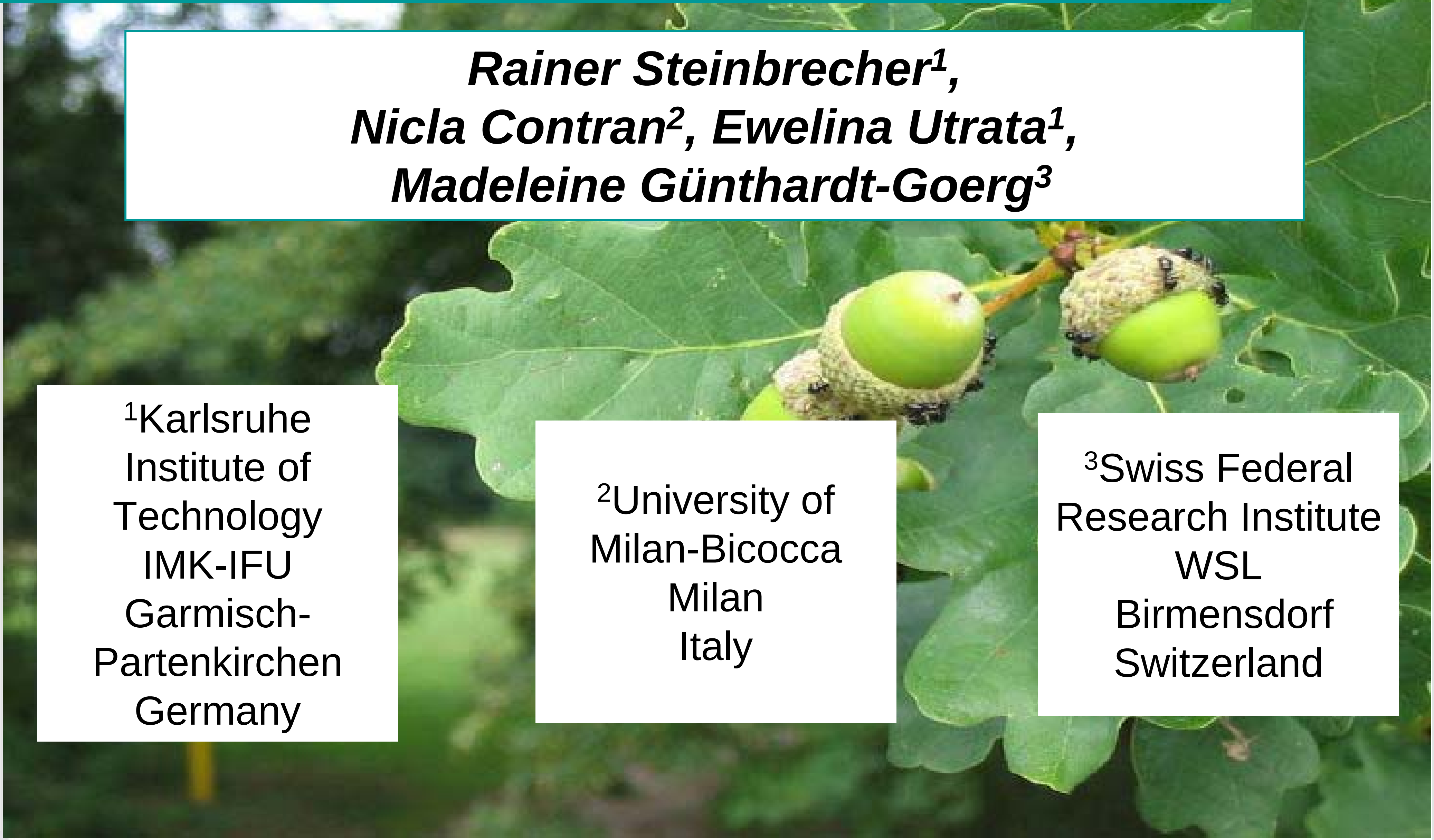
Feedback of Climate Change to Biological Isoprenoid Emission Potential



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[1]Karlsruhe Institute of Technology IMK-IFU Garmisch-Partenkirchen Germany

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Outline

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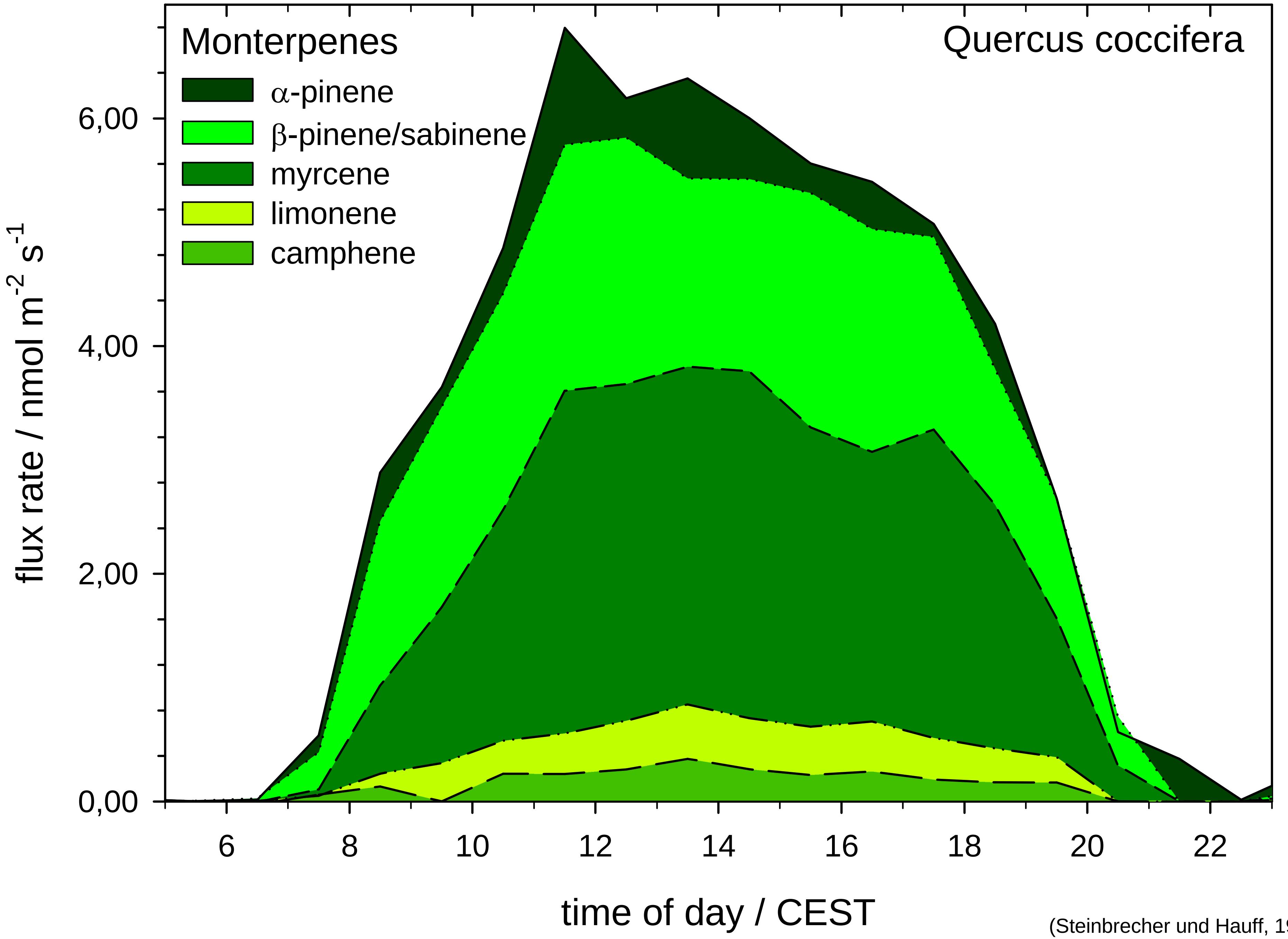
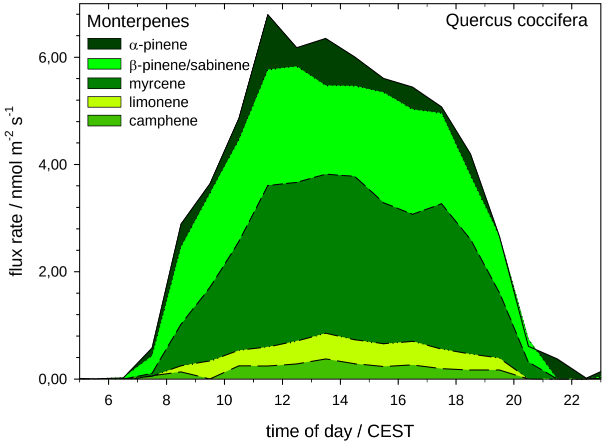
- *Introduction*
  - Basics on environmental factors controlling biogenic emission.
  - Projected biogenic emissions and climate.
- *Results*
  - Feedback of elevated temperature and soil drought on isoprene emission potential of European oak trees.
- *Conclusions*
  - Climate change and isoprene emission potential.

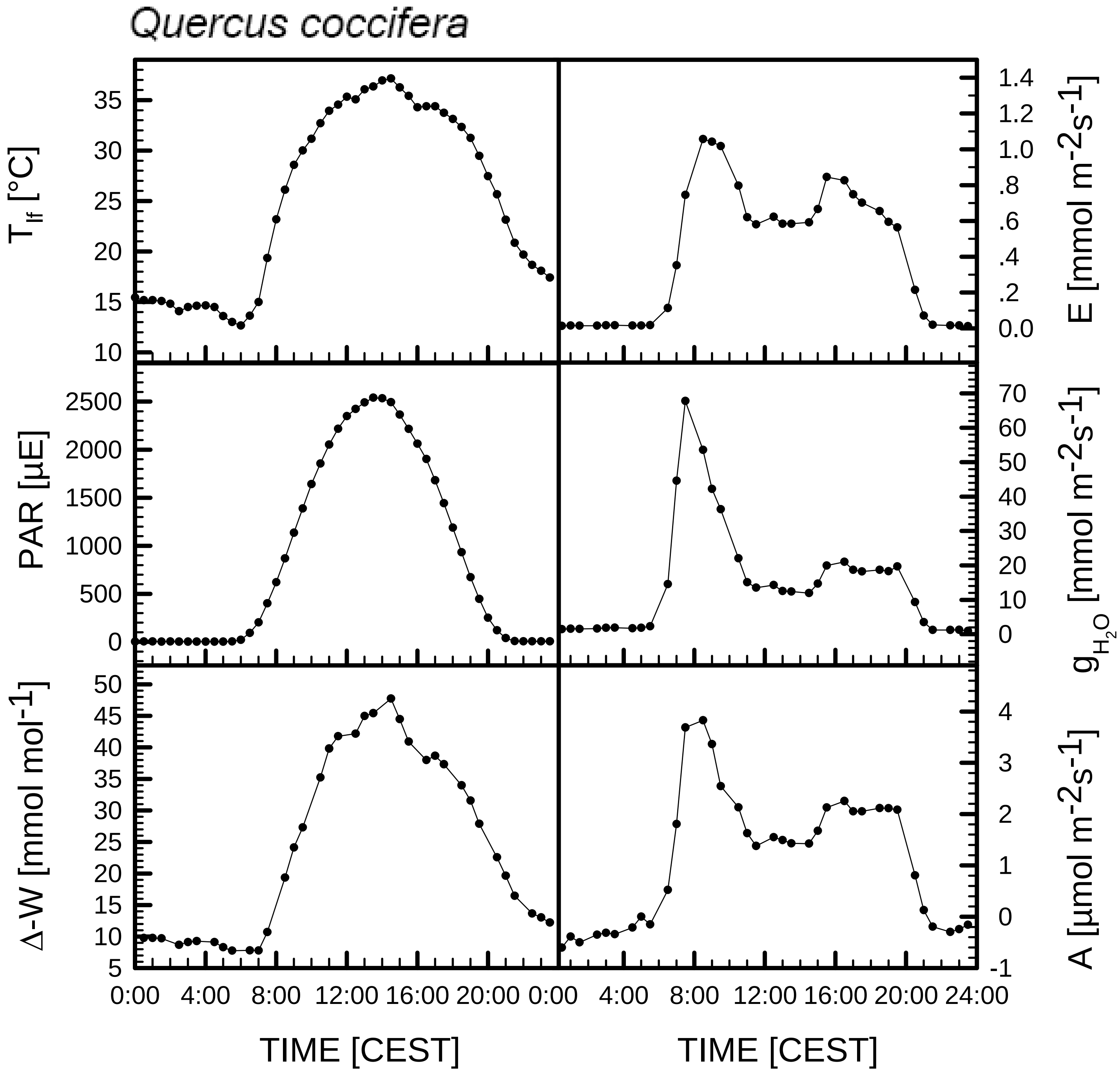
Environment and Biogenic VOC Emission



(Steinbrecher und Hauff, 1996)

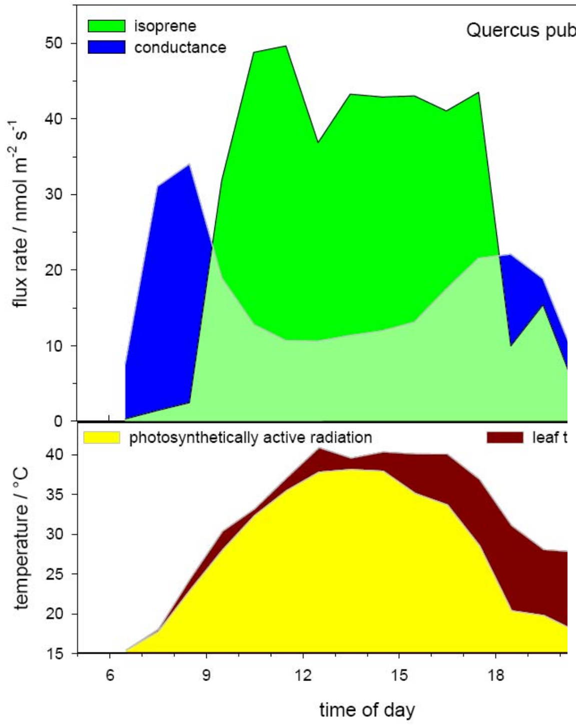
Environment and Biogenic VOC Emission

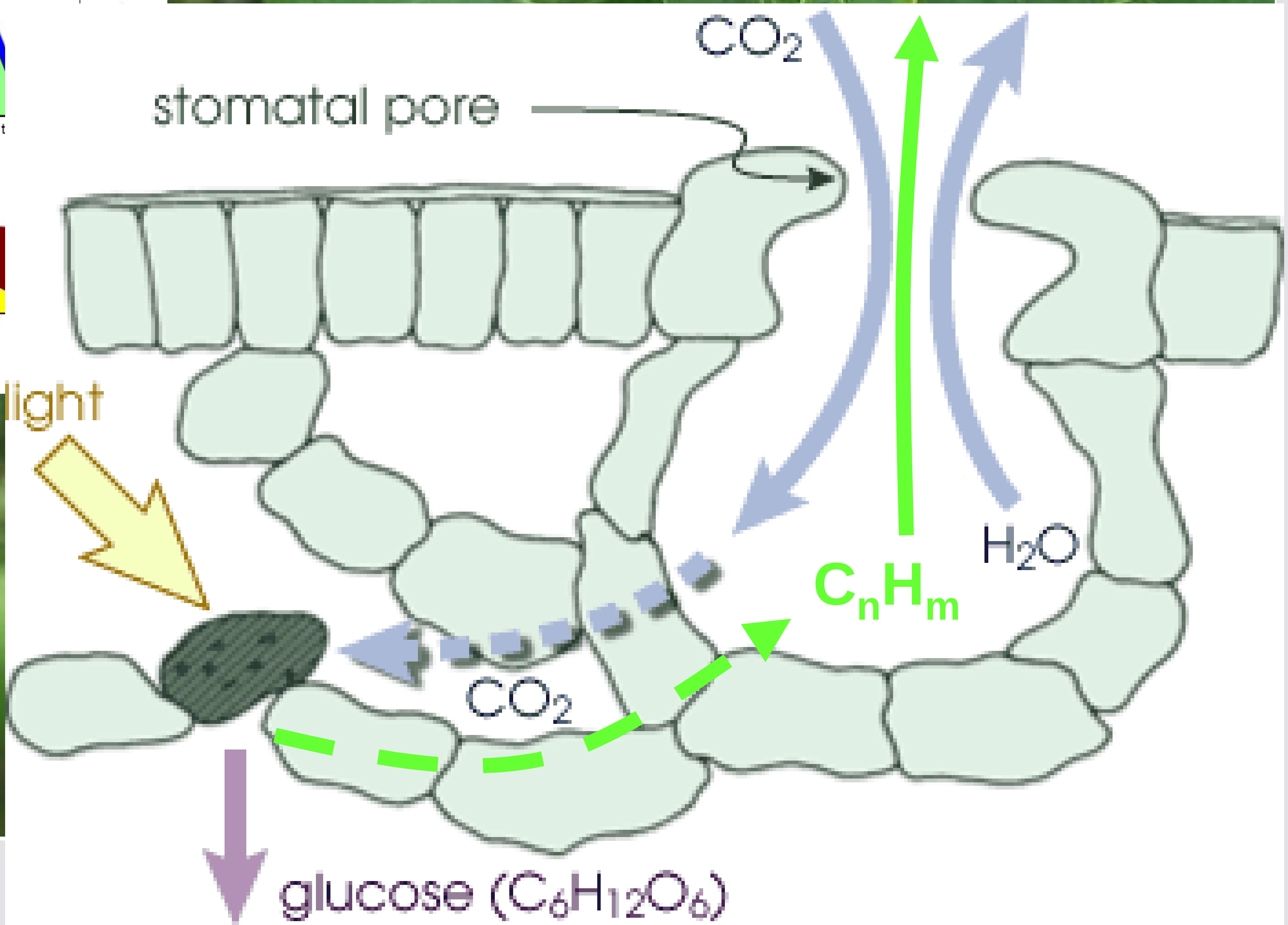




(Steinbrecher und Hauff, 1996)

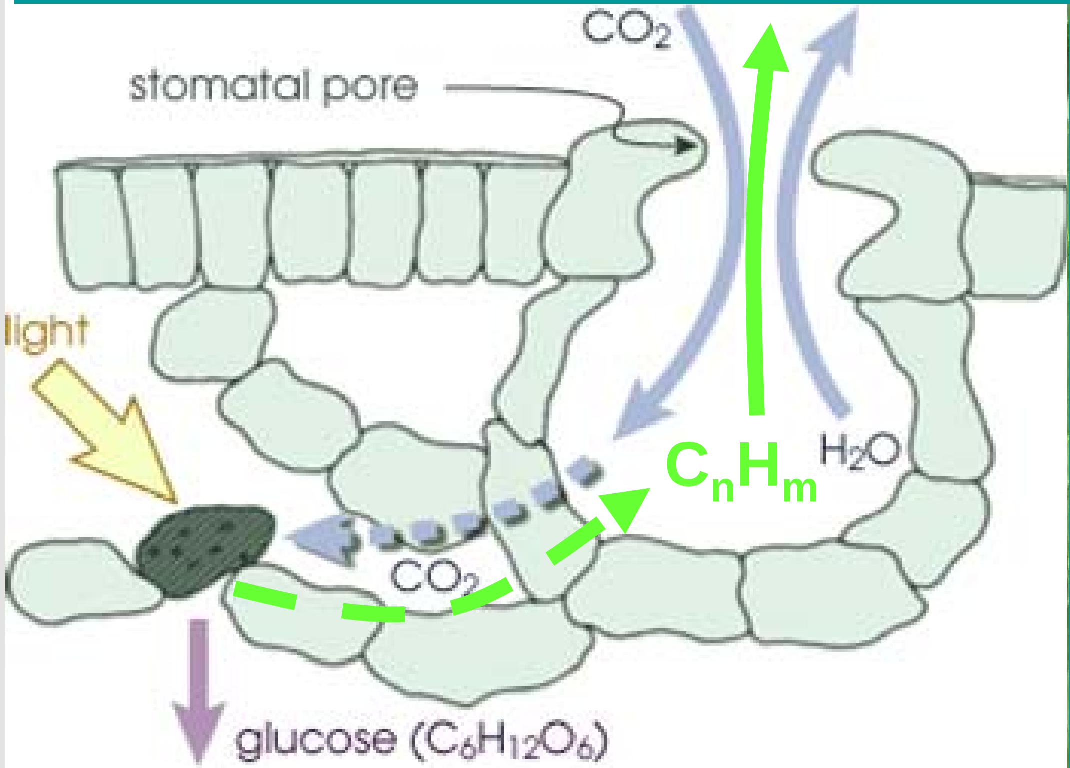
Environment and Biogenic VOC Emission





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

Environment and Biogenic VOC Emission

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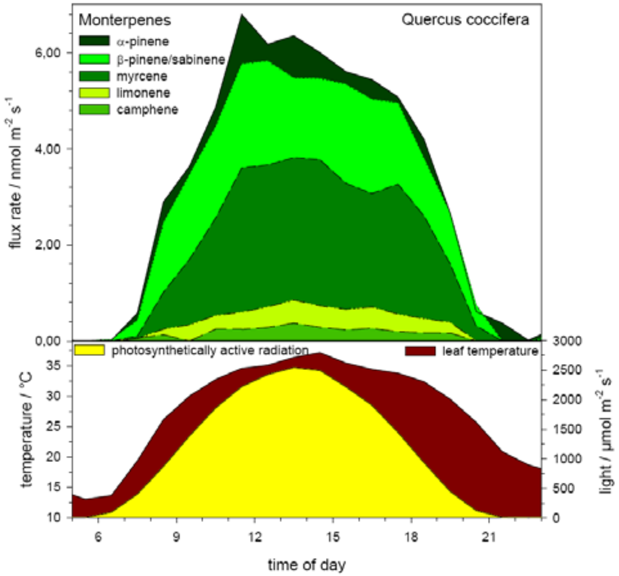
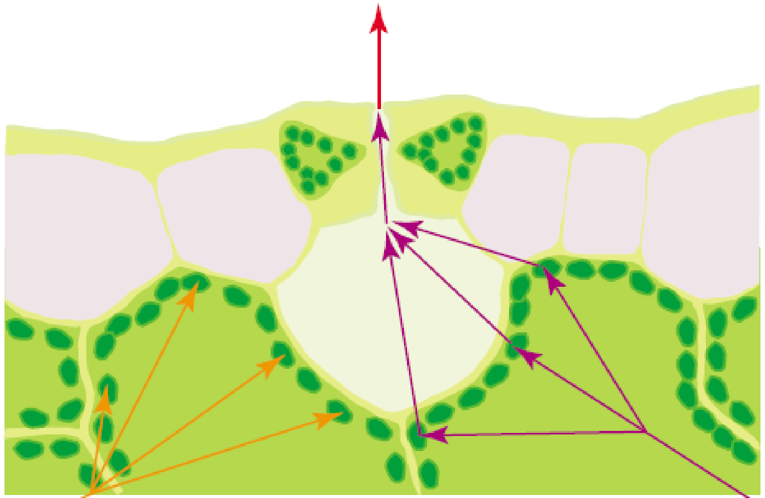
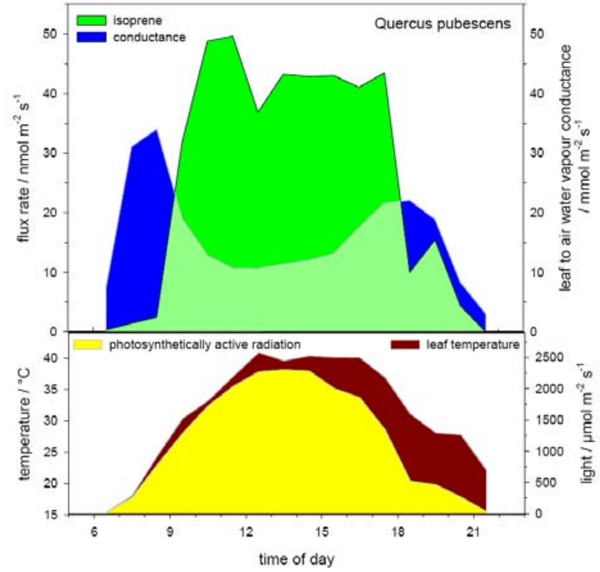


Emission





(Niinemets, et al., 2004)

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

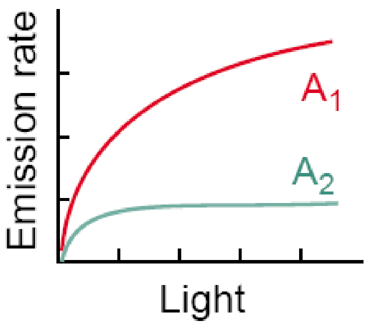
Physicochemical constraints
(*T*, leaf structure, stomatal openness)

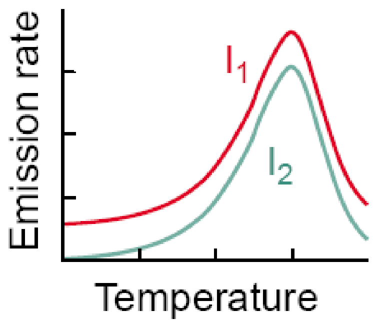
Intermediate production

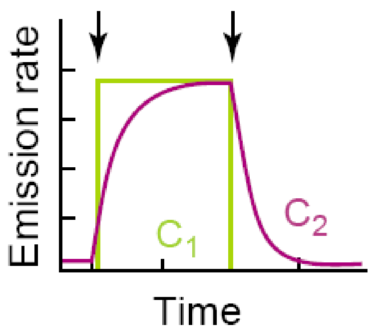
Maximum activity of flux controlling enzymes

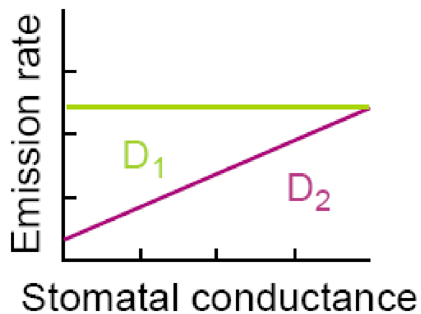
Volatility

Diffusion









Reactive Compound Emission Modelling

Pragmatic approach:

$$E(RC_i, T, PAR) = E(RC_i, T)_{Pool} + E(RC_i, T, PAR)_{Synthesis}$$

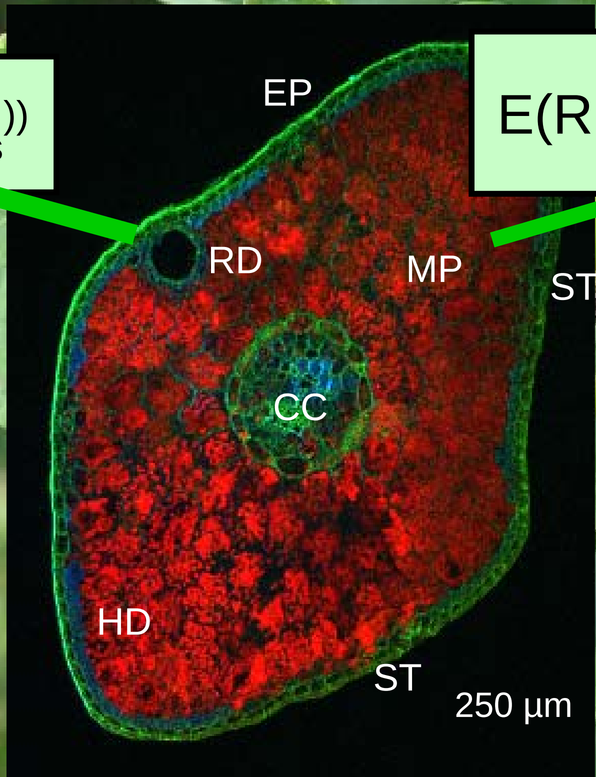
$$E(RC_i, T) = Ef_{RC_i} \times e^{(ß(T - T_s))}$$

Ef_{RC_i} = emission factor of compound emitted from pools in pmol m^{-2} total leaf area s^{-1} at 30°C leaf temperature

ß = 0.09°C^{-1}[a]

T_s = 30°C

T = T_{leaf} [°C]



CC Central cylinder
EP Epidermis
HD Hypodermis
MP Mesophyll
RD Resin Vessel
ST Stomata

$$E(RC_i, T, PAR) = Ef_{RC_i} \times C_L \times C_T$$

Ef_{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]

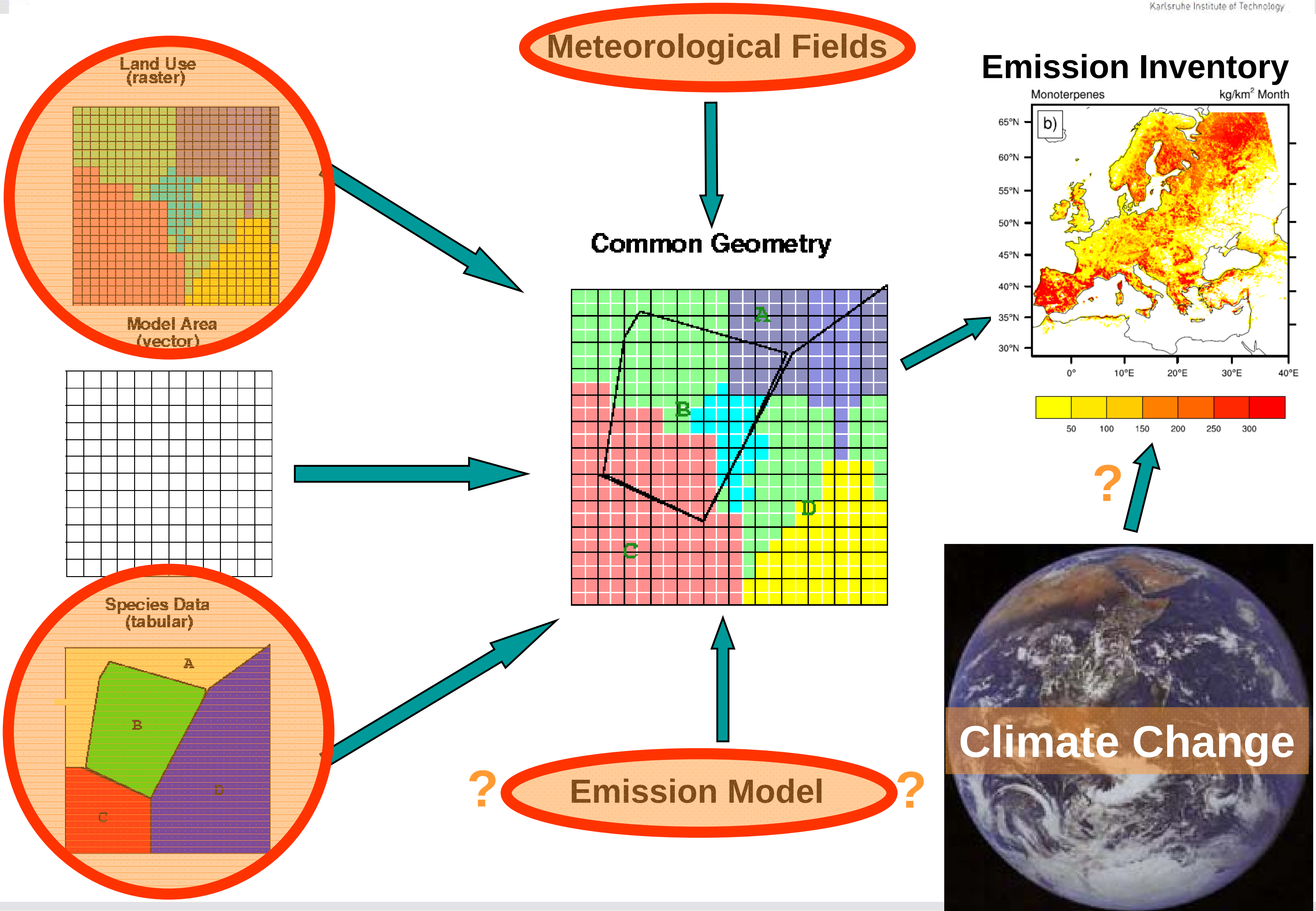
C_T = correction term for temperature [a]

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

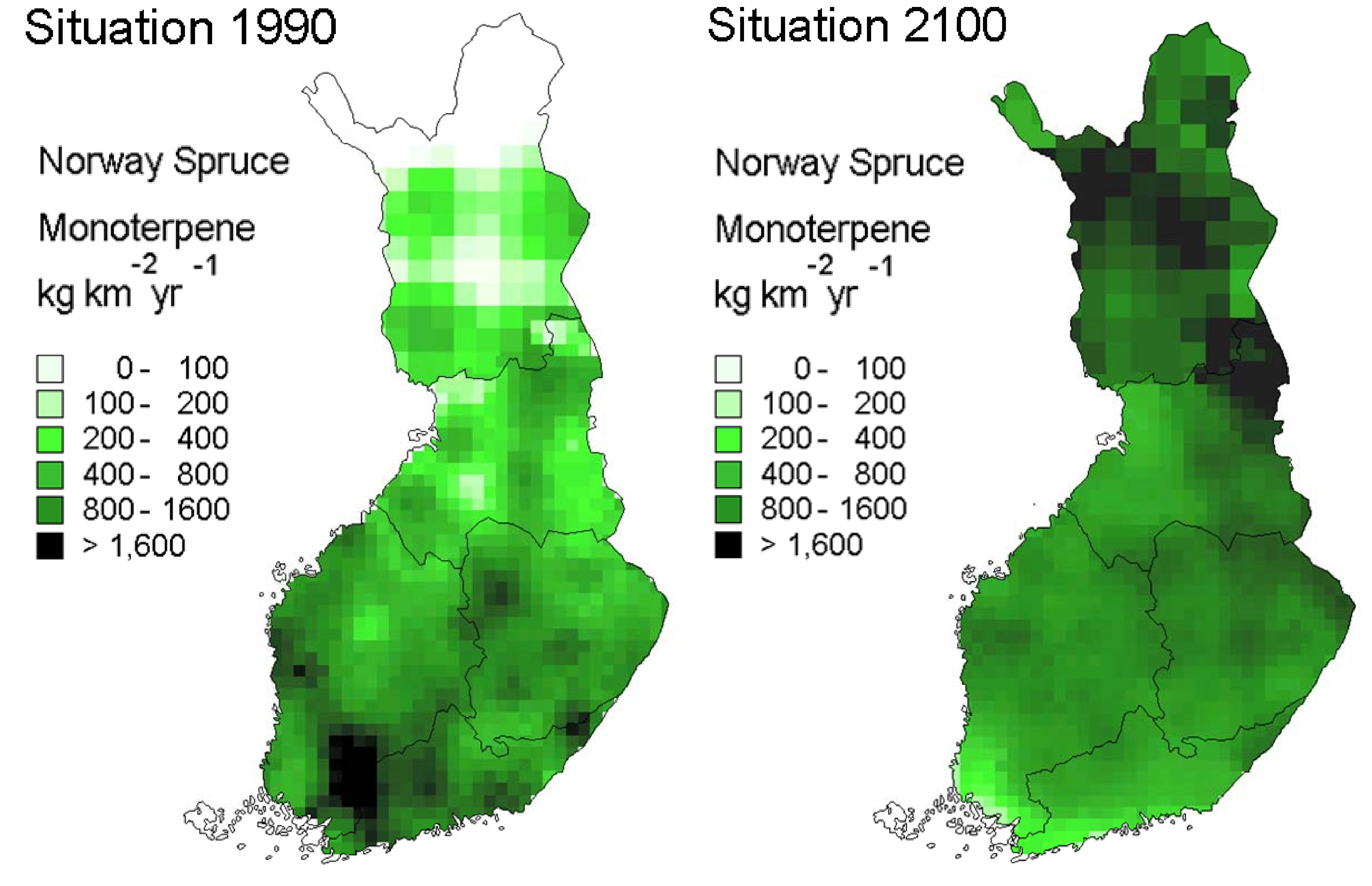
TLSM-Image: Schnitzler, IFU; Fischbach, IFU; Hutzler, GSF-Inst. Pathology

([a] Guenther 1997, Steinbrecher et al, 1999)

Reactive Compound Emission Modelling



Biogenic Isoprenoid Emission in Finland



projected biogenic emissions and climate

Kellomäki S., Rouvinen P., Peltola H., Strandman H., Steinbrecher R. (2001): Impact of global warming on the tree species composition of boreal forests in Finland and effects on emission of isoprenoids. Global Change Biology 7, 531-544.

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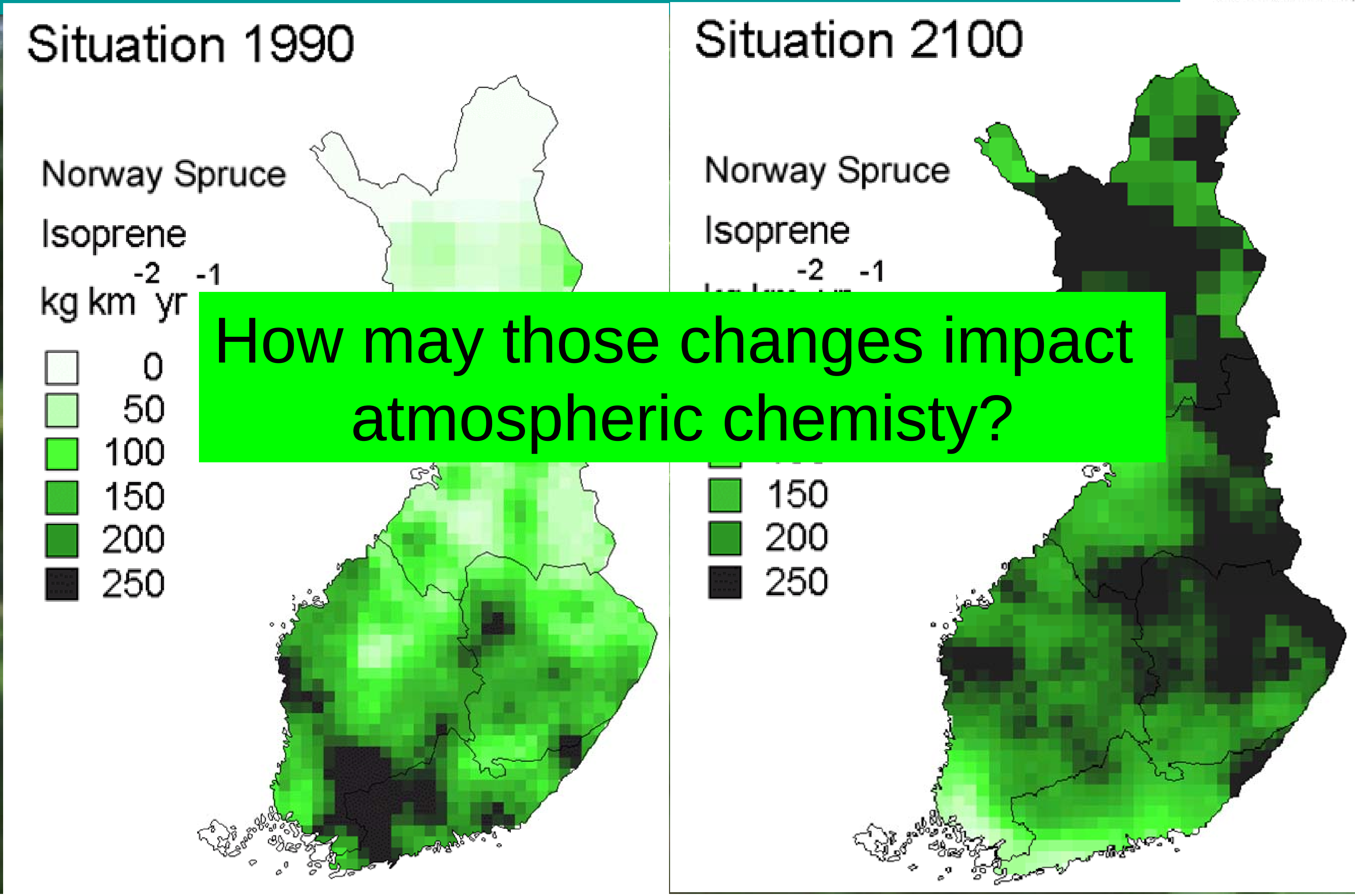
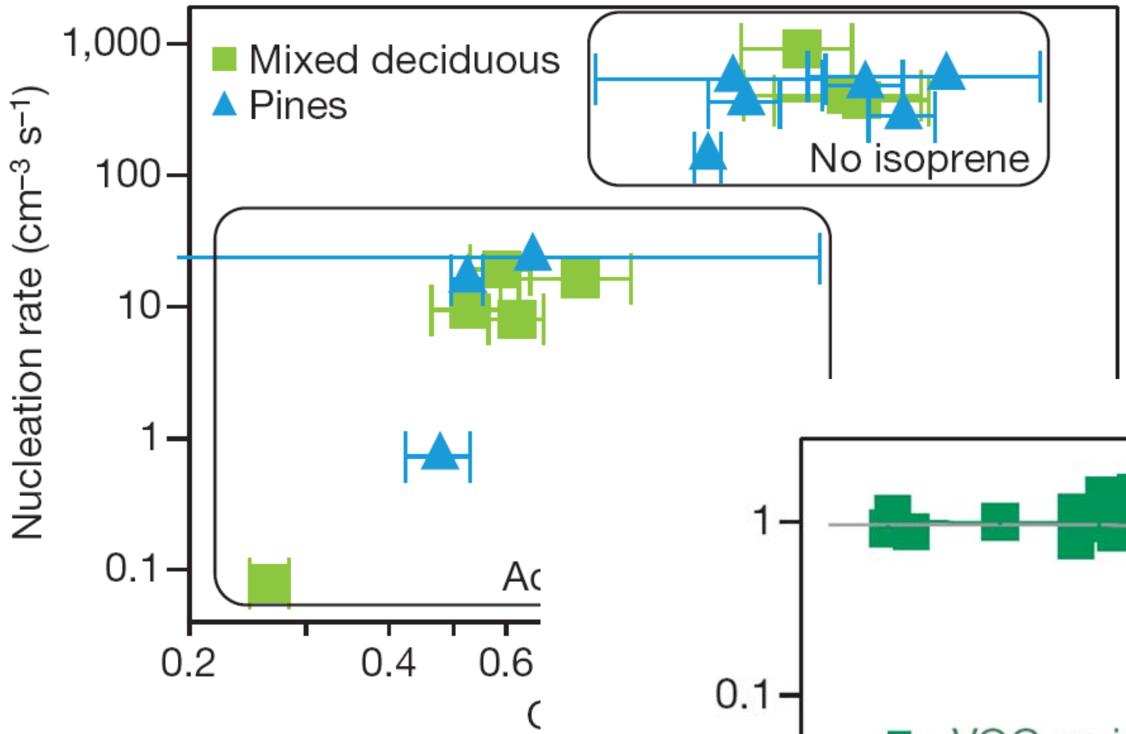


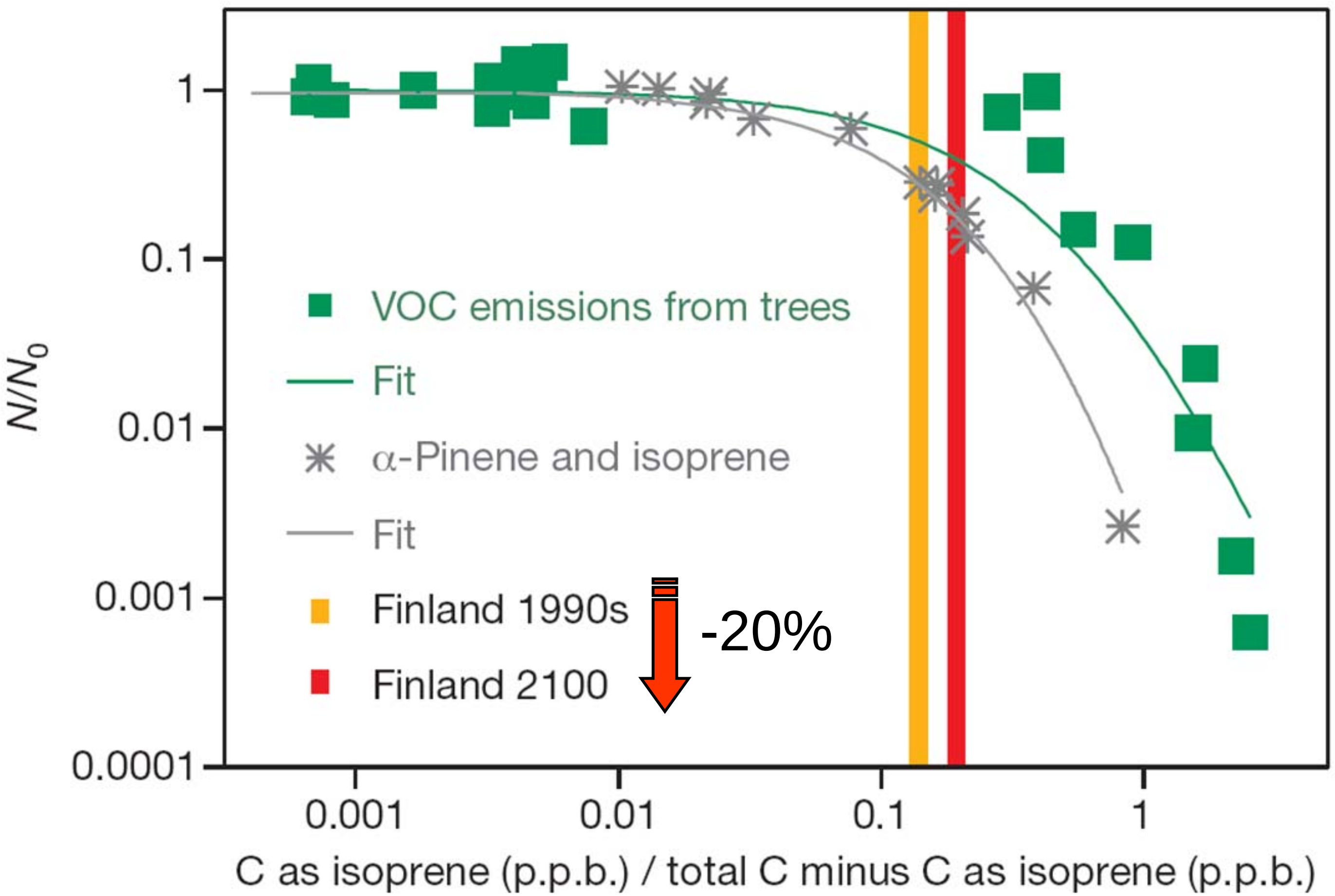
How may those changes impact atmospheric chemisty?

projected biogenic emissions and climate

Kellomäki S., Rouvinen P., Peltola H., Strandman H., Steinbrecher R. (2001): Impact of global warming on the tree species composition of boreal forests in Finland and effects on emission of isoprenoids. Global Change Biology 7, 531-544.

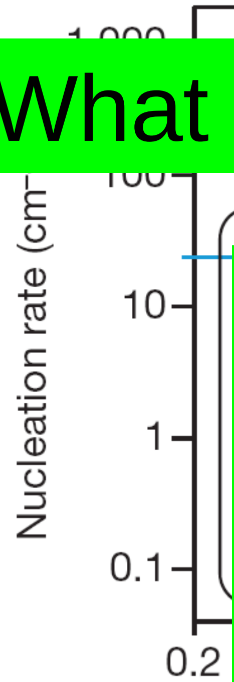
Projected Emissions and SOA Formation

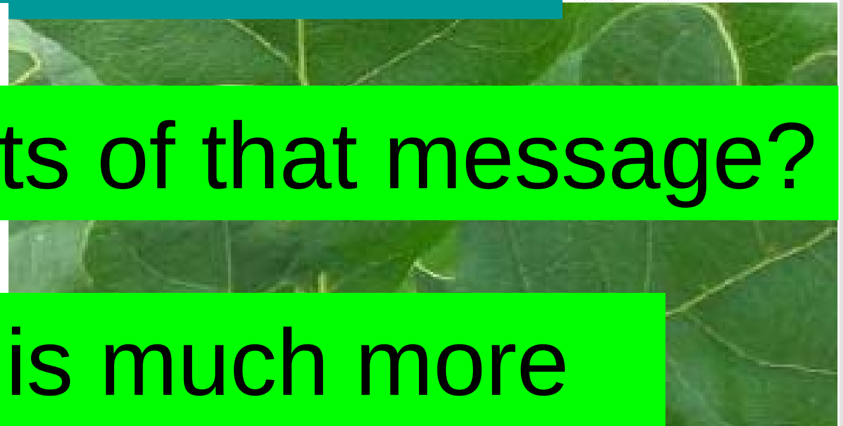




Kiendler-Scharr, A., Wildt, J., Dal Maso, M., Hohaus, T., Kleist, E., Mentel, T.F., Tillmann, R., Uerlings, R., Schurr, U., Wahner, A., 2009. New particle formation in forest inhibited by isoprene emissions. Nature, 461, 381-384.

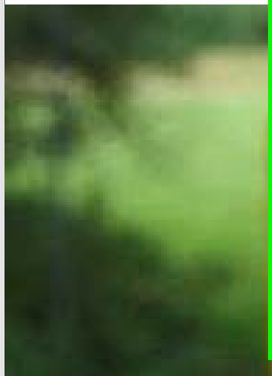
Projected Emissions and SOA Formation

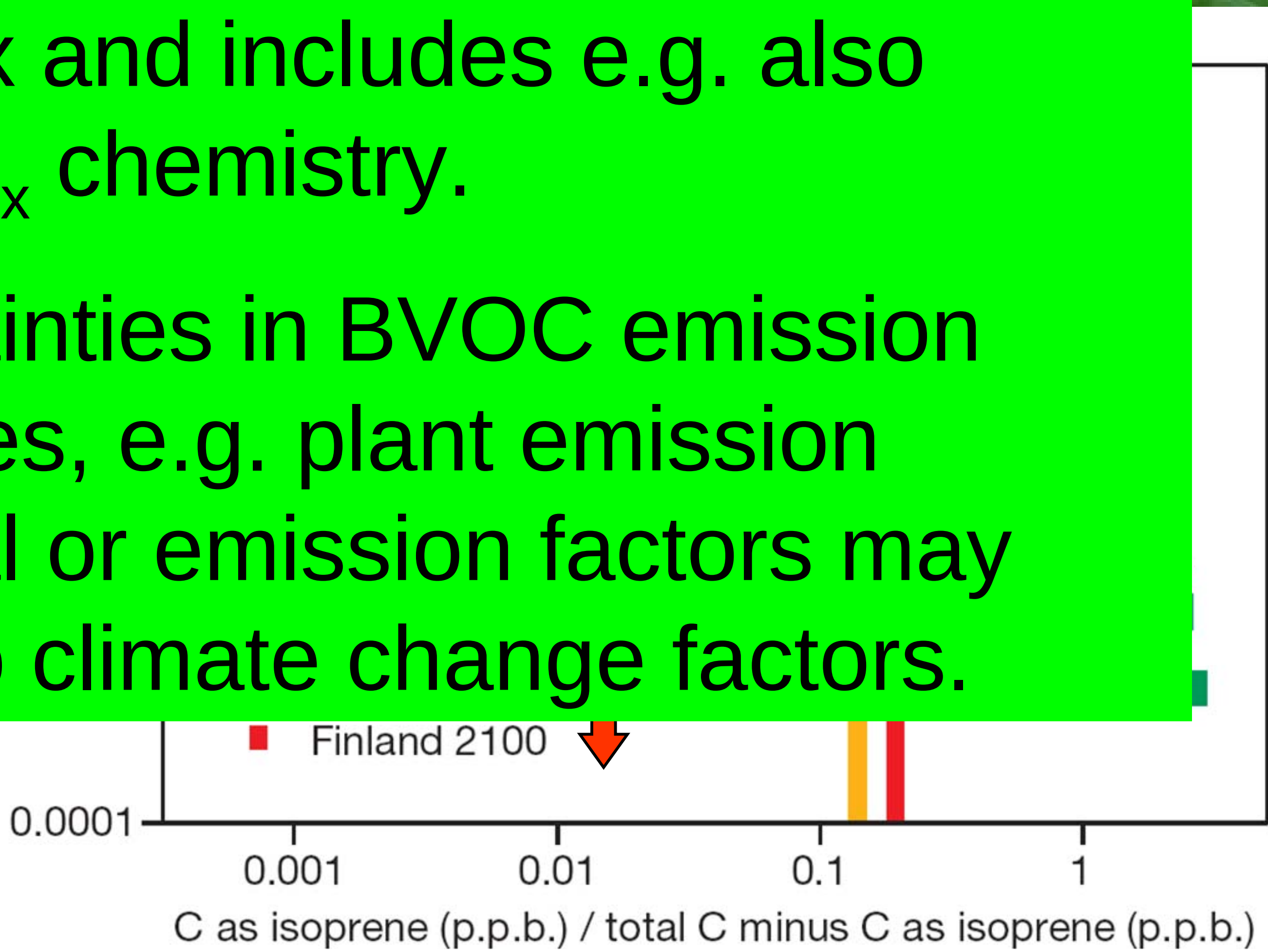




What are the major constraints of that message?

- The real atmosphere is much more complex and includes e.g. also NO_x/SO_x chemistry.
- Uncertainties in BVOC emission estimates, e.g. plant emission potential or emission factors may adapt to climate change factors.





Kiendler-Scharr, A., Wildt, J., Dal Maso, M., Hohaus, T., Kleist, E., Mentel, T.F., Tillmann, R., Uerlings, R., Schurr, U., Wahner, A., 2009. New particle formation in forest inhibited by isoprene emissions. Nature, 461, 381-384.

Reactive Compound Emission Modelling

Recall: What are emission factors?

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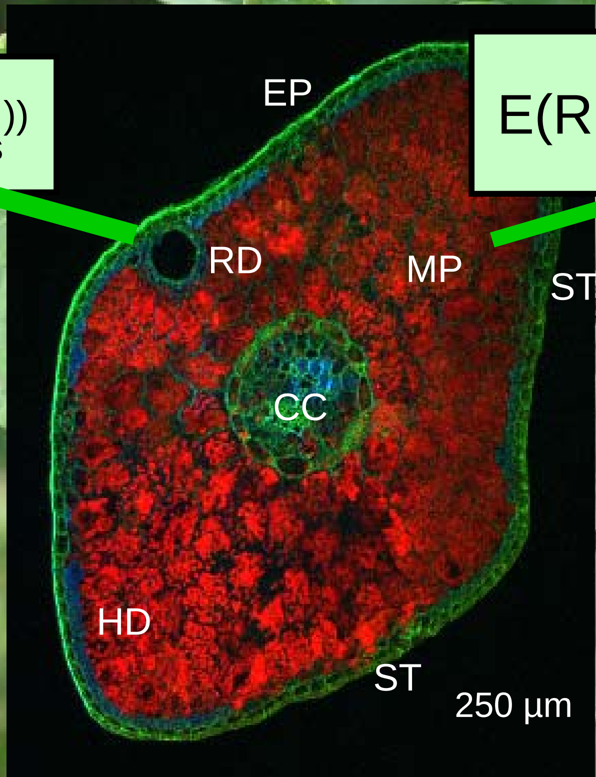

CC Central cylinder
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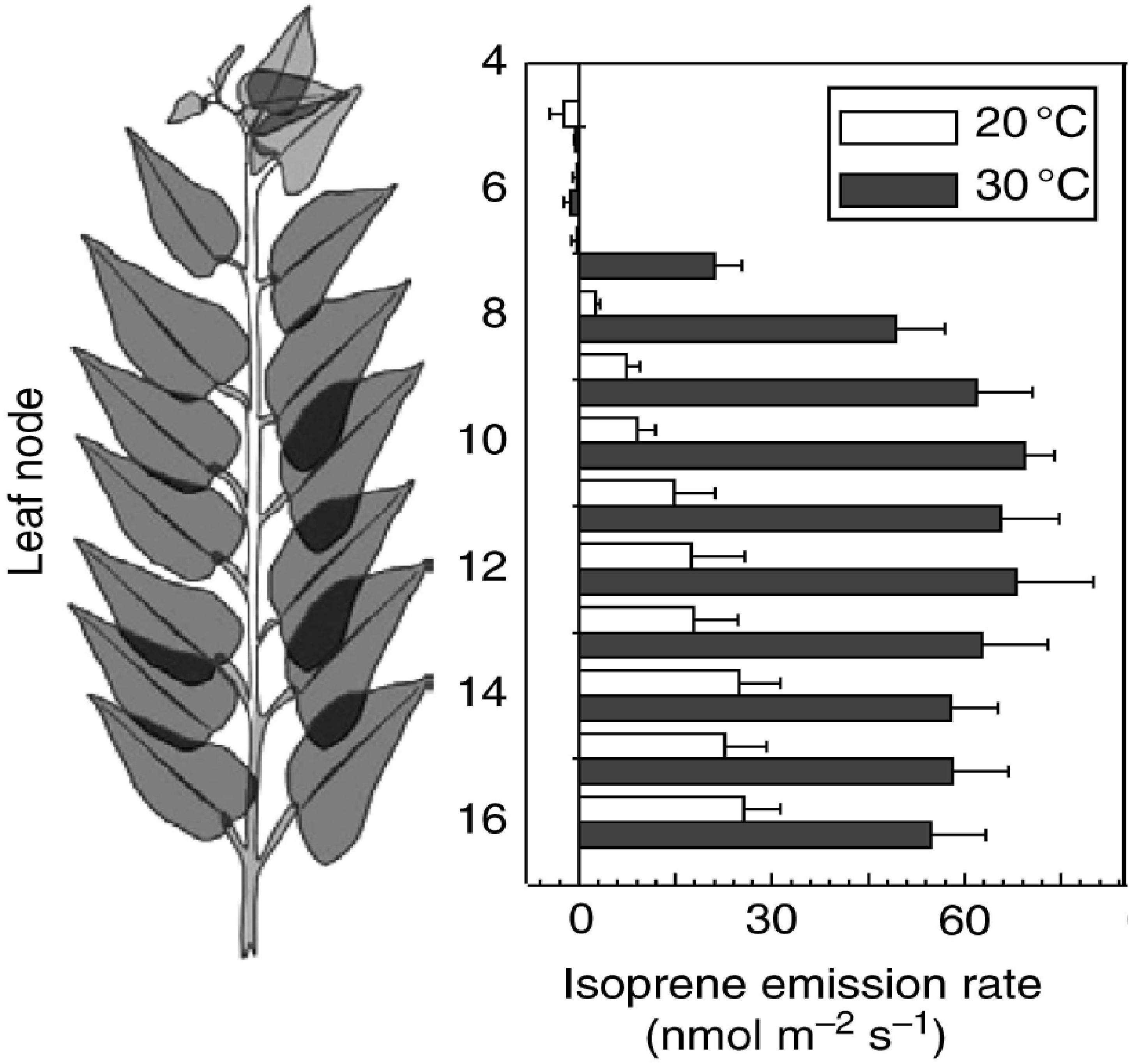
TLSM-Image: Schnitzler, IFU; Fischbach, IFU; Hutzler, GSF-Inst. Pathology

([a] Guenther 1997, Steinbrecher et al, 1999)

Emission Potential and Adaption



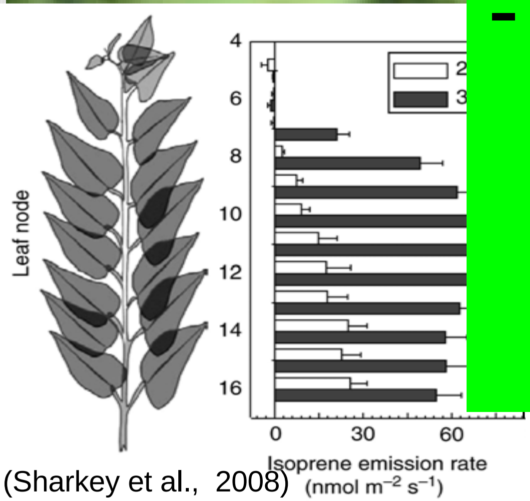
Sharkey, T.D., Wiberley, A.E., Donohue, A.R., 2008. Isoprene Emission from Plants: Why and How. Ann. Bot. 101, 5-18.

Emission Potential and Adaption

- Plants are able to adapt to environmental conditions.
- This may impact the emission potential for BVOC under extreme environmental conditions.

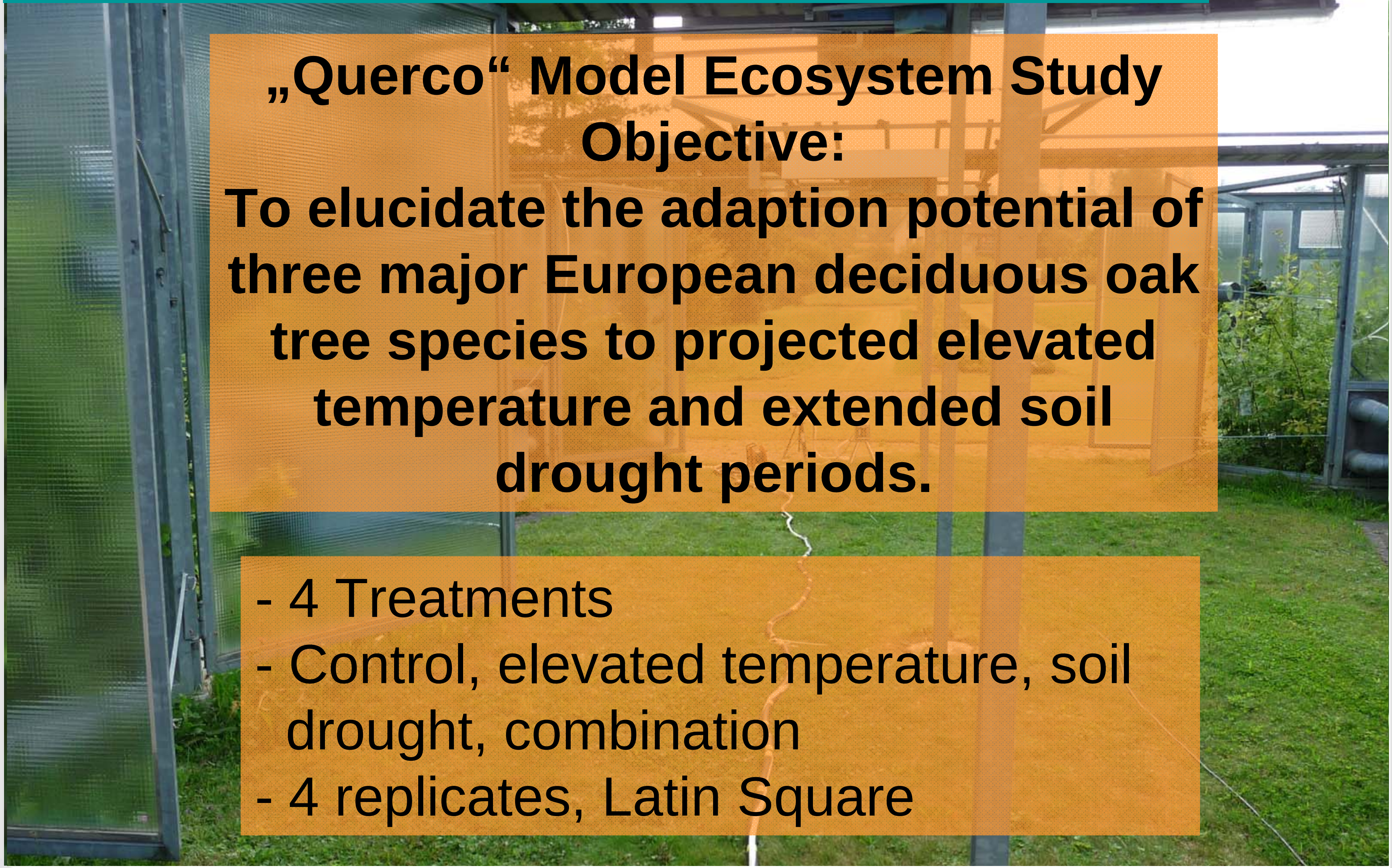
But:

- 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

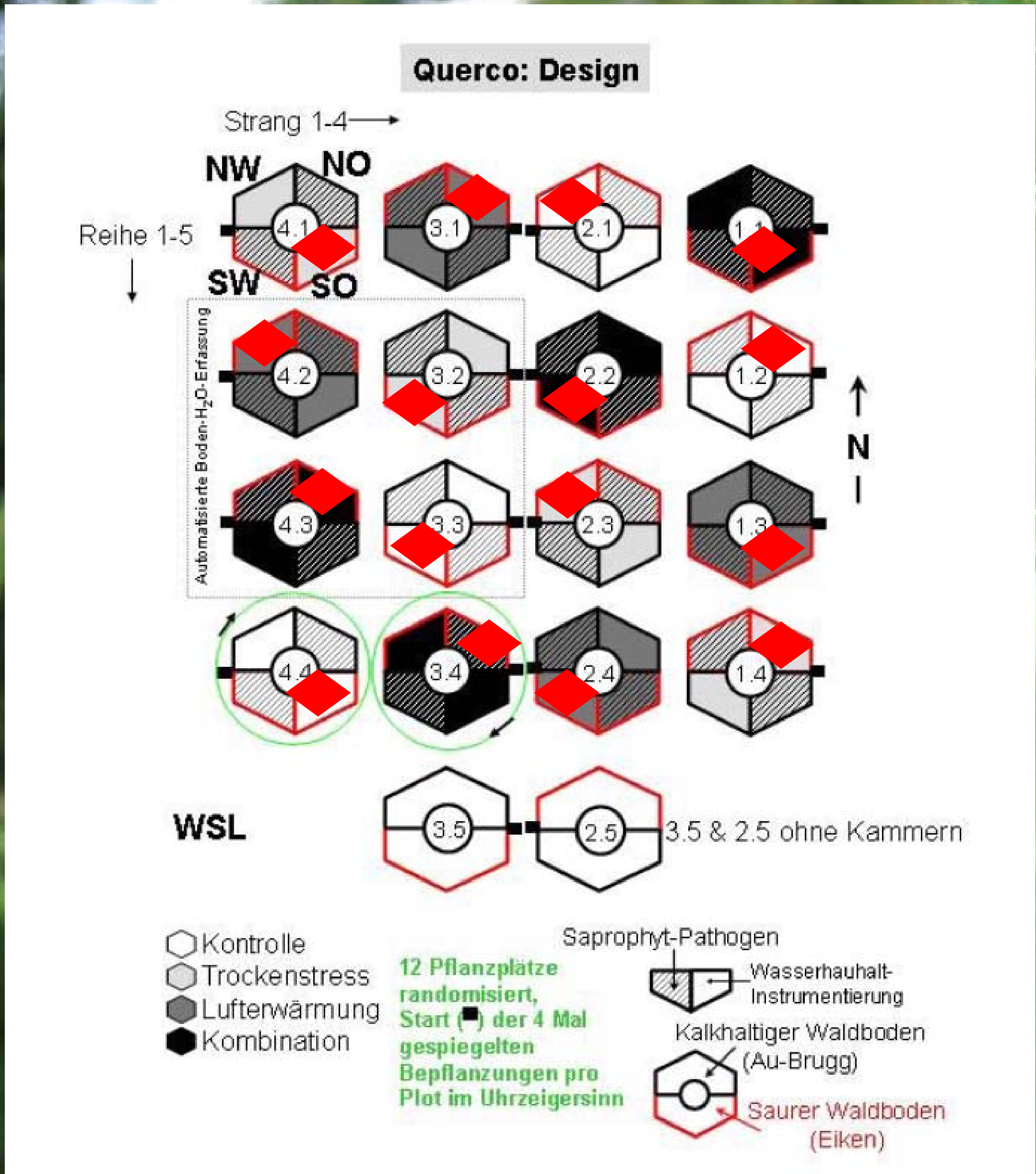


„Querco“ Model Ecosystem Study

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

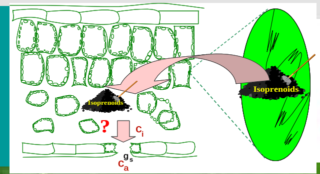
European Oak trees and Climate Change



Measurements:

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

Methods: Gas Exchange

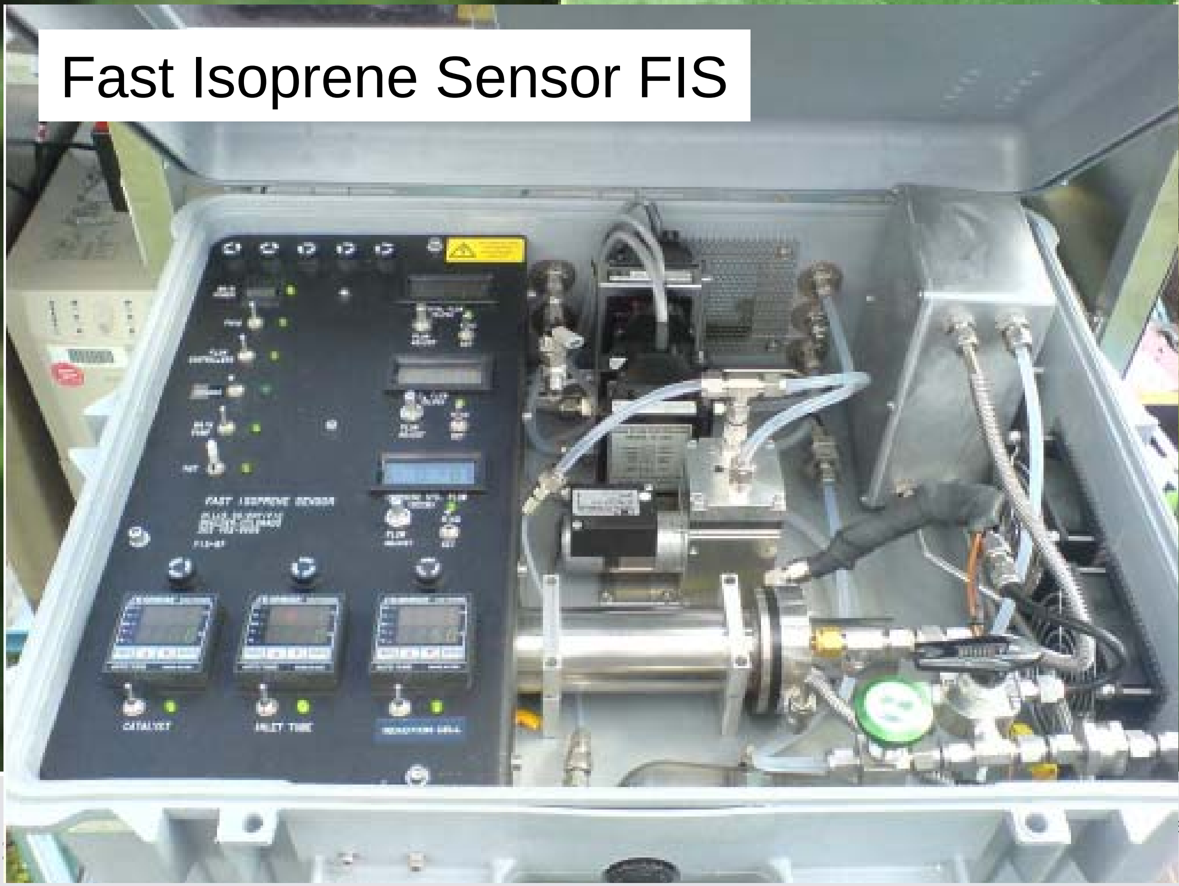


Isoprene, CO_2, Water vapor

Standardised conditions:
28 °C leaf temperature; 1500 µE PAR; rel. Hum. 45%; CO_2 380 ppm

Checking
LI6400 Gas Exchange System

Fast Isoprene Sensor FIS



Methods: Leaf Surface Temperatures

Infrared Thermography

Thermography with Infratec VarioCAM

Results: Leaf Surface Temperatures: August 06, 2008; 15:00 CEST

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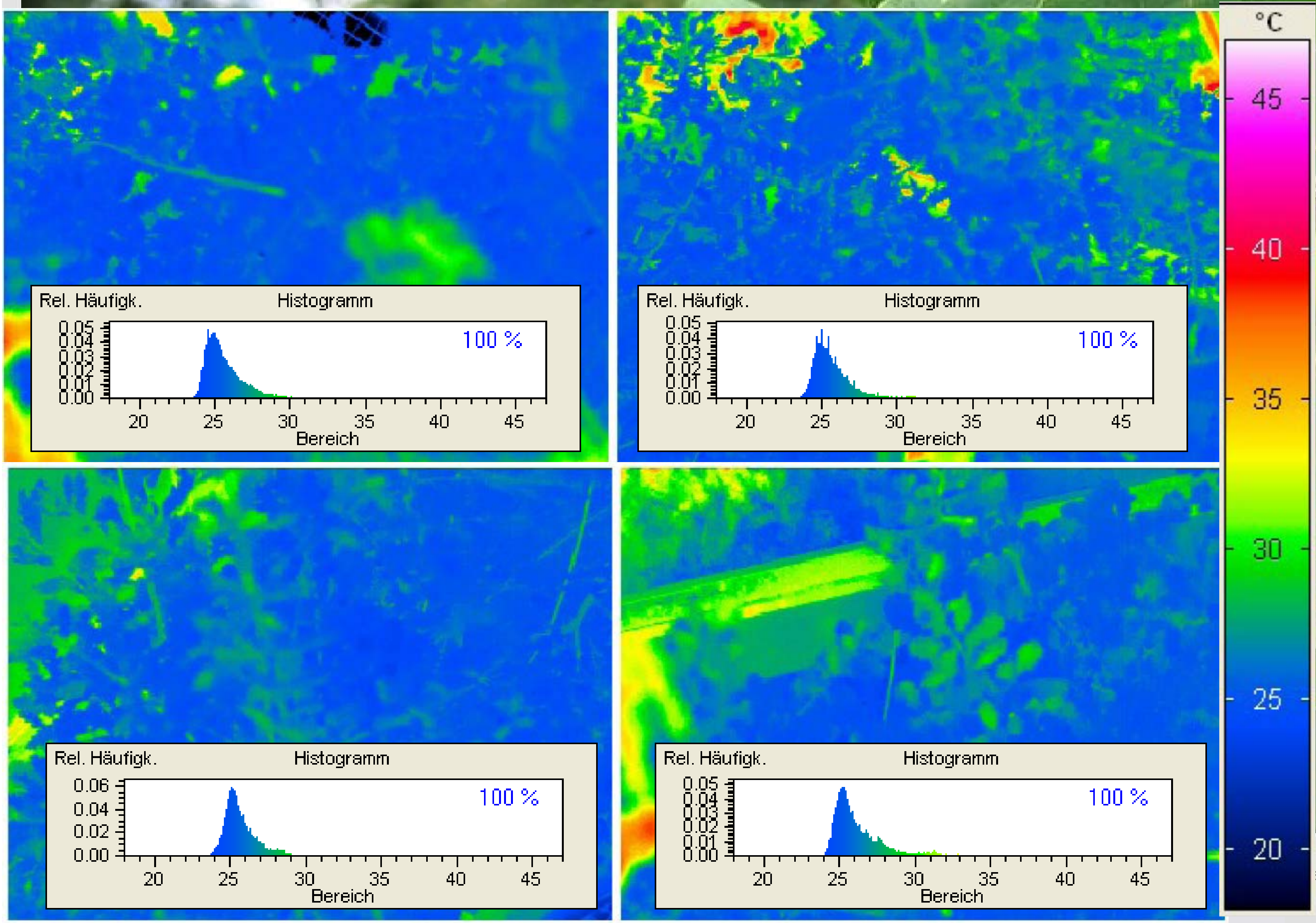
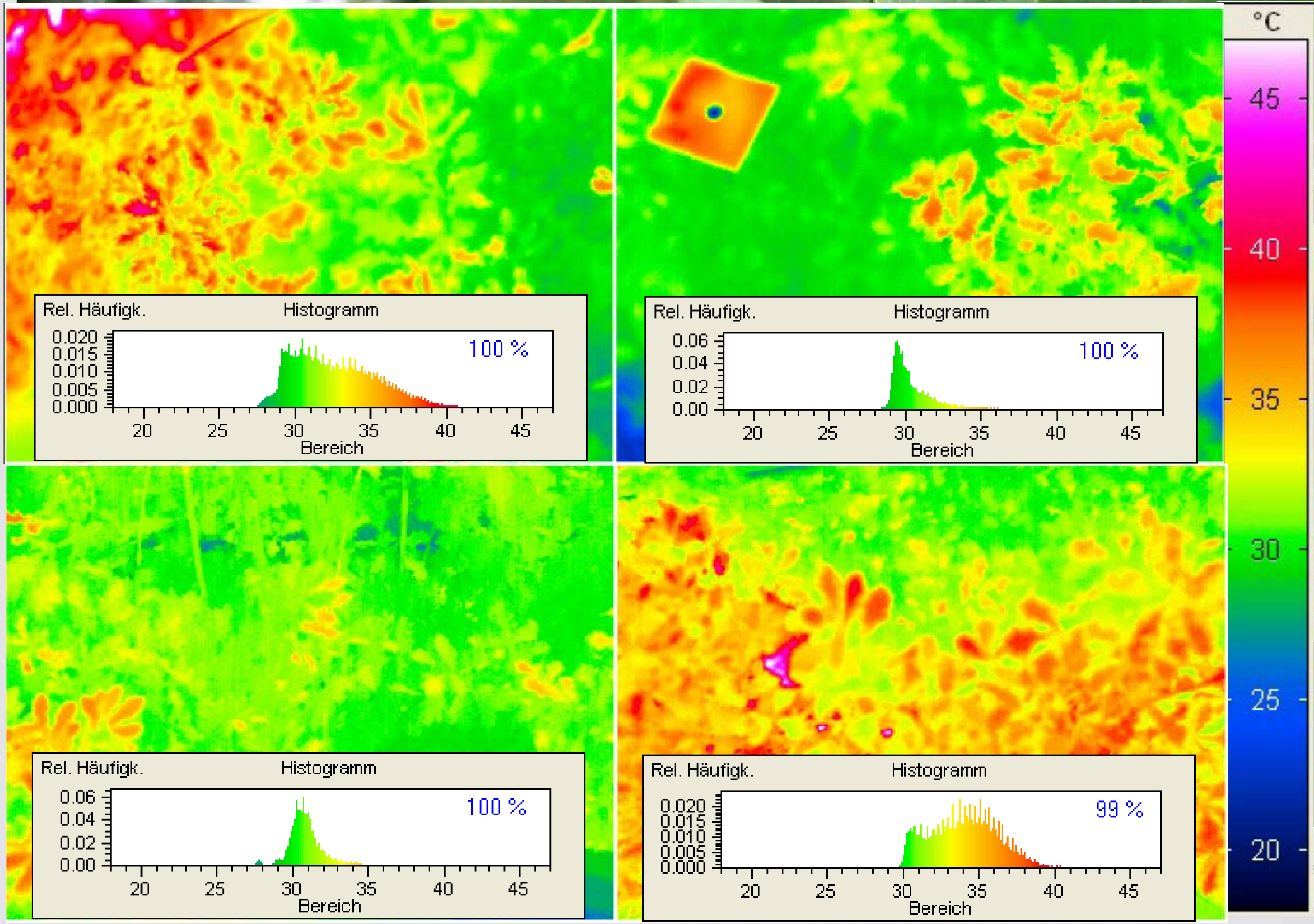
Chamber 1.2: Control



Median: 25°C

Results: Leaf Surface Temperatures August 06, 2008; 15:35 CEST

Chamber 4.1: Combination

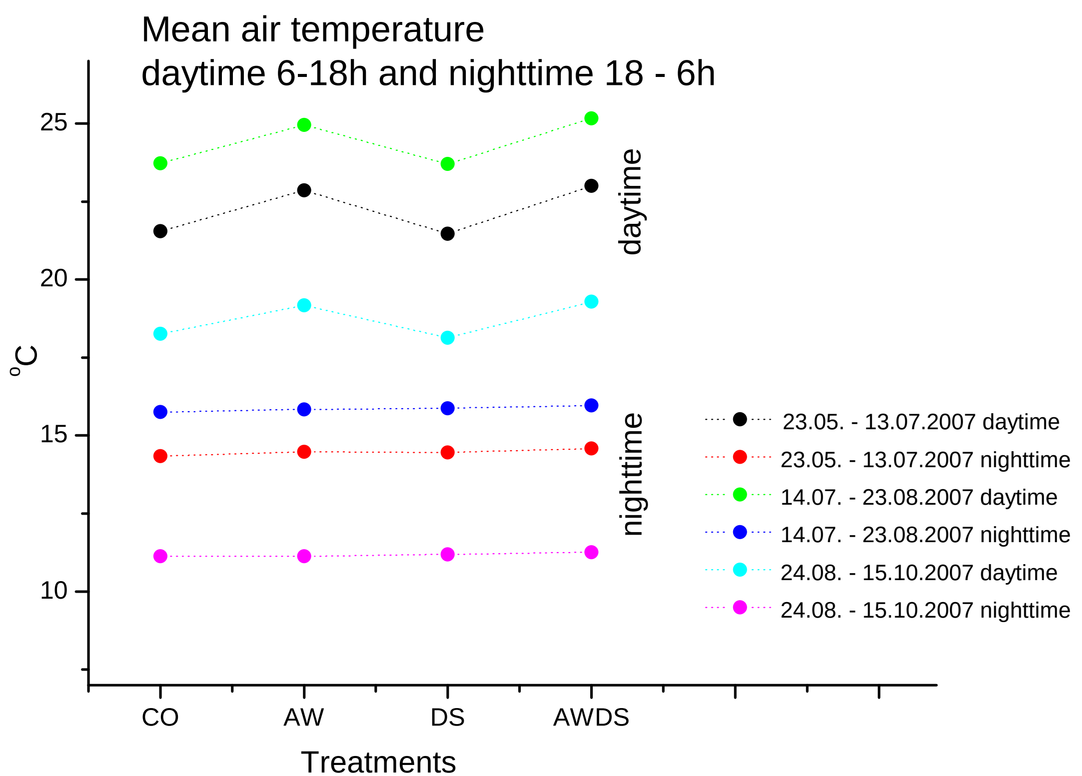


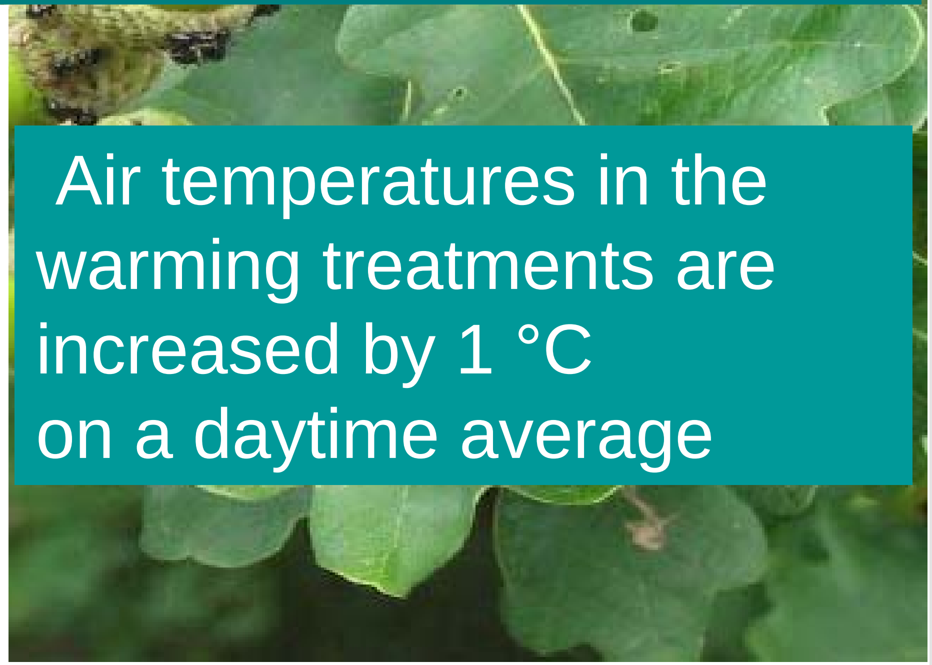
Median: 31°C

Results: Temperatures

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

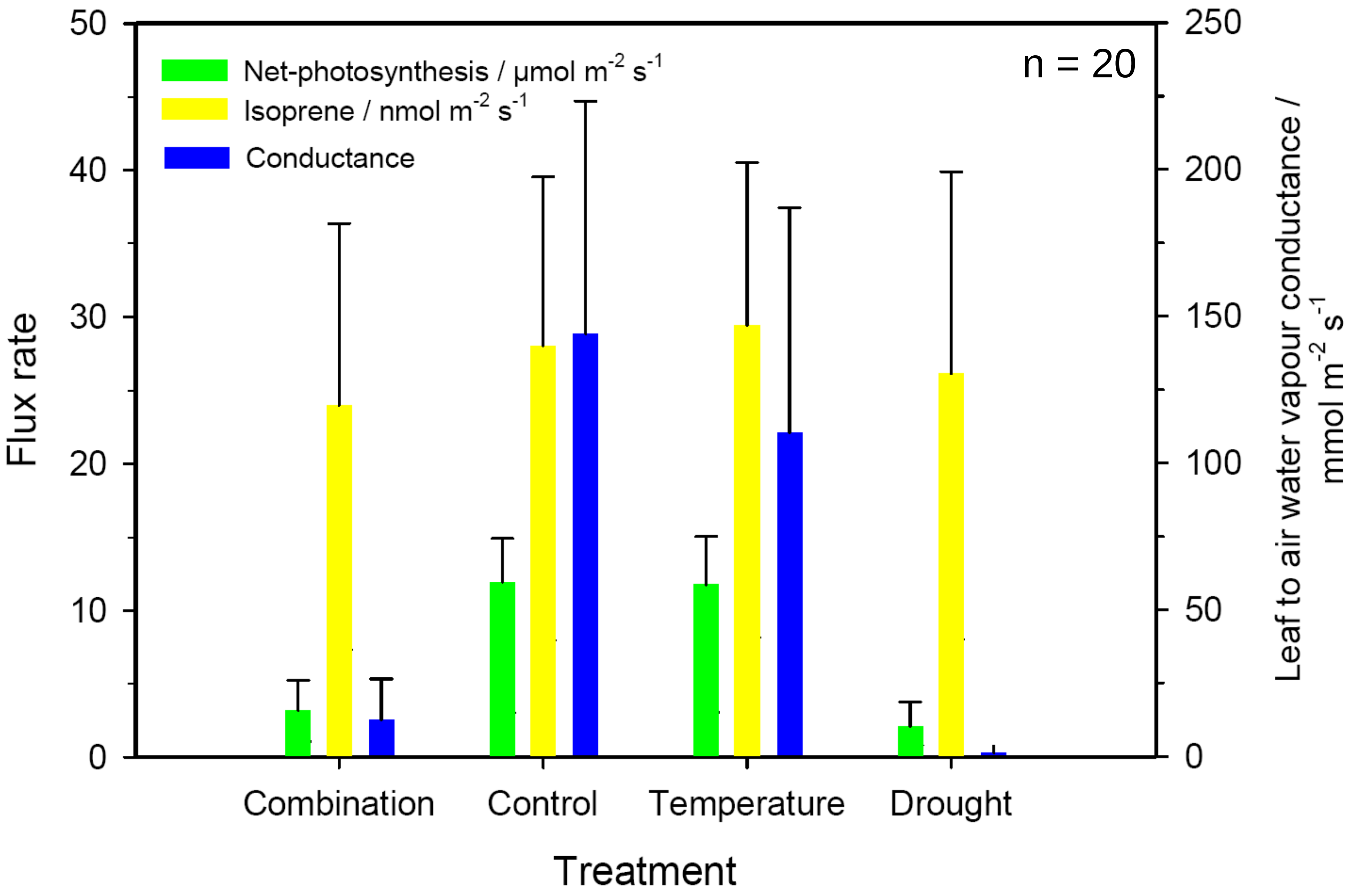
treatment	control	warming	drought	combination
leaf temperature / °C	27.3 ± 1.90	28.0 ± 1.99	32.3 ± 2.54	34.0 ± 2.68





Air temperatures in the warming treatments are increased by 1 °C on a daytime average

Results: Isoprene Emission and Photosynthesis



Conclusions

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- 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