National Air Quality Forecast Capability

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NOAA NWS/OSTI

with contributions from the entire NAQFC Implementation Team

Outline:
Background on NAQFC
Recent progress and updates for AQ predictions:
- Ozone, smoke, dust, PM2.5
- CMAQ upgrade in February 2016
- CMAQ upgrade proposed for FY 2017
- Display, dissemination and web presence
- Outreach and feedback

Summary and plans

AQ Forecaster Focus Group Workshop, College Park, MD

September 15, 2016
National Air Quality Forecast Capability status in September 2016

- 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
- Fine particulate matter (PM2.5) predictions

**Testing of improvements:**
- Ozone
- Smoke
- PM2.5
Model: Linked numerical prediction system

Operationally integrated on NCEP’s supercomputer
- NOAA NCEP mesoscale numerical weather prediction
- NOAA/EPA community model for air quality: CMAQ
- NOAA HYSPLIT model for smoke and dust prediction

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

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

Verification basis, near-real time:
- Ground-level AIRNow observations of surface ozone
- Satellite observations of smoke and dust

Customer outreach/feedback
- State & Local AQ forecasters coordinated with EPA
- Public and Private Sector AQ constituents
Ozone predictions
Operational predictions at http://airquality.weather.gov
over expanding domains since 2004

1-Hr Average Ozone
8-Hr Average Ozone

1-Hr Average Ozone
8-Hr Average Ozone

1-Hr Average Ozone
8-Hr Average Ozone

CONUS, wrt 70 ppb Threshold

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

Fraction correct of daily maximum of 8h average wrt 70 ppb threshold

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<tr>
<th>Date</th>
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<tr>
<td>8/29/2016</td>
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Performance of operational ozone predictions

Fraction correct for 8h daily maximum of NOAA's operational ozone predictions for CONUS with respect to three thresholds showing performance for May, June, July & August for each year.
Smoke predictions

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

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

- Smoke predictions for CONUS (continental US), Alaska and Hawaii
- NESDIS provides wildfire locations detected from satellite imagery
- Bluesky provides emissions estimates
- HYSPLIT model for transport, dispersion and deposition (Rolph et. al., W&F, 2009)
- Increased plume rise, decreased wet deposition, changes in daily emissions cycling
- Developed satellite product for verification (Kondragunta et.al. AMS 2008)

Current testing includes

- Updated BlueSky System v3.5.1 for smoke emissions (first update since predictions became operational in 2007)
Verification of smoke predictions for CONUS

- Figure of merit in space (FMS), which is a fraction of overlap between predicted and observed smoke plumes, threshold is 0.08 marked by red line
- NESDIS GOES Aerosol/Smoke Product is used for verification
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 for 2003-2006 (Ginoux et. al. 2010).
- Emissions modulated by real-time soil moisture.
- HYSPLIT model for transport, dispersion and deposition (Draxler et al., JGR, 2010).
- Wet deposition updates in July 2013.
- Developed satellite product for verification (Ciren et.al., JGR 2014).
PM2.5 predictions – development and testing

Predictions for 48h at 12km resolution over CONUS
From NEI sources only before summer 2014
- CMAQ:
  CB05 gases, AERO-4 aerosols
- Sea salt emissions
- Wildfire and dust emissions and suppression of soil emissions from snow/ice covered terrain included since summer 2014 (Lee et al., submitted manuscript)
- Model predictions exhibit seasonal prediction biases: overestimate in the winter; underestimate in summer

Forecast challenges
- Improving sources for wildfire smoke and dust
- Chemical mechanisms eg. SOA
- Meteorology eg. PBL height
- Chemical boundary conditions/trans-boundary inputs

Lee et al. (2016): NAQFC developmental forecast guidance for fine particulate matter (PM2.5), Weather and Forecasting, http://journals.ametsoc.org/doi/abs/10.1175/WAF-D-15-0163.1
The bias in the total mass of PM2.5 is dominated by overpredictions of unspecified PM in the winter and by underpredictions of carbon aerosols in the summer. (Foley et. al., *Incremental testing of the Community Multiscale Air Quality (CMAQ) modeling system version 4.7*, Geosci. Model Dev., 3, 205-226, 2010)

Saylor et. al. found same type of seasonal speciation biases in the CMAQ v4.6 for IMPROVE sites.
CMAQ UPDATE IN FEBRUARY 2016
CMAQ system update in February 2016

Public release of raw model predictions and bias-corrected PM2.5 predictions

- Lateral boundary conditions from global dust predictions
- Increased vertical resolution from 22 to 35 layers in CMAQ v4.6
- Analog forecast technique for PM2.5 bias correction
NGAC simulation of Saharan dust layer transport

- Provides dust lateral boundary conditions for CMAQ
- Global-regional prediction linkage
- Increased number of model levels to better align CMAQ and global model levels
# Impact of NGAC LBCs on CMAQ predictions of PM2.5

**Model Predictions Compared to AIRNOW PM2.5 over Miami Fire Station #5, FL Lat=25.795 Lon= -80.216**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Observed</th>
<th>CMAQ default</th>
<th>CMAQ with NGAC LBCs</th>
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<td>X R=0.42</td>
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<td></td>
<td>Y=3.365+0.600*</td>
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<td>Y=2.770+.617*X</td>
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<td>X R=0.41</td>
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<tr>
<td>Whole domain</td>
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<td></td>
</tr>
<tr>
<td>July 18– July 30</td>
<td>MB= -2.79</td>
<td>Y=2.059+0.520*</td>
<td>X R=0.31</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>MB= -0.33</td>
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<tr>
<td></td>
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<td></td>
<td>Y=2.584+0.795*</td>
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<td>X R=0.37</td>
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<td>MB= -4.79</td>
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<td>July 18– July 30</td>
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<td>X R=0.41</td>
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</table>

Time series of PM2.5 from EPA AIRNOW observations (black dot), CMAQ baseline run using static Lateral Boundary Conditions (LBCs) (green dot) and CMAQ experimental run using NGAC LBCs (blue square) at Miami, FL (top panel) and Kenner, LA (bottom panel).

Credit: Youhua Tang
Bias correction for PM2.5 predictions

- Quality control of the observations is essential
- Five different post-processing techniques were tested

Unsystematic component of the RMSE (top panel) and systematic component of RMSE (bottom panel) using hourly values for the month of November evaluated at the 518 AIRNow PM2.5 sites.

Raw and bias-corrected PM2.5 predictions

Winter (Jan 2015)

Regional mean for each of 48 prediction hours

Western US

Observations
Previous model
Updated model
Bias correction of new model

Eastern US

Summer (July 2015)
CMAQ UPDATE PROPOSED FOR FY 2017
Testing of the CMAQ system update proposed for FY 17

• Update to CMAQ v5.0.2

• Better representation of wildfire smoke emissions (updated BlueSky system and 24-hour “analysis cycle” to include emissions when they were observed)

• Updated mobile NOx emissions: NEI 2005 projected to 2011 using Cross-State Air Pollution Rule (CSAPR) projection for US sources and then adjusted further to the forecast year using trends from surface and satellite observations from 2011 to 2014

• Update of bias correction method to KFAN
Summary of Emission Data Sources for CMAQ 5.0.2 testing

- **Area Sources**
  - US EPA 2011 NEIs;
  - Canada 2006 Emission Inventories (in NEI2011 package);
  - Mexico 2012 EI for six border states (in NEI2011 package);
  - New US residential wood combustion and oil and gas sectors;
  - Snow/Ice effect on fugitive dust emissions;

- **Mobile Sources (onroad)**
  - NEI 2005 projected to 2011 using Cross-State Air Pollution Rule (CSAPR) projection for US sources and then adjusted further to the forecast year using trends from surface and satellite observations from 2011 to 2014;
  - Canada 2006 Emission Inventories;
  - Mexico 2012 EIs;

- **Point Sources (EGUs and non-EGUs)**
  - Baseline emissions from NEI2011;
  - US EGU sources updated with 2014 Continuous Emission Monitoring (CEM);
  - Projected into forecast year using DOE Annual Energy Outlook projection factors;

- **Natural Sources**
  - *Terrestrial biogenic emission*: BEIS model v3.14;
  - *Sea-salt emission*: CMAQ online Sea-salt emission model based on 10m wind;
  - Fire emissions based on HMS fire detection and BlueSky emission model;
  - Windblown dust emission: FENGSHA model;
NOx emission update

Emission inventory (NEI) lags 4+ years behind the forecast year

Apply emission adjustment using fused satellite and ground observations to represent recent trends

Adjustment Factors

NOx Emission Changes

Ground: Air Quality System (6-9 LST)
Satellite: GOME-2 (10:30AM)

Tong et al., submitted manuscript

(2011-2014)
Retrospective testing for 2015
Daily maximum 8h average ozone regional statistics for August 2015

- CONUS-wide statistics are all improved
- Bias and RMSE are improved in four regions in the eastern part of the US

<table>
<thead>
<tr>
<th>Region</th>
<th></th>
<th>Obs.</th>
<th>Mean</th>
<th>Bias</th>
<th>RMSE</th>
<th>Corr. coef.</th>
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<td>51.65</td>
<td>4.65</td>
<td>13.50</td>
<td>0.64</td>
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Representation of wildfires

- Better representation of wildfire smoke emissions based on detections of wildfire locations from satellite imagery, BlueSky system emissions, included over previous 24 hours when fires were detected and projected with reduced intensity into the 48 hour forecast period.

PM2.5 in August 2015

Daily mean for Western US

- Observations
- Current model
- New model
- Bias correction of current model
Wildfires are strongly impacting air quality in the region.
- Observed daily maximum of hourly PM2.5 exceeds 55 µg/m³ and even 100 µg/m³.
- Operational system predicts values below 25 µg/m³ for many of these monitors.
- Updated system in testing predicts values much closer observed.
24 hour average PM2.5 concentrations regional statistics for August 2015

<table>
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<tr>
<th>[µg/m³]</th>
<th>Sample size</th>
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<td>7.70</td>
<td>-2.30</td>
<td>5.28</td>
<td>0.31</td>
</tr>
</tbody>
</table>

- CONUS-wide statistics are improved.
- Largest improvements are for wildfire-impacted western US regions.
Real-time testing
California Fires (July 2016)

July 24, 2016 12Z run Day 1 1hr max PM2.5

Some signature from fires in V5.02

NESDIS HMS Fire smoke graphic

VIIRS high res (375 m) imagery
Verification of Ozone for August 2016

New model:
CMAQ 5.0.2
Updated NOx emissions
Updated wildfire emission specification

Statistics for 48 contiguous States (CONUS)
Verification of PM2.5 for August 2016

New model:
CMAQ 5.0.2
Updated NOx emissions
Updated wildfire emission specification

Statistics for 48 contiguous States (CONUS)
DISPLAY, DISSEMINATION AND WEB PRESENCE UPDATES
Next Generation of AQ display/distribution on the Web

- Uses a PostgreSQL Database with PostGIS extensions to manage data
- Open Geospatial Consortium (OGC) Web Mapping Service (WMS)
- Possible expansion of NWS XML/SOAP Services to include Air Quality Data
- Uses Open Layers with a ESRI Map Background
- Very Interactive – zoom and roam/data interrogation
- Faster data refresh
- Mobile device support
Example of ozone predictions in web enabled map service currently in development based on GIS application
Operational AQ forecast guidance at [airquality.weather.gov](http://airquality.weather.gov)

Ozone products
Nationwide since 2010

Smoke Products
Nationwide since 2010

Dust Products
Implemented 2012

New web site: [https://www.weather.gov/sti/stimodeling_airquality](https://www.weather.gov/sti/stimodeling_airquality)
Partnering with AQ Forecasters

Focus group, State/local AQ forecasters:

- Participate in real-time developmental testing of new capabilities, e.g. aerosol predictions
- Provide feedback on reliability, utility of test products
- Local episodes/case studies emphasis
- Regular meetings; working together with EPA’s AIRNow and NOAA
- Feedback is essential for refining/improving coordination

Examples of AQ forecaster feedback after emissions update in 2012:

- 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)

Evaluation in Feb. 2016:

- Received recommendation to implement system upgrade as proposed from AQ forecasters from Virginia, Texas, Maryland, South Carolina, Maine, Pennsylvania, Connecticut, Washington with some caveats.

Currently evaluating updates for ozone, PM2.5 and smoke predictions
## Acknowledgments:

**AQF implementation team members**

Special thanks to previous NOAA and EPA team members who contributed to the system development

<table>
<thead>
<tr>
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<th>Members</th>
<th>Roles</th>
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<tr>
<td>NOAA/NWS/OSTI</td>
<td>Ivanka Stajner</td>
<td>NAQFC Manager</td>
</tr>
<tr>
<td>NWS/AFSO</td>
<td>Jannie Ferrell</td>
<td>Outreach, Feedback</td>
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<td>NWS/OD</td>
<td>Cynthia Jones</td>
<td>Data Communications</td>
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<td>NWS/OSTI/MDL</td>
<td>Marc Saccucci, Dave Ruth</td>
<td>Dev. Verification, NDGD Product Development</td>
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<tr>
<td>NWS/NCEP</td>
<td>Jeff McQueen, Jianping Huang, Ho-Chun Huang</td>
<td>AQF model interface development, testing, &amp; integration</td>
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<tr>
<td></td>
<td>Jun Wang, *Sarah Lu</td>
<td>Global dust aerosol and feedback testing</td>
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<td>*Brad Ferrier, *Eric Rogers,</td>
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<td>Geoff Manikin</td>
<td>Smoke and dust product testing and integration</td>
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<td>Rebecca Cosgrove, Chris Magee</td>
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<td>Mike Bodner, Andrew Orrison</td>
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<td>NOAA/OAR/ARL</td>
<td>Pius Lee, Daniel Tong, Tianfeng Chai</td>
<td>CMAQ development, adaptation of AQ simulations for AQF</td>
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<td>EPA/OAQPS partners:</td>
<td>Chet Wayland, Phil Dickerson, Brad Johns, John White</td>
<td>AIRNow development, coordination with NAQFC</td>
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* Guest Contributors
Summary and plans

US national AQ forecasting capability:
• **Ozone** prediction nationwide; CMAQ with CB05 mechanism
• **Smoke** prediction nationwide
• **Dust** prediction for CONUS sources
• **PM2.5** predictions; CMAQ with NEI, wildfire and dust emissions, dust LBCs from global predictions - new since February 2016

Current testing and plans to improve O3 and PM2.5 accuracy and utility:
• Updating to newer CMAQ version 5.0.2
• Updated wildfire smoke emissions with a newer Bluesky system and Canadian sources
• Update NOx emissions using recent observed trends
• Refinement of bias correction for PM2.5 using KFAN approach
• Linkage with additional aerosols from global predictions
• Extend predictions to 72 hours
• Update display, dissemination and web presence
• Finer resolution (longer term)
Backup
Impact of forest fires in testing of PM2.5 predictions

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

Detection of wildfire locations from satellite imagery
Blowing dust event in testing of PM2.5 predictions

Independent NOAA/NESDIS analysis narrative based on satellite imagery:

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