Modeling Background Ozone: A Comparison between global, hemispheric and regional models

Barron H. Henderson¹, Christopher Emery², Lin Zhang³, Rohit Mathur⁴ and Joseph P. Pinto⁴

¹Environmental Engineering Sciences, University of Florida
²ENVIRON International Corporation, Novato, CA
³Atmospheric Chemistry Modeling Group, Harvard University
⁴Office of Research and Development, US EPA
What is Background Ozone?

**Historically** - Policy Relevant Background is ozone concentrations that would exist in the absence of anthropogenic emissions of ozone precursors in the U.S., Canada and Mexico (North American Background)

Background $O_3$ is not directly observable → Must be estimated with models

**Definitions**
“Ozone concentrations that would exist in the absence of anthropogenic emissions of ozone precursors in ______”

- “all people” - Natural Background
- “the U.S. only” - U.S. Background
- “the U.S., Canada and Mexico” - North American Background (historically PRB)
Simulations used here

<table>
<thead>
<tr>
<th>Model</th>
<th>CQ*</th>
<th>GC†</th>
<th>CX‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>108km x 108km</td>
<td>1/2° x 1/3°</td>
<td>12km x 12km</td>
</tr>
<tr>
<td>Meteorology</td>
<td>WRF</td>
<td>GEOS5</td>
<td>WRF</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Carbon Bond ‘05§</td>
<td>Version 8-02-03‖</td>
<td>Carbon Bond ’05</td>
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<tr>
<td>Boundaries</td>
<td>N/A</td>
<td>GC 2x2.5°</td>
<td>GC 2x2.5°</td>
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<tr>
<td>Biogenic</td>
<td>BEIS</td>
<td>MEGAN</td>
<td>BEIS</td>
</tr>
<tr>
<td>Lightning</td>
<td>N/A</td>
<td>LTDIS scaled with Pickering 1997 profile</td>
<td>Scaled with Koo et al. profile</td>
</tr>
<tr>
<td>Wildfires</td>
<td>N/A</td>
<td>GFED monthly average</td>
<td>SmartFire daily estimate</td>
</tr>
</tbody>
</table>

*Simulations in development
†Zhang et al. JGR 2011
‡Emery et al. AE 2012
§Nitrates updated to account for isoprene nitrates
‖Updates in chemistry will decrease NOx loss to isoprene nitrates
Contributions will vary in space

+ = Monitor Locations – Zhang + Emery CASTNet
Rank Paired Evaluation Example

Western in MAMJJA

predicted (ppb)

observed (ppb)

GC ($r^2 = 0.40$)  CX ($r^2 = 0.42$)  CQ ($r^2 = 0.36$)
Relatively Consistent Performance
Stein and Alpert 1993 showed $2^n$ zero-out simulations separate nonlinear factors and interactions – How much ozone in the absence of emissions?

Each model has 2 simulations
- Base case: all emissions
- NAB: United States, Canada, and Mexico anthropogenic emissions removed

Do the models agree about how NAB varies as a function of total ozone?
Background varies by season

- MAM, JJA
  - Prevalence and extent of wildfires
  - Biogenic emissions are a function of temperature

- Ozone Lifetime
  - Inter-continental transport enhanced in spring and winter
  - Local production more important in summer

**Fig. 1.** Percentage of regional annual fire starts (bars) and area burned (line) by month.

Westerling et al., BAMS, 2003

**Fig. 3.** Average log10 acres burned by month for each grid cell. White areas indicate no available data.

**Ozone Lifetime (Liu and Trainer 1988)**

Winter

Summer

0 25 50 75 100 125
Background Contribution Example

Western MAM

NA Background vs. MDA8 Bin Boundaries
Relatively Consistent Spring Contribution

Western MAM

North MAM

California MAM

Southeast MAM

SE: isoprene nitrates are important
Inconsistent Summer

Contribution

Western JJA

W: Dry lightning

California JJA

North JJA

SE: Lightning and isoprene nitrates are important

Southeast JJA
Simulation Overview

- Rank-paired evaluation
  - All models show relatively good performance
  - Best performance depends on region/season

- NAB contributions to total ozone
  - Consistent in Spring, the West and Southeast
  - Differences in Summer California and North

- Background contributes more to CAMx results

- Does that correlate with observations?
Component Correlation with Observations
Component Correlations with Observations

Met Model?

Chemistry or Resolution?

Westem

North

California

Southeast

\( \text{sgm}(r) \cdot r^2 \)

\( \text{sgm}(r) \cdot r^2 \)

\( \text{sgm}(r) \cdot r^2 \)

\( \text{sgm}(r) \cdot r^2 \)

- ▼ - NAB  ▲ - NA  ■ - STD

- ▼ - NAB  ▲ - NA  ■ - STD

- ▼ - NAB  ▲ - NA  ■ - STD

- ▼ - NAB  ▲ - NA  ■ - STD
CAMx Compared to GEOS-Chem
Model Differences and Isoprene Emissions

CAMx – GEOS-Chem (NAB)  Leaf Area Index times emission factor
Conclusions

- Encouraging NAB/Base consistency
  - Spring with exception of Southeast
  - Western summer

- Differences in background
  - NAB better correlated with observations in CAMx
  - Appear related to isoprene emissions

- Isoprene affects:
  - VOC budget
  - NOx budget via organic nitrate formation
Future Work

Why do models disagree about NAB correlation?

- 3 different treatments of organic nitrates
  - Update mechanisms focused on isoprene nitrates
- 2 emission inventories that are known to differ
  - MEGAN > BEIS (Carlton and Baker EST 2011)

Need sensitivity studies to identify cause of the difference
Acknowledgements

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