The Impact of Pine Beetle Kill on Monoterpene Emissions and SOA Formation in Western North America

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Beetle Infestation

- Beetle infestation in western North America has lasted more than a decade, aided by climate change
- Impacts carbon cycling, fuel distributions, sfc-atm exchanges...
- What about atmospheric composition?
Beetle Infestation

Very few quantitative studies have been done

Amin et al. (2012) measure emissions from Lodgepole pine under attack by mountain pine beetle

Significant increase in emissions of certain compounds

Trees respond to beetle attack with enhanced VOC emissions
Objective

Use beetle mortality data from 1997-2010 and beetle-induced monoterpene data in the Community Earth System Model

- Oxidation of Monoterpenes
- SOA Formation

• Vegetation
• Monoterpene Emissions
Beetle Mortality Data

- 1-km grid of % mortality from aerial overview surveys, 1997 – 2010
- 13 Beetles, 17 Host types

Figures: Meddens et al., 2012 (submitted)
Apply mortality to Needleleaf PFTs
And convert to 1.9x2.5 degrees:
Enhanced Monoterpene Emissions Data

Scale-up factors calculated from data are applied to monoterpene emissions from fraction of Needleleaf trees under attack.

<table>
<thead>
<tr>
<th>Monoterpene</th>
<th>Scale-Up Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>β-pinene</td>
<td>7.7</td>
</tr>
<tr>
<td>3-carene</td>
<td>7.3</td>
</tr>
<tr>
<td>β-phellandrene</td>
<td>33</td>
</tr>
<tr>
<td>P-cymene</td>
<td>5.4</td>
</tr>
</tbody>
</table>

H. Amin et al., Environ. Sci. Technol., 2012 (online)
SOA data

• In the chemical mechanism: add photochemical (OH) and ozonolysis reactions for SOA formation from single monoterpenes as irreversible yields
  – SOA yields from Lee et al. (2006)
  – Reaction rates at 298K from Atkinson (1997)

<table>
<thead>
<tr>
<th>Monoterpene</th>
<th>SOA Yield (OH)</th>
<th>Lifetime assuming [OH] = 1x10^6 molecules cm^{-3}</th>
<th>SOA Yield (O_3)</th>
<th>Lifetime assuming [O_3] = 40 ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-pinene</td>
<td>29%</td>
<td>3.5 hours</td>
<td>16%</td>
<td>17 hours</td>
</tr>
<tr>
<td>3-carene</td>
<td>36%</td>
<td>3.2 hours</td>
<td>51%</td>
<td>7 hours</td>
</tr>
<tr>
<td>B-phellandrene</td>
<td>55%</td>
<td>1.7 hours</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P-cymene</td>
<td>6%</td>
<td>19 hours</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Impact on Monoterpene Emissions

B-pinene, B-phellandrene, 3-carene, P-cymene

Mortality Effect – decrease due to beetle kill
Attack Effect – increase due to beetle attack

2004 Mountain Pine Beetle Attack
Largest impact of MPB in British Columbia
Maximum increase above baseline 70%

2008 Mountain Pine Beetle Attack
Largest impact of MPB in United States
Maximum increase above baseline 104%
Impact on SOA Concentrations
from B-pinene, B-phellandrene, 3-carene, P-cymene

**Mortality Effect** – decrease due to beetle kill

**Attack Effect** – increase due to beetle attack

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**2004 Mountain Pine Beetle Attack**
Largest impact of MPB in British Columbia
Maximum increase above baseline **43%**

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**2008 Mountain Pine Beetle Attack**
Largest impact of MPB in United States
Maximum increase above baseline **36%**
Impact due to Other Beetles on monoterpenes and SOA

**Mortality Effect** – decrease due to beetle kill
**Attack Effect** – increase due to beetle attack

**Monoterpenes**
2002 Other Beetle Attack
Largest impact of OB in British Columbia and the United States
Maximum increase above baseline **111%**

**SOA**
2002 Other Beetle Attack
Largest impact of OB in British Columbia and the United States
Maximum increase above baseline **37%**
A second beetle attack scenario: Spruce under attack by mountain pine beetle

Scale-up Factors

<table>
<thead>
<tr>
<th>Monoterpene</th>
<th>Pine</th>
<th>Spruce</th>
</tr>
</thead>
<tbody>
<tr>
<td>β-pinene</td>
<td>7.7</td>
<td>16</td>
</tr>
<tr>
<td>3-carene</td>
<td>7.3</td>
<td>65</td>
</tr>
<tr>
<td>β-phellandrene</td>
<td>33</td>
<td>5.3</td>
</tr>
<tr>
<td>P-cymene</td>
<td>5.4</td>
<td>42</td>
</tr>
</tbody>
</table>

Pine calculated from Amin et al., 2012, Spruce from same group

2004 Mountain Pine Beetle Mortality Effect + Attack Effect

- Large species-variability in response to beetle attack
- Highlights uncertainties surrounding impact of beetles on atmospheric composition
Now let’s provide some context:

IMPROVE OM observations

Comparing simulated SOA to monthly average OM (2005-2010) observed at MOZI - a Colorado site

- Annual/interannual variability in OM observations is much larger than beetle-induced SOA changes – not observable
- While changes are not large compared to OM observations in Colorado, some other regions may be experiencing higher localized impacts
Summary and future work

- Limited to broad PFT categories
- SOA may be overestimated
- Need more quantitative studies of MT emission changes
- Beetle infestation may have a significant impact on atmospheric composition in western North America. Future studies may help constrain these impacts.