Tracing ecosystem scale interactions of volatile organic compound (VOC) and CO_2 emissions by position-specific and whole ecosystem isotope labelling

Christiane Werner, Laura Meredith[2], Nemiah Ladd[1], Lars Erik Daber[1], Ines Bamberger[1], Ana Maria Yañez-Serrano[1], Jürgen Kreuzwieser, ERC-, B2WALD Team

Ecosystem Physiology, University Freiburg, Germany; [2]Ecosystem Genomics, University of Arizona, US c.werner@cep.uni-freiburg.de

AIMS AND SCOPE

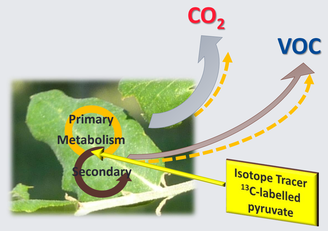
Ecosystem processes present a complex interplay between different components, such as vegetation, soil, and the rhizosphere. All components can emit (or even uptake) a plethora of volatile organic compound (VOC) with highly dynamic response to environmental stress.

However, processes controlling carbon allocation into primary and secondary metabolism such as VOC synthesis or respiratory CO_2 emission remain unclear.

The ERC Project VOCO$_2$ investigates the **linkage between carbon allocation into primary and secondary metabolism at the metabolic, organ and ecosystem scale in response to environmental drivers.**

POSITION-SPECIFIC LABELING

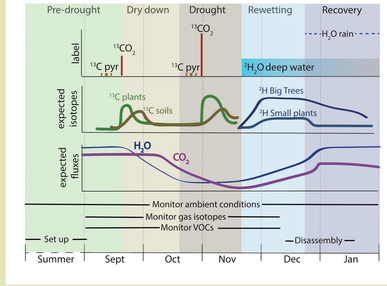
We use position specific ^{13}C-pyruvate labeling experiments to trace carbon partitioning within the metabolic branching points into VOCs versus CO_2 emissions by simultaneous real-time measurements of stable carbon isotope composition of respired $^{13}CO_2$ and ^{13}BVOC fluxes.



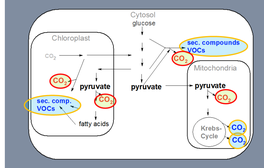
ECOSYSTEM SCALE

First **whole-ecosystem labelling** experiment:

In the Biosphere 2 Water, Atmosphere, and Life Dynamics (**B2 WALD**) experiment, we did implement an ecosystem scale drought and trace carbon allocation and dynamics of VOC, CO_2 and H_2O fluxes from leaf, root, soil and atmospheric scales.



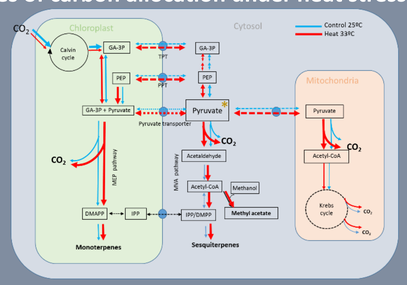
METABOLIC SCALE



C1-labelled pyruvate is decarboxylated in the mitochondria or during many synthesis pathways for VOCs

C2-labelled pyruvate is decarboxylated in the Krebs cycle or used as carbon source for synthesis of many secondary compounds

Changes of carbon allocation under heat stress

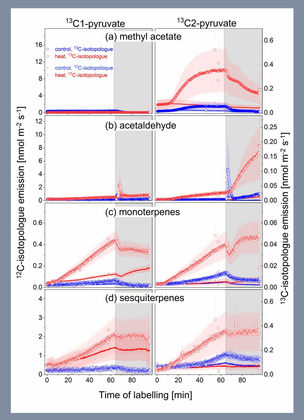


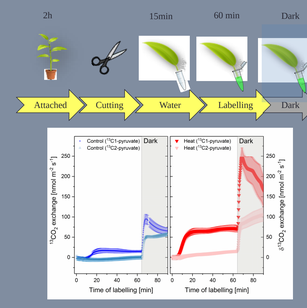
Example of enhanced use (red lines) of cytosolic pyruvate for isoprene emission under heat stress compares to control (blue line) in a tropical species (Yañez-Serrano et al. 2019)

See poster Ladd et al.

ORGAN SCALE

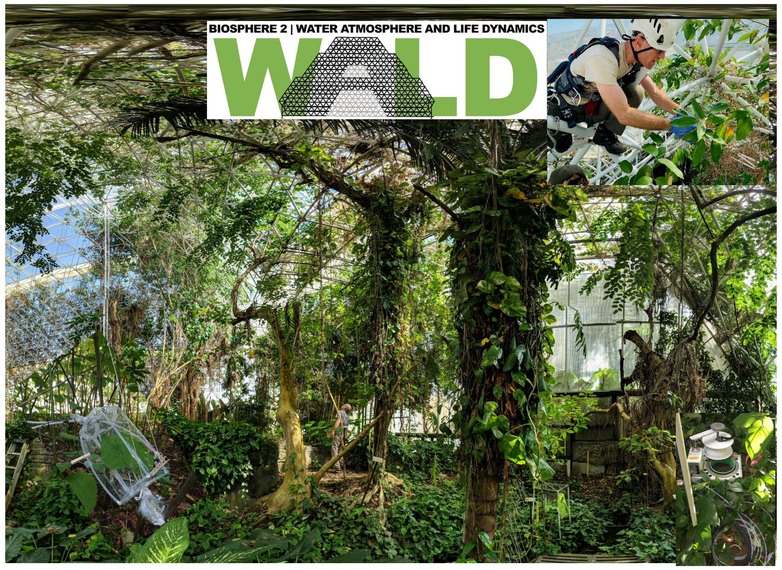
Changes of leaf carbon allocation into VOC and CO_2 under heat stress

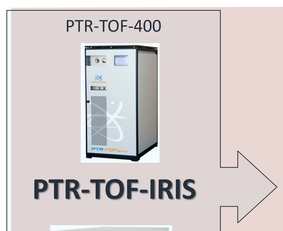




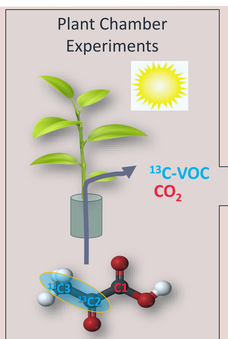
Higher investment of C2-labelled pyruvate in several VOC after 10 days 40°C heat stress

VOC production is associated with high CO_2 decarboxylation in the light and the dark





$^{13}CO_2$ Laser Spectrometer



Rapid synchronised real-time measurements of VOCs and $^{13}CO_2$ using PTR-TOF-MS, GC-MS and ^{13}C and ^{18}O laser spectroscopy (Fasbender et al. 2018)

LABELING OF DIFFERENT ECOSYSTEM COMPONENTS

Soil Labelling

Leaf Labelling

Root Labelling

See Poster by Ingrisch et al.

See Poster by Darber et al.

OUTLOOK

In an interdisciplinary approach we aim to shed new light into the biological mechanisms controlling the fate of CO_2, VOC and water cycling in an ecosystem in response to drought and deep water rewetting

Total ecosystem labelling will enable to trace the fate of carbon and water fluxes along the plant-soil-atmosphere interface and identify key drivers and processes controlling these fluxes in response to drought

We will explore the interaction between different ecosystem components and how they feed back to ecosystem response

LITERATURE

Fasbender, L., Yáñez-Serrano, A.M., Kreuzwieser, J., Dubbert, D. and Werner, C., 2018. Real-time carbon allocation into biogenic volatile organic compounds (BVOCs) and respiratory carbon dioxide (CO2) traced by PTR-TOF-MS, 13CO2 laser spectroscopy and 13C-pyruvate labelling. *PloS one*, *13*(9), p.e0204398.

2 Yáñez-Serrano Ana Maria, Lucas Mahlau, Lukas Fasbender, Joseph Byron, Jonathan Williams, Jürgen Kreuzwieser, and Christiane Werner (2019). Incorporation of cytosolic pyruvate in isoprene biosynthesis is enhanced under heat as a mechanism of plants to increase thermotolerance. Journal of exp. Botany: 70, 5827–5838, .

Acknowledgement

This study is funded by ERC-Grant VOCO #647008, Biosphere 2, the Philecology Foundation, and Susan and Daniel Warmack

Photos by: Erik Darber, Gemma Purser, Laura Meredith and CW