NAQFC Upgrades

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Current NAQFC: Prod

Chemical Transport Model:
- **CMAQ4.6** for CONUS, AK & HI
- CB05 gas chemistry
- Aero4 aerosol chemistry
- LBC: monthly varying GEOS-CHEM Dynamic LBC for dust derived from NGAC

- O₃ product dissemination: TOC

**O₃ Performance (FVS by NCO):**
Max Daily 8h (MDA8) O₃ for domains above: Bias, RMSE, and % Hit Rate
Feed of EPA AIRNow O₃ and PM₂.₅ in Bufr format

Lee, McQueen, Stajner et al., *Weather & Forecasting* 2016
DOI: WAF-D-15-0163.1
NAQFC: Prod targeting 2017

Chemical Transport Model:

- **CMAQ5.0.2** for CONUS, AK, HI
  - CB05 gas chemistry: increased from 135 to 157 species
  - Aero6 aerosol chemistry
- For CONUS:
  - LBC: Static from GEOS-CHEM + Dynamic LBC for dust derived from NGAC
  - 24 h analysis PM field for initialization adjustment
  - Follow Prod SMOKE for assumed fire duration, speciation and strengths
  - New Bluesky

PM$_{2.5}$ Performance (Exceedance w.r.t 35 μg/m$^3$): EMC website mmb/aq
24 h averaged PM$_{2.5}$ for the above domains: Bias, RMSE, and % Hit Rate
Emissions accompany CMAQ5.0.2

- **Point source**: Baselined from NEI2011v1 & updated by 2014 CEM & 2016 DoE Energy Outlook
  - Canada: Environment Canada 2006 Inventory made available as part of US EPA NEI2011;
  - Mexico: Inventory (MI) 2012 version2.2 northern states & 2.1 other states

- **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;

- **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
Sahara dust event May 9-11 2015
VIIRS AOD
Courtesy: Shobha Kondragunta (NESDIS)
Surface concentration of PM$_{2.5}$ at 10 UTC May 11 2015: modeled (background shading), measured (filled circle)

Without dynamic boundary condition | With dynamic boundary condition

PM$_{2.5}$ in µg m$^{-3}$
MOVES2014a has similar O$_3$ precursor rate (g/mile) as MOVES2014

Helps PM$_{2.5}$ but exacerbate O$_3$ over-prediction

Pie chart shows % of PM$_{2.5}$ emission

Courtesy: Jin-Sheng Lin et al., VDEQ, 2016
complex terrain e.g., South Coast poses challenge

MDA8 O₃ on June 2, 2016

24 h avg PM₂.₅ on June 2, 2016

Courtesy A. Sleinkofer et al. EMC internship
Analysis of the June 9-12 2015 Canadian fire: Surface PM$_{2.5}$ with frontal passages
Analysis of the June 9-12 2015 Canadian fire (cont’d) Surface PM$_{2.5}$ with frontal passages
Analysis of the June 9-12 2015 Canadian fire (cont’d)
Surface PM$_{2.5}$ with frontal passages
Analysis of the June 9-12 2015 Canadian fire (cont’d)
Surface PM$_{2.5}$ with frontal passages

Showed improved skills and awaits NGAC upgrades
CMAQ upgrade to accommodate 3 km and/or 72 h

**pnetCDF:** In newer versions of CMAQ to tackle the I/O bottleneck known for emission & conc file handling

- Northwestern University and Argonne National Laboratory
- Build on top of MPI2
- Based on netCDF format
- Requires Parallel File System (e.g. Lustre, GPFS)
- Publicly available free software

*Courtesy D. Wong et al. CMAS 2015*
Performance comparison between Prod & CMAQ5.0.2

Bias for MDA8 O₃ 8/01-9/15/2016: Prod; CMAQ5.0.2 12Z 1/day; bias correct
Bias for hourly PM$_{2.5}$ 8/01-9/15/16: Prod; CMAQ5.0.2 12Z 1/day; bias correct

Performance comparison between Prod & CMAQ5.0.2 cont’d
Performance comparison between Prod & CMAQ5.0.2 cont’d

Bias for hourly PM$_{2.5}$ 8/01-9/15/16: Prod; CMAQ5.0.2 12Z 1/day; bias correct
Performance comparison between Prod & CMAQ5.0.2 cont’d

Bias for hourly PM$_{2.5}$ 8/01-9/15/16: Prod; CMAQ5.0.2 12Z 1/day; bias correct

1-h Avg PM25 BIAS (ug-m$^3$) avged by fcst hrs 20160801 to 20160905
Midwest

Operational BIAS
CMAQ5XBC BIAS
Para-V5.0.2-4x-day BIAS
Para-V5.0.2-1x-day BIAS

1-h Avg PM25 BIAS (ug-m$^3$) avged by fcst hrs 20160801 to 20160905
LMiss-Vall

Operational BIAS
CMAQ5XBC BIAS
Para-V5.0.2-4x-day BIAS
Para-V5.0.2-1x-day BIAS

UM

LM
Performance comparison between Prod & CMAQ5.0.2 con’d

Bias for hourly PM$_{2.5}$ 8/01-9/15/16: Prod; CMAQ5.0.2 12Z 1/day; bias correct

1-h Avg PM25 BIAS (ug–m$^3$) avged by fcst hrs
20160801 to 20160905
NWEST–Coast

Operational BIAS
CMAQ5XBC BIAS
PARA–V5.0.2–4x–day BIAS
PARA–V5.0.2–1x–day BIAS

1-h Avg PM25 BIAS (ug–m$^3$) avged by fcst hrs
20160801 to 20160905
SWEST–Coast

Operational BIAS
CMAQ5XBC BIAS
PARA–V5.0.2–4x–day BIAS
PARA–V5.0.2–1x–day BIAS

NW coast

SW coast

FORECAST HOUR 12 UTC CYCLE

FORECAST HOUR 12 UTC CYCLE
Evaluation Metrics:

\[ N \_ Mean \_ Bias = \frac{1}{N} \sum_{i=1}^{N} \frac{(P_i - O_i)}{O_i} \]

\[ RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (y_i - \bar{y})^2} \]

\[ index \_ agreement = 1 - \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} (|P_i - \bar{O}| + |O_i - \bar{O}|)^2} \]

e.g., Willmott et al., 2011
I.J. Climatology
doi:10.1002/joc.2419
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<th>obs</th>
<th>Bias</th>
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MDA8 O₃ (ppb) performance metrics between Prod and CMAQ 5.0.2.
24h avg PM$_{2.5}$ (μg m$^{-3}$) performance between Prod and CMAQ5.0.2

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Summary

- Anticipated FY17 implementation of CMAQ5.0.2

Improves $O_3$ forecasting skill
- Reduced RMSE $\rightarrow$ improved spatial & temporal accuracy
  This improvement is attributable to NAM and chemistry in CMAQ5.0.2 & the use of the most updated trend to modulate mobile NOx

Improve PM$_{2.5}$ forecasting skill, esp. during the wildfire season
- Reduced under-estimation of PM$_{2.5}$ in the initialization fields by including a 24 h analysis assisted initialization adjustment
- New BlueSky improves fuel and consumption models
- The NGAC-provided dust boundary condition
- Fugitive dust -- crustal elements, are explicit in cmaq5.0.2
Challenges remains beyond FY17:

- Finer resolution
- Evaluation metrics for fine resolution output
- Complex terrains
- Coastal region over-estimation of O₃
- CMAQ I/O operation bottle-neck
- Test and improve NGAC-Smoke derived dynamic BC
- Irregularity of oil and gas emission inventory
- Mobile emission sources modeled by MOVES2014a