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SIMULTANEOUS O_2 AND CO_2 FLUX MEASUREMENTS WITH CUSTOM-MADE BRANCH CHAMBERS FOR *FAGUS SYLVATICA*

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erc European Research Council Established by the European Commission

DFG Deutsche Forschungsgemeinschaft

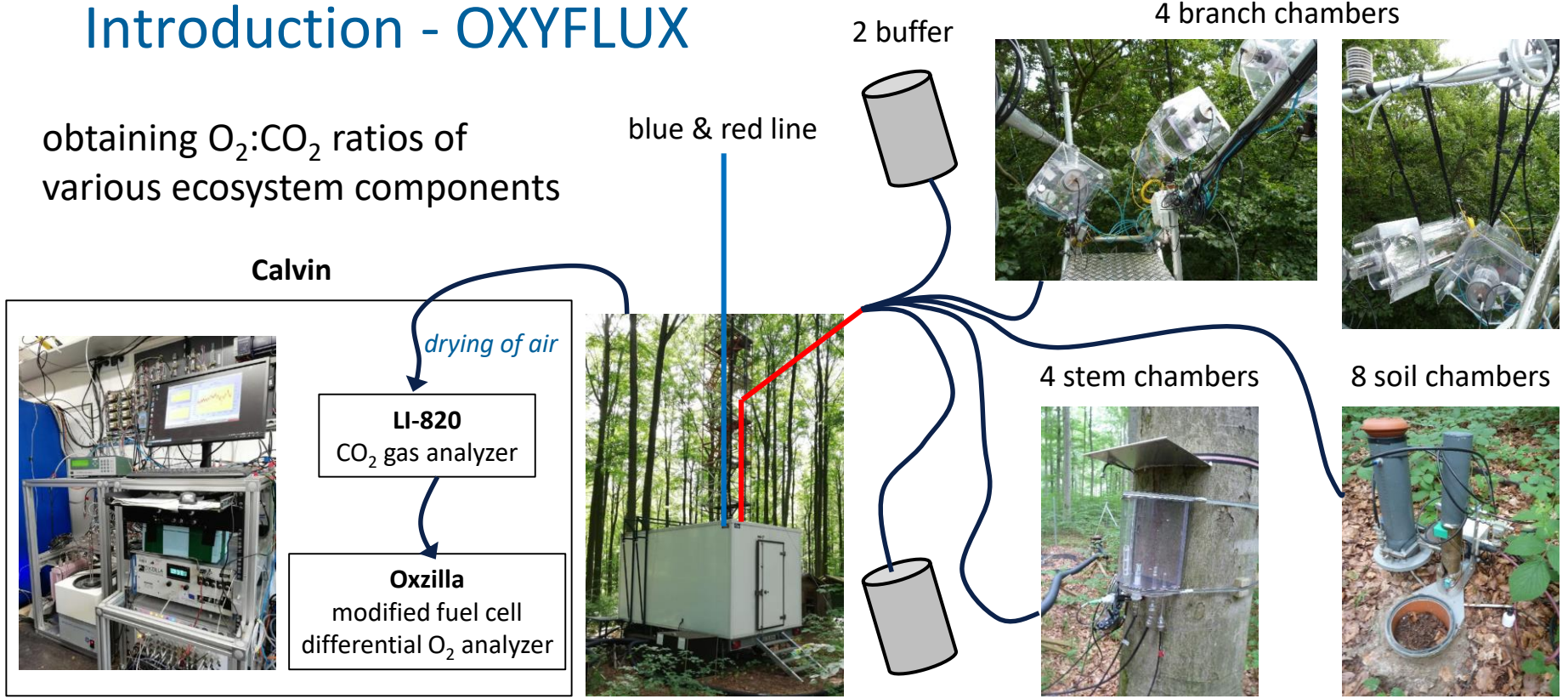
UEA University of East Anglia

Introduction

- In terrestrial ecosystems, fluxes of CO_2 and O_2 are typically anti-correlated via the processes of photosynthesis and respiration.
- The molar exchange ratio O_2:CO_2 is widely assumed to be around -1.1 mol mol^{-1} on larger spatial and temporal scales (KEELING and MANNING 2014).
- However, recent work suggests that individual components of ecosystems have considerable variation in their O_2:CO_2 exchange ratios (temporal and spatial).
- O_2:CO_2 measurements have rarely been performed due to technical challenges of measuring small fluctuations against the large atmospheric background of O_2.

Introduction - OXYFLUX

obtaining O_2:CO_2 ratios of various ecosystem components



Introduction - Instrumental set-up

- Leinefelde site in Central Germany:
  - 51°19’41.6” N, 10°22’04.1” E
  - pure beech forest, managed
  - even-aged, about 140 years old

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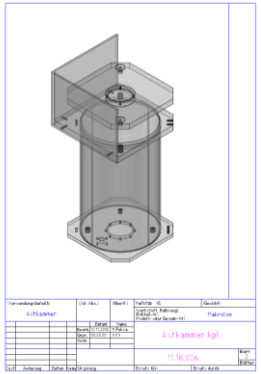
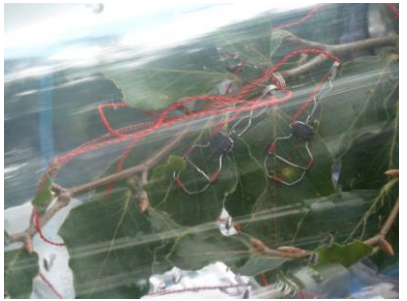
- available data:
  - CO_2, O_2 and H_2O mole fractions for chambers and buffer
  - chamber meteorology: PAR, T, T_{leaf}, RH
  - tower meteorology: SW_IN, T_{air}, RH, P, …
  - eddy-covariance flux data: NEE, GPP, LE



Marek Peksa



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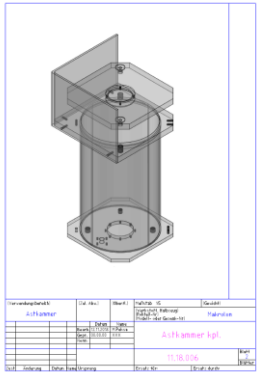
1 min • CO_2, O_2 and H_2O mole fractions for chambers and buffer

1 min • chamber meteorology: PAR, T, T_{leaf}, RH

10 min • tower meteorology: SW_IN, T_{air}, RH, P, …

30 min • eddy-covariance flux data: NEE, GPP, LE



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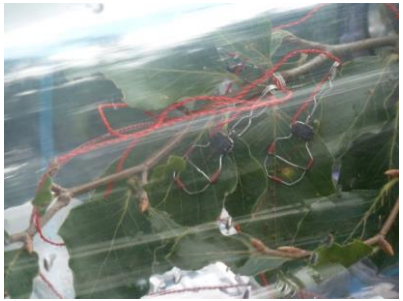
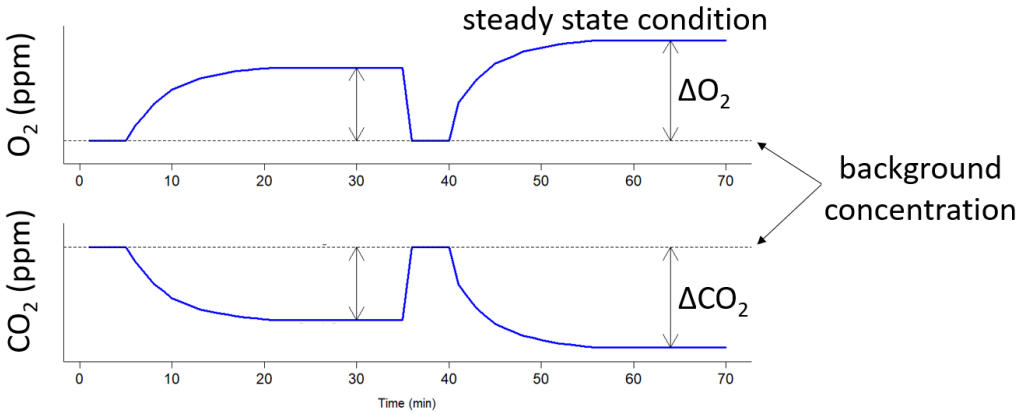


Methods - Data processing

- quality check based on absolute limits and despiking approach
- $\Delta CO_2 = CO_{2,\ chamber} - CO_{2,\ ref}$
- $\Delta O_2 = O_{2,\ chamber} - O_{2,\ ref}$



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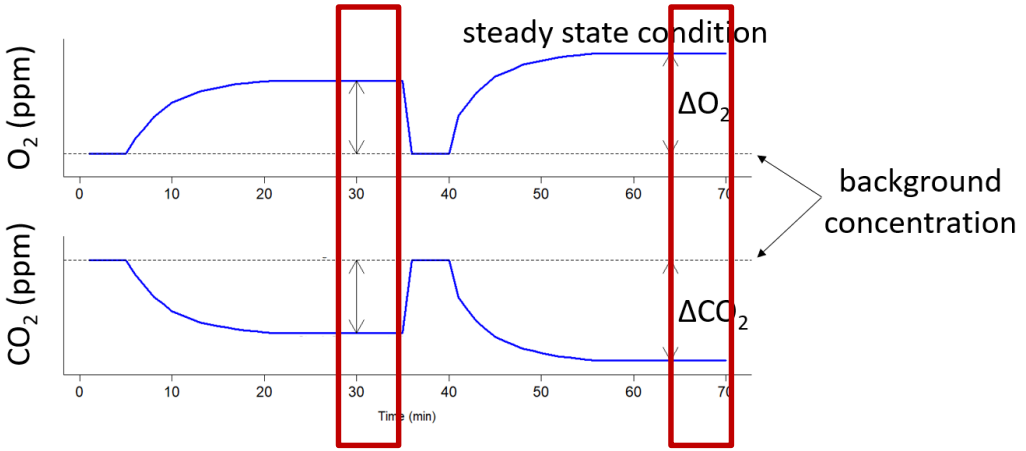
- choosing last 7 min of each measurement cycle and discarding very last minute
- calculation of:
  - rate of change of CO_2 or O_2
  - ΔCO_2 and ΔO_2 from 6-min average
  - O_2:CO_2 exchange ratio
  - CO_2 and O_2 fluxes



Methods - Data processing

- flux calculation (F_{CO_2}, F_{O_2}) for steady and unsteady state conditions:

$$F_{CO_2} = \frac{\Delta CO_2 \cdot flow - V\rho \frac{dCO_2}{dt}}{S} \qquad F_{O_2} = \frac{\Delta O_2 \cdot flow - V\rho \frac{dO_2}{dt}}{S}$$

with

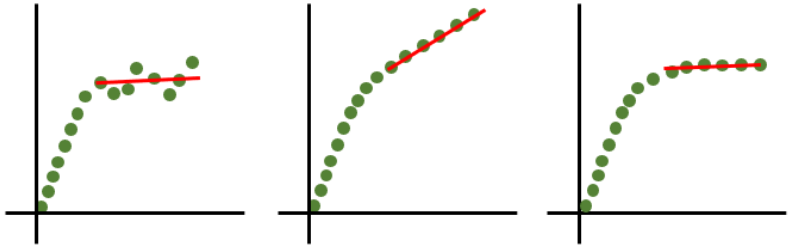
$\Delta CO_2,\ \Delta O_2$	difference between incoming and outgoing CO_2 or O_2 mole fractions (µmol mol^{-1})
$flow$	flow rate (mol s^{-1})
S	leaf area (m^2)
V	chamber volume (m^3)
ρ	air density (mol m^{-3})
$\frac{dCO_2}{dt}, \frac{dO_2}{dt}$	rate of change of CO_2 or O_2 mole fractions (µmol mol^{-1} s^{-1})

after Saathoff and Welles et al. (2021), doi: 10.1111/pce.14178.

Methods - Data processing

- finding measurement cycles of high quality (steady state):

change of mole fraction with time
(— last 6 min of each cycle)



detection with R^2 slope R^2 and slope

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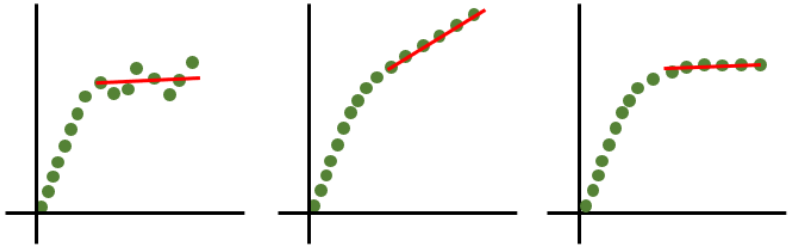

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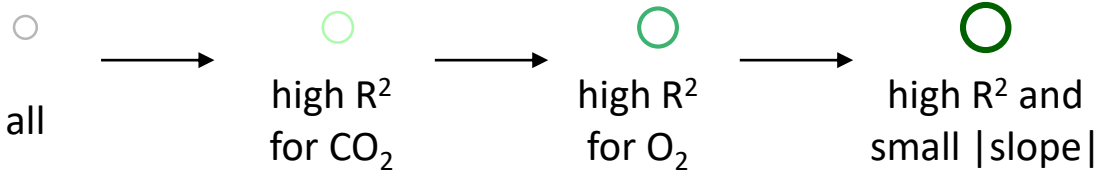
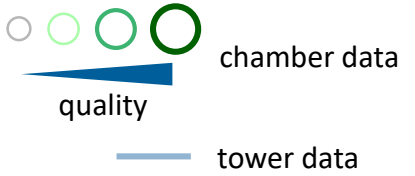
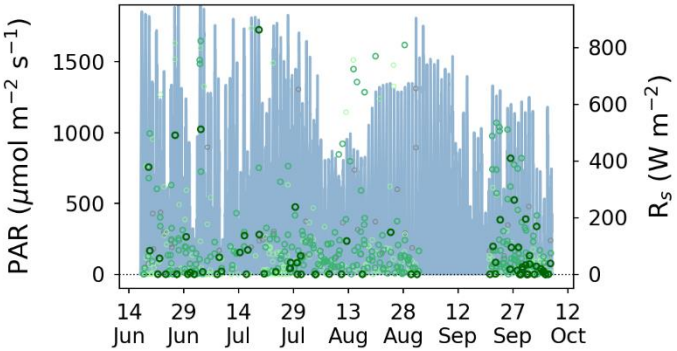
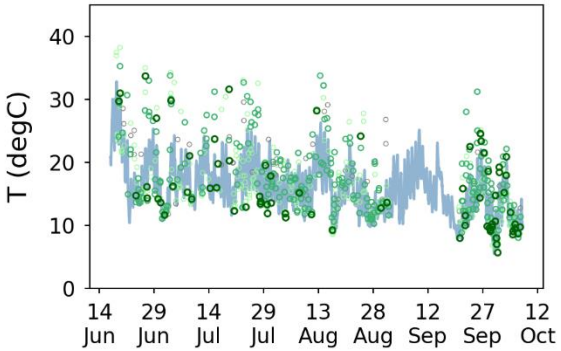
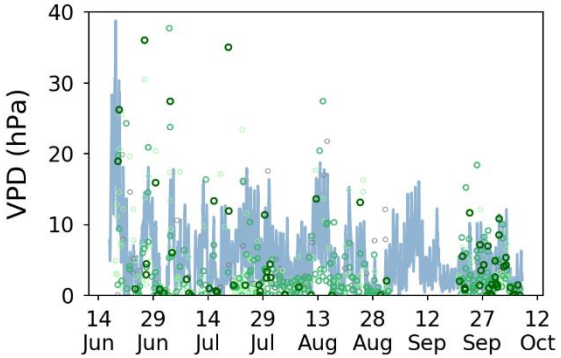


Results - Meteorological conditions







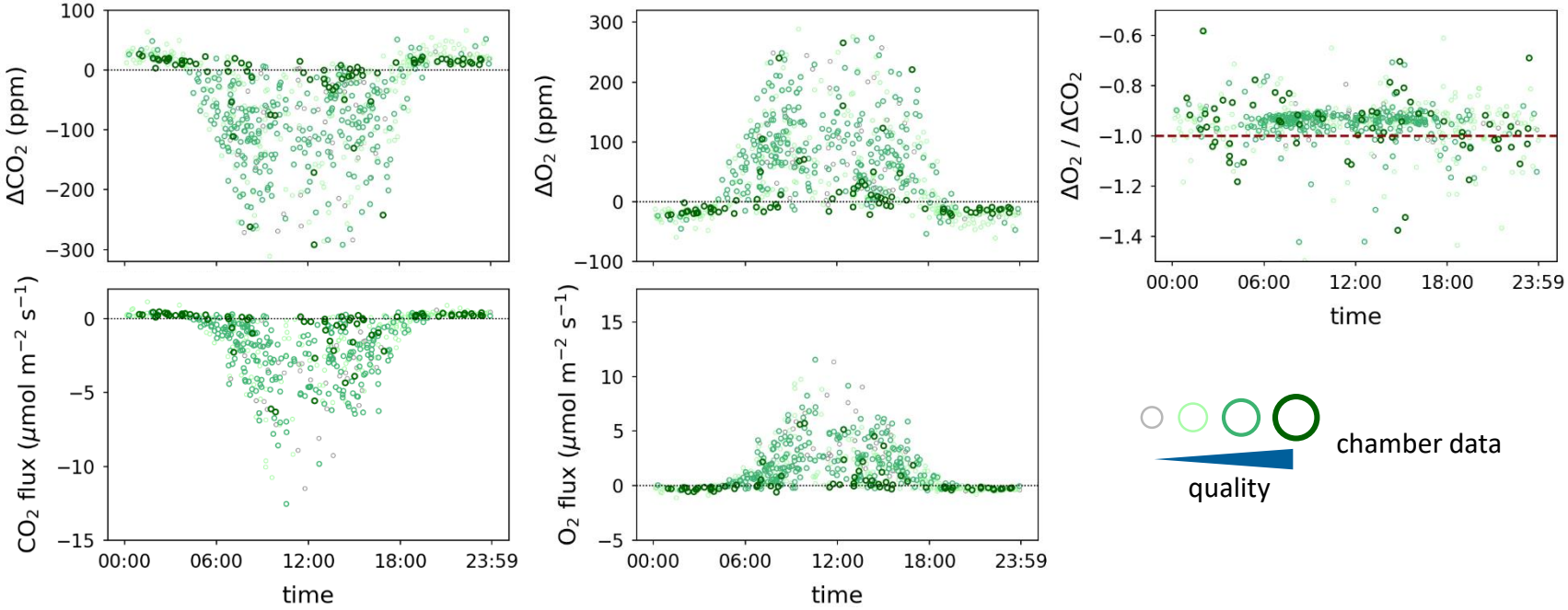


Results - Diel variations

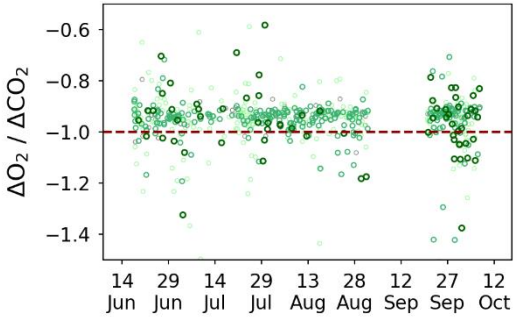
- 632 measurement cycles (425 daytime, 207 nighttime)

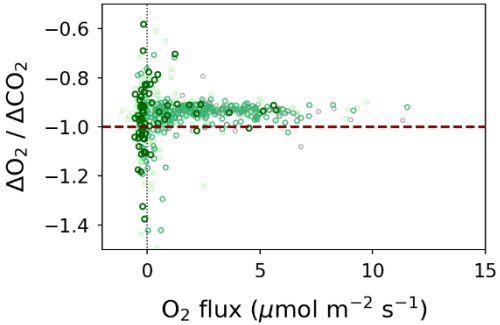
mole fractions

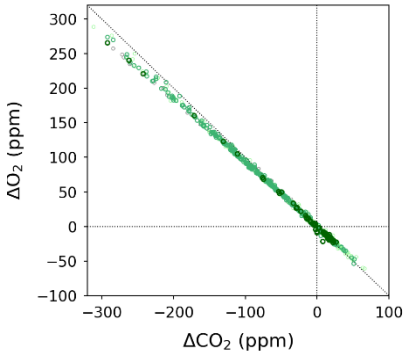
fluxes



Results - O_2:CO_2 exchange ratio





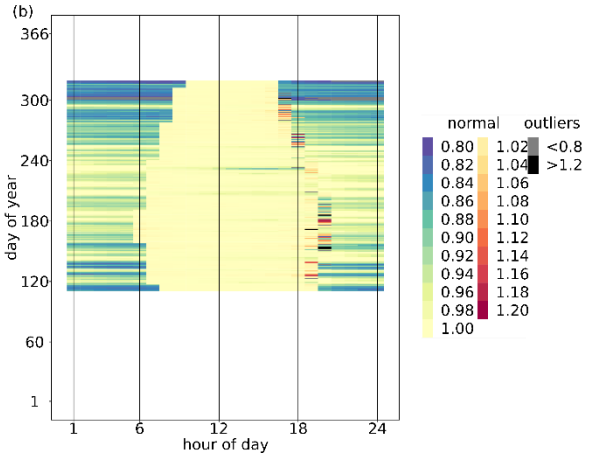


- exchange ratio between -0.9 and -1.0 mol mol^{-1}
- high variation for low flux magnitudes

⟶ but most 'high quality' conditions

⟶ extra filtering necessary

CANVEG simulations

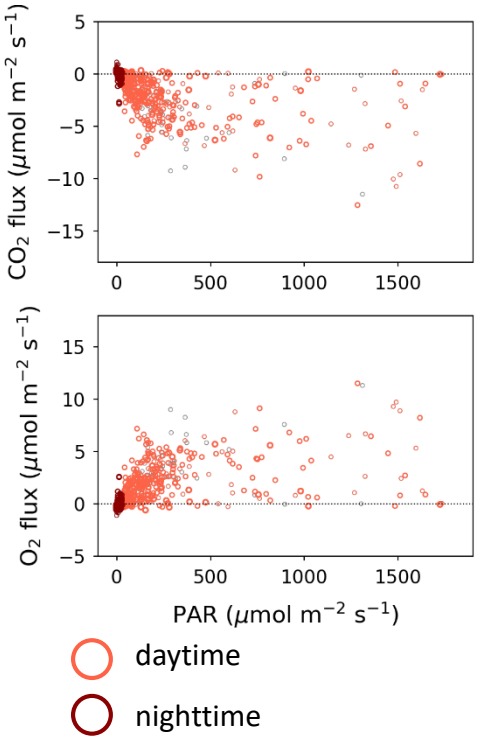


Yan et al. (2023), Biogeosciences Discussion, doi: 10.5194/bg-2023-30

Results - correlations with meteorological conditions

CO_2 flux

O_2 flux



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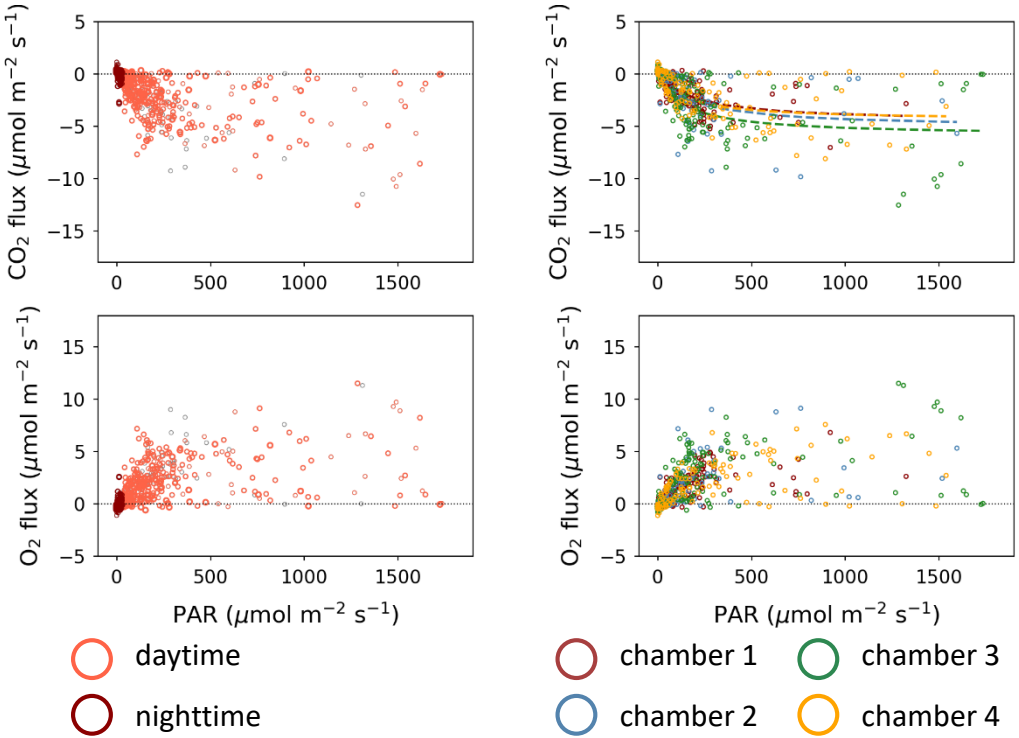

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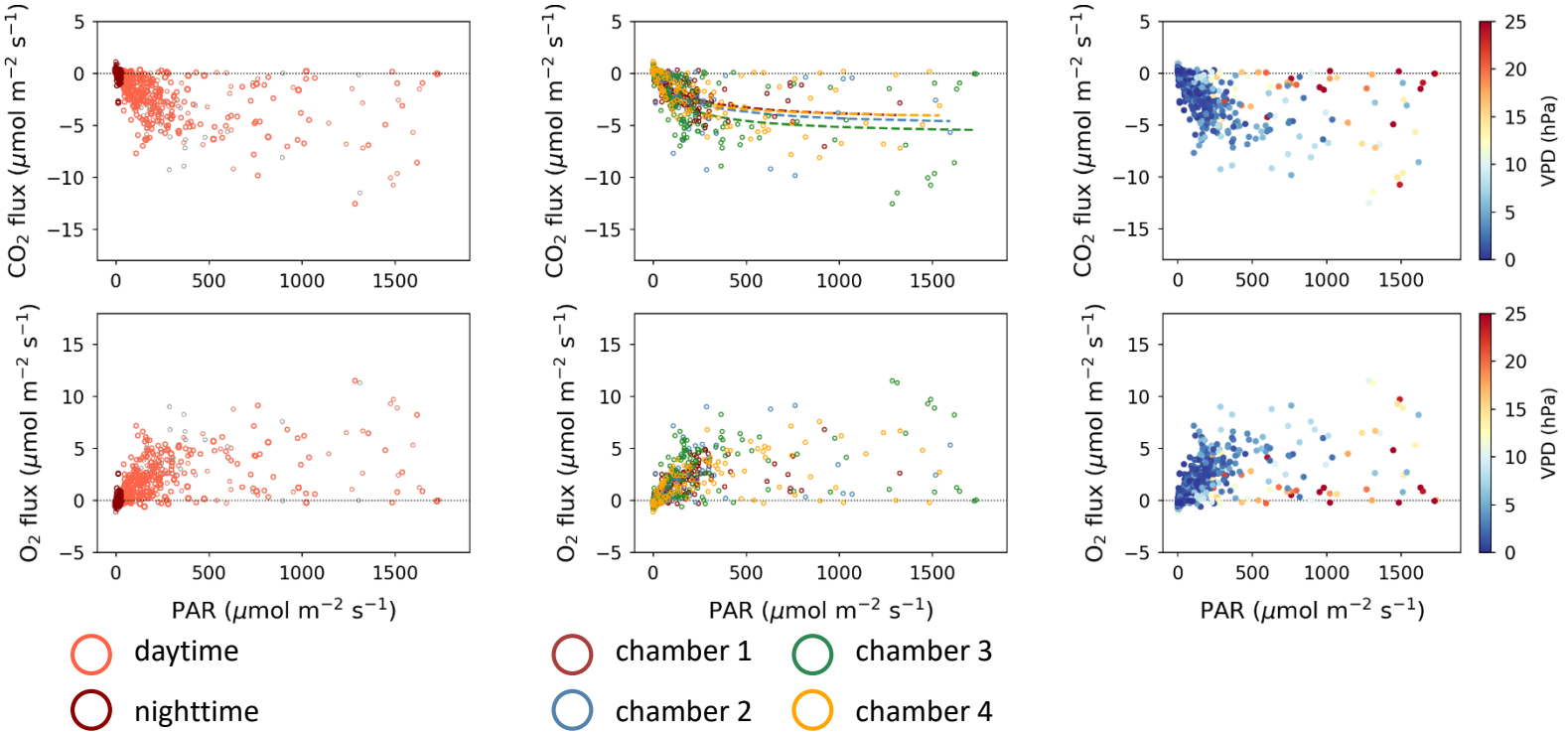

Conclusions and Outlook

- O_2:CO_2 exchange ratio was between -0.9 and -1.0 mol mol^{-1}, but also showed high variation for low flux magnitudes.
- Diel and seasonal cycle was not pronounced during study period.
- Further development of the quality check for chamber data and a comparison of steady and unsteady state conditions are necessary.

- comparison of other flux calculation strategies
- analysis of correlations with meteorological conditions
- development of upscaling procedure of leaf-scale data to ecosystem-scale
- comparison with model simulations

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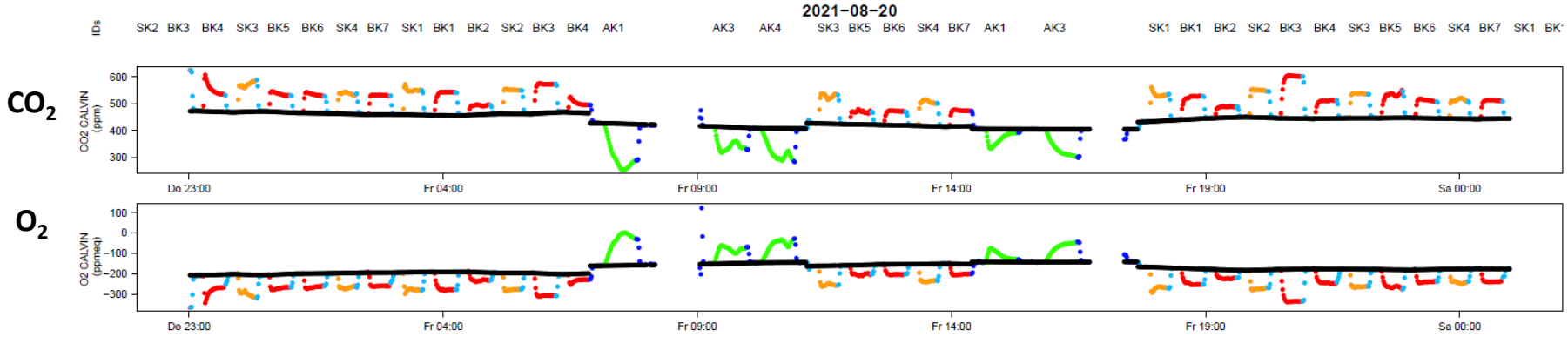
Thank you for your attention!

Introduction - Instrumental set-up

- sequential measurement scheme for 16 chambers
- each measurement cycle (one chamber) for 20-40 minutes

background reference (buffer)
soil chambers
stem chambers
branch chambers



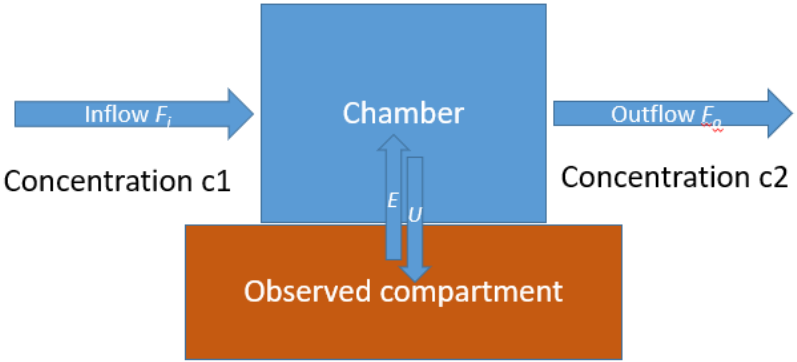
CO_2

O_2

→ 4 steady-state, open-throughflow branch chambers

Introduction - Flux calculation

Leak-free system:
$F_i = F_o$
At steady state:
$(c_2\text{-}c_1) \times F_o$ = E – U = Net flux



⇨Prerequisites for the method to work:

1. Steady state in chamber
2. Perfect knowledge of all fluxes in and out of the chamber
3. Concentration before and after chamber

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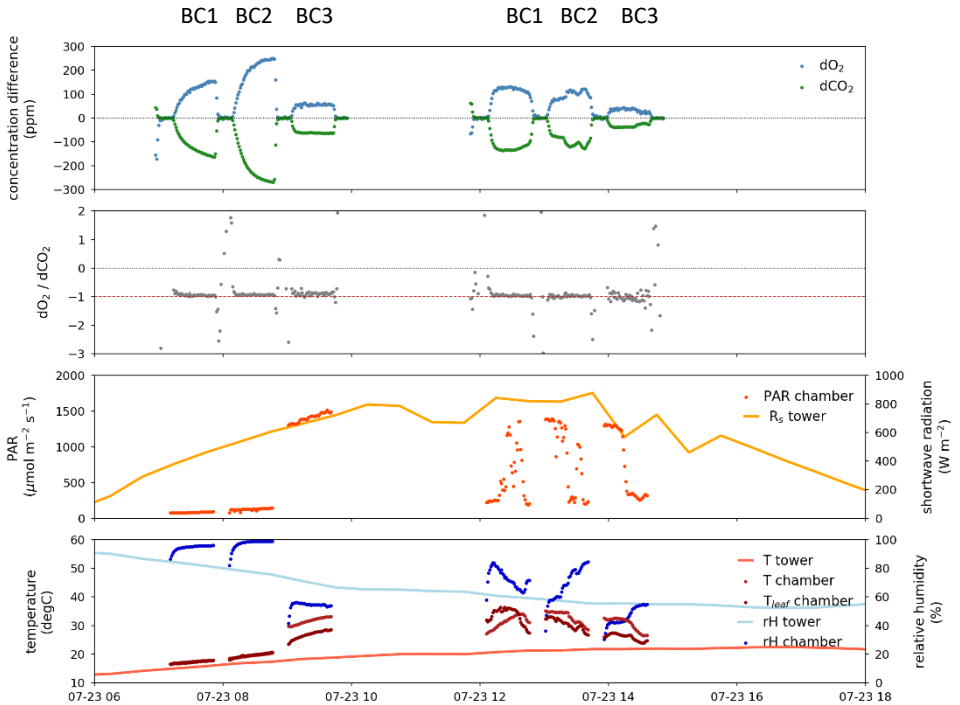
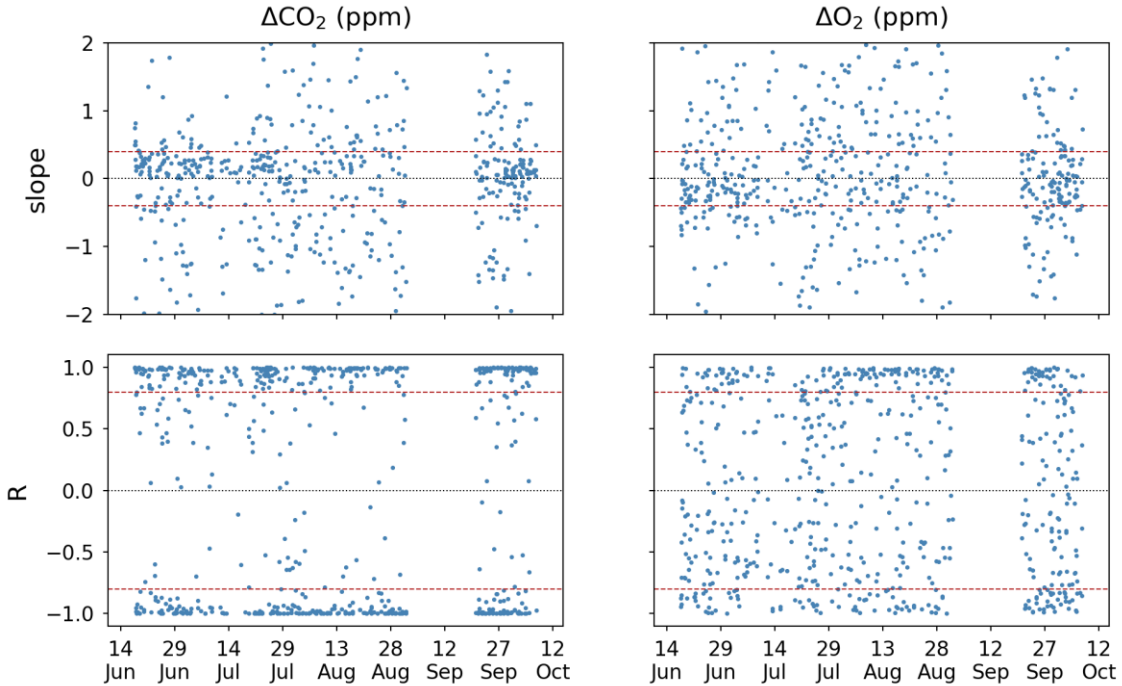


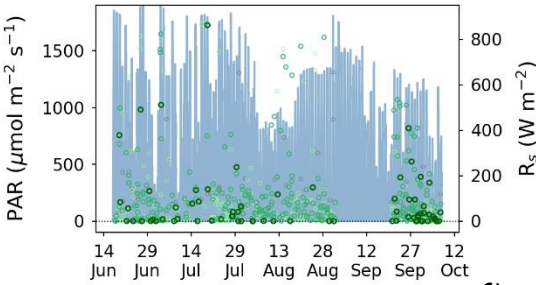
Results - Quality check

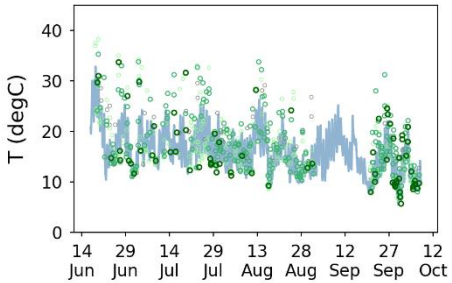


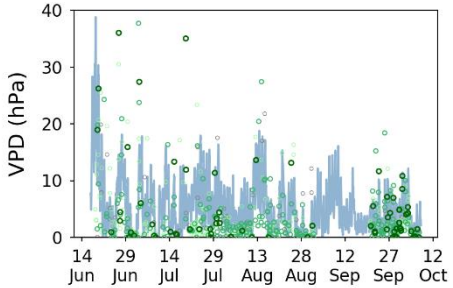
Results - Seasonal dynamics

- 632 measurement cycles (425 daytime, 207 nighttime)

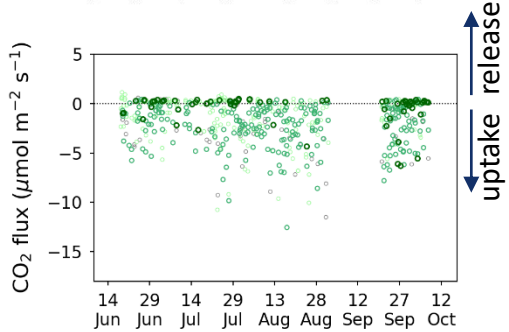
meteorology

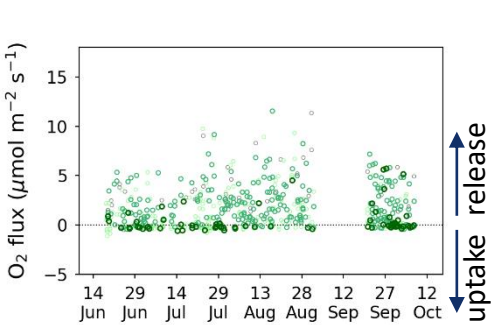


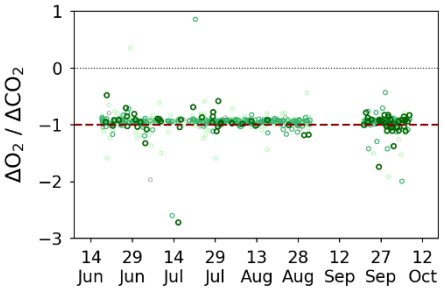


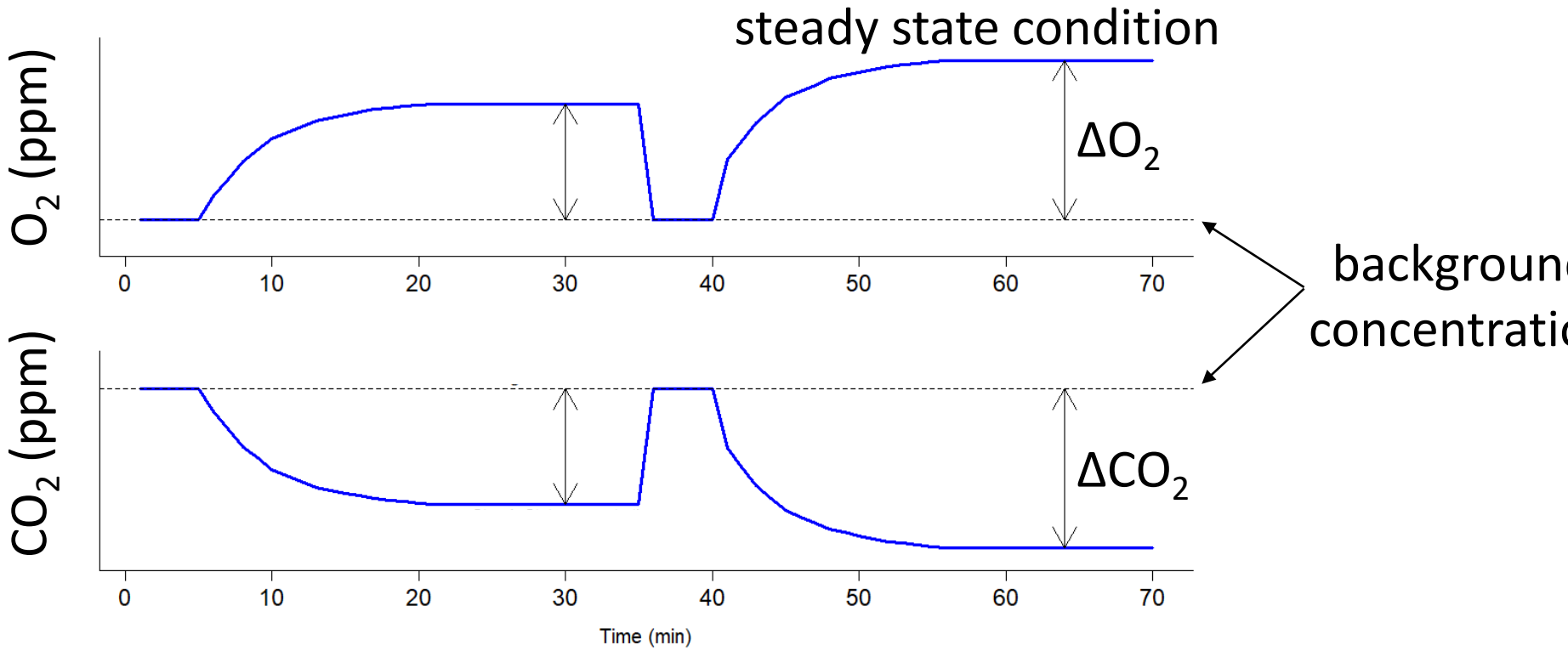


fluxes








steady state condition
O_2 (ppm)
ΔO_2
0
10
20
30
40
50
60
70
CO_2 (ppm)
ΔCO_2
Time (min)