Implementation and Evaluation of a Biogenic Isoprene Emissions scheme in JULES

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Subject of Study

BVOCs

Vegetation emits a wide range of Biogenic Volatile Organic Compounds

SOA

Accumulation of CH₄

SUNLIGHT+NOX+VOC=O₃

O₃ vegetation damage

Reduce quality and quantity of the crops
This model is based on Arneth et al., 2007 and Niinemets et al., 1999

\[ I = IEF \frac{A_{canopy} + R_{Dcanopy}}{A_{st} + R_{Dst}} f_T \cdot f_{CO_2} \]

- **I**  Above-canopy isoprene emission
- **IEF** Isoprene Emission Factor, i.e. basal isoprene emission at the leaf level in standard conditions. This factor is Plant Functional Type-dependent in JULES.
- **\( A_{canopy} \)** Net photosynthesis rate at the canopy level
- **\( R_{Dcanopy} \)** Respiration rate at the canopy level
- **\( f_T \)** This empirical factor takes into account the fact that although isoprene is produced in the chloroplast from precursors formed during photosynthesis, there are differences in the short-term response of carbon assimilation and isoprene emission, such as the higher temperature optimum of isoprene synthase.
- **\( f_{CO_2} \)** This empirical factor models the inhibition of isoprene emission with increasing atmospheric CO\(_2\) concentration, and vice versa the increase of isoprene emissions with decreasing atmospheric CO\(_2\) concentration. It is relevant for past and future estimates of isoprene emissions.
- **-st** indicates standard conditions, i.e. temperature \( T_{st} \) of 30°C, photosynthetically active radiation of 1000\( \mu \)mol/m\(^2\)/s and CO\(_2\) atmospheric concentration of 370 ppm.
Diurnal and Seasonal Variability at the above-canopy isoprene flux measurement sites.
Comparison with satellite-derived isoprene estimates over south America and east and south Asia
Present-day (1990s) global isoprene emissions with JULES: 535 TgC/yr.

Published estimates: 400-600 TgC/yr (Arneth et al., 2008 ACP).
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Model Applications

### BIOGENIC ISOPRENE EMISSIONS

![World map showing biogenic isoprene emissions](image)

<table>
<thead>
<tr>
<th>Isoprene Emission at LGM (TgC/yr)</th>
<th>Isoprene Emission at PI (TgC/yr)</th>
<th>Decrease in Isoprene Emission at the LGM compared with PI (%)</th>
<th>Impact on CH&lt;sub&gt;4&lt;/sub&gt; (ppb)</th>
<th>Isoprene Emission Model</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>343</td>
<td>502</td>
<td>-32%</td>
<td>n.a.</td>
<td>Guenther et al., 1995</td>
<td>Adams et al., 2001</td>
</tr>
<tr>
<td>331</td>
<td>702</td>
<td>-33%</td>
<td>n.a.</td>
<td>Guenther et al., 1995</td>
<td>Lathière et al., 2005</td>
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<tr>
<td>229</td>
<td>394</td>
<td>-61%</td>
<td>-238</td>
<td>Guenther et al., 1995</td>
<td>Valdés et al., 2005</td>
</tr>
<tr>
<td>335</td>
<td>541</td>
<td>-38%</td>
<td>-385</td>
<td>Guenther et al., 1995</td>
<td>Kaplan et al., 2006</td>
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<tr>
<td>357</td>
<td>447</td>
<td>-20%</td>
<td>n.a.</td>
<td>Arneth et al., 2007b</td>
<td>Arneth et al., 2007</td>
</tr>
<tr>
<td>428</td>
<td>567</td>
<td>-24%</td>
<td>-108</td>
<td>Pacifico et al., 2011</td>
<td>This study</td>
</tr>
</tbody>
</table>

(early 20th century)
## Federica Pacifico: Biogenic Isoprene Emissions in JULES

### Model Applications

<table>
<thead>
<tr>
<th></th>
<th>Isoprene Emissions (TgC/yr)</th>
<th>GPP (PgC/yr)</th>
<th>CO₂ (ppm)</th>
<th>Air Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present-day 2000-2009</td>
<td>460</td>
<td>146</td>
<td>368</td>
<td>14.1</td>
</tr>
<tr>
<td>Pre-Industrial 1860-1869</td>
<td>579</td>
<td>119</td>
<td>286</td>
<td>13.4</td>
</tr>
<tr>
<td>Future (RCP 8.5) 2100-2109</td>
<td>456</td>
<td>239</td>
<td>936</td>
<td>18.8</td>
</tr>
<tr>
<td>Future (RCP 2.6) 2100-2109</td>
<td>461</td>
<td>162</td>
<td>421</td>
<td>15.4</td>
</tr>
</tbody>
</table>

Pacifico et al., 2012 JGR

### BIOTIC ISOPRENE EMISSIONS CHANGES

**PRESENT-DAY**

- **Isoprene Emissions (TgC/yr)**: 460
- **GPP (PgC/yr)**: 146
- **CO₂ (ppm)**: 368
- **Air Temperature (°C)**: 14.1

**PRE-INDUSTRIAL**

- **Isoprene Emissions (TgC/yr)**: 579
- **GPP (PgC/yr)**: 119
- **CO₂ (ppm)**: 286
- **Air Temperature (°C)**: 13.4

**FUTURE**

- **Isoprene Emissions (TgC/yr)**: 456
- **GPP (PgC/yr)**: 239
- **CO₂ (ppm)**: 936
- **Air Temperature (°C)**: 18.8

- **Isoprene Emissions (TgC/yr)**: 461
- **GPP (PgC/yr)**: 162
- **CO₂ (ppm)**: 421
- **Air Temperature (°C)**: 15.4
### Model Applications

<table>
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<tr>
<th>20% decrease in isoprene emissions</th>
<th>Ozone burden</th>
<th>Methane Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Under Pre-Industrial (1860-1869) conditions</strong></td>
<td>+ 0.7 Tg + 0.2%</td>
<td>- 9 months - 80 ppb - 44 mW/m²</td>
</tr>
<tr>
<td><strong>Under Present-day (2000-2009) conditions</strong></td>
<td>- 2 Tg - 2%</td>
<td>- 3 months - 59 ppb - 22 mW/m²</td>
</tr>
</tbody>
</table>

Pacifico et al., 2012 JGR

**BIOGENIC ISOPRENE EMISSIONS**

![Map of global distribution of biogenic isoprene emissions.](image)
Conclusions

- Scheme available to study Biogenic Isoprene Emissions at different locations/historical periods

- Modifying the Photosynthesis Scheme will affect the isoprene scheme, e.g. direct/diffuse radiation (can_rad_mod 5)

- Possible Improvements: phenology; make the isoprene scheme more process-based, less empirical; evaluation against newly available data
Thanks