Impacts of Biogenic and Anthropogenic Emissions on Summertime Ozone Formation in the Guanzhong Basin, China

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\[ \text{NO}_x \ & \text{VOCs} \quad + \quad \text{VOCs} \quad = \quad \text{Ozone} \quad 2 \ + \ X \]
Increasing O_3 pollution in China

Surface O\(_3\) level has been increasing in most Chinese cities in recent years. Particularly, in the Guanzhong basin (increased by 33%), BTH (17%), and YRD (13%).

[From China National Environmental Monitoring Centre]
Biogenic sources are important for O$_3$ formation

Biogenic emission have remarkable impacts on O$_3$ in eastern China, increasing urban O$_3$ concentration by 20-50%.

Biogenic emission from the forest in Zhejiang can even enhance O$_3$ production (6-8 ppb h$^{-1}$) in Shanghai, a city ~300 km apart.
Biogenic effect on O\textsubscript{3} may increase in future due to global warning and land-use change

Future increases in North America isoprene emissions could offset decreases in Europe surface O\textsubscript{3} resulting from controls on North America anthropogenic emissions.

Surface O\textsubscript{3} would increase by \textasciitilde 5 ppb in Southern China due to climate and biogenic emission changes between 2050 and 2000.

[Fiore et al., 2011]

[Fiore et al., 2011]
Research region and sampling sites

Simulation setting
Model: WRF-Chem
Domain: 200*200 grids
Horizontal: 28 layers
Resolution: 3km

Urban air quality site
Biogenic VOC sampling
How to quantify the pure and synergistic impacts of Anth and Bio sources on O₃

Total O₃ = Pure Anth O₃ + Pure Bio O₃
+ Synergistic Anth-Bio O₃ + Background O₃

Factor Separation Approach (FSA) \([\text{Stein and Alpert, 1993}]\)

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Simulation results</th>
<th>Anthropogenic emission</th>
<th>Biogenic emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASE</td>
<td>(f_{\text{anth-bio}})</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ANTH</td>
<td>(f_{\text{anth}})</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>BIO</td>
<td>(f_{\text{bio}})</td>
<td>×</td>
<td>✓</td>
</tr>
<tr>
<td>NEITHER</td>
<td>(f_0)</td>
<td>×</td>
<td>×</td>
</tr>
</tbody>
</table>

**Contribution**

\[
\begin{align*}
&f'_{\text{anth-bio}} = f_{\text{anth-bio}} - f_{\text{bio}} & \text{Actual contribution of anthropogenic emissions} \\
&f'_{\text{anth}} = f_{\text{anth}} - f_0 & \text{Actual contribution of biogenic emissions} \\
&f'_0 = f_0 & \text{The contribution of background transport} \\
&f'_{\text{anth}} = f_{\text{anth}} - f_0 & \text{Pure contribution of anthropogenic emissions} \\
&f'_{\text{bio}} = f_{\text{bio}} - f_0 & \text{Pure contribution of biogenic emissions} \\
&f'_{\text{anth-bio}} = f_{\text{anth-bio}} - (f_{\text{anth}} + f_{\text{bio}}) + f_0 & \text{Synergistic contribution of anthropogenic and biogenic emissions}
\end{align*}
\]
Anth and Bio emission estimates in the Guanzhong basin

**Biogenic emission from WRF-MEGAN**
- ISOP = 157 Gg mon⁻¹
- MONO = 22.8 Gg mon⁻¹

**Anthropogenic emission from MEIC (downscaled to 3km)**
- NOₓ = 110 Gg mon⁻¹
- AVOC = 72.2 Gg mon⁻¹
Model evaluation

<table>
<thead>
<tr>
<th></th>
<th>Observation</th>
<th>Simulation</th>
<th>( r^d )</th>
<th>NMB(^d )</th>
<th>RMSE(^d )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Meteorology</strong>(^b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind speed (m s(^{-1}))</td>
<td>2.6</td>
<td>2.5</td>
<td>-</td>
<td>-6%</td>
<td>1.8</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>25.1</td>
<td>24.2</td>
<td>0.86</td>
<td>4%</td>
<td>2.5</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>73.6%</td>
<td>74.2%</td>
<td>0.72</td>
<td>1%</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Air quality</strong>(^c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO(_x) (ppb)</td>
<td>47.0</td>
<td>46.6</td>
<td>0.36</td>
<td>-1%</td>
<td>18.1</td>
</tr>
<tr>
<td>O(_3) (ppb)</td>
<td>31.5</td>
<td>38.7</td>
<td>0.72</td>
<td>21%</td>
<td>8.1</td>
</tr>
<tr>
<td>PM(_{2.5}) (μg m(^{-3}))</td>
<td>107</td>
<td>94.6</td>
<td>-</td>
<td>-12%</td>
<td>49.3</td>
</tr>
<tr>
<td>Isoprene (ppb)</td>
<td>1.3</td>
<td>1.4</td>
<td>-</td>
<td>4%</td>
<td>0.66</td>
</tr>
<tr>
<td>Monoterpenes (ppb)</td>
<td>0.21</td>
<td>0.22</td>
<td>-</td>
<td>6%</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Our model well-reproduced observed air quality, BVOC and meteorological parameters, with normalized mean bias less than ±21%.
Sources of NO$_x$, VOC and PM$_{2.5}$ in Guanzhong
O₃ formation is promoted by interaction between Bio VOCs and Anth NOₓ
Conclusion

Pure Anth contribution

- NO\textsubscript{x} 99%
- VOCs 33%
- PM\textsubscript{2.5} 80%
- Daily Peak O\textsubscript{3} 30%

Pure Bio contribution

- NO\textsubscript{x} 1%
- VOCs 40%
- PM\textsubscript{2.5} 5%
- Daily Peak O\textsubscript{3} 3%

Synergistic Anth-Bio contribution

- NO\textsubscript{x} -1%
- VOCs -1%
- PM\textsubscript{2.5} 2%
- Daily Peak O\textsubscript{3} 14%
Thank you
$O_3$ formation mechanism and the precursors

AVOC (~150 Tg yr$^{-1}$)

NO$_x$ (~130 Tg yr$^{-1}$)

BVOC (~500 Tg yr$^{-1}$), Isoprene, monoterpenes, ...

[Wang et al., 2017; Heald et al., 2016; Zeng et al., 2008]