Effects of biogenic emissions on atmospheric composition

Paul Young

Centre for Atmospheric Science, University of Cambridge, UK
Outline

1. Why biogenic VOCs?
2. BVOCs and atmospheric chemistry
3. Future (?) BVOC emissions
   • The experiment
   • Some results
   • Some conclusions & caveats
4. Where next? (JULES)
Why are we interested?

Biogenic VOCs

Anthropogenic VOCs

~ 1000 Tg C yr⁻¹
Why are we interested?

May be highly reactive
→ large contribution to \( \text{O}_3 \) chem

Oxidation products important globally

Ethene, acetone, methane (?), terpenes (isoprene, \( \alpha \)-pinene, \( \beta \)-caryophylene

Role in organic aerosol formation

\( T, \text{ light, H}_2\text{O, CO}_2, \text{ species, nutrients} \)
Chemistry 101 – Tropospheric ozone

VOCs ‘fuel’ O₃ production

Chemical Production

NMHCs CO, CH₄

HO₂, RO₂

OH

Emissions

NO

NO₂

hv

Deposition

Ocean

Moderately Polluted areas

Urban

based on a diagram by Oliver Wild
Climate-chemistry links

Climate feedbacks on emission: temp, light, CO$_2$, soil moisture…

Based on Ramanathan et al. [1987]
Atmospheric chemistry

ATMOSPHERIC CHEMISTRY

- H₂O → OH
- M → O³(P) → O³(D)
- NO + NO₂ → NOx/VOCs
- PAN
- ISOPRENE SOURCES
- ANTHROPOGENIC SOURCES
- REMOTE REGIONS
Increasing isoprene emissions in a pessimistic (A2) future
The experiment (a)

• Increase isoprene to a 2100 (2xCO$_2$) level using Guenther et al. [1995] algorithms and HadCM3 surf temperature output*

Present day  Future (2100)
398 Tg C yr$^{-1}$ 771 Tg C yr$^{-1}$

• Just consider potential isoprene response to temperature (e.g. no vegetation shifts)

*ΔT ~ 4K
Isoprene emissions

(a) BASE: 398 Tg C yr\(^{-1}\)

(b) 2100: 771 Tg C yr\(^{-1}\)

Isoprene emissions / Tg month\(^{-1}\) (non-linear scale!)
The experiment (b)

- Experiment matrix

<table>
<thead>
<tr>
<th></th>
<th>“Anthro.”*</th>
<th>Isoprene</th>
<th>Climate</th>
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<tbody>
<tr>
<td>ISOP</td>
<td>2000</td>
<td>2100</td>
<td>2000</td>
</tr>
<tr>
<td>ANTH</td>
<td>2100</td>
<td>2000</td>
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<tr>
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<td>2100</td>
<td>2100</td>
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<tr>
<td>ALLcc</td>
<td>2100</td>
<td>2100</td>
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</tbody>
</table>

*e.g. NO\textsubscript{x}, CO, NMHCs (all non-isoprene emissions); based on SRES A2 Scenario*
$\Delta$O3 boundary layer [Jul] / ppbv

ANTH - BASE
ΔO3 boundary layer [Jul] / ppbv

ALL - BASE
$\Delta$O3 boundary layer [Jul] / ppbv

ALL - ANTH
Tropospheric methane lifetime [Yr avg]

Impact of OH changes…

![Bar chart showing methane lifetime across different scenarios.]

- **BASE**: 10.5 years
- **ANTH**: 8.0 years
- **ALL**: 8.7 years
- **ALLcc**: 7.4 years
Tropospheric NO$_y$ speciation [Yr avg]

What is the potential for NO$_x$ redistribution?

<table>
<thead>
<tr>
<th>ORG N</th>
<th>PAN</th>
<th>INORG N</th>
<th>HNO3</th>
<th>NO2</th>
<th>NO</th>
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<tr>
<td>12.4</td>
<td>4.2</td>
<td>6.2</td>
<td>30.4</td>
<td>3.8</td>
<td>21.8</td>
</tr>
<tr>
<td>11.1</td>
<td>3.4</td>
<td>3.8</td>
<td>21.8</td>
<td>2.3</td>
<td>42.8</td>
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<tr>
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<td>2.7</td>
<td>5.2</td>
<td>31.1</td>
<td>1.9</td>
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<tr>
<td>10.5</td>
<td>2.6</td>
<td>5.7</td>
<td>22.2</td>
<td>1.8</td>
<td>55.1</td>
</tr>
</tbody>
</table>

Tg N (as NO$_y$)

<table>
<thead>
<tr>
<th>BASE</th>
<th>ANTH</th>
<th>ALL</th>
<th>ALLcc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.15</td>
<td>2.92</td>
<td>3.09</td>
<td>2.60</td>
</tr>
</tbody>
</table>
Conclusions & Caveats

Isoprene changes are important for atmospheric composition [Sanderson et al., 2003; Hauglustaine et al., 2005; Steiner et al., 2006; Wiedinmyer et al., 2006]
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- Impact is heterogeneous and complex: balance of HO$_x$ and NO$_y$ changes; depend on chemical characteristics of the region → sensitive to future emission estimates.
**Conclusions & Caveats**

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- **But** models obviously over-simplify the problem: chemistry, canopy processes, sub-grid scale phenomena, vegetation-climate feedbacks, *etc. etc.*
Where next?

• Conducting model study using emissions estimated from LPJ-GUESS [Arneth et al., 2007]

• Comparison with results from Juliette et al.’s work with JULES (‘ensemble chemistry/emissions’)

• …If isoprene CO$_2$-effect counteracts T effect, changes in land use become important
Tropospheric OH [Yr avg]

ALL versus ANTH
ΔO3 boundary layer [Jul] / ppbv
ΔO3 boundary layer [Jul] / ppbv
$\Delta$O$_3$ boundary layer [Jul] / ppbv