CMAQ V5.0 Upgrade for ozone and Particulate Matter Predictions

http://www.emc.ncep.noaa.gov/mmb/aq

Jeff McQueen, Jianping Huang, Ho-Chun Huang, Pius Lee, Li Pan, Daniel Tong – NOAA/ARL
Perry Shafran, Geoff DiMego – NCEP/EMC
Jim Wilczak, Irina Djalalova, Dave Allerud – NOAA/ESRL/PSD
Ivanka Stajner, Sikchya Upadhaya – NWS/STI
Amanda Sleinkofer – Millersville University

May 31, 2017
CMAQ weaknesses Identified

• Overprediction of ozone in Eastern U.S. in Summer
  – Especially along coastal areas (NYC, DC, Great Lakes)
    → Update National Emission Inventory point sources to 2011 (project to present)
    → Adjust NOx emissions based on OMI satellite trends (deferred)
    → Evaluate Impact of NAM-X and reduced SW radiation under clouds
    → Update CMAQ gas and aerosol chemistry/biogenic emissions to EPA V5.0.2

• Underprediction of particulate matter (PM) in Summer and near wild-fires
  → Update 10 year old USFS BlueSky smoke emission system
  → Introduce 24 h pre-analysis cycle to correct fire time mismatch with CMAQ initial time

• Underprediction of Ozone and PM during strong fire smoke/dust intrusions into CMAQ domain
  → Test NGAC full aerosol predictions for CMAQ lateral boundaries

• Overprediction of PM during winter-time stagnation episodes (cold, stable)
  → update emissions/chemistry as in bullet 1
  → Test updates to bias correction
Evaluations Performed  
Ozone and PM

• EMC Real-Time: July 2016 → March 2017
• NCO Real-Time: April 2017 → Present
• EMC NAM-X Retrospectives: July 2016
• EMC/ARL NOx emissions adjustments: Aug-Sept. 2016 retros

• NWS/STI & AQ Focus Group: Aug. Retros + NRT runs
  – EMC maintains NRT comparison graphics and verification web sites
  – EMC provides daily text predictions at monitor sites to following state forecasters:
    • AL, AZ, CA, CT, DE, GA, IA, MD, ME, NY, OH, PA, TN, VA
July 2016 NRT CMAQ Prod vs V5.0.2

1 h avg Diurnal Ozone

**EAST**
- **CMAQ V5.0.2 NAM-X**: improvement in ozone over-prediction over the East

**WEST**
- **CMAQ V5.0.2 NAM-X**: Strongest underestimate over West
- Meteorological impact nearly as large as CMAQ/Emissions upgrade
Day 2  8h O3 Daily Max
August 12, 2016

Operational  EMC Parallel w/ NOx Emissions reduced

CT & PA  DEP Noted numerous mixed exceedences with V5.0.2 Near Real-time parallels
Experiments to address missed exceedences

- No NOx Adjustment for Mobile Emissions (green line) NAMX
  - Cross State Air Pollution Rule (CSAPR) 2011 Mobile Emission
  - Should result in increased ozone production

- Gridded NOx Mobile emission adjustment (red line) NAMX
  - Adjustment factor also considers fine-scale features by taking into account the 12 x 12 km grid-by-grid satellite-observed NOx to NAQFC forecasted NOx ratio

- V5.0.2 Para: State wide NOx adjustment using NAM
August 2016
East vs West  Ozone

No-NOX: Slight improvement during day over East
Slightly better over West late August
August 18, 2016 Day 1

- NAM-X CMAQ V5.0.2:
  - showed a great improvement over PROD
  - Eliminated the four false alarms in PROD for August

Mike Geigart, CT DEP
May 17, 2017 8h Max Ozone

- More ozone formation in parallel run

- Parallel

- Chesapeake Bay
  - Overestimate along N. Bay
  - Bay Temps too warm

- New York

- Production
May 17, 2017  2 m Temperature/ZPBL

- N. Bay ~ 20° too warm in Parent
- Treated as land
Wintertime PM
January 16, 2017 1hr PM2.5 Max

- V5: Small impact
- Bias Correction improves over-prediction
Operational runs: Most sites impacted by fire smoke are severely under-predicted.
Parallel model: Updated BlueSky and use of current day fire info
Underpredict PM over Western U.S.
Slight overprediction over Eastern U.S.
Bias Correction strong improvement
May 7-15, 2017 Florida/Georgia Fires

1hr PM2.5

Raw-Parallel (solid red) follows diurnal pattern well
Bias correction underestimates fire event PM
May 11 2017 Florida/Georgia Fires

1hr PM2.5 loop

Para Captures FL and Bahama fires

NESDIS HMS fire locations and smoke
Summary

– V5.0.2 Ozone w/ NAM V4
  • Improvement correcting over-prediction esp along coasts
    – Long Island Sound (CT DEP analysis)
      » 7 False Alarms compared to 17 from production for NYC area
    – Lake Erie/Michigan and Ohio Coastline
  • Much improved for Southwest and marginal or non-events
  • Missed exceedences in NE corrected after removing NOx adjustments

– PM
  • Large positive impact near forest fires :
    – Updated BlueSky and 24 h pre analysis run
    – Underprediction when smoke external sources (Canadian fires) are impacting CONUS
    – Smoke emission timing and ejection height uncertainties
  • Continued overprediction in Winter from raw predictions
    – PM bias correction improves overprediction

– Updated NAM alone strongly improves ozone forecast
  • Amount of incoming radiation under clouds critical
Future Emphasis

– Extend to 72 hours, update emissions to 2017 base
– Near real-time fire locations, strength, emissions
  • Canadian, Mexican & external source impacts (from NGAC)
  • Improved temporal profiles and plume rise algorithms
  • Impact of wild-fire gas emissions on ozone
  • Top down (satellite) vs Bottom up (BlueSky) approaches
– NGAC full aerosol boundaries
– Unification of AQ systems
  • HYSPLIT smoke/dust → NGAC Aerosol
  • CMAQ ozone & total PM
  • HRRR-smoke
– Extend Kalman Filter bias correction to ozone
– Improved Evaluations
  • Transition to MET+
  • Use of VIIRS/GOES-R/AERONET AOD, CALIPSO aerosols
  • Evaluate Operational models for field experiments (ESRL FireX 2019, FASMEE)
BACKUPS
Web pages
CMAQ V5.0.2

• Real-time parallel runs (July 2016-Present)

• No NOx adj/NAM-X/4x-day cycling (Aug. 7-Sept 10)

• Gridpoint NOx adj/NAM-X/1x-day cycling (Aug. 1-Sept 10)

• Verification statistics (prod,para, cmaqnox11, cmaqnox)
Is smoke from fires moving too far downwind (Midwest)
BC does good job for correcting in prod & para runs
• Improved out west, but overprediction sometimes worsened over East
Analog Ensemble for PM$_{2.5}$ Bias Correction

- Analog metric is determined by (Monache et al. 2011)

$$\|F_t, A_{t'}\| = \sum_{i=1}^{N_v} \frac{w_i}{\sigma_{f_i}} \sqrt{\sum_{j=-\bar{t}}^{\bar{t}} (F_{i,t+j} - A_{i',t+j})^2},$$

where $F_t$ is current NWP forecast valid at future time $t$, $A_{t'}$ is analog at past time $t'$, $N_v$ is the number of variables, $\bar{t}$ is half the number of additional computation time, $w_i$ weight, $\sigma_{f_i}$ standard deviation.

Implementation in NAQFC
- Variables for Analog search: PM$_{2.5}$, T$_2$, WS/WD
- Ensemble members: 5
- Training period: one year

(Source: Djalalova et al., 2015)
May 18, 2017   8h Max Ozone

I95 Event  VA to Maine/Nova Scotia Exceedences

Courtesy Mike Geigart, CT DEP