Continuous, Near Real-Time Application and Evaluation of the Community Multiscale Air Quality (CMAQ) Model

Brian Eder
Robert Gilliam
George Poulion
Rohit Mathur

Atmospheric Modeling and Analysis Division
National Exposure Research Lab
Office of Research and Development
U.S. Environmental Protection Agency

Research Triangle Park, NC 27711
Historically, AMAD has evaluated retrospective, often annual length, simulations of CMAQ, summarizing the performance using monthly or seasonal statistical summaries.

While informative, such an approach often masks finer scale temporal (i.e., diurnal to weekly) and spatial (meso to synoptic) variability that greatly impacts the atmosphere and hence air quality.

In order to maintain CMAQ’s state-of-the-science status as well as its ability to address emerging Agency needs, it is crucial that newer evaluation approaches are utilized that will allow for more rapid testing and hence more efficient evolution of the modeling system’s science.

Conceptual schematic of the test bed process for a hypothetical project, tool, or concept—including innovation, demonstration, evaluation, and, where suitable, a transition to operations within a federal, state, or local organization.

Accordingly, the Division began running CMAQ continuously and in near real-time in 2013, allowing for immediate and ongoing analysis at finer spatial and temporal scales, thereby facilitating model evaluation of \( \text{PM}_{2.5} \) mass and \( \text{O}_3 \) concentration.

Results from the simulations are examined and discussed by Division scientists in bi-weekly meetings while antecedent meteorological and air quality conditions remain familiar. Advantages of running CMAQ in near real-time are numerous, the simulations:

- have led to improvements in characterizing lateral boundary conditions, planetary boundary conditions, lake temperatures and episodic emission events, both natural (i.e. wildfires) and anthropogenic (i.e., residential wood burning);

Additionally, output from these simulations is being archived and has been made available for immediate dissemination to scientists across EPA and external agencies.
<table>
<thead>
<tr>
<th></th>
<th>O₃</th>
<th>PM₂.₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Obs Mean</td>
<td>Model Mean</td>
</tr>
<tr>
<td>868</td>
<td>34.5</td>
<td>39.2</td>
</tr>
<tr>
<td>450</td>
<td>7.4</td>
<td>10.5</td>
</tr>
</tbody>
</table>
Select highlights to be shown:

**PM$_{2.5}$ errors/biases:**
- associated with Midwest NH$_3$ emissions which were later ameliorated via scientific improvements of bi-directional NH$_3$ exchange;
- associated with outdated emissions and unrealistic residential wood burning in major metropolitan areas;
- related to unrealistic lateral boundary conditions; agricultural burning and forest fire emission.

**Ozone errors /biases:**
- related to meteorology (i.e., cloud cover, frontal passage, precipitation, water temperatures);
- related to unrealistic lateral boundary conditions.
2015 PM$_{2.5}$ Concentrations (µg/m$^3$)
2015 O$_3$ Concentrations (ppb)
2015 O₃ Concentrations (ppb)

Ozone Correlation

<table>
<thead>
<tr>
<th></th>
<th>Obs Mean</th>
<th>Model Mean</th>
<th>RMSE (ppb)</th>
<th>NME (%)</th>
<th>MB (ppb)</th>
<th>NMB (%)</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>455</td>
<td>12.0</td>
<td>21.0</td>
<td>15.3</td>
<td>87.6</td>
<td>9.0</td>
<td>75.7</td>
<td>0.56</td>
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</table>

Representative Case Studies - PM$_{2.5}$ (Without NH$_3$ Bi-Di Flux)
NH₃ emissions and deposition sensitivity performed by Jesse Bash

Parallel Run with NH₃ bidirectional exchange (Results 3/19/13-4/04/13)
The Residential Wood Combustion (RWC) Emission Inventory methodology greatly overestimated emissions in high-density urban areas because the underlying data is calculated for MSAs. The spatial allocation within each MSA does not account for reduced use of wood for heating in high density areas such as New York City.

The updated NEI2011 Version 2 reduced this high-bias by using an improved spatial allocation of RWC emissions.
Anthropogenic dust emissions in Las Vegas were found to be outdated (as they were based on “new construction” prior to the economic downturn).
Emissions from Mexico (including the Yucatan Peninsula) posed problems, especially with sustained southerly floc as the BCs had no fire emissions. We now incorporate Fire INventory from NCAR (FINN) emissions with the hemispheric run.
Emissions from prescribed agricultural burning was problematic. This was addressed using NOAA’s HMS emissions beginning in the fall of 2014.
Emissions from active wild fires are still an issue that we are currently addressing.
### Representative Case Studies - PM$_{2.5}$ (Fireworks)

| Domain size: 299x459, Max=53.32 at (278, 165) |

<table>
<thead>
<tr>
<th>N</th>
<th>Obs Mean</th>
<th>Model Mean</th>
<th>RMSE $\mu$g m$^{-3}$</th>
<th>NME (%)</th>
<th>MB $\mu$g m$^{-3}$</th>
<th>NMB (%)</th>
<th>$r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>435</td>
<td>19.8</td>
<td>9.5</td>
<td>17.7</td>
<td>57.0</td>
<td>-10.3</td>
<td>-52</td>
<td>0.5</td>
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7th International Workshop on Air Quality Forecasting Research
September 1-3, 2015
Model has difficulty capturing cold pools under strong cP air masses
In June 2014, we started using hemispheric boundaries conditions for CMAQ. An evaluation compared to standard (monthly averaged) GEOS-Chem boundaries clearly showed improvements in O$_3$ particularly in reducing background concentrations over Canada and increasing them over the Eastern Pacific.

**GEOS-Chem**

**Hemispheric CMAQ**
In May 2015, we started including halogen chemistry with the hemispheric boundaries. This has significantly reduced boundary layer ozone over marine environments, especially in the Gulf of Mexico region.

Hemispheric CMAQ with Halogen

Domain size: 290x459, Max=85.71 at (58, 105)
Representative Case Studies - $O_3$ (Planetary Boundary Conditions)

**Daily Maximum 8-hr $O_3$ (ppb): 20150412**

Domain size: 299x459, Max=142.4 at (331, 178)

**OMAQ $O_3$ and PBL Height (m)**

14Z

22Z
Representative Case Studies - O$_3$ (Lake Temperatures)

Started using real-time GHRSSST in October, 2014 because lake temperatures and been poorly prescribed.
Following the:

protocol established when EPA was involved with:

the National Air Quality Forecast Capability (NAQFC), and

recommendations established in the Bull. Amer. Meteor. Soc., 94, 1187–1211:

the Emergence of Weather-Related Test Beds …,

EPA has been running CMAQ continuously and in near real-time since 2013, allowing for immediate and ongoing analysis, thereby facilitating model evaluation (both performance and diagnostic) of PM$_{2.5}$ mass and O$_3$ concentration. These simulations:

- have identified numerous deficiencies in the modelling system that have been targeted for improvement,
- are being archived and disseminated to scientists across EPA and external agencies.