National Air Quality Forecast Capability Progress and Plans

Air Quality Forecaster Focus Group Workshop

September 18, 2007

Paula Davidson

Outline

- **Background**
  - *Air Quality Forecast Program Goals, Planned Capabilities*
  - *Implementation Schedule; Looking Ahead*
- **Recent Progress, Highlights**
  - *Phased Development/Testing/Implementation: Expanding Capabilities*
  - *Ozone, Smoke, PM*
- **Focus Group: Discussion Topics**
  - *Challenges: Science, Changing Threshold*
  - *Opportunities: Increasing Coordination, Linkages*

Background

National Air Quality Forecast Capability

Vision and Strategy

Vision

National Air Quality Forecast Capability which provides the US with ozone, particulate matter and other pollutant forecasts with enough accuracy and advance notice to take action to prevent or reduce adverse effects

Strategy

Work with EPA, State and Local Air Quality agencies and private sector to develop end-to-end air quality forecast capability for the Nation

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: WRF-NMM*
- *NOAA/EPA community model for AQ: CMAQ*

Observational Input:

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

Gridded forecast guidance products

- *On NWS Telecommunications Gateway and EPA servers*
- *Updated 2x daily*

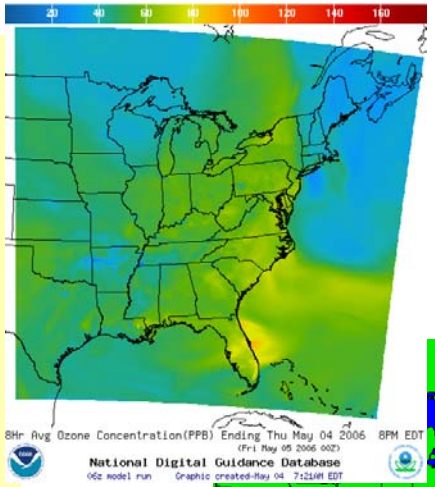
Verification basis

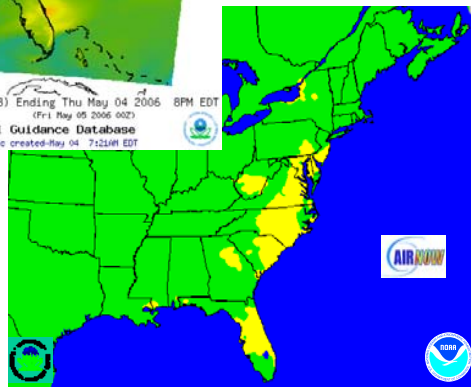
EPA compilation:

- *Ground-level ozone observations*

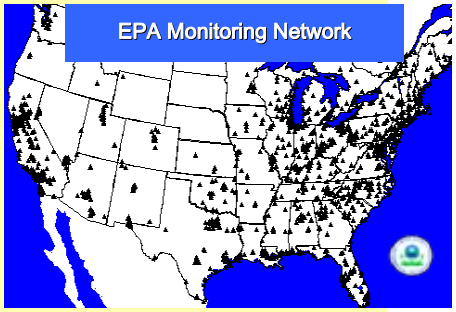
Customer outreach/feedback

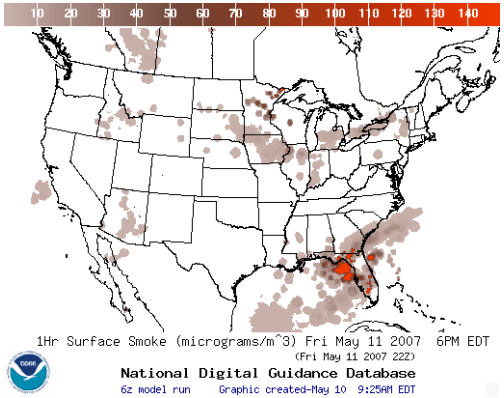
- *State & Local AQ forecasters coordinated with EPA*
- *Public and Private Sector AQ constituents*





AQI: Peak May 4





National Air Quality Forecast Capability

Major Model Components: Ozone Predictions

NWP Model

NAM/WRF-NMM

NOAA/NWS

Weather Observations

NOAA

EPA

NWP Post-processors for AQ Modules

EPA's National Emissions Inventory:

EPA/OAQPS

AQ Module:

Emissions Preprocessor PREMAQ

NOAA/OAR, NWS/NCEP, EPA/ORD

IT /Comms

NOAA/NWS

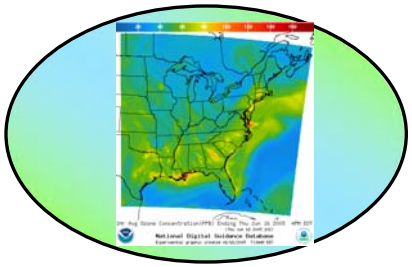
and

EPA/OAQPS

AQ Module:

Air Quality Reactive Transport CMAQ

NOAA/OAR, NWS/NCEP, EPA/ORD



Smoke Forecast Tool
Major Components

NOAA

USFS

NWP Model

NAM / WRF-NMM

NOAA / NWS

Weather Observations

NWP Post-processors for AQ Modules

NESDIS HMS Fire Locations

HYSPLIT Module:

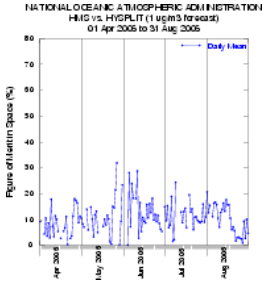
NOAA / OAR

USFS's BlueSky Emissions Inventory:

USFS

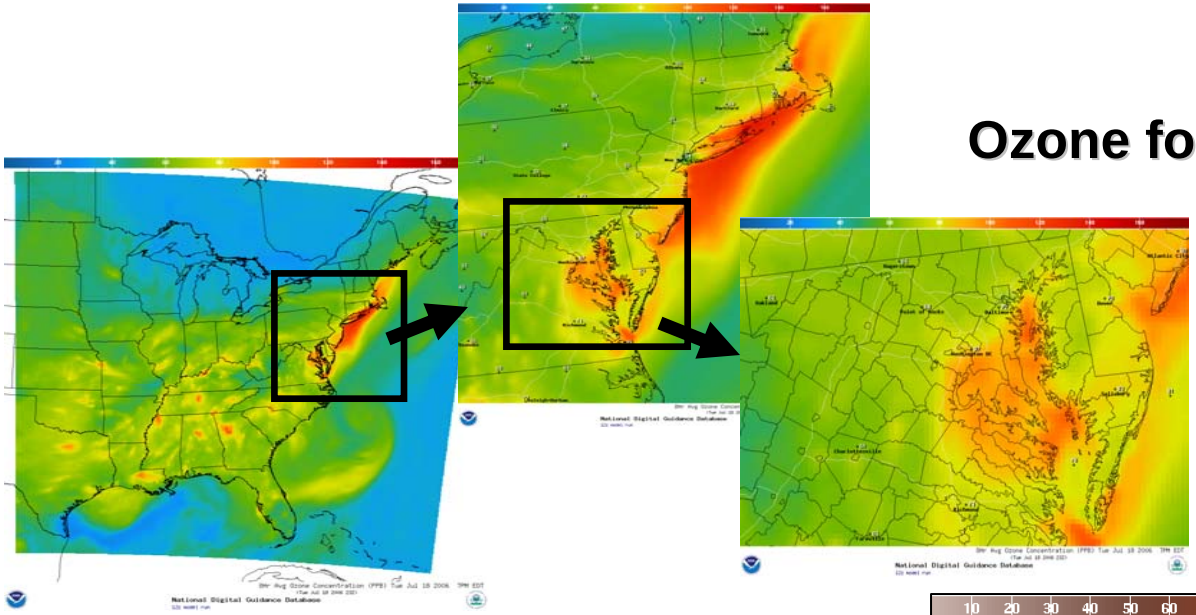
Verification:

NESDIS/GASP Smoke



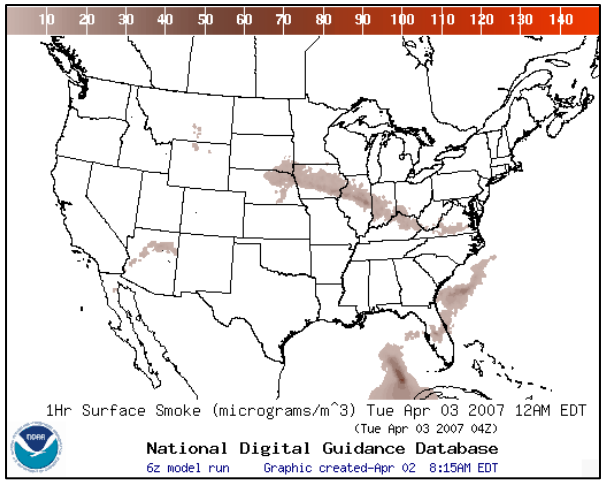
Operational AQ forecast guidance

www.weather.gov/aq



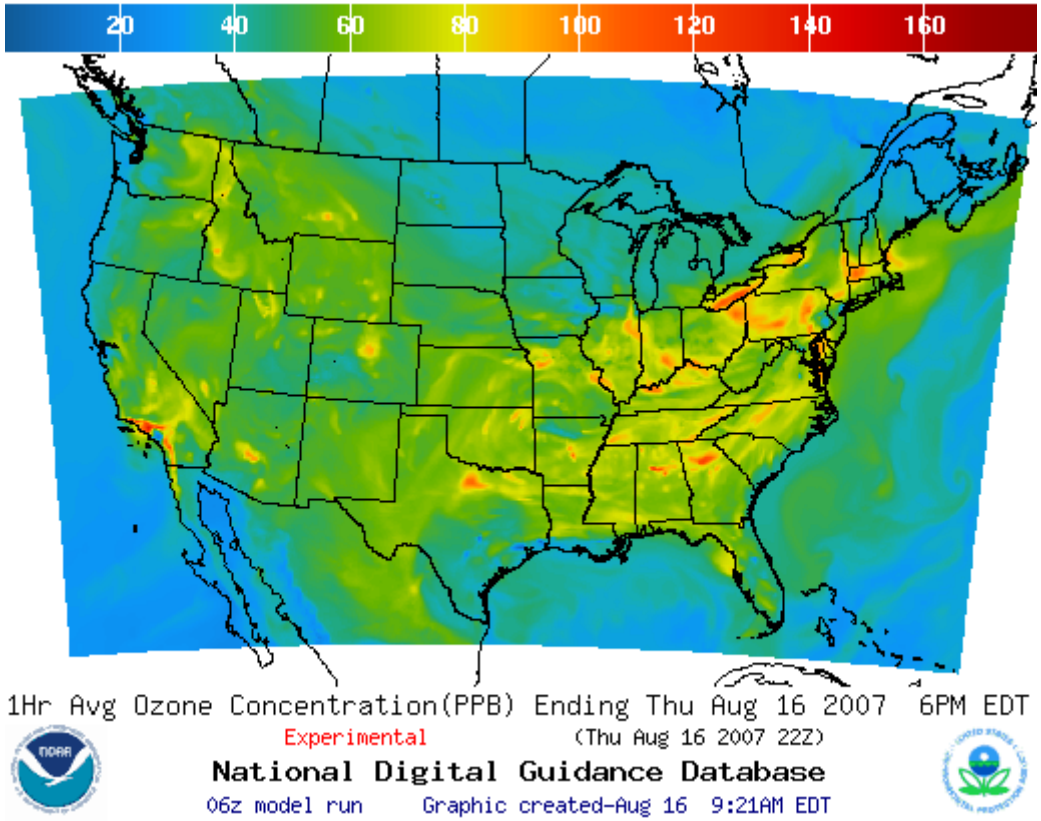
Ozone for Eastern US

Smoke Products Implemented March, 2007



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

Experimental Products:
Coast-to-coast Ozone



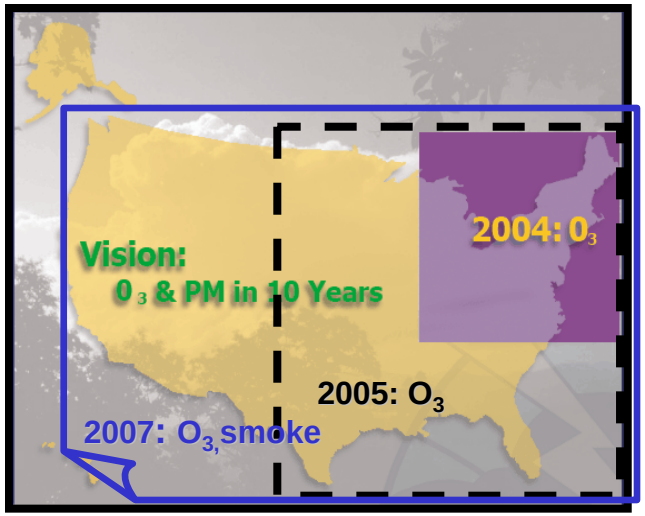
www.weather.gov/aq-expr

National Air Quality Forecast Capability

Planned Capabilities

Near-term: 1-day forecast guidance for ozone

- **Operational for Eastern US as of August, 2005**
- **Extend to CONUS in FY07; Nationwide by FY10**



Intermediate (5-7 years):

- **Implement quantitative capability to forecast particulate matter concentration**
  - *Particulate size $\leq$ 2.5 microns*

Longer range (within 10 years):

- **Extend air quality forecast range to 48-72 hours**
- **Include broader range of significant pollutants**

Recent Progress

Ozone Upgrades: Experimental (5X) testing from June, 2006

- *Approved by NWS Director for Operational Implementation, Sept 10, 2007*
- *Improvements in 2007 tests (from May 4): vertical mixing/ ACM2, CA off-road emissions,*

Smoke: Implemented into Operations March, 2007 over CONUS

- *Fire Locations and verification based on satellite observations, NESDIS' Hazard Mapping System (HMS) analysis, NESDIS' new AOD verification product*
- *Fire emissions estimates from USFS (BlueSky)*
- *HYSPLIT/NAM transport*

Aerosols: Developmental testing providing comprehensive dataset for diagnostic evaluations. (CONUS from mid-FY06)

- *CMAQ (aerosol option)*
- *Qualitative; summertime underprediction consistent with missing source inputs*

Phased Testing for Transition to Operations

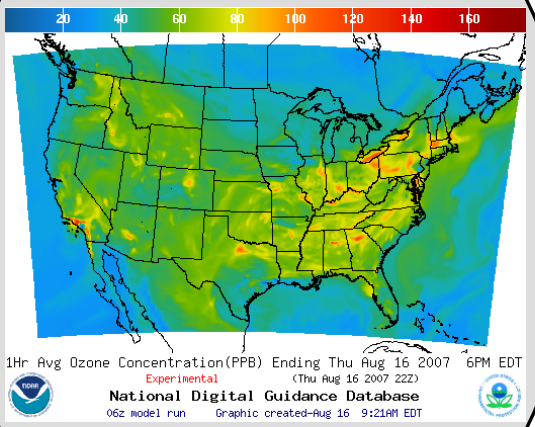
Phased Testing

Research
Does the science work?

Developmental Testing
Does it work with operational systems?

Experimental Testing
Does it meet deployment readiness criteria?

Deploy into Operations



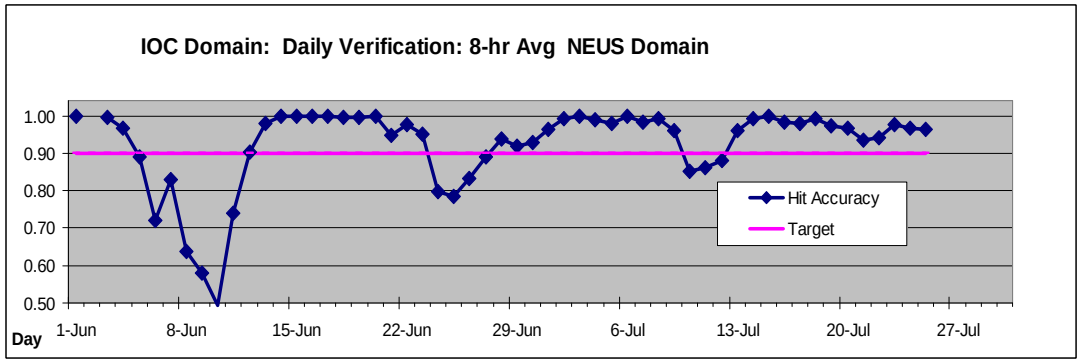
Key S &T Tests, Summer 2007 (O_3)

More advanced PBL mixing in CMAQ (CB05)

PBL mixing (ACM2) in CMAQ, CA off-road emissions, dry deposition upgrades

NAM and emissions data updates; Plume rise correction

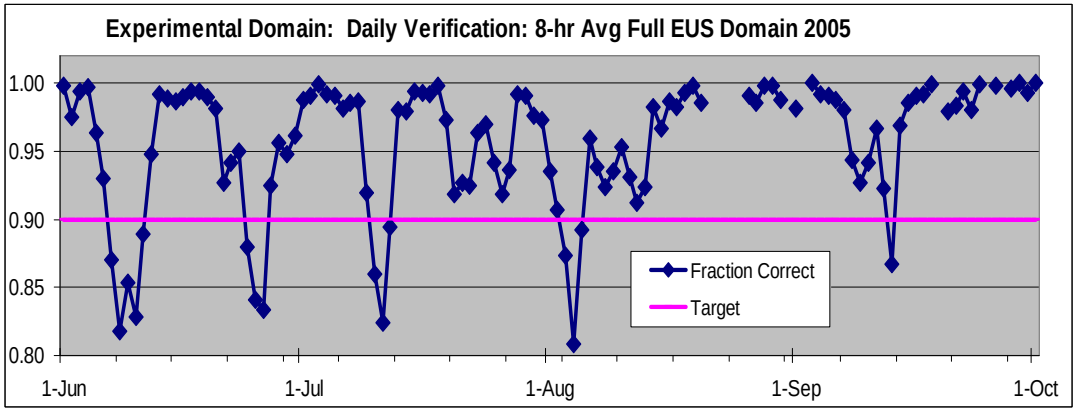
Progress from 2005 to 2006:
Summary Verification, Operational Capabilities



2005 **Operational**

Initial Operational Capability (IOC)

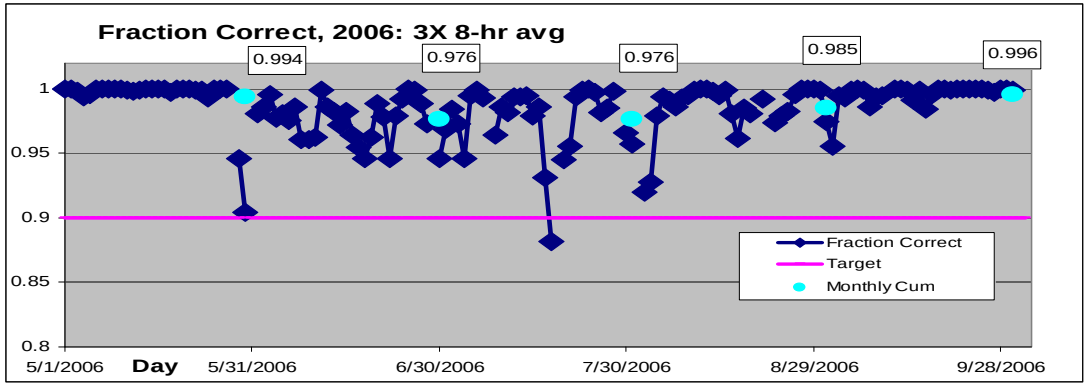
Operational, NE US Domain



2005 **Experimental**

Experimental, Eastern US

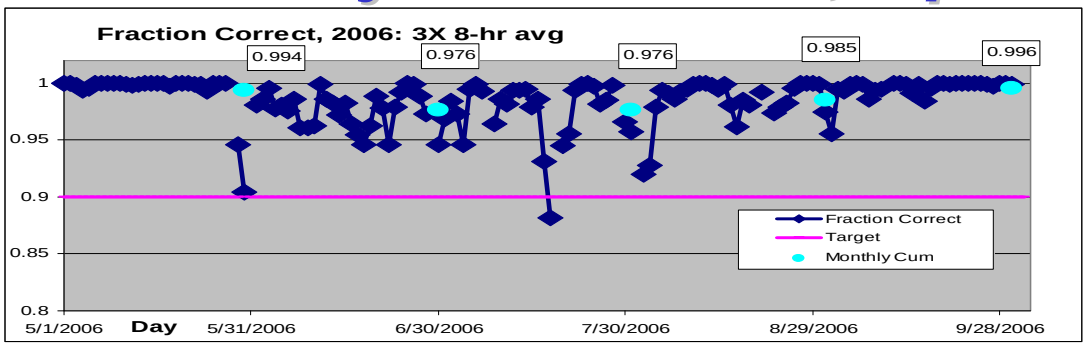
Approved 8/05 to replace IOC (NE US) in operations



2006 **Operational**

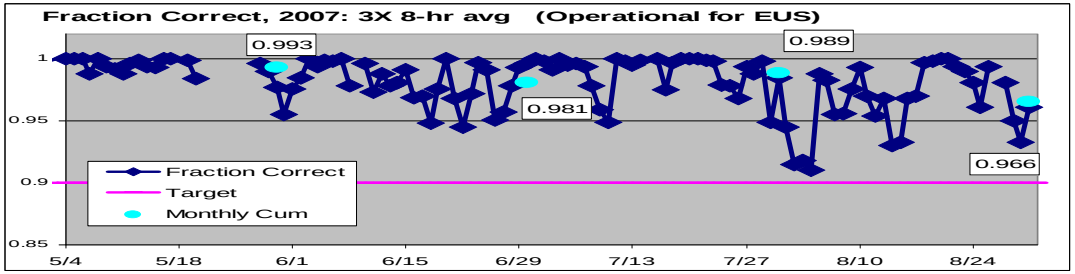
Operational, Eastern US

Progress from 2006 to 2007:
Summary Verification, Operational Capabilities



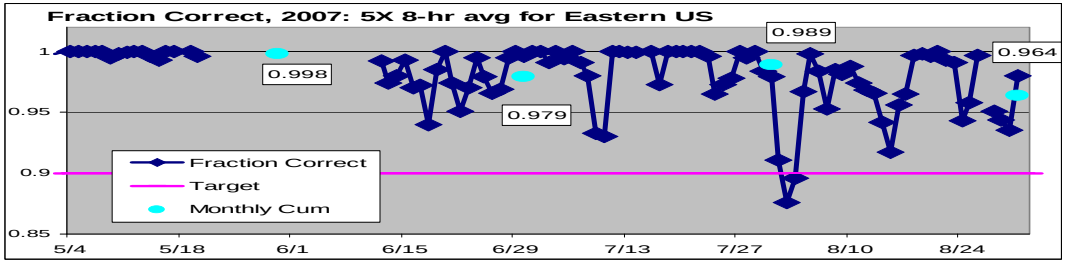
2006 **Operational**

Operational, Eastern US



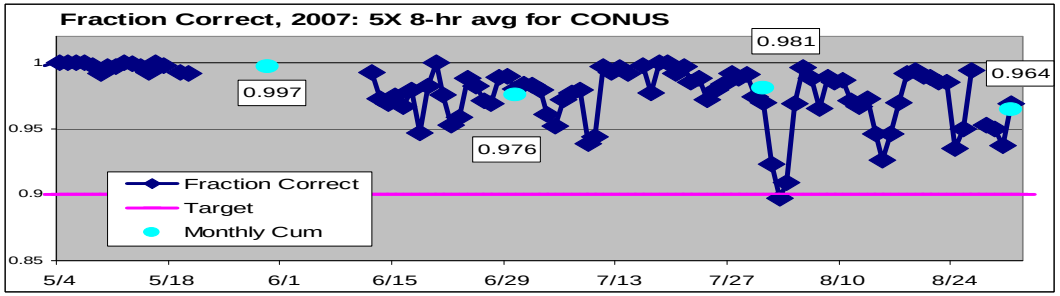
2007 **Operational**

Operational, Eastern US



2007 **Experimental**

Experimental CONUS, breakout EUS



2007 **Experimental**

Experimental CONUS, domain-wide

Expanded Ozone Forecast Guidance:
Operational Readiness Criteria Summary

Criterion	*Lead*	*Metric*	*Dates*	*Status* 2/07
Objective Evaluation: Accuracy	*NCEP*	*> 90%*	*5/4/07 – 8/31/07*	C
Subjective Feedback	*OCWWS*	*Positive on balance*	*5/4/07 – 8/31/07*	C
Production Readiness	*OCIO, NCEP*			C
On-time delivery		*> 95 %*	*5/4/07 –8/31/07*	C
Back-up		*In place*	*6/1/06*	C
Data retention		*In place*	*6/1/06*	C
Near-real time verification*	*NCEP*	*In place*	*6/1/06*	C
Final go/no go decision	*NWS*		*9/10/07*	C

* NESDIS automated (objective) product

Key	*Complete*	*On schedule*	*At risk*	*Remedial Action Required*

Objective Verification (NCEP, OAR)

Criterion	Metric	Dates	Status
Objective Evaluation: Accuracy	Fraction Correct > 90 % for predicted daily maximum ground-level ozone concentration (8-hr avg ≥ 85 ppb)	5/4/07 – 8/317/07	C

Domain-wide Performance meets Target

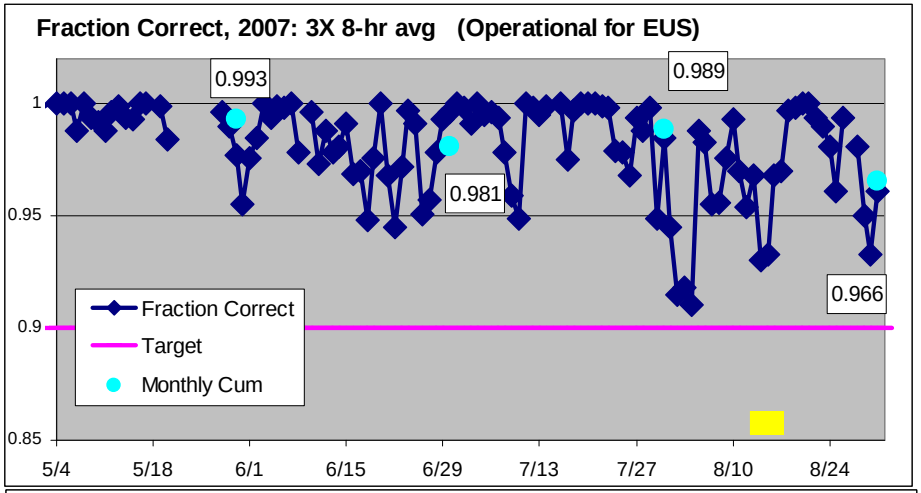
- For 94/95 days tested. 1 miss, Aug 2: FC= 0.897
- Fraction Correct (FC), cum: 0.978
- Operational (EUS) cum: 0.986

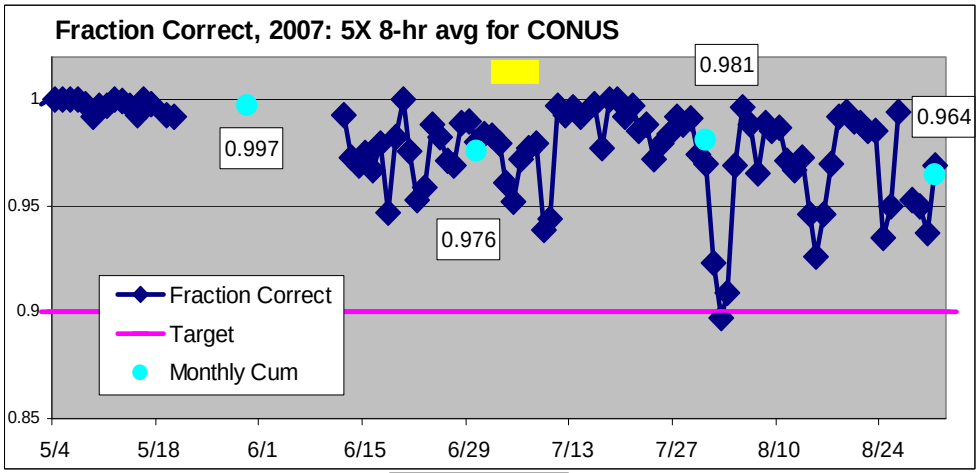
Regional Variations within Target

- Eastern CONUS, FC = 0.980
- Western CONUS, FC = 0.969; So CA, FC = 0.906

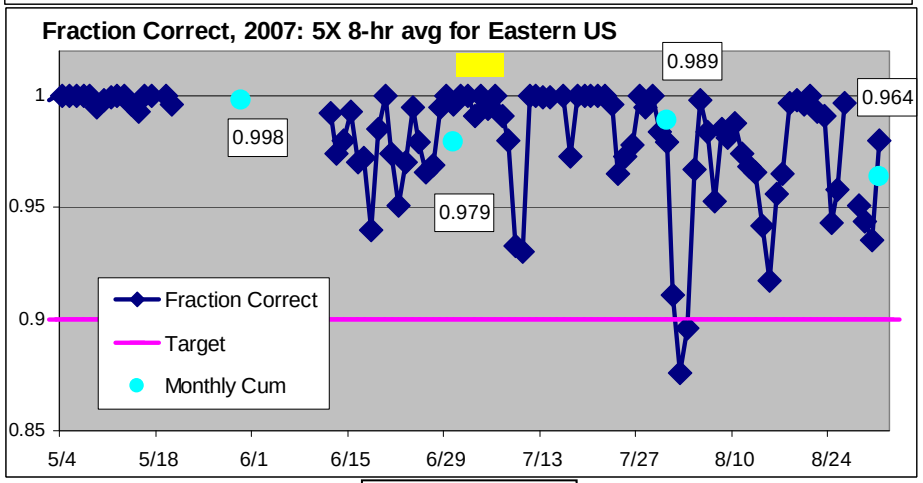
Poor AQ Episodes:

- Examples July 3-8, August 14-16
- Patterns captured (next slides)





CONUS



Eastern US

Objective Verification: Model Imrovements

Experimental Upgrades to CMAQ

Summer, 2006: Experimental testing over CONUS did not achieve accuracy requirements in the western US.

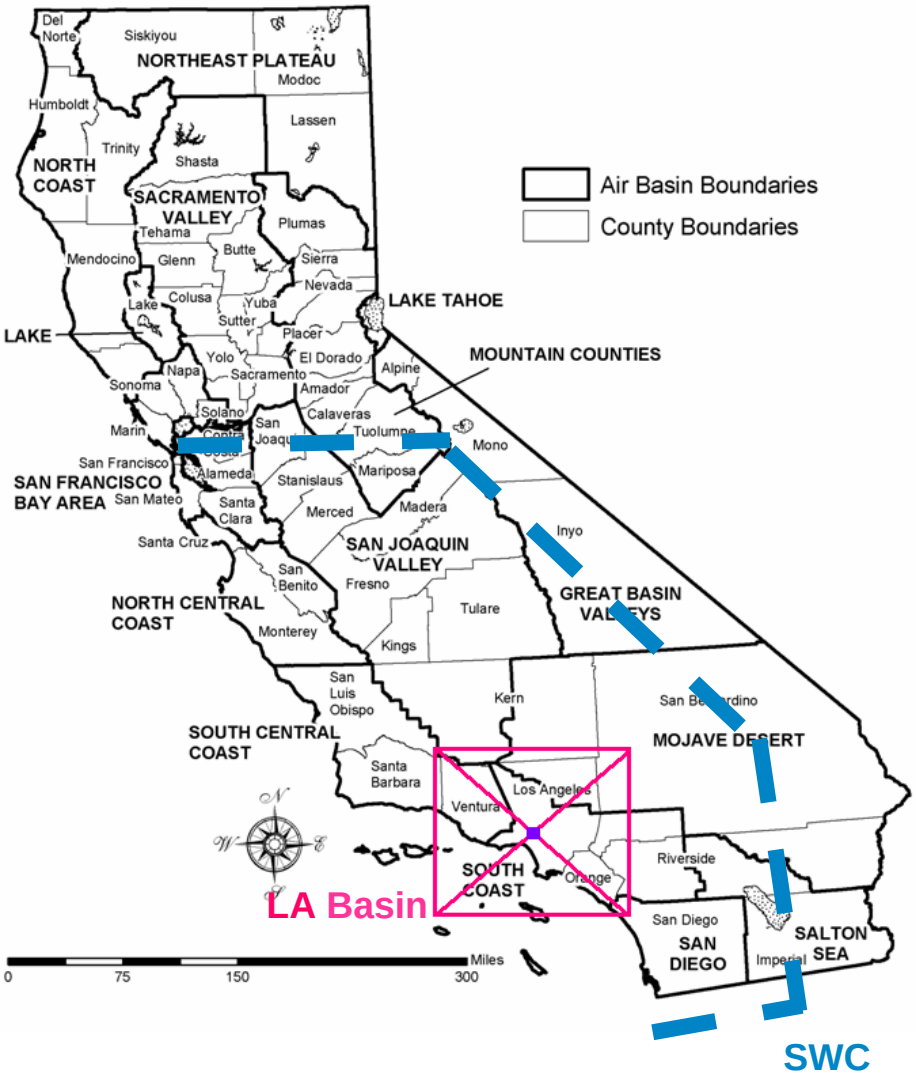
- **Identified severe underprediction of ozone in CA**
- **Corrections to errors in pollutant emissions in Aug 2006 – improvements, but deficiencies remained.**

Summer, 2007: Experimental Testing with upgraded configurations, beginning May 4.

- **Upgrades based on diagnostic analyses, retrospective testing.**
- **Real-time testing/evaluation led to 2 minor corrections (Jul 22)**

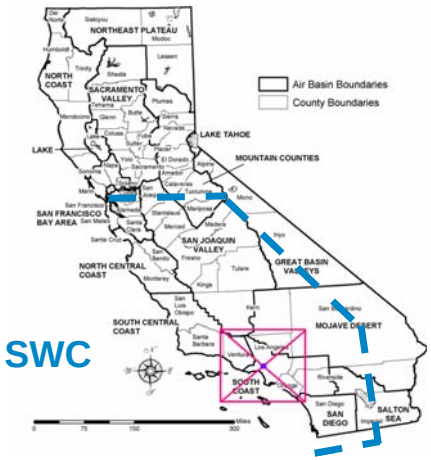
Component	Change Tested, 2007	Impact on pred. O3	Incorp.
CA Pollutant emissions	Revisions (incr) to CA off-road vehicular emissions	Pos for CA	5/4/07
CMAQ PBL mixing	ACM2	Pos for most regions	5/4/07
Vertical resolution, 22L	Tested 29, 40 layers	Negligible	
Boundary conditions, static	Upper boundary from GFS	Minor increase in upper midwest	
Plume rise (power plants)	Correction, vertical coordinate	Negligible	7/22/07
Leaf canopy parameters	Uptake of non-biotic gases severely limited	Modest (2-3 ppb) increase in upper midwest	7/22/07

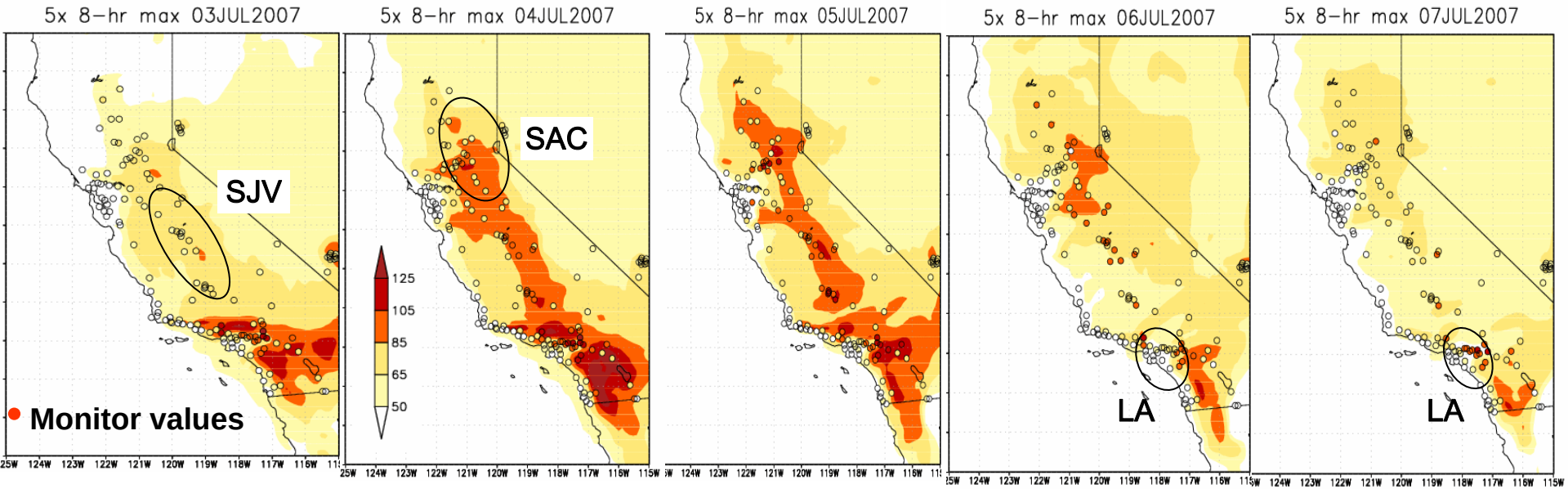
Regional Performance, California:
Air Districts, Complex Topography



California Performance:
July 3-7, 2007

SWC Region: Ozone under-predicted.
Bias negative; from -2 ppb (7/3) to -13 ppb (7/7)



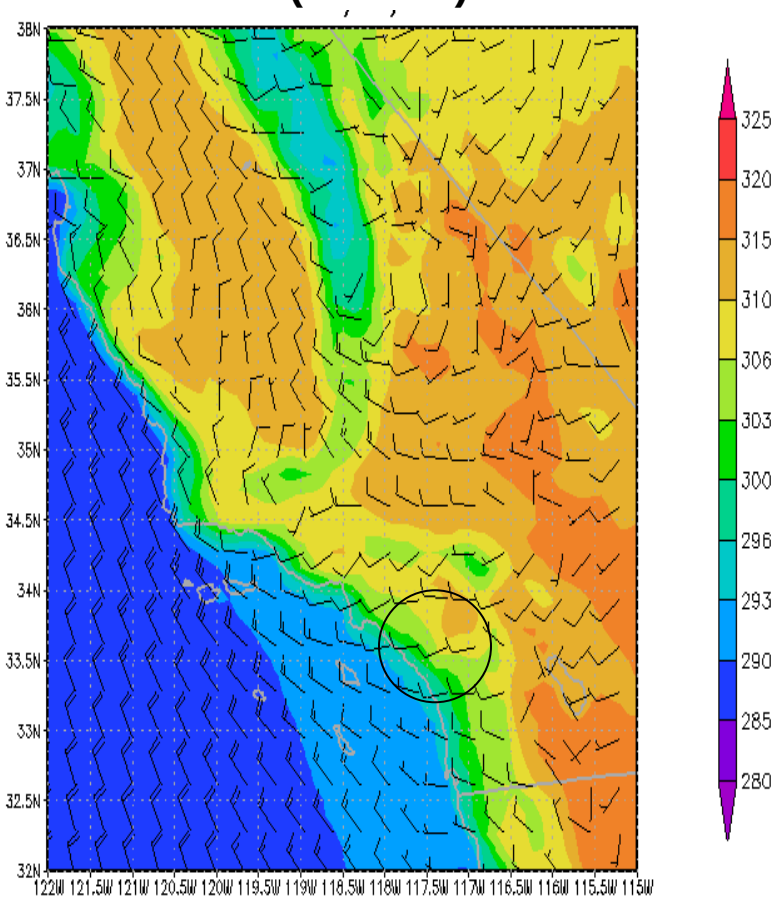


Good: SAC, SJV	**Good: SJV**	**Good: SJV**	**Good: Coast**	**Good: SAC, SJV**
Under: LA	**Under: LA**	**Under: LA**	**Under: SJV, LA**	**Under: LA**
Over: E of LA	**Over: SAC, E of LA**	**Over: SAC, E of LA**	**Over: SAC, E of LA**	

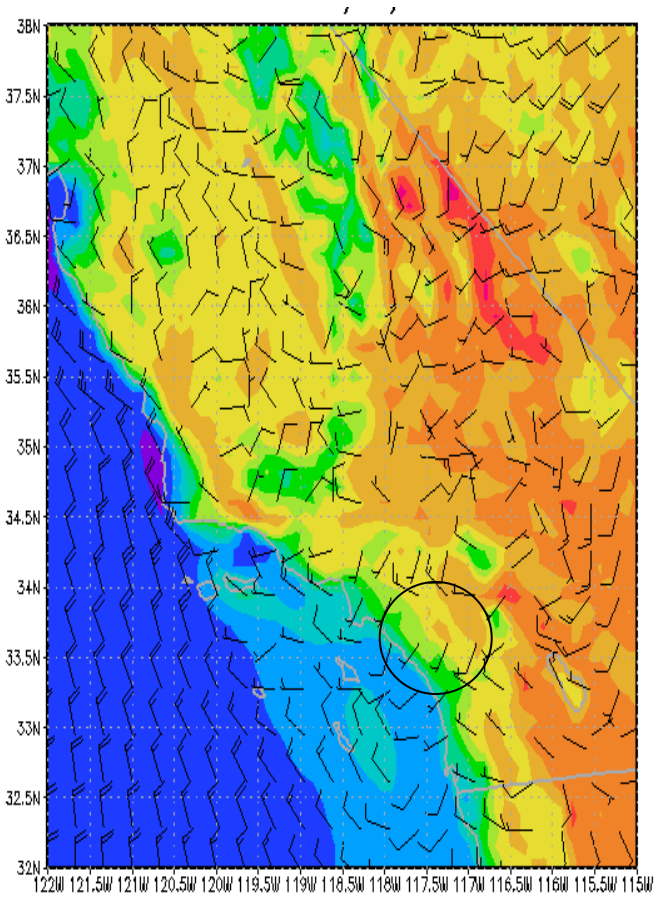
Factors in California Ozone Predictions: *Wind Direction*

NAM 36h forecast

Valid Jul 3 0Z (5PM LT)



RTMA Analysis



LA Basin: Winds are more westerly, NAM Temps are warmer

Not shown: Dry bias, Southern CA

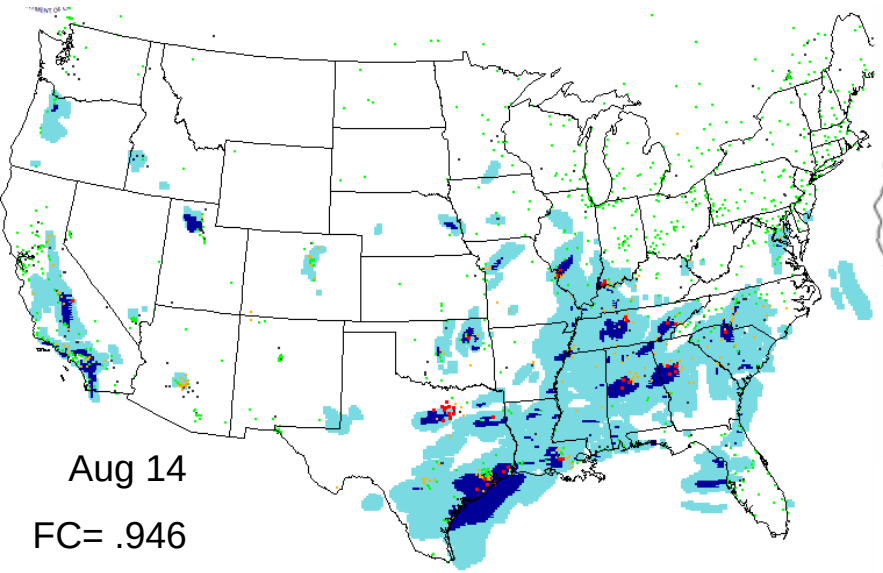
Summary, California Episode, June 3-7

- **Predicted timing, location of elevate ozone:**
  - *Generally good in SJV*
  - *Sharp gradients, Coast to East LA displaced ~20 km E (7/5)*
  - *Under-prediction in LA urban area*
  - *High ozone too widespread in Sacramento area and East of LA*

- **Meteorology, NAM predictions vs analysis:**
  - *Predictions for T, windspeed generally good; dry dew-point bias*
  - *Small negative speed bias & often westerly along SW Coast*
  - *Generally good winds in Central valley, Northern CA*
  - *Timing of onshore winds difficult near LA Basin*

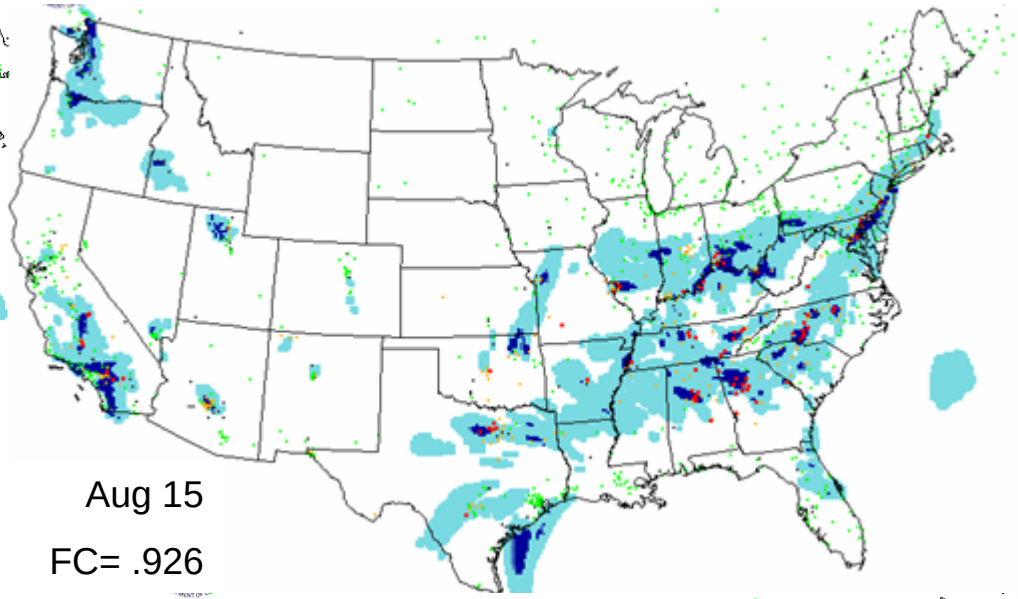
- **Challenges for predicting ozone in California, especially urban areas:**
  - *Emissions estimates?*
  - *Transport too strong?*

Poor Air Quality Episode:
August 14-16, 2007



Aug 14

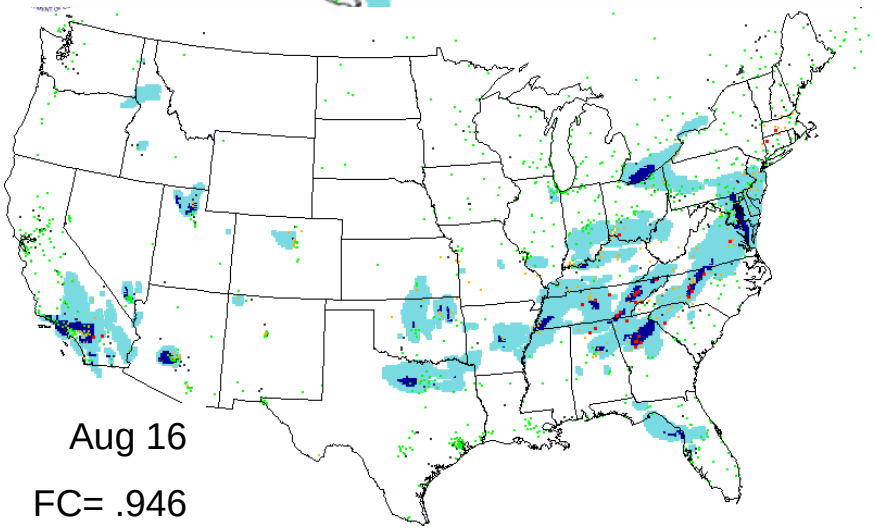
FC= .946



Aug 15

FC= .926

- Accuracy (FC) above target but below average
- Timing, location, of elevated ozone captured
- In EUS, test guidance performance comparable to operational guidance



Aug 16

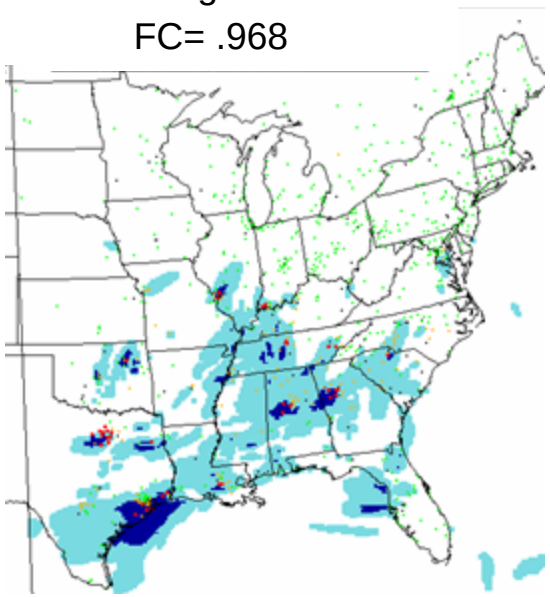
FC= .946

24 Hr Ozone Maxima, Obs and Model	
Eight Hour Average, Threshold = 85 ppb	
Midnight To Midnight EDT	
5X (Experimental) Grid 12Z	

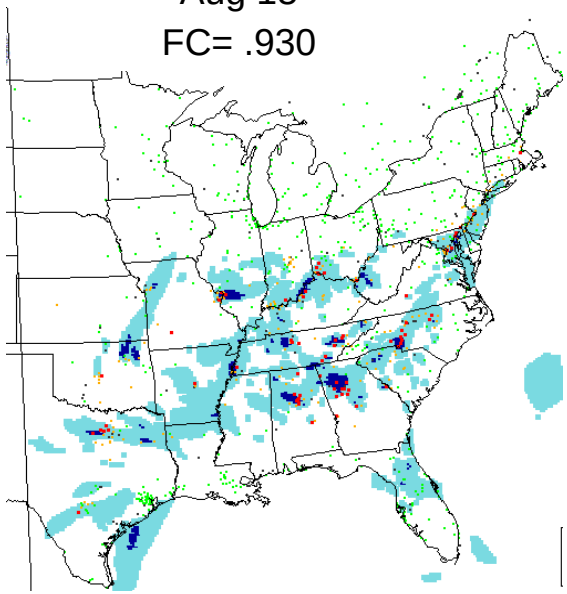
Gray	No Data
Green	Low
Gold/MdBlue	71-84 ppb
Red/DkBlue	Exceedance

Poor Air Quality episode:
August 14-16, 2007, Operational Guidance

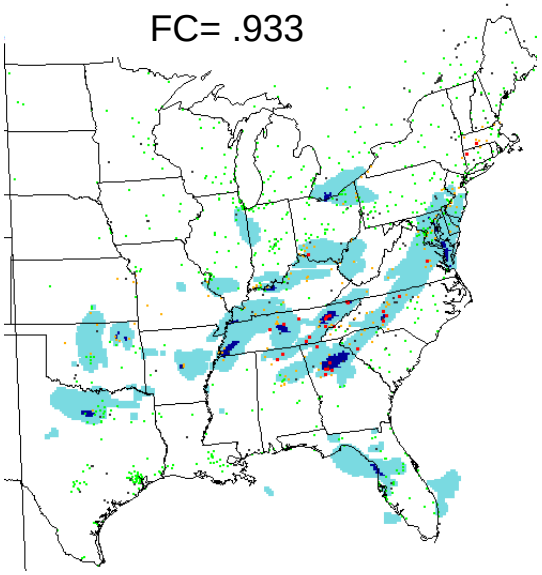
Aug 14
FC= .968



Aug 15
FC= .930



Aug 16
FC= .933



- FC lower than average
- Locations of predicted elevated ozone generally captured, but areal extent too limited
- Comparable performance to test guidance

24 Hr Ozone Maxima, Obs and Model
Eight Hour Average, Threshold = 85 ppb
Midnight To Midnight EDT
3X (Operational) Grid 12Z

Gray	No Data
Green	Low
Gold/MdBlue	71-84 ppb
Red/DkBlue	Exceedance

Subjective Feedback:
Comments on experimental ozone products

Feedback Sources:

- ***State and Local AQ forecasters***
- ***Constituent group***
- ***Other responses/comments on experimental products***
- ***Feedback link from NDGD***

NDGD Responders: Mix of public, AQ forecasters; 22 states including all NWS CONUS Regions

General Summary: 57 Apache Surveys received from 6/06 through 8/07

- ***54/57 neutral/positive, including requests for further coverage, explanation/clarification***
- ***16 very positive (28%)***
- ***14/57 use the product for planning purposes/health reasons/exercise (25%)***
- ***3/57 Negative***

Sample Comments:

- **"I suffer from bronchitis…which is irritated by smoke, etc. in the air. The air quality forecasts have helped me avoid going outside when the air is alive with smoke and they tell me when it is safe to go out. Thank you!" - DW – Auburn, AL, 5/29/07**
- **"From the observations I have been making, the model is doing a good job." "The NWS Experimental Model is showing good agreement." - DR, WA State Dept. of Ecology. 7/9 & 7/17/07**
- **"I use this product for farm workers, children outside and livestock/animals safety." M.L-E, Greenville, NC, 8/9/07**

Summary, Experimental O_3 Testing 2007

Domain-wide:

- **Target accuracy achieved**

Western US:

- **Target Accuracy achieved**
- **Good in Pacific Northwest**
- **Mixed in CA, but much improved over 2006 testing**
  - *Better performance in Central Valley, Bay area*
  - *Under-prediction in LA basin*
  - *Some over-prediction in Sacramento area and downwind of LA*

Eastern US:

- **Performance comparable to operational predictions**

Episodes:

- **Timing, location of poor AQ captured**

Approved for Operations, NWS Director, 9/10/07

Smoke Forecast Tool:
A step toward quantitative PM predictions

- ***Required for particulate matter (PM) forecasts***
  - **Fire emissions significant source of fine particle pollution (PM2.5)**
  - **Direct (e.g. soot) and indirect (from secondary reactions) contributions**
  - **Large fires locally dominate PM**
  - **Challenges: how much and how far do fire emissions contribute to PM2.5?**
- ***Real-time information on fire emissions essential***
  - **Inventory-based aerosol component tests for PM forecasting consistently underpredict: errors ~ 2-5 X**
  - **Wildfire smoke sources too large and variable for success with inventory-based, climatological approximations**
- ***Effectively leverages existing capabilities***
  - **NOAA/NESDIS observations of fire locations, extent**
  - **USFS estimates for wildfire smoke emissions based on vegetation cover**
  - **NOAA/OAR expertise in dispersion prediction: HYSPLIT**
  - **Scalable for CONUS, North American and global domains as needed**

Smoke Forecast Tool:
Operational Readiness Criteria Summary

Criterion	*Lead*	*Metric*	*Dates*	*Status* 2/07
Objective Evaluation: Accuracy	*NCEP*	*> 8%*	*9/1/06 – 2/1/07*	C
Subjective Feedback	*OCWWS*	*Positive on balance*	*4/1/06 – 2/1/07*	C
Production Readiness	*OCIO, NCEP*			C
On-time delivery		*> 95 %*	*4/1/06 –2/1/07*	C
Back-up		*In place*	*6/1/06*	C
Data retention		*In place*	*6/1/06*	C
Near-real time verification*	*NCEP*	*In place*	*9/1/06 (at OAR)* *11/1/06 (at NCEP)*	C
Final go/no go decision	*NWS*		*2/22/07*	C

* NESDIS automated (objective) product

Key	*Complete*	*On schedule*	*At risk*	*Remedial Action Required*

Subjective Feedback:
experimental smoke products

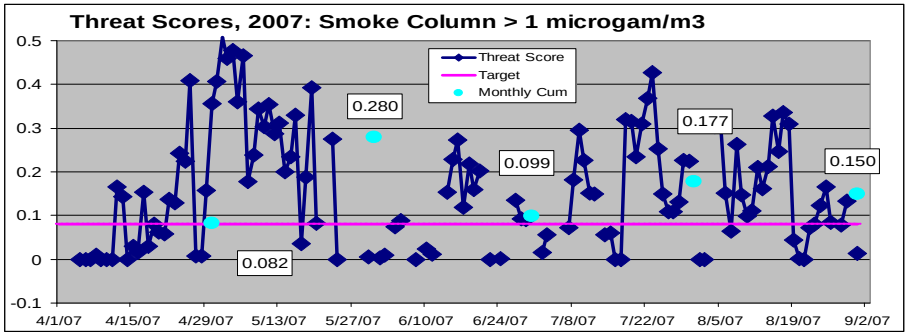
Responders represented a mix of public, AQ forecasters, and researchers from a dozen states including all NWS CONUS Regions.

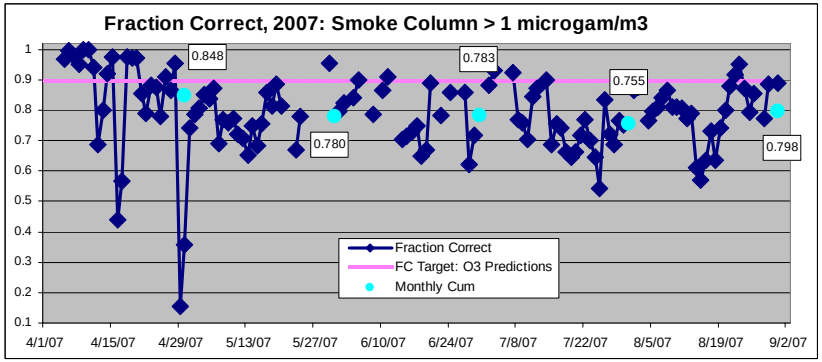
Sample Comments:

- **"Very useful for visualizing transport of …smoke. This is a superb product. The smoke feature is very important."**
  - *AQ researcher and consultant; member of two government air quality committees*

- **"Fire emission important in SJV/CA in general… Important to incorporate real-time fire emissions"**
  - *AQF focus group member, California*

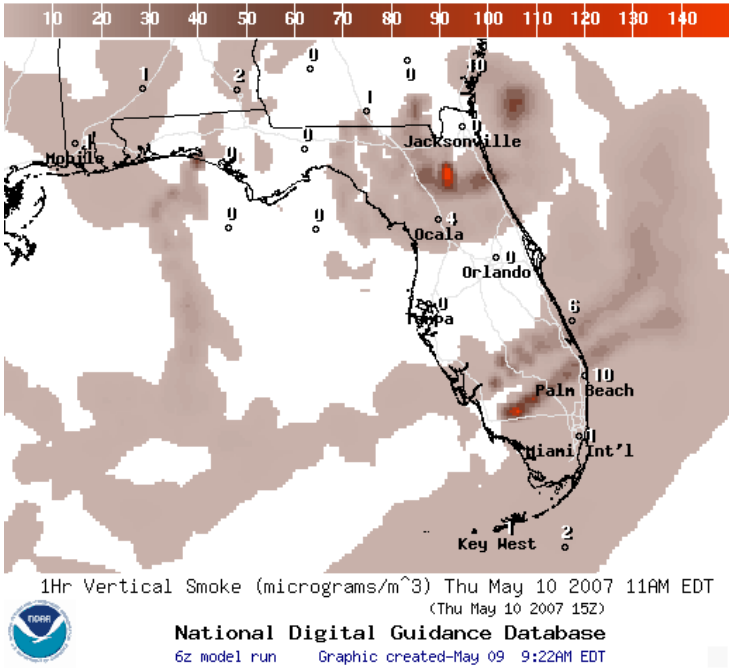
Summary, Smoke Predictions:
Warm Season, 2007





- **TS cum = 0.159; Target = 0.08 (Column verification)**

- **FC generally > 0.7**
- **FC Target not established for qualitative smoke tool**
- **Based on satellite AOD; column verification only**



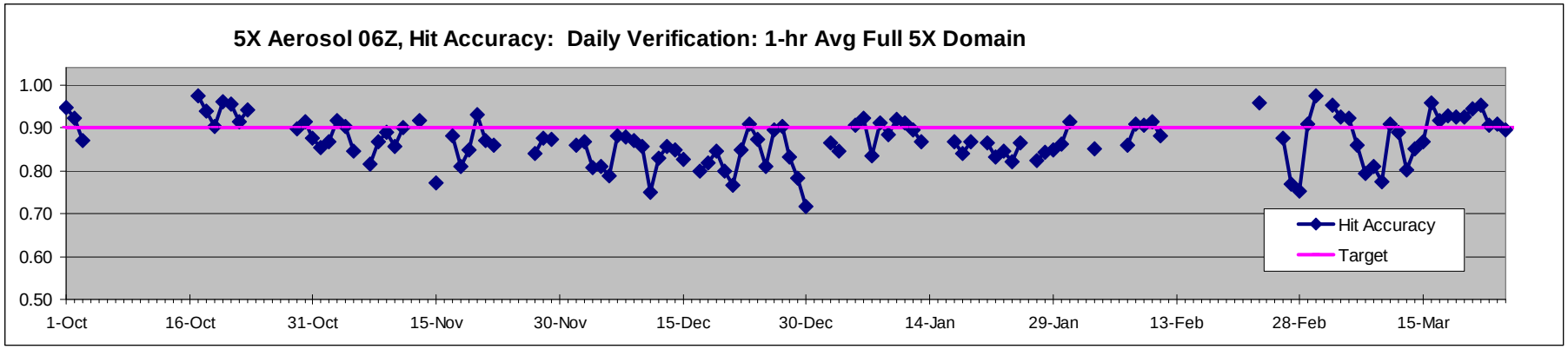
May 10, 2007

Andrea and the Florida/Georgia fires

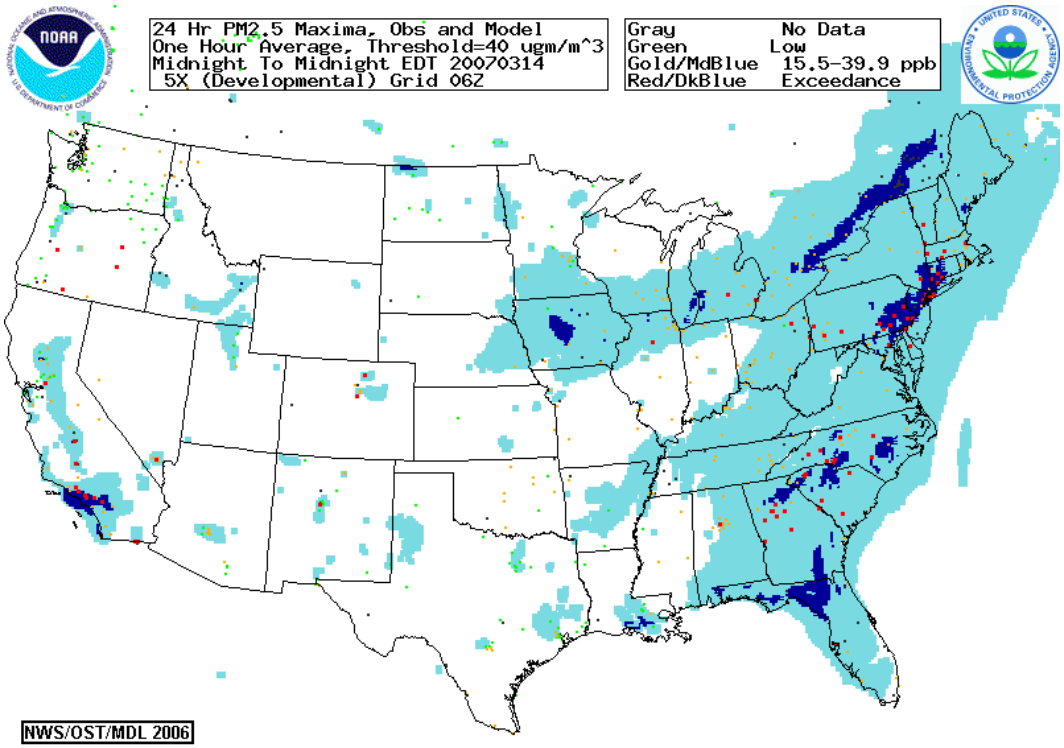
WonderBlog Post By: JeffMasters at 1:44 PM GMT on May 10, 2007

The counter-clockwise circulation of air around Andrea's center of low pressure can be seen in the forecast movement of smoke from the fires burning in northern Florida and Southeastern Georgia (Figure 1). ***The Hurricane Hunters reported that dense smoke was obscuring visibility over the ocean waters near Jacksonville during their mission into Andrea this morning--the first time I've ever seen that observation during a hurricane hunter mission.*** This smoke is expected to form a ring encircling Jacksonville, and an air pollution alert for unhealthy levels of particulate matter pollution has been posted today for that city. Particulate matter pollution advisories have also been posted along a swath from Orlando to Miami. People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion in these areas.

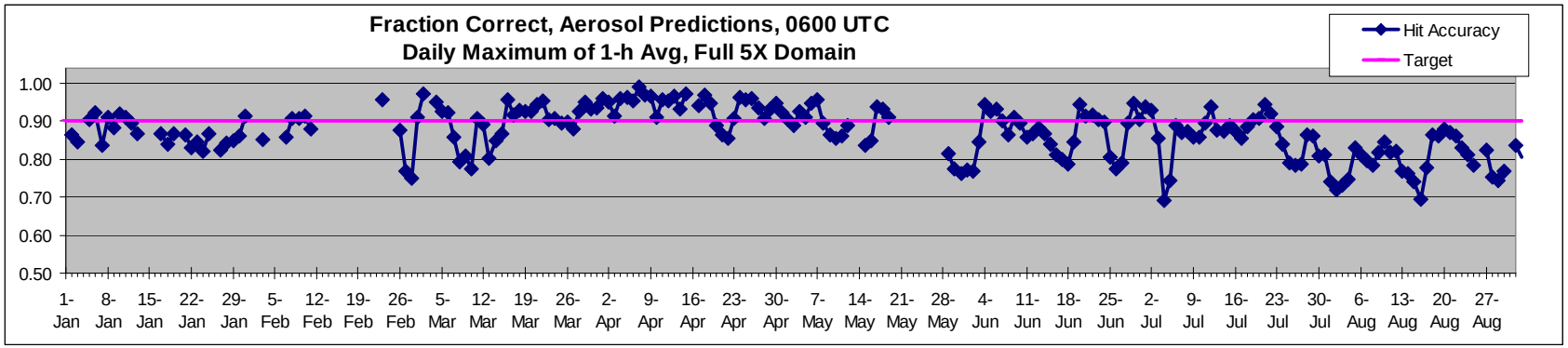
Developmental Aerosol Predictions:
Winter, 2006/7

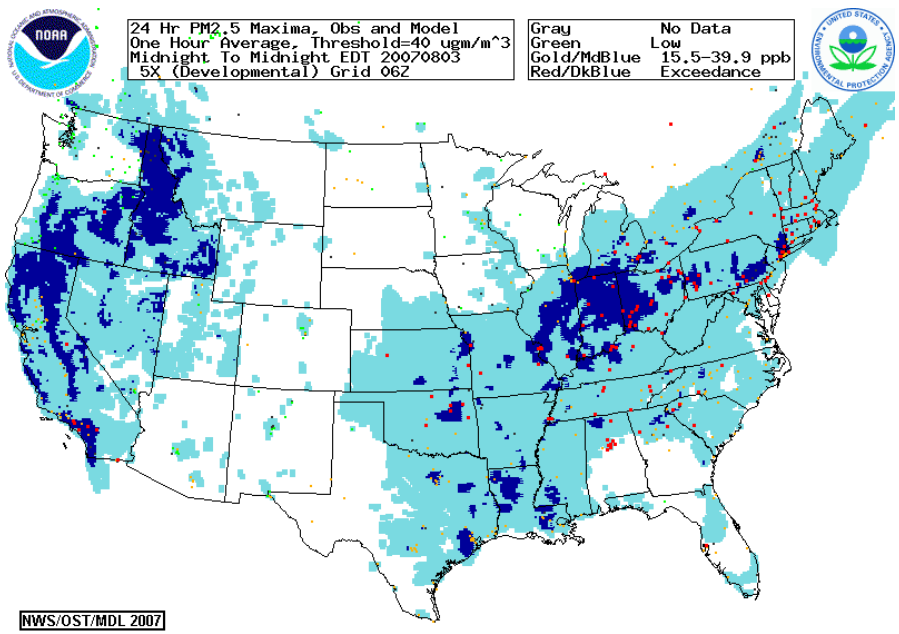


March 14, 2007

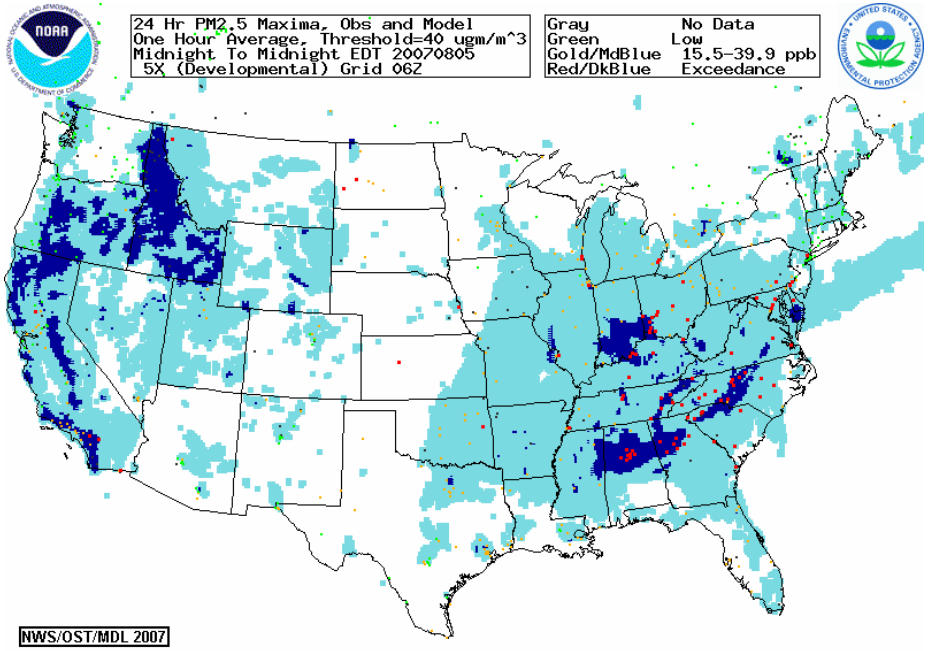


Developmental Aerosol Predictions: *2007*





August 3, 2007



August 5, 2007

National AQF Capability: *Testing Targets for 2007 and Longer-Term*

Ozone forecast guidance (WRF-CMAQ)

- **Improving day-to-day performance, especially in the west**
- **Transitioning experimental CONUS predictions to operations (9/07)**
- **Further development:**
  - *Closer coupling of AQ with WRF prediction; examine impacts of vertical resolution, vertical mixing treatments, horizontal boundary conditions…*
  - *Testing over all 50 states with target operational implementation in FY10*
  - *Extend forecast range to Day 2 and beyond*

Particulate matter components:

- **Smoke from large fires: implemented over CONUS in operations (3/07)**
  - *Planning for experimental testing in AK, HI*
- **Further development, quantitative PM forecast capability:**
  - *Objective satellite products for verification (on going)*
  - *Aerosols predictions from anthropogenic source emissions in inventories: continued development/testing/analysis*
  - *Further component development, chemical data assimilation, dust, speciated fire emissions, "in-line" coupling of weather and AQ simulation*
  - *Developmental and experimental testing, integrated quantitative PM capability*
  - *Target operational implementation for initial PM forecasts, NE US: FY14*

Future Science Infusion

NOAA planning for improvements to the air quality forecast capability

- Expansion to Nationwide ozone coverage by FY10
- Closer coupling of meteorological and air quality models to improve forecast accuracy
- Expanded capabilities for PM2.5 prediction components in development; more comprehensive atmospheric chemical model will integrate ozone and particulate matter prediction
  - *Additional sources from forest fires and dust storms*
- Boundary conditions from GFS

Continuing R&D required

- OAR and EPA working actively with NWS to provide prototype capabilities for pre-operational development, testing experimental production, and implementation

Assuring quality with science peer reviews:

- Design review of major system upgrades (initial, yearly upgrades)
- Diagnostic evaluations with field campaigns and evaluations
- Publication of T&E in peer-reviewed literature

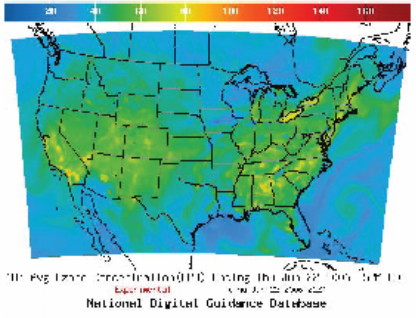
Ozone Capability

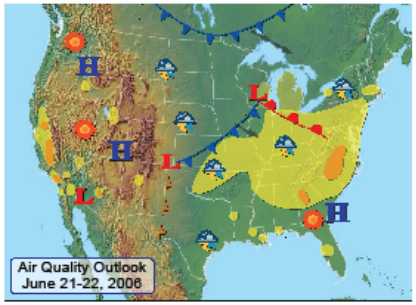
- ***Otte et al. Weather and Forecasting, 20, 367-385 (2005)***
- ***Lee et al., J Applied Meteorology and Climatology, in press (2007)***
- ***Mckeen et al., J. Geophys. Res. 110, D21307 (2005)***
- ***Yu, et al. , J. Geophys. Res. (2007)***

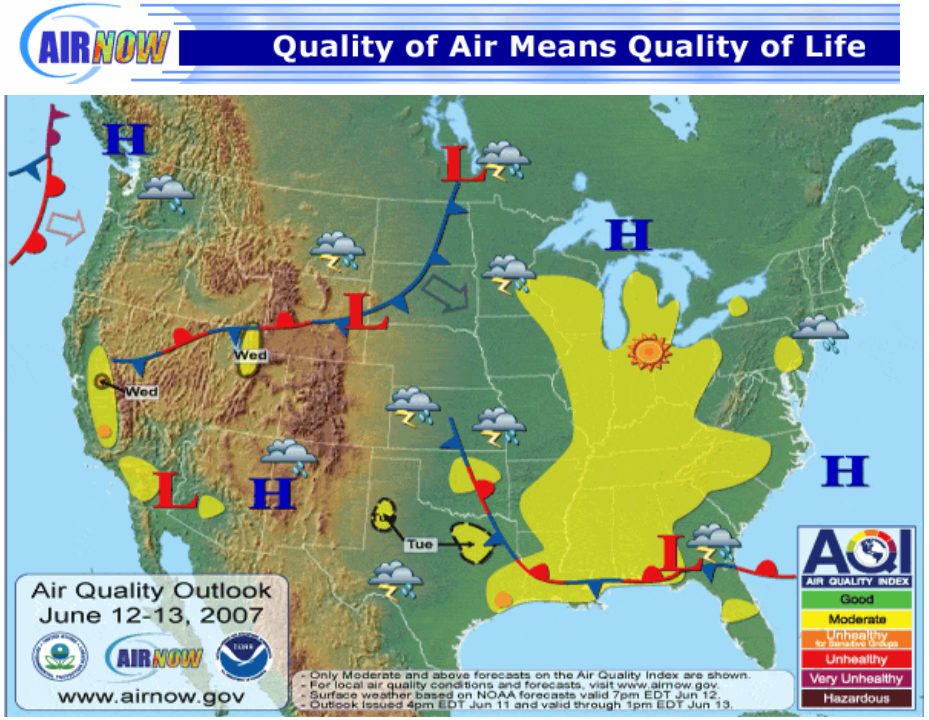
Smoke Tool

- ***Prados et al., J. Geophys. Res. 112, D15201 (2007)***
- ***Kondragunta et al., submitted for publication***
- ***Zeng and Kondragunta, ms. in preparation***
- ***Ruminski, Kondragunta, Draxler and Zeng, in preparation***

Partnership with EPA, AQ forecasters:
Examples: AQ Awareness Week, AQ outlook







www.airnow.gov

Focus Group Discussion

Examples, Episodes

- Please send examples of poor AQ episodes, forecast guidance performance in your areas

Additional Tools: HPC "AQ Forecasters web-drawer" at http://www.hpc.ncep.noaa.gov/aqtest/

- Convenient collection of NWS weather and AQ forecast guidance.
  - ***Add ventilation index product?***
- **It's your site! Your feedback is important**

Changing thresholds for AQ forecasters:

- What are FG expectations for adjusting ozone USG?
  - *Implications for threshold-dependent NAQFC guidance verification statistics:*
    - **Fraction correct Comparison for cumulative 2007 over CONUS exptl tests: FC .97 (85 ppb); .92 (75 ppb)**
    - **In general: Threat Scores and POD rise; FAR decreases**
- Impacts of recently changed PM standards?

Your expertise is invaluable:

- Front-line forecasters have bird's-eye view of air quality forecast problems
- Sharing knowledge of local conditions and insights on what caused the predictions to succeed … or not… drives improvements

Acknowledgments:
AQF Implementation Team

OCWWS	***Mike Dion***	***Outreach, Feedback***
OCIO	***Cindy Cromwell, Allan Darling, Bob Bunge***	***Data Communications***
OST/MDL	***Jerry Gorline***	***Dev. Verification***
OST/MDL	***Marc Saccucci, Tim Boyer, Dave Ruth***	***NDGD Product Development***
OST	***Ken Carey***	***Program Support***
NESDIS/NCDC	***Alan Hall***	***Product Archiving***
NOAA/OAR	***Jim Meagher***	***NOAA AQ Matrix Manager***

NCEP

Jeff McQueen	***EMC AQF model team leader***
Pius Lee	***System design and implementation***
Marina Tsidulko	***PBL & Chem Verification***
Youhua Tang	***Regional testing***
Ho-Chun Huang	***Global dust/smoke system DT&E***
****Sarah Lu***	***Global data assimilation and feedback testing (NASA, NESDIS)***
****Brad Ferrier, *Dan Johnson***	***WRF retrospective run***
****Eric Rogers, *Hui-Ya Chuang***	***NAM products***
John Ward, Brent Gordon, Dave Michaud	***NCO transition and systems testing***

* Guest Contributors

NOAA/OAR

Rohit Mathur	***ASMD AQF team leader***
Daiwen Kang	***CMAQ verification, PM testing***
Shaocai Yu	***CMAQ diagnostic studies***
Hsin-Mu Lin, Tanya Otte	***PREMAQ development***
Jon Pleim	***CMAQ met processing development***
Jeff Young, David Wong	***Code optimization***
George Pouliot, Daniel Tong	***Emissions processingOA***
Ken Schere	***ASMD Science oversight***