Secondary Organic Aerosols: Will they change in the Future?

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Winter CESM Working Group meeting; February 8-11, 2016, Boulder, CO

Thanks to Sponsors:
NASA Atmospheric Composition: Modeling and Analysis Program
Michigan Energy Institute
One of the strongest feedbacks between climate change and chemistry involves the formation of biogenic Secondary Organic Aerosols

- Biogenic VOC emissions increase with temperature, but also depend on soil moisture, atmospheric composition, vegetation type
  - 20-55% increase based on climate effect alone leads to a 26-150% increase in SOA (Liao et al., 2006; Tsigaridis and Kanakidou, 2007; Heald et al., 2008;
- Could act to moderate the overall future warming via aerosol direct and indirect effects
However some feedbacks act to decrease biogenic VOCs and SOA

- Increasing CO$_2$ inhibits isoprene emissions
- Land use change may decrease emissions
- Decreases in anthropogenic emissions (SO$_2$) may inhibit formation of SOA

Previous model estimates did not use an explicit mechanism for SOA formation
Explicit gas phase chemistry

- Basic photochemistry of $\text{O}_3$, $\text{OH}$, $\text{NO}_x$ and VOCs (Ito et al., 2007).
- Epoxide formation from isoprene (Paulot et al., 2009).
- $\text{HO}_x$ regeneration through isoprene oxidation proposed by Peeters et al. (2009) but with a recycled rate reduced by a factor of 10 (Karl et al. 2009).

SOA formed from gas-particle partitioning of semi-volatiles (Pankow 1994). For example,

\[
\text{Toulene} \xrightarrow{\text{OH}} \text{CRES} \xrightarrow{\text{OH}} \text{POXY} \xrightarrow{\text{NO}_2} \text{NITP} \xrightarrow{\text{NO}_3} \text{R4N2}.
\]

(Paulsen et al., 2006) 1 day

\[
\text{lv}_\text{SOA} \xleftrightarrow{\text{Gas-particle partitioning}} \text{sv}_\text{SOA}
\]
SOA formation mechanisms

- SOA formed from the cloud processing of glyoxal and methylglyoxal

SOA formation mechanisms

- SOA formed from the reactive uptake of glyoxal, methylglyoxal and epoxide onto sulfate aerosol

\[
\frac{dC_{\text{SOA}}}{dt} = \frac{-1}{4} \cdot \gamma \cdot A \cdot \langle \nu \rangle \cdot C_{\text{gas}}
\]

\(\gamma\): reactive uptake parameter.
A: surface area of aqueous sulfate aerosols
Major products: oligomers and organosulfate

### Scenarios

- Biogenic emissions based on MEGAN 2.1

<table>
<thead>
<tr>
<th>Species</th>
<th>Present day (year 2000)</th>
<th>Future (year 2100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isoprene</td>
<td>440</td>
<td>534</td>
</tr>
<tr>
<td>C_{10}H_{16}</td>
<td>131.9</td>
<td>246.5</td>
</tr>
<tr>
<td>PRPE(&gt;=C4 alkenes)</td>
<td>14.0</td>
<td>24.3</td>
</tr>
<tr>
<td>Methanol</td>
<td>85.0</td>
<td>159.4</td>
</tr>
<tr>
<td>Acetone</td>
<td>38.6</td>
<td>67.2</td>
</tr>
<tr>
<td>C_{2}H_{4}</td>
<td>23.4</td>
<td>46.0</td>
</tr>
<tr>
<td>CO</td>
<td>64.8</td>
<td>127.4</td>
</tr>
<tr>
<td>HCHO</td>
<td>4.1</td>
<td>8.7</td>
</tr>
</tbody>
</table>
### Scenarios: anthropogenic 2100 emissions based on RCP 8.5

<table>
<thead>
<tr>
<th>Species</th>
<th>Present day (year 2000)</th>
<th>Future (year 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO$_2$</td>
<td>129.2</td>
<td>49.5</td>
</tr>
<tr>
<td>NO</td>
<td>88.6</td>
<td>65.5</td>
</tr>
<tr>
<td>CO</td>
<td>956.7</td>
<td>711.0</td>
</tr>
<tr>
<td>NH$_3$</td>
<td>64.8</td>
<td>92.1</td>
</tr>
<tr>
<td>ALK4((&gt;=)C4 alkanes)</td>
<td>35.2</td>
<td>15.1</td>
</tr>
<tr>
<td>HCHO</td>
<td>3.2</td>
<td>5.5</td>
</tr>
<tr>
<td>ALK7(C6-C8 alkanes)</td>
<td>38.5</td>
<td>16.5</td>
</tr>
<tr>
<td>Aromatics</td>
<td>31.7</td>
<td>37.4</td>
</tr>
<tr>
<td>HCOOH</td>
<td>7.0</td>
<td>8.7</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>8.2</td>
<td>11.4</td>
</tr>
<tr>
<td>Acetone</td>
<td>2.5</td>
<td>4.2</td>
</tr>
<tr>
<td>POA</td>
<td>49.8</td>
<td>33.2</td>
</tr>
</tbody>
</table>
Experiment design: Separate effects of climate, anthropogenic emissions, land use

- Change in anthropogenic emissions
- Change in climate and CO$_2$ concentrations
- Change in anthropogenic land use
- All effects acting in combination
- Examine effects of changing particle acidity, which lowers uptake of IEPOX
Effects on isoprene emissions

Climate change and CO$_2$

Anthropogenic land use change
Today’s SOA burden is 1.06 Tg, 80% from oxidation of isoprene; 11% from anthropogenic emissions.
Predicted SOA is lower than AMS observations by 57% in NH and higher by 41% in tropical regions.

Only small changes when acidity of aerosols for IEPOX uptake: Decrease of 2% near surface, Increase of 2.5% above surface.
Net effect:
Increases from gas-particle partitioning (0.06 Tg)
Decrease from uptake of glyoxal, methylglyoxal and IEPOX (-0.1 Tg)
Effect of climate and CO$_2$ change: +25%

Effect of climate change and CO$_2$ on isoprene emissions ($\mu gC/m^2/h$)
Effect of anthropogenic land use change: -14%

Isoprene emissions change due to anthropogenic land use change
Large increase anticipated from change in climate offset due to:

Decrease in isoprene from CO₂ inhibition
Decrease in anthropogenic emissions of SO₂
Decrease in isoprene from anthropogenic land use change
Regional variations in SOA can be large:
Thank you!