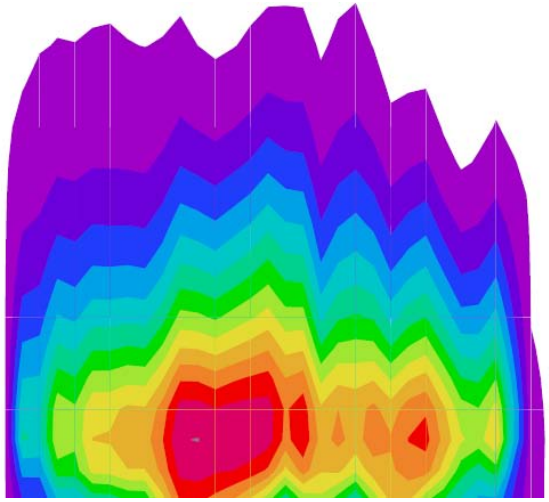
Plant effects on air chemistry

Wie Pflanzen die Luftchemie beeinflussen



Dr. Rüdiger Grote, Institute für Meteorologie und Klimaforschung (IMK-IFU), Garmisch-Partenkirchen

Email: ruediger.grote@kit.edu

KIT – die Kooperation von Forschungszentrum Karlsruhe GmbH und Universität Karlsruhe (TH)

HELMHOLTZ GEMEINSCHAFT

Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft

Questions Related to Plant - Air Interaction

How can plants protect themselves against heat stress?

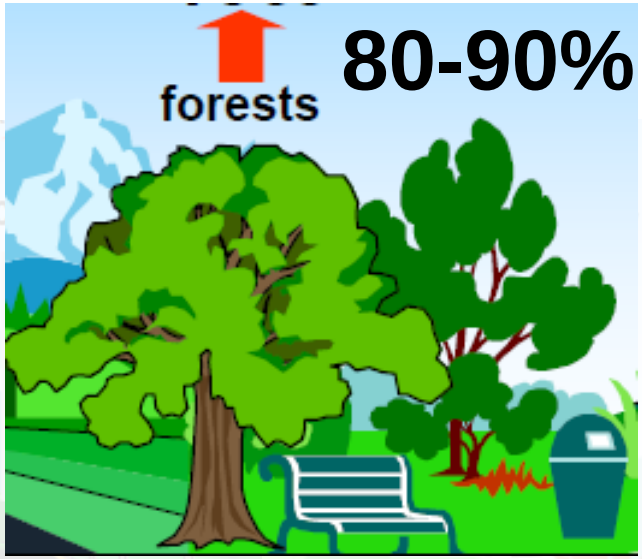
How do plants communicate?

Why are ozone concentrations highest at city boundaries?

How do plants modify the greenhouse effect?

Email: ruediger.grote@kit.edu

From Where?



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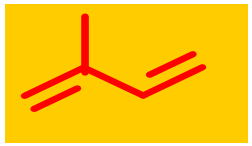
What and How Much?

Species	Global emission (Tg C a^{-1})	Atmospheric lifetime (h)	Atmospheric concentrations	Examples
Isoprene	412 – 601	4.8	pmol - several nmol mol^{-1}	
Monoterpenes	32 – 127	2.4 - 4.8	pmol - several nmol mol^{-1}	α-pinen, β-pinen, limonen
Other reactive VOCs	~260	< 24	1-3 nmol mol^{-1}	2-methyl-3-buten-2-ol, hexenal, acetaldehyde
Other VOCs	~260	> 24	2-30 nmol mol^{-1}	methanol, ethanol, formic acid, acetic acid, acetone

Σ > 1000 Tg (= 1 000 000 000 000 000 g = 1 000 000 000 t = 1 Gt)

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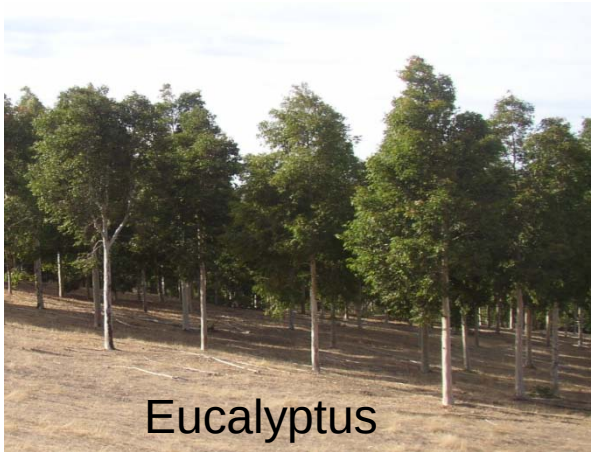
Who?



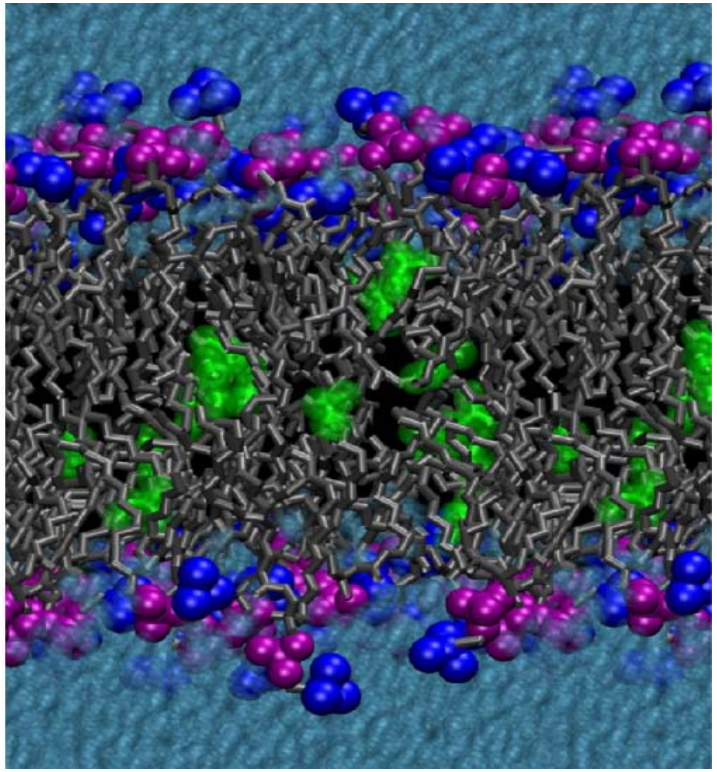
Email: ruediger.grote@kit.edu

Importance for the Plant Realm

1. Protection against heat stress

„A concentration of 20 mol% isoprene … is equivalent to a reduction in temperature of 10 K.“

Siwko et al. 2007



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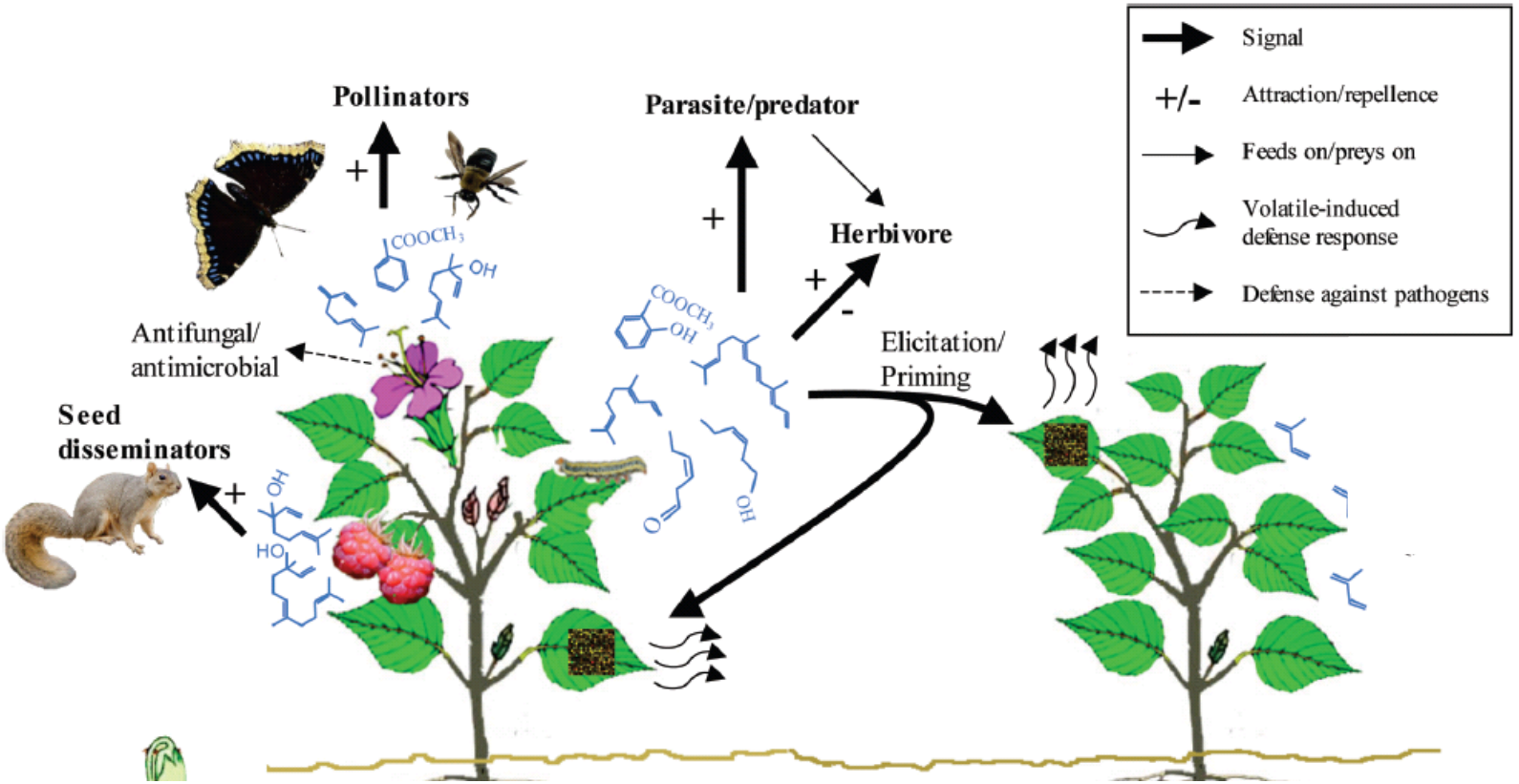
Importance for the Plant Realm

2. Communication



From Dudareva et al. 2006

Email: ruediger.grote@kit.edu

Plant Communication - Example

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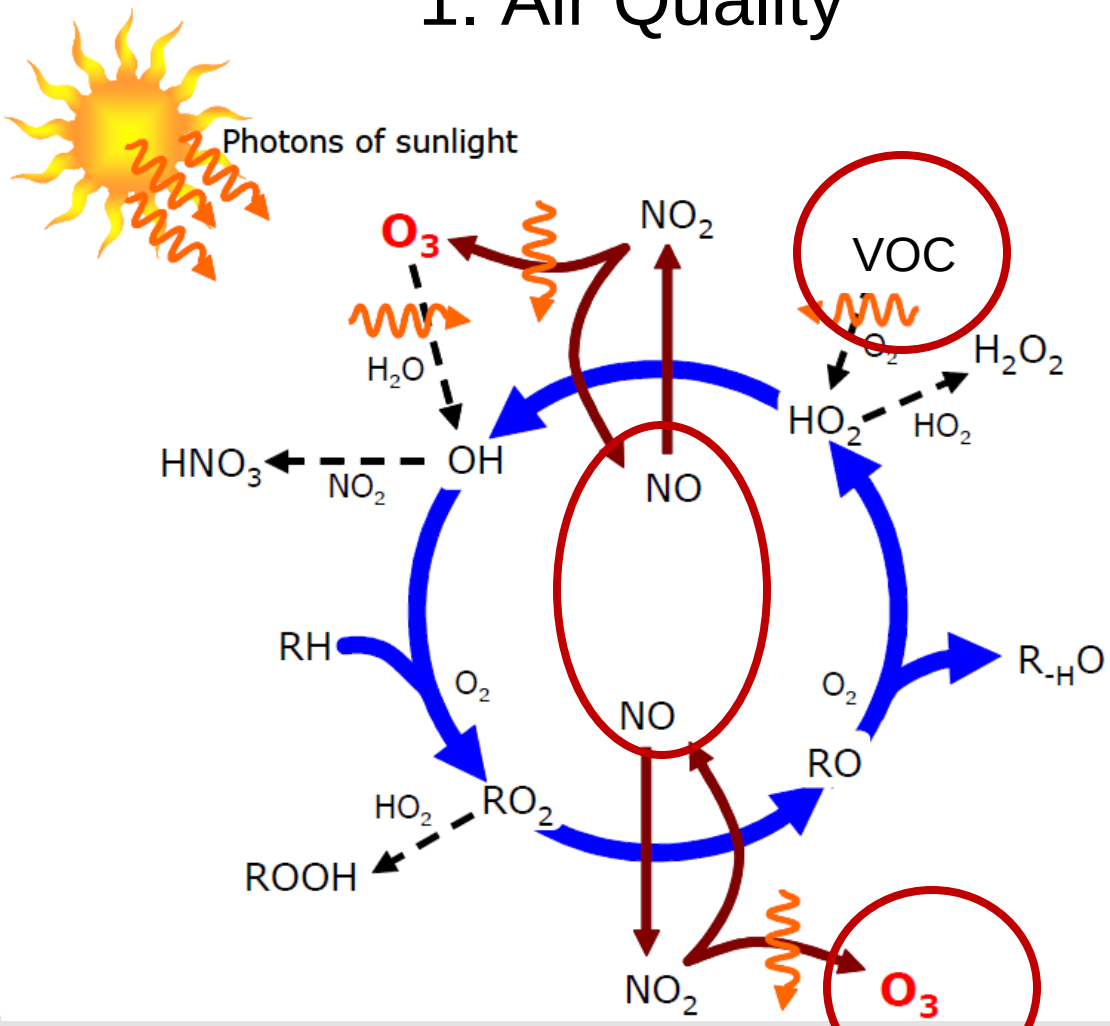
Importance for Mankind

1. Air Quality



From Coyle 2006

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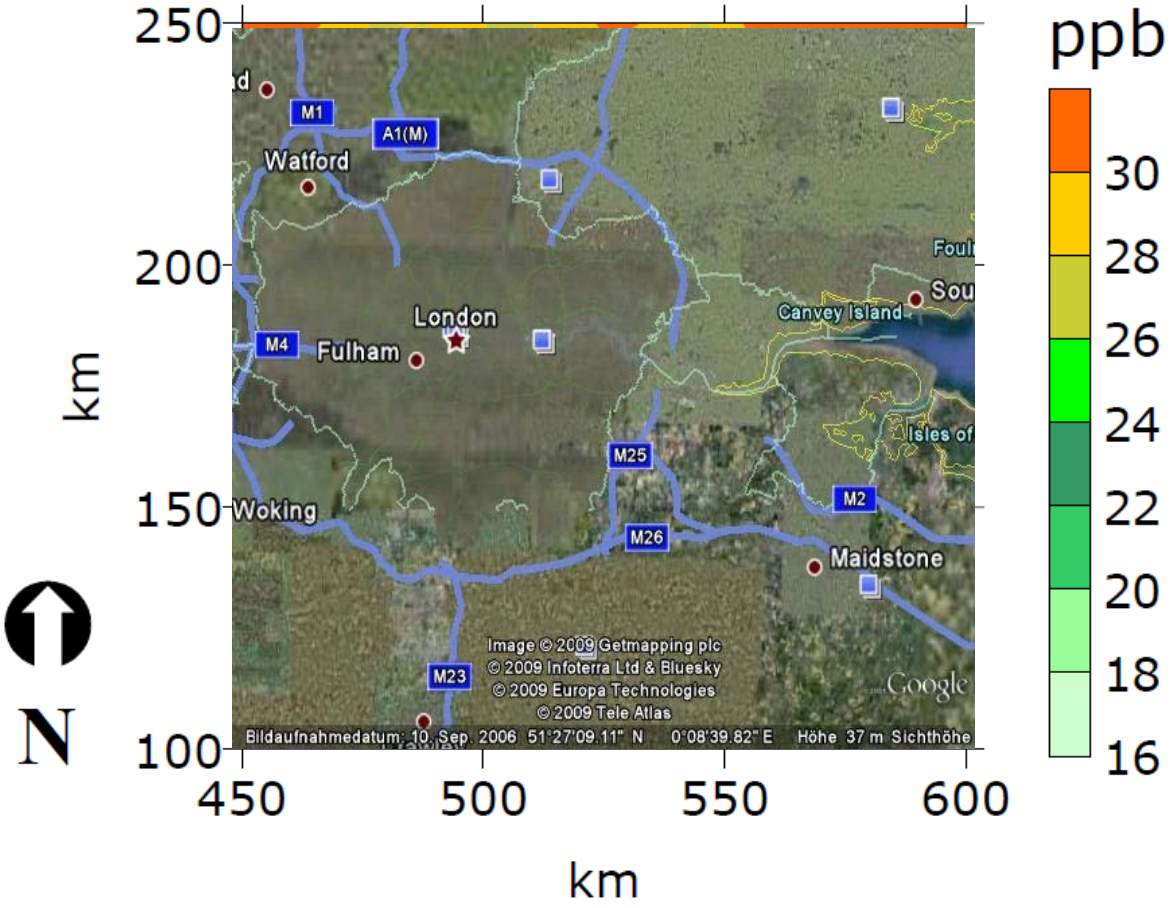
Air Quality - Example

- London (average ozone concentration summer 2001)



From Coyle 2006

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Importance for Mankind

2. Direct Greenhouse Effect

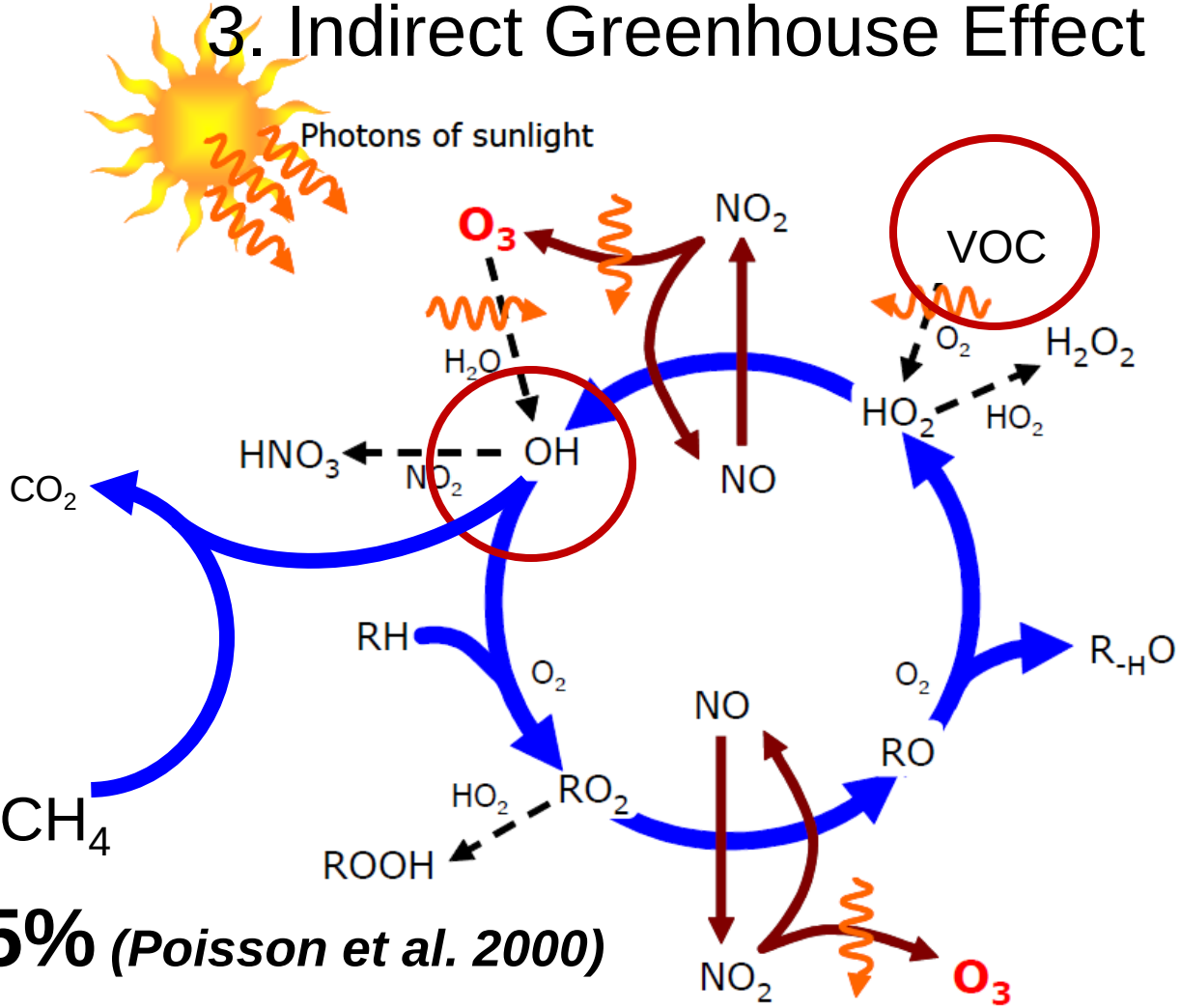
„BVOC emissions … are responsible for a large fraction of the total column aerosol load in the region … *(that)* appears to act as a negative climate feedback regionally."

Goldstein et al. 2009

Email: ruediger.grote@kit.edu

Importance for Mankind

3. Indirect Greenhouse Effect



+15% ***(Poisson et al. 2000)***

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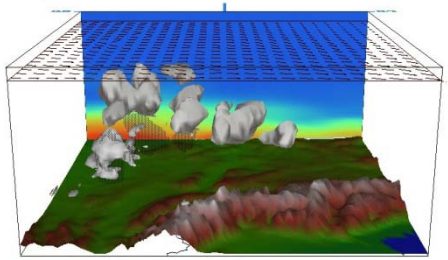
BVOC Emission Modeling

BVOC production and emission

Scaling from leaf to stand
(For the example of a
Mediterranean Holm oak stand)



Scaling from stand to region

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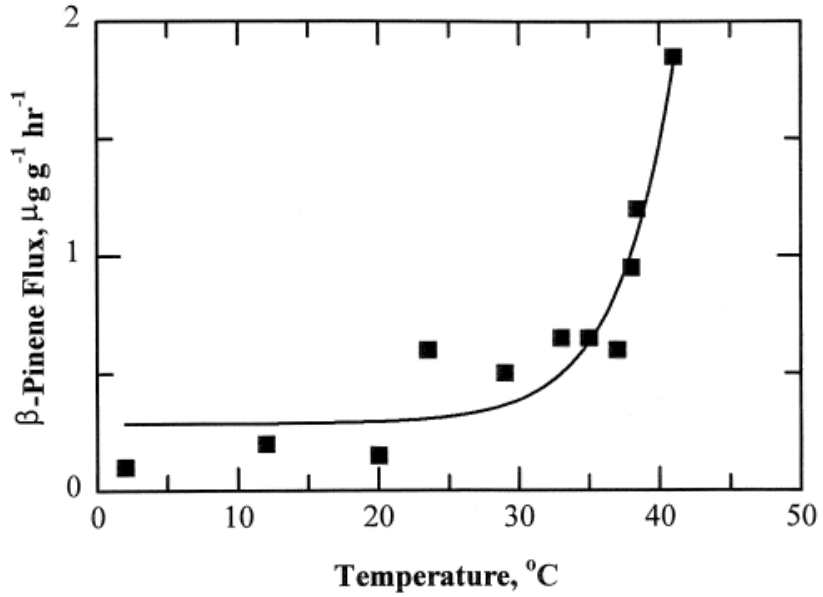
BVOC production and emission

1. Indirectly from storages



$$E_s = EF_s * \exp(0.09 * (T - 303))$$

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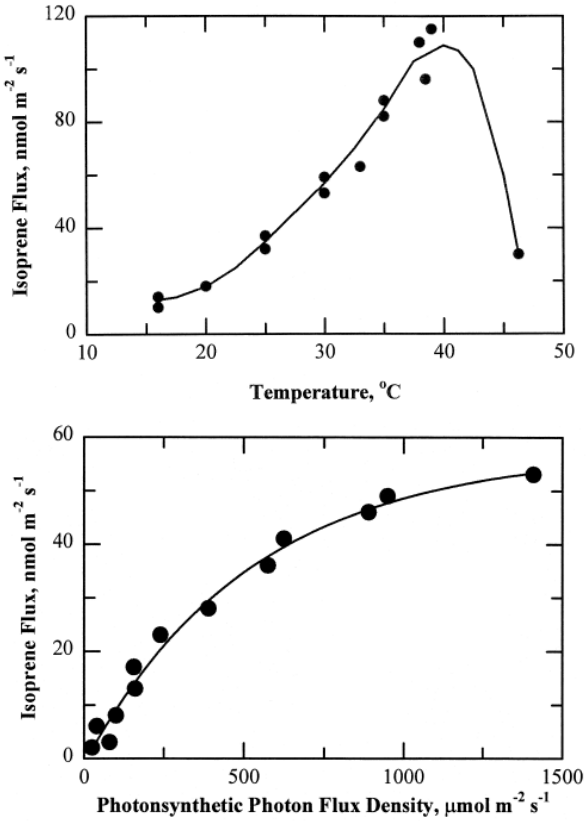
BVOC production and emission

2. Directly from production



$$E_P = EF_P * f(L) * f(T)$$

$$E_P = EF_P * f(L) * f(T) * f(S) * f(D) * f(CO_2)\ldots.$$

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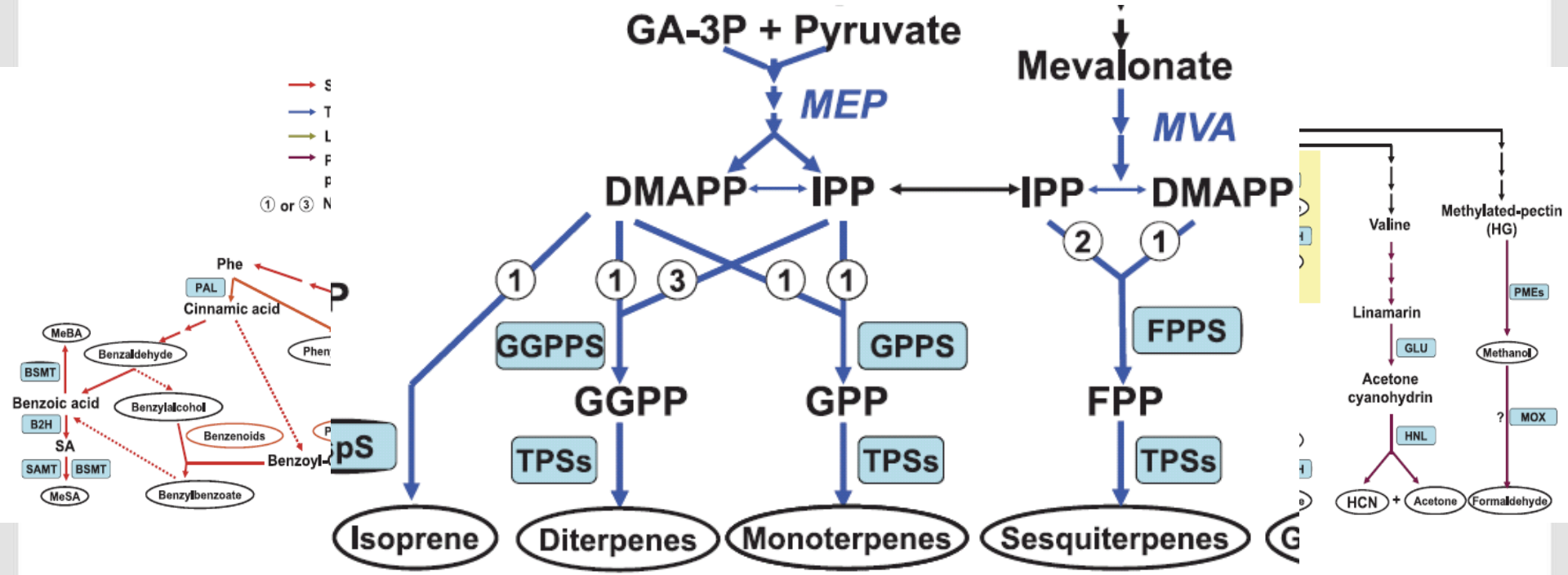
BVOC production and emission

Alternative: Mechanistic Simulation



$$E(Product)_P = Vmax(Product) * c(Substrate) / [KM(Substrate) * c(Substrate)]$$

From Laothawornkitkul et al. 2009

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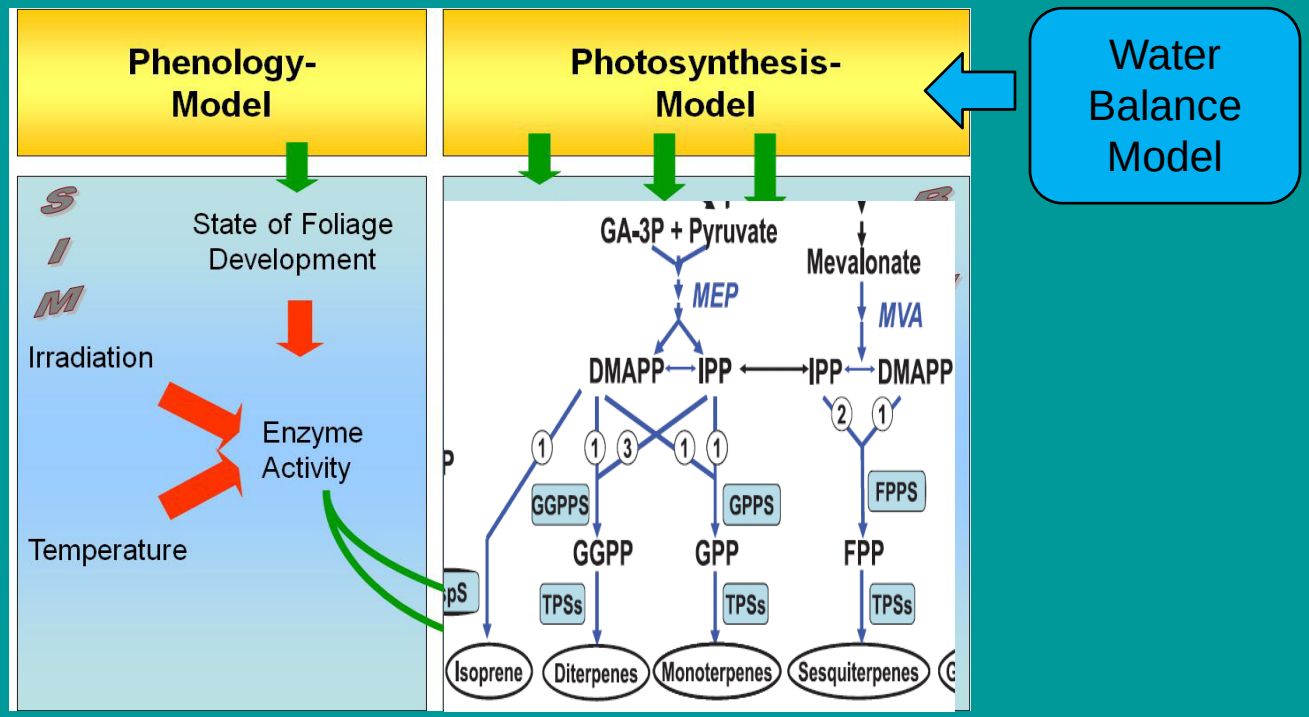
BVOC production and emission

Mechanistic Model: Biochemical Isoprenoid Model (BIM2)

(Grote et al. 2006)



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BVOC production and emission

Empirical vs. Mechanistic (BIM2)

Fast Calculation Easy Top-Down Parameterization	Consistent Complementation Reliable Bottom-Up Parameterization
Not fully covered range of conditions Danger of Inconsistency	Uncertainty of biochemical pathways Uncertain Species Variability

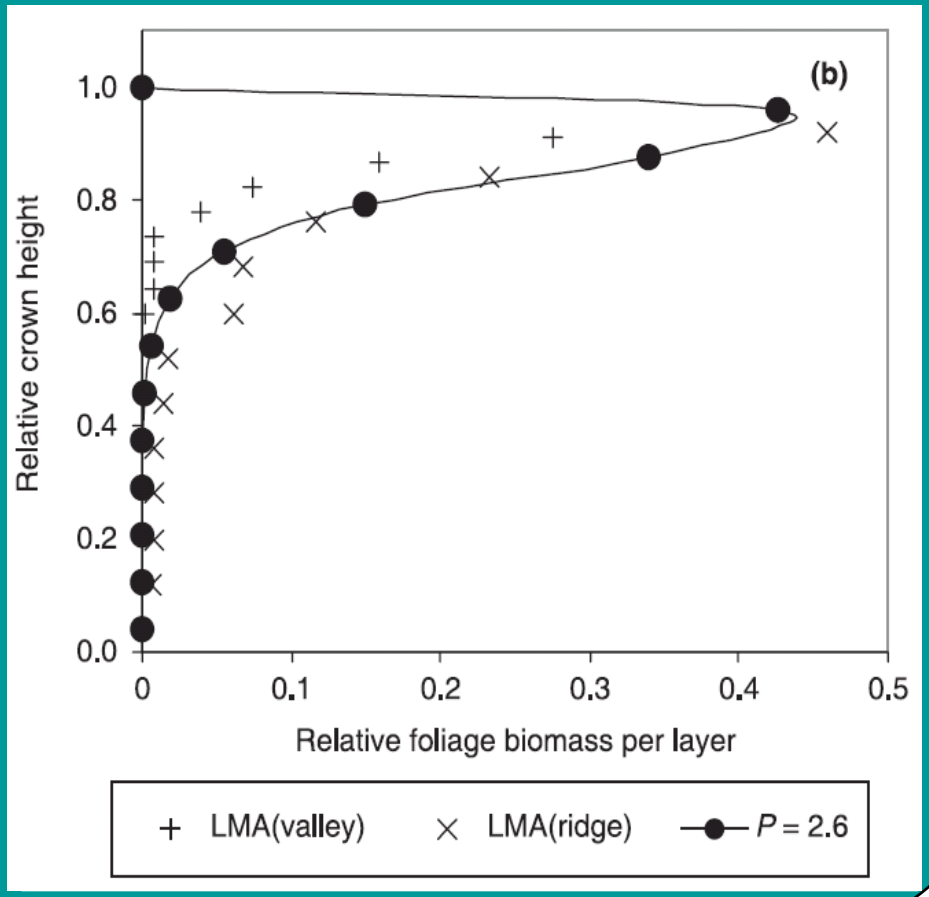
(Grote and Niinemets 2008)

Email: ruediger.grote@kit.edu

Scaling from leaf to stand

Physiological Response per Unit Ground

(Grote 2007)



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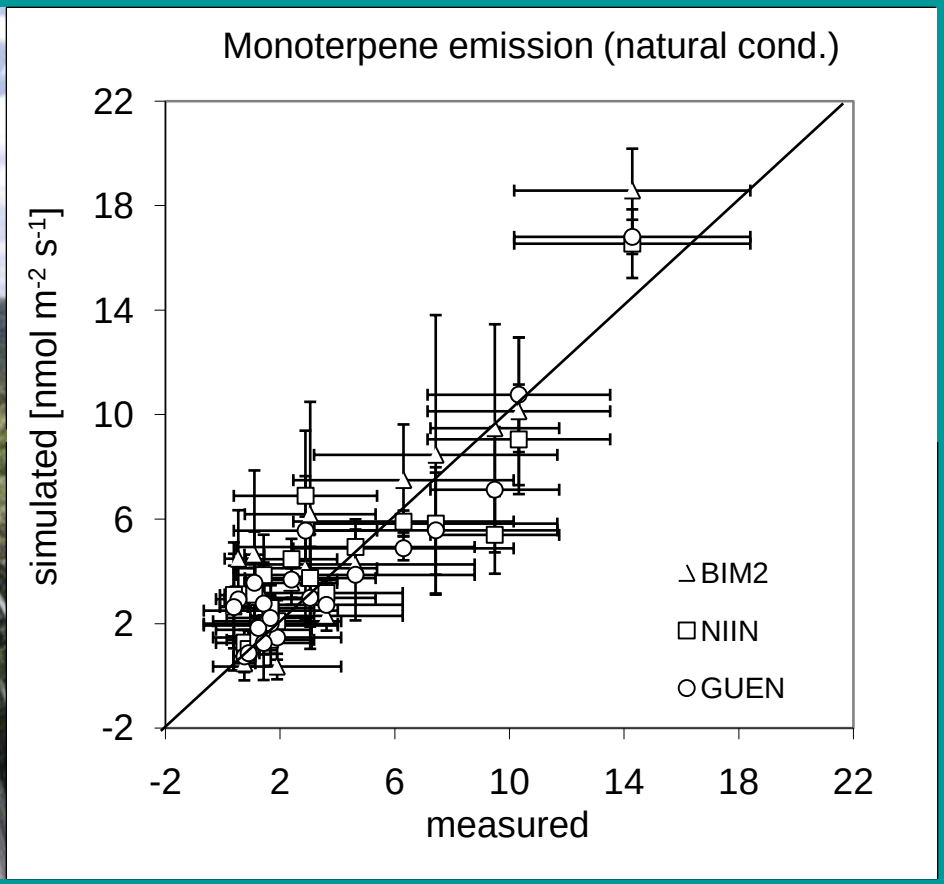
Scaling from leaf to stand

Example: Mediterranean Holm Oak Forest

(Grote et al. 2009)



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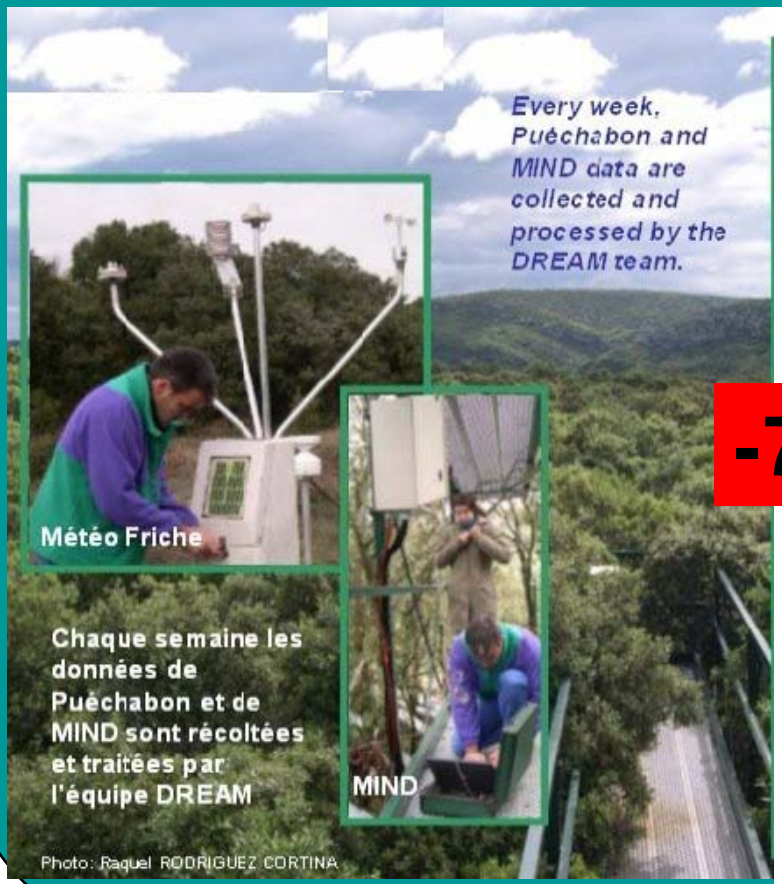
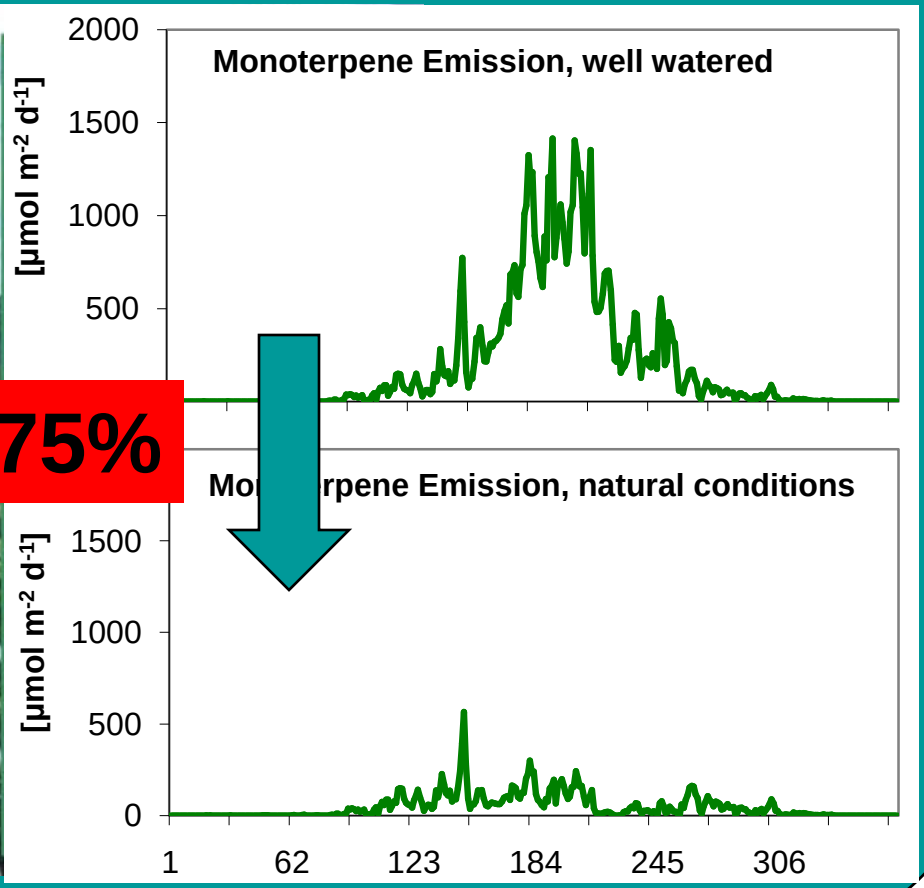
Scaling from leaf to stand

Model Scenario Analysis

(Grote et al. submitted)





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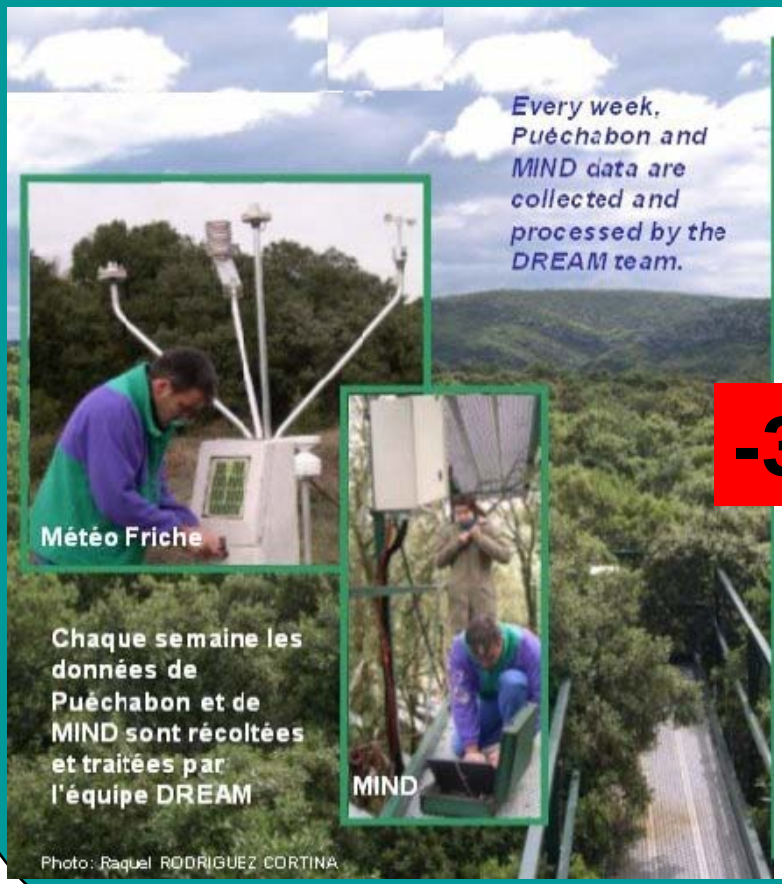
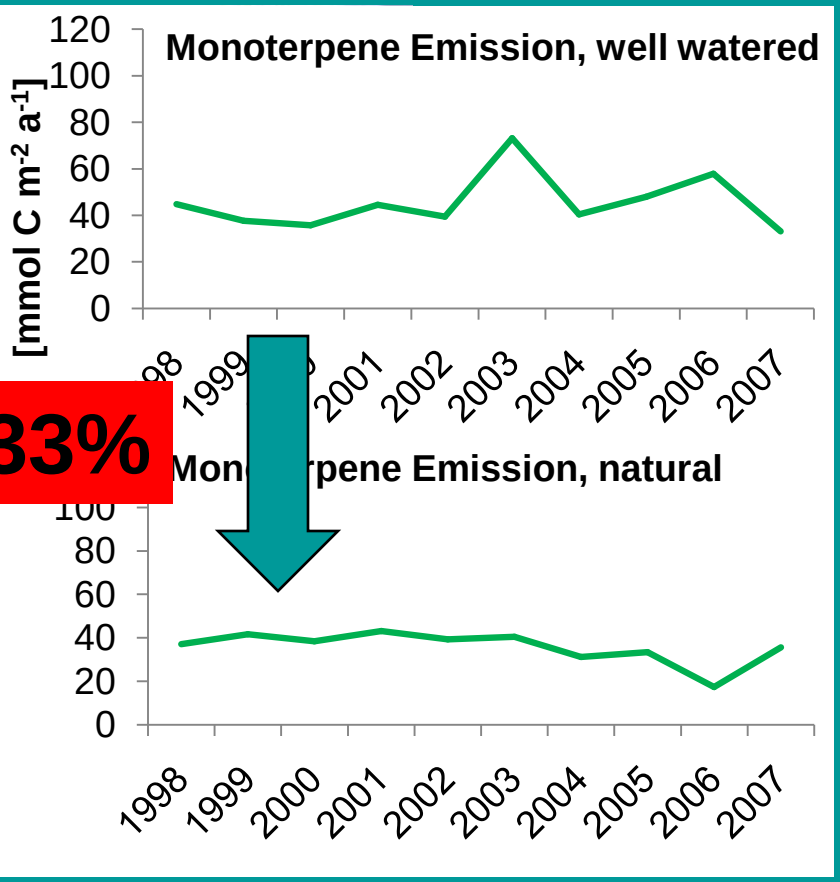
Scaling from leaf to stand

Long-Term Model Scenario Analysis

(Grote et al. submitted to GCB)





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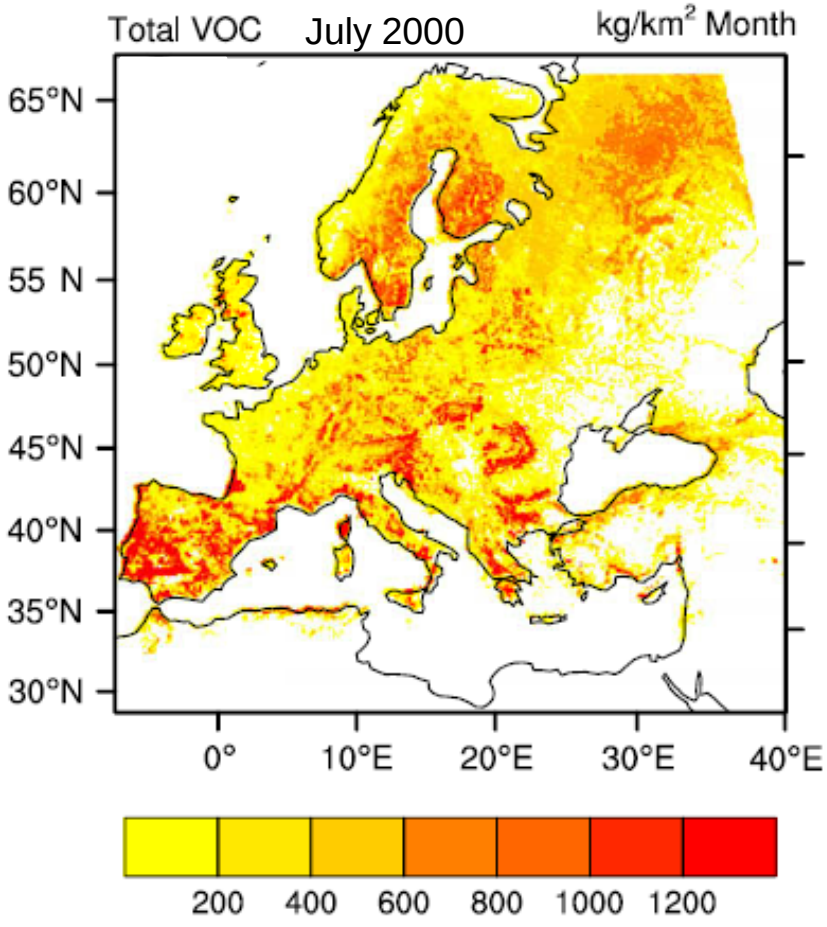
Scaling from stand to region

Emission of VOC in Europe

Projekt NATAIR

- 116 species (groups)
- 10 ×10 km
- 4 years
- hourly calculations
- (no drought stress)



From Steinbrecher et al. 2009

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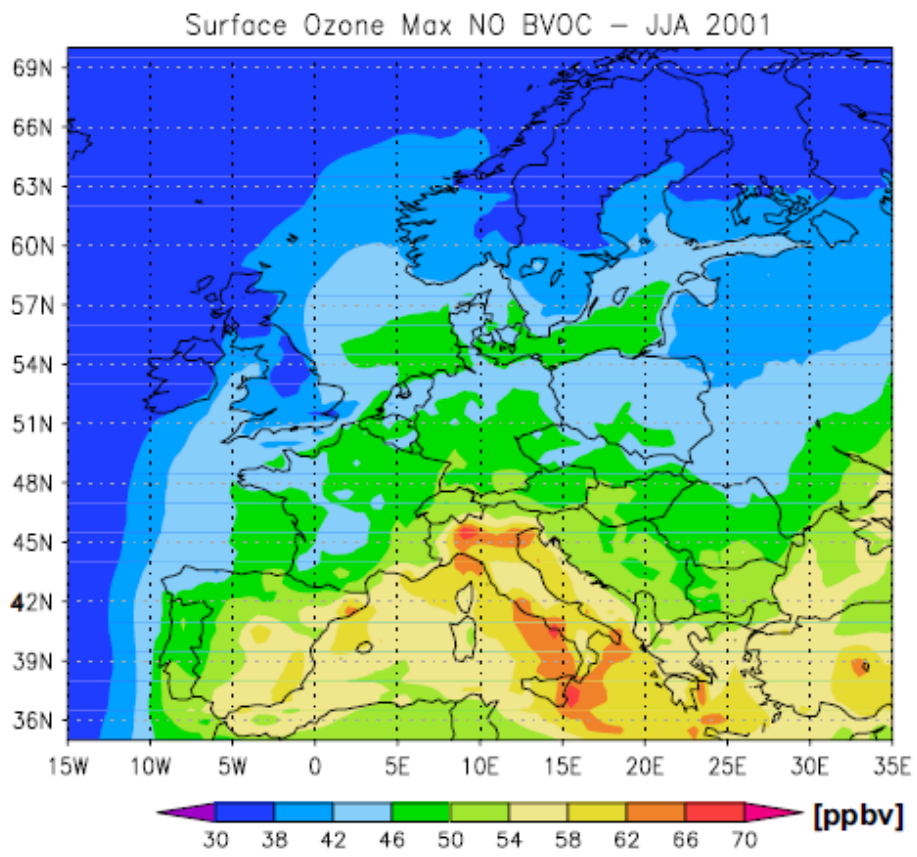
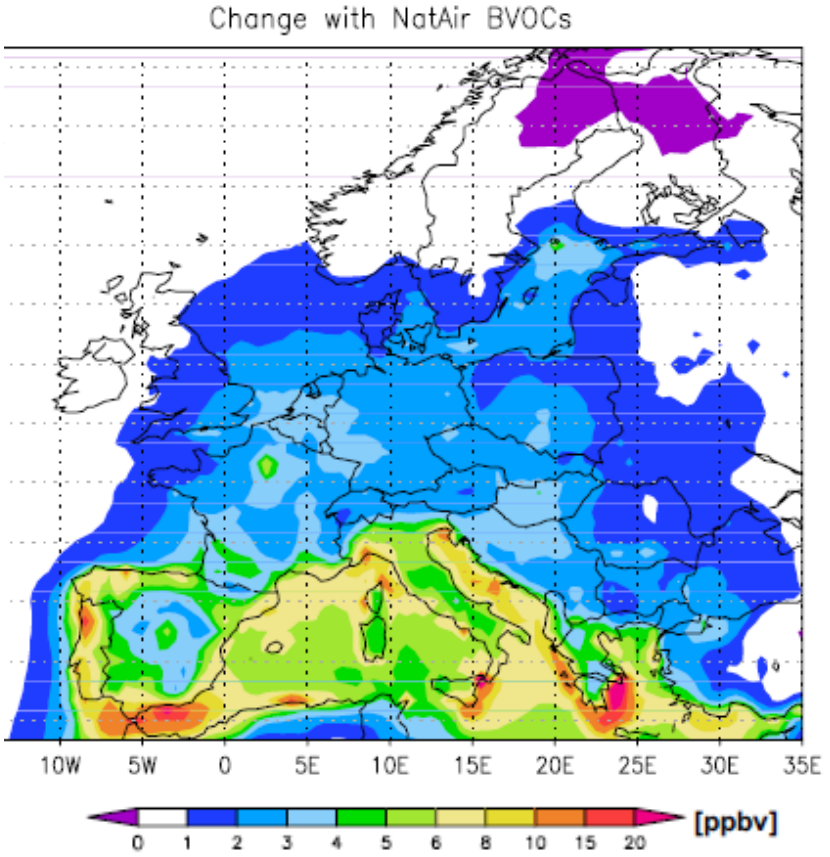
Scaling from stand to region

BVOC Impact on Ozone





From Curci et al. 2009

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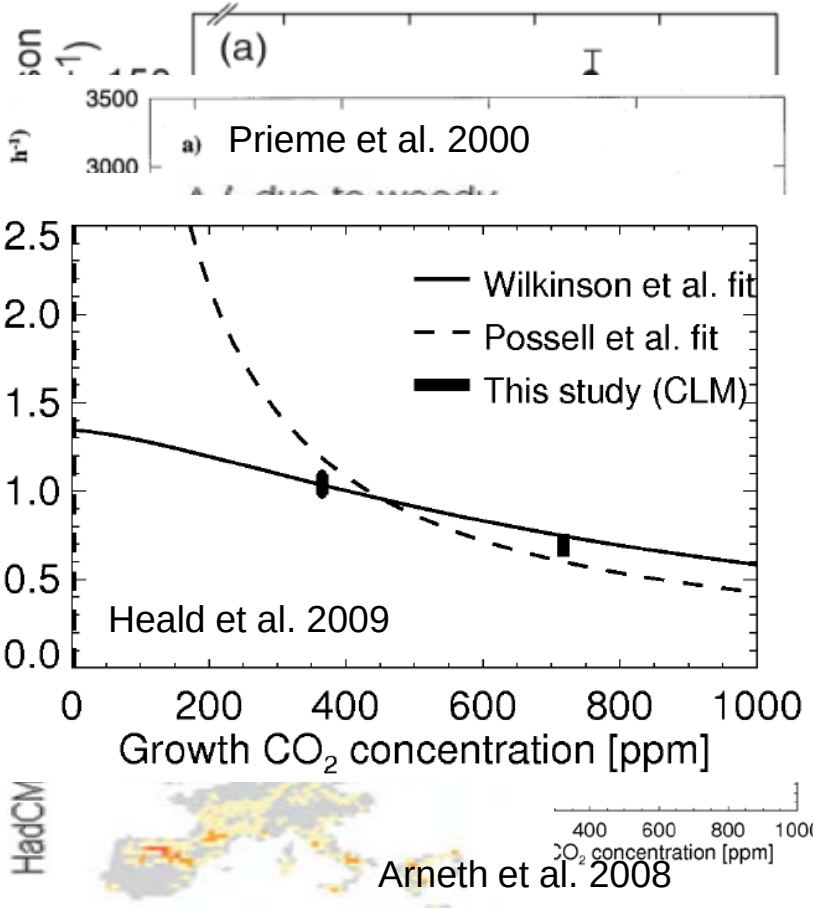
(Some) Research Challenges

Plant growth response on genetically changed plants?

Higher BVOC emission with increasing insect damages?

Land use change and bio-fuel production impact on air pollution?

Can climate warming impact on BVOC production be decreased/ counterbalanced by increasing CO_2



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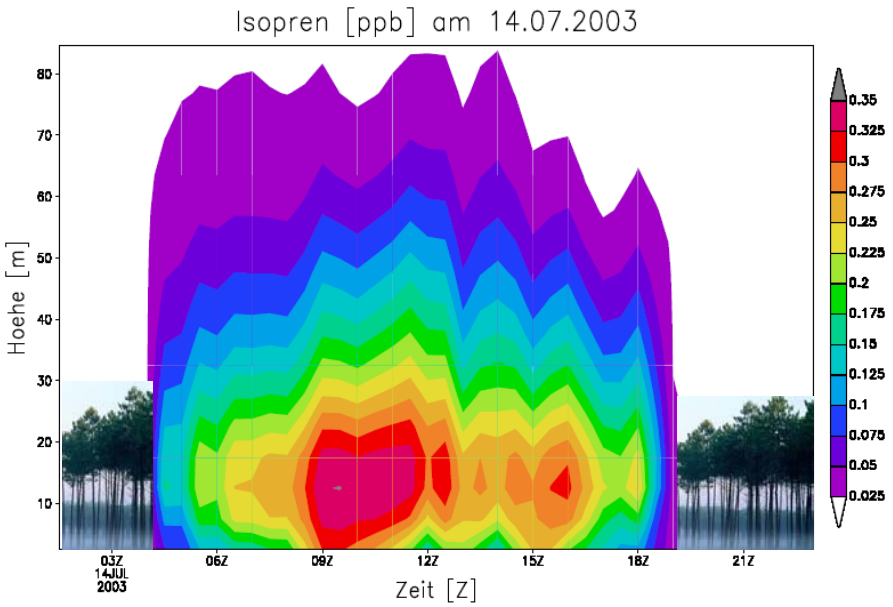
And what was that first picture about?



Schlueter 2006: **Simulation des Transports biogener Emissionen in und über einem Waldbestand mit einem mikroskaligen Modellsystem**

Email: ruediger.grote@kit.edu