Feedback of Climate Change to Biological Isoprenoid Emission Potential

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Outline

Introduction
- Basics on environmental factors controlling biogenic emission.
- Projected biogenic emissions and climate.

Results
- Feedback of elevated temperature and soil drought on isoprene emission potential of European oak trees.

Conclusions
- Climate change and isoprene emission potential.
Environment and Biogenic VOC Emission

Monoterpenes

- α-pinene
- β-pinene/sabinene
- myrcene
- limonene
- camphene

Quercus coccifera

(Steinbrecher und Hauff, 1996)
Environment and Biogenic VOC Emission

Quercus coccifera

<table>
<thead>
<tr>
<th>Flux rate / nmol m⁻² s⁻¹</th>
<th>T_f [°C]</th>
<th>PAR [µE]</th>
<th>Δ-W [mmol mol⁻¹]</th>
<th>E [mmol m⁻² s⁻¹]</th>
<th>g_H₂O [mmol m⁻² s⁻¹]</th>
<th>A [µmol m⁻² s⁻¹]</th>
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(Steinbrecher und Hauff, 1996)
Environment and Biogenic VOC Emission

From Synthesis to Emission

Environment and Biogenic VOC Emission

From Synthesis to Emission

Processes:

- Synthesis and storage in specific leaf compartments
- Solution/storage in membranes
- Diffusion from membranes into the leaf intra-cellular air space
- Diffusion/co-transport through the stomata into the environment

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Environment and Biogenic VOC Emission

Physiological constraints ($T$, light, protein synthesis)

Physicochemical constraints ($T$, leaf structure, stomatal openness)

Intermediate production

Maximum activity of flux controlling enzymes

Volatility

Diffusion

(Emission)

(Niinemets, et al., 2004)
E (RC\textsubscript{i}, T, PAR) = E (RC\textsubscript{i}, T)\textsubscript{Pool} + E (RC\textsubscript{i}, T, PAR)\textsubscript{Synthesis}

E(RC\textsubscript{i}, T) = Ef\textsubscript{RC\textsubscript{i}} x e^{\beta (T - T_s)}

Ef\textsubscript{RC\textsubscript{i}} = emission factor of compound emitted from pools in pmol m\textsuperscript{-2} total leaf area s\textsuperscript{-1} at 30°C leaf temperature
\beta = 0.09°C\textsuperscript{-1}[a]
T_s = 30°C
T = T\text{leaf} [°C]

E(RC\textsubscript{i}, T, PAR) = Ef\textsubscript{RC\textsubscript{i}} x C_L x C_T

Ef\textsubscript{RC\textsubscript{i}} = emission factor of compound emitted from de novo synthesis in pmol m\textsuperscript{-2} total leaf area s\textsuperscript{-1} at 30°C leaf temperature
C_L = correction term for light [a]
C_T = correction term for temperature [a]

E(RC\textsubscript{i}, T) = Ef\textsubscript{RC\textsubscript{i}} x e^{\beta (T - T_s)}

\((^a\text{Guenther 1997, Steinbrecher et al, 1999})\)

Projected biogenic emissions and climate change.
Biogenic Isoprenoid Emission in Finland

How may those changes impact atmospheric chemistry?

Projected biogenic emissions and climate change in Finland.

Projected Emissions and SOA Formation


-20%
Projected Emissions and SOA Formation

What are the major constraints of that message?

- The real atmosphere is much more complex and includes e.g. also NO\textsubscript{x}/SO\textsubscript{x} chemistry.

- Uncertainties in BVOC emission estimates, e.g. plant emission potential or emission factors may adapt to climate change factors.

Reactive Compound Emission Modelling

Recall: What are emission factors?

\[ E_{(RC_i, T, PAR)} = E_{(RC_i, T)_{Pool}} + E_{(RC_i, T, PAR)_{Synthesis}} \]

\[ E(RC_i, T) = E_{RC_i} \times e^{(\beta (T - T_s))} \]

\[ E(RC_i, T, PAR) = E_{RC_i} \times C_L \times C_T \]

- \( E_{RC_i} \) = emission factor of compound emitted from pools in pmol m\(^{-2}\) total leaf area s\(^{-1}\) at 30°C leaf temperature
- \( \beta = 0.09°C^{-1} \)
- \( T_s = 30°C \)
- \( T = T_{leaf} [°C] \)

\( E_{RC_i} \) = emission factor of compound emitted from de novo synthesis in pmol m\(^{-2}\) total leaf area s\(^{-1}\) at 30°C leaf temperature
- \( C_L \) = correction term for light \([a]\)
- \( C_T \) = correction term for temperature \([a]\)

\( EF_{RC_i} \) = emission factor in pmol m\(^{-2}\) total leaf area s\(^{-1}\) at 30°C leaf temperature and 1000 µE PAR

\(^{[a]}\) Guenther 1997, Steinbrecher et al, 1999
Emission Potential and Adaption

Emission Potential and Adaption

- Plants are able to adapt to environmental conditions.

- This may impact the emission potential for BVOC under extreme environmental conditions.

But:

- Are these effects still obvious if conducting experiments with projected changes in temperature and precipitation?

(Sharkey et al., 2008)
European Oak trees and Climate Change

„Querco“ Model Ecosystem Study

Objective:
To elucidate the adaption potential of three major European deciduous oak tree species to projected elevated temperature and extended soil drought periods.

- 4 Treatments
- Control, elevated temperature, soil drought, combination
- 4 replicates, Latin Square
European Oak trees and Climate Change

Measurements:

- All treatments
- Acidic soil
- *Quercus petraea* (Sessile Oak), provenance Corcelles-P. Concise
- *Q. robur* (English Oak), provenances Bonfol and Tagerwilien
- *Q. pubescens* (Downy Oak), provenances Arrezo and Leuk
Methods: Gas Exchange

Isoprene, CO$_2$, Water vapor

Standardised conditions:
28 °C leaf temperature; 1500 µE PAR; rel. Hum. 45%; CO$_2$ 380 ppm

Checking LI6400 Gas Exchange System
Methods: Leaf Surface Temperatures

Infrared Thermography

Thermography with Infratec VarioCAM

Methods: Leaf Surface Temperatures

Infrared Thermography

Thermography with Infratec VarioCAM
Results: Leaf Surface Temperatures:
August 06, 2008; 15:00 CEST

Chamber 1.2: Control

Median: 25°C
Results: Leaf Surface Temperatures
August 06, 2008; 15:35 CEST

Chamber 4.1: Combination

Median: 31°C
Results: Temperatures

Leaf surface temperatures and its variability on August 6, 2008, 15:00 to 15:35 CEST (mean ± 1σ; n = (80 sun leaves + 80 shadow leaves)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>Warming</th>
<th>Drought</th>
<th>Combination</th>
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</thead>
<tbody>
<tr>
<td>Leaf temperature / °C</td>
<td>27.3 ± 1.90</td>
<td>28.0 ± 1.99</td>
<td>32.3 ± 2.54</td>
<td>34.0 ± 2.68</td>
</tr>
</tbody>
</table>

Mean air temperature
daytime 6-18h and nighttime 18-6h

Air temperatures in the warming treatments are increased by 1 °C on a daytime average.
Results: Isoprene Emission and Photosynthesis

- Net-photosynthesis / μmol m⁻² s⁻¹
- Isoprene / nmol m⁻² s⁻¹
- Conductance

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Flux rate</th>
<th>Leaf to air water vapour conductance / mmol m⁻² s⁻¹</th>
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<td>Combination</td>
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<td>Temperature</td>
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<td>Drought</td>
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Conclusions

- Standardised isoprene emission of deciduous oak trees – the major isoprene emitter type in natural forests of Europe - is not statistically significant (P=0.05) impacted by elevated temperature, soil drought or by both parameters combined.

- Consequences for BVOC emission modelling: If the year 2009 experiments confirm the presented results, the model ecosystem study Querco indicates that at least for European deciduous oak trees a specific adaptation of isoprene emission factors / emission potential in response to projected elevated temperature and soil drought is not needed.

- Therefore, it may be hypothesised that current up-to date emission factors are also valid for projections of BVOC emission in climate change scenarios.
Conclusions

BUT:

- Emission factors for many compounds emitted are still unknown.
- Some emission controlling processes are still unknown.
- Estimates of emission active surfaces (e.g. leaves, bark, dead/damaged wood) are still insufficient accurate.
- Projections of land use change and forest management practices are still inconsistent.

Uncertainties in BVOC inventories may be as large as the estimated emission itself!

(Steinbrecher et al., 2009)
Thank You for Your Attention!

and

the Querco TEAM for their support during the field experiments