. You eat right. You exercise. You don't smoke. Are you paying attention to air quality? If not, today's the day to start. [More](#)

**Thursday: Where there's smoke ... there's particulate pollution**

If you've ever been near a forest fire, you know how thick the smoke can get. But did you know that means particle levels may be extremely high? [More](#)

**Friday: You Can Help Keep the Air Cleaner and Your Family Healthier**

Because particle sources include vehicles and power plants, you can help reduce particle pollution by driving less, keeping your car well-maintained, and using less energy. Also, avoid using gas-powered lawn and garden equipment when particle levels are forecast to be high. [More](#)

**School Flag Program**



# Feedback from state and local AQ forecasters

## Examples provided in September 2012

- Good performance by NAQFC ozone forecast in 2012 in the Philadelphia metropolitan area. Sunday false alarms not an issue in 2012. (*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 forecast capability:*

- **Smoke** predictions nationwide
- **Dust** predictions for CONUS sources

- **Ozone** predictions nationwide
- Experimental ozone predictions over CONUS using CB05 chemical mechanism
- Prototype CMAQ **fine particulate matter** predictions with NEI sources

These predictions are proposed for termination, see

[http://www.nws.noaa.gov/om/notification/pns12ozone\\_pm2.5removal.htm](http://www.nws.noaa.gov/om/notification/pns12ozone_pm2.5removal.htm)

NWS is requesting comments sent to [nwssp.comments@noaa.gov](mailto:nwssp.comments@noaa.gov)  
by November 26, 2012.



# 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**  
**NWS/OCWWS**  
**NWS/OPS/TOC**  
**NWS/OST/MDL**

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*Data Communications*  
*Dev. Verification, NDGD Product Development*

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**NESDIS/NCDC**  
**NWS/NCEP**

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*Program Support*  
*Product Archiving*

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*AQF model interface development, testing, & integration*  
*Global dust aerosol and feedback testing*  
*NAM coordination*  
  
*Smoke and dust product testing and integration*  
*NCO transition and systems testing*  
*HPC coordination and AQF webdrawer*

**NOAA/OAR/ARL**

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*CMAQ development, adaptation of AQ simulations for AQF*

**NESDIS/STAR** *Shobha Kondragunta, Jian Zeng*

*HYSPLIT adaptations*  
*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*

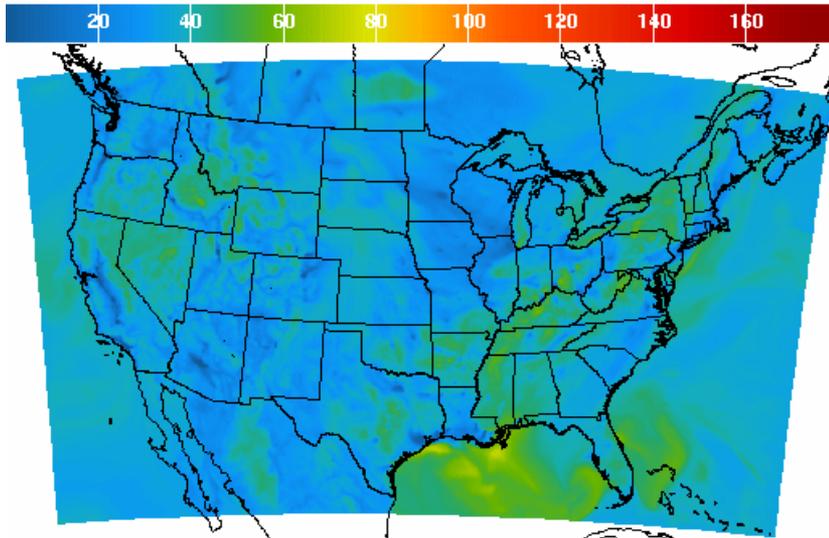
*AIRNow development, coordination with NAQFC*

\* Guest Contributors



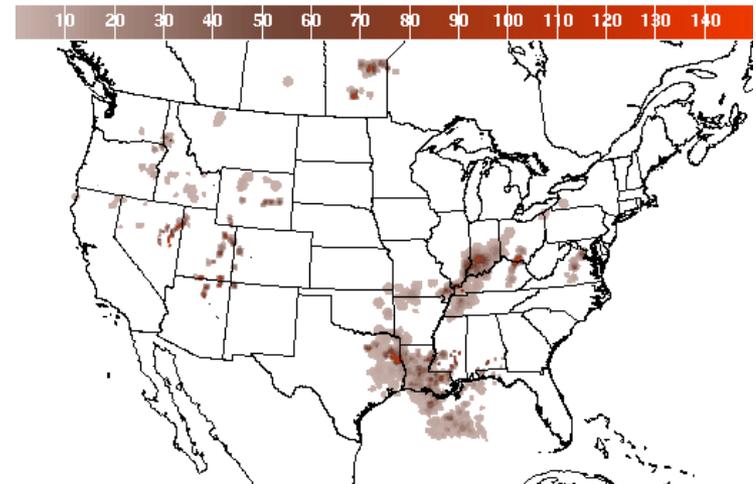
# Operational AQ forecast guidance

[airquality.weather.gov](http://airquality.weather.gov)



1Hr Avg Ozone Concentration(PPB) Ending Thu Sep 20 2007 10AM EDT  
(Thu Sep 20 2007 14Z)  
National Digital Guidance Database  
06z model run Graphic created-Sep 20 7:23AM EDT

## Ozone products Nationwide since 2010



1Hr Surface Smoke (micrograms/m<sup>3</sup>) Thu Sep 20 2007 9AM EDT  
(Thu Sep 20 2007 13Z)  
National Digital Guidance Database  
6z model run Graphic created-Sep 20 8:24AM EDT

**Smoke Products**  
**Nationwide since 2010**  
**Dust Products**  
**Implemented 2012**

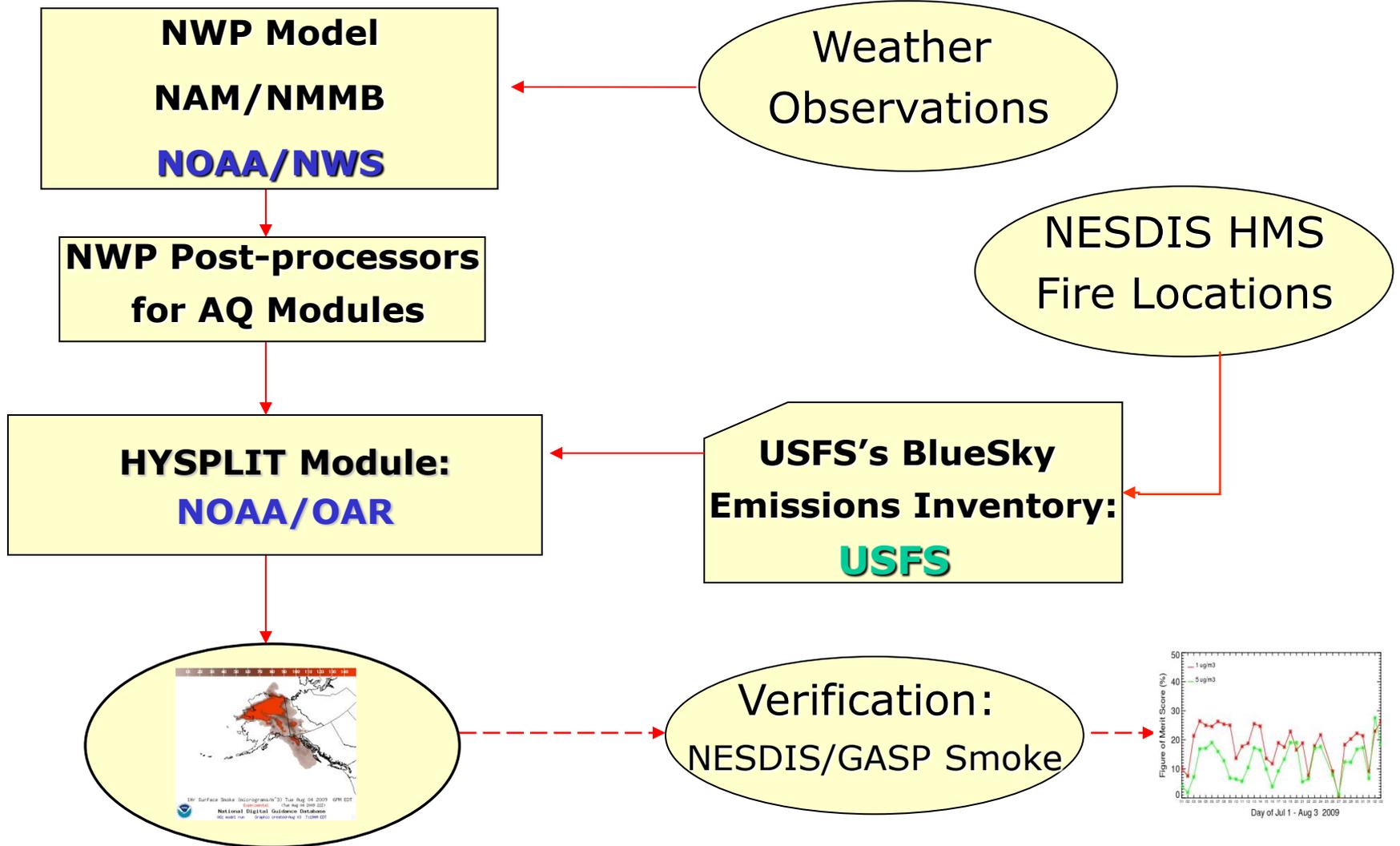
Further information: [www.nws.noaa.gov/ost/air\\_quality](http://www.nws.noaa.gov/ost/air_quality)



# Backup

# Smoke Forecast Tool

## Major Components





# Verification of dust predictions with 10 min and 6 min time step

