Continuous measurements of O_2:CO_2 flux exchange ratios above a cropland in central Germany

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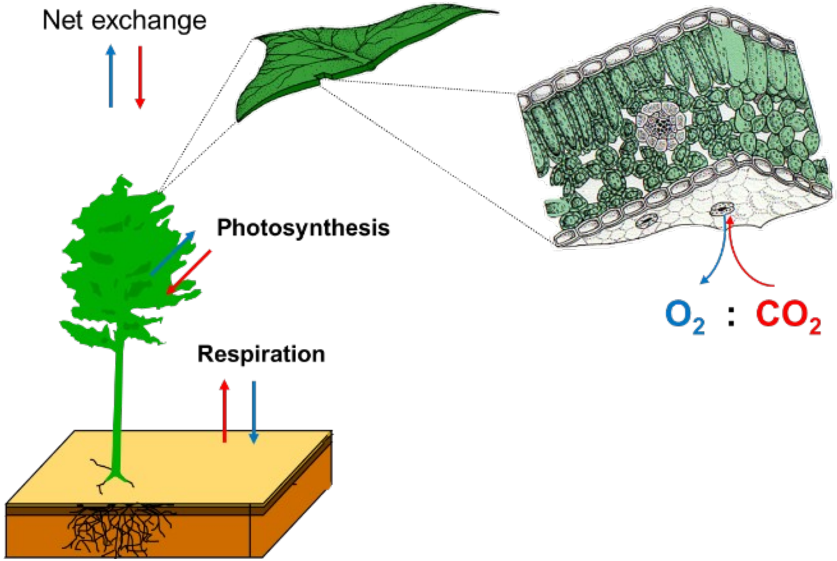
O_2 fluxes at ecosystem scale



From **studies in forest ecosystems** we know that O_2:CO_2 exchange ratios can

→ be different than the expected 1:1 relationship (Hilman et al. 2016, 2019)

→ differ for different ecosystem components (Ishidoya et al. 2013)

→ be used for partitioning net fluxes into photosynthesis and respiration (Ishidoya et al. 2015, Faassen et al. 2023)

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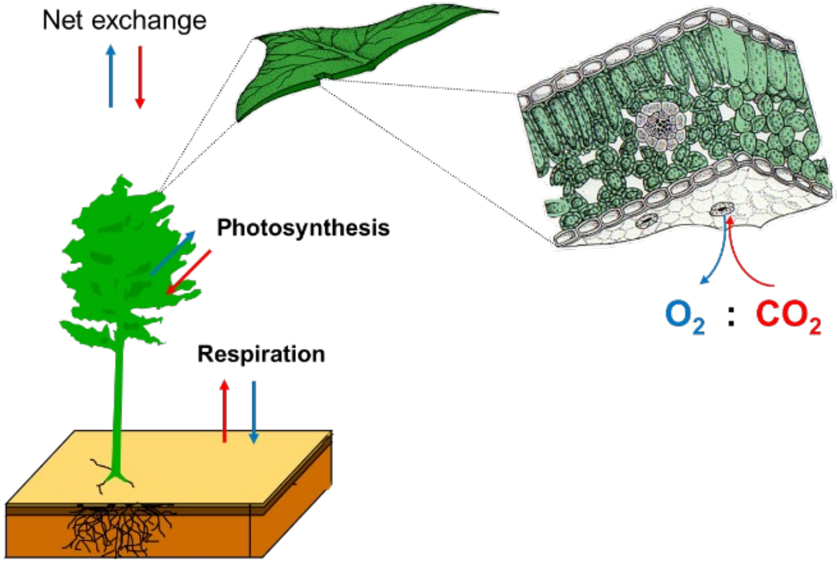

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O_2:CO_2 ratio of net flux from agricultural sites yet largely unknown

Objectives

1) To estimate O_2:CO_2 exchange ratios from mole fraction measurements at different time scales from a agricultural field.

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2) To assess O_2 fluxes above the agricultural field using the flux-gradient approach for estimating flux-based O_2:CO_2 exchange ratios.

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O_2:CO_2 exchange ratios (ER) and flux estimates

1) $$ER = \frac{\mathrm{d}O_2}{\mathrm{d}CO_2}$$

O_2 - mole fraction (µmol mol^{-1})*
CO_2 - mole fraction (µmol mol^{-1})
* deviation from a reference mole fraction

2) $$ER_{flux} = \frac{F_{O_2}}{F_{CO_2}}$$

F_{O2}, F_{CO2} – O_2 or CO_2 flux (µmol m^{-2} s^{-1})

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<u>Flux-gradient approach</u>: $$F_\Phi = -K_\Phi \frac{\partial \Phi}{\partial z}$$

1) with K_ϕ from Monin-Obukhov similarity:

$$K = \frac{u^* k (z-d)}{\phi_m}$$

2) … or K_{O2} = K_{CO2} (trace gas similarity):

$$K_{O_2} = K_{CO_2}$$
$$F_{O_2} = F_{CO_2} \frac{\Delta O_2}{\Delta CO_2}$$

→ *required*: CO_2-flux from eddy covariance and vertical gradient of O_2 and CO_2 mole fraction

Site description

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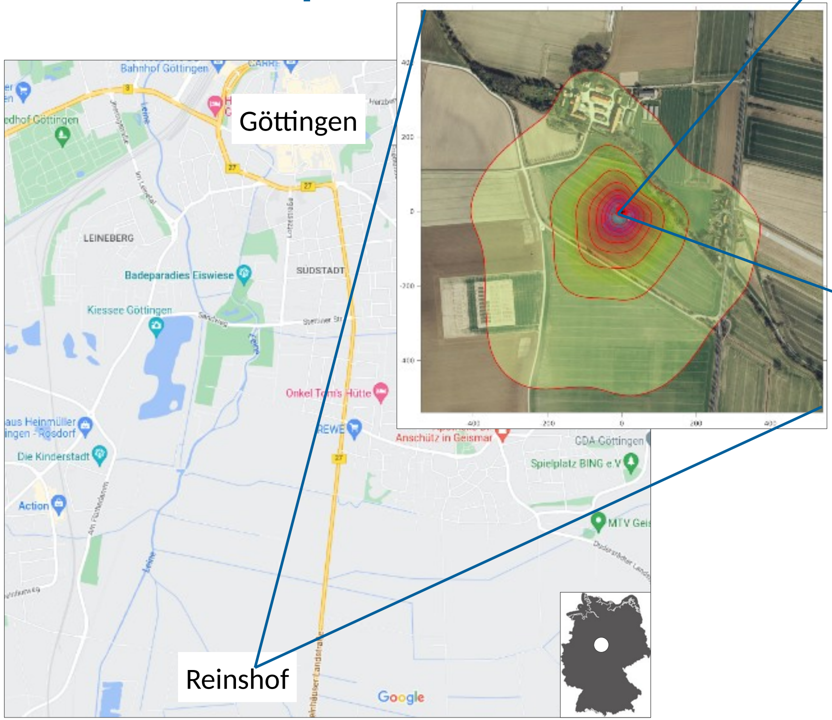

Photo by Ana Meijide

Site description

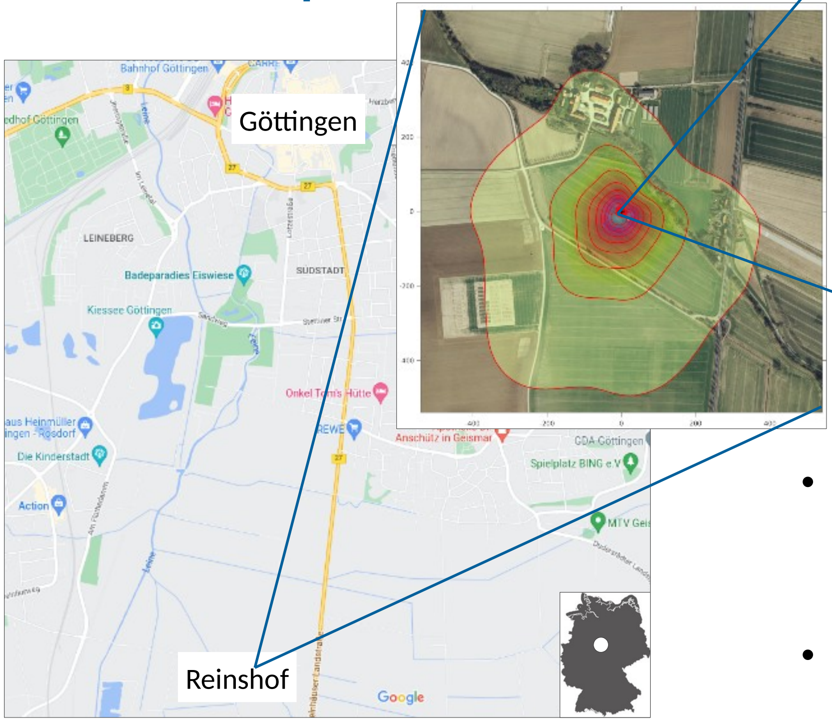

Photo by Ana Meijide

<u>Reinshof (DE-Rns Fluxnet site)</u>

- **monocropping** agricultural system with annually varying crop rotation (2023 → sugar beet; 2024 → winter wheat)
- **conventional soil cultivation** (deep tillage, fertilisation)

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O_2 and CO_2 measurements

3 m

1 m

0.5 m

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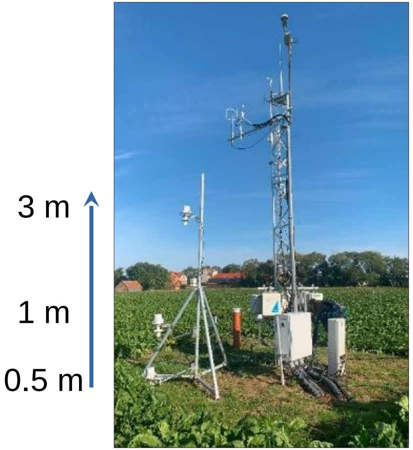
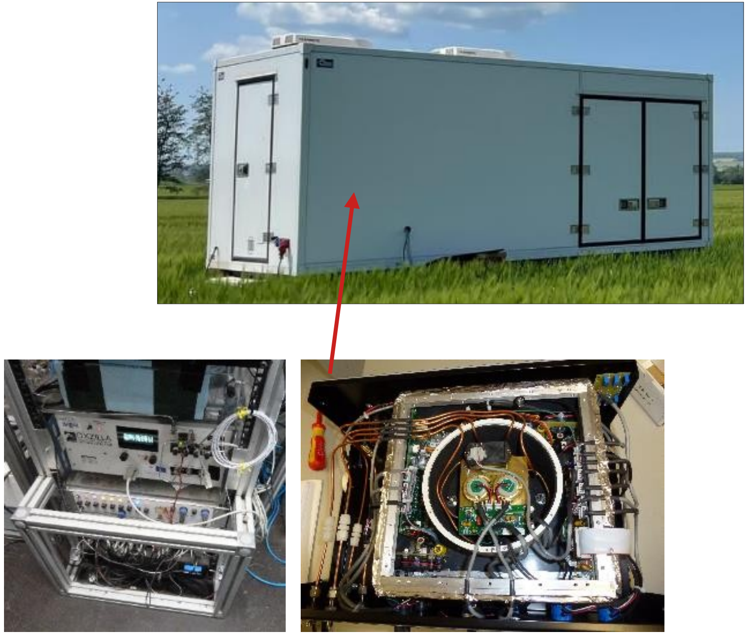
O_2 and CO_2 measurements





FC-2 Differential Oxygen Analyzer (Oxzilla)

O_2 and CO_2 measurements

3 m
1 m
0.5 m

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LI-820 CO_2 gas analyser (LI-COR)

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'Blue-box' with calibration cylinders

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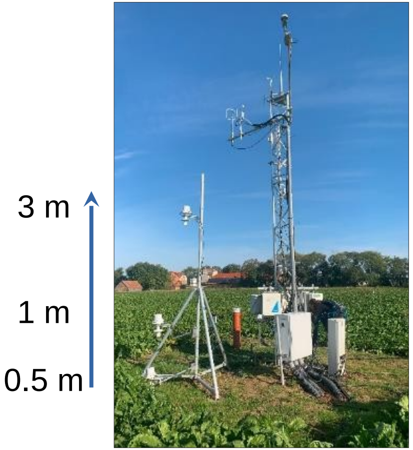


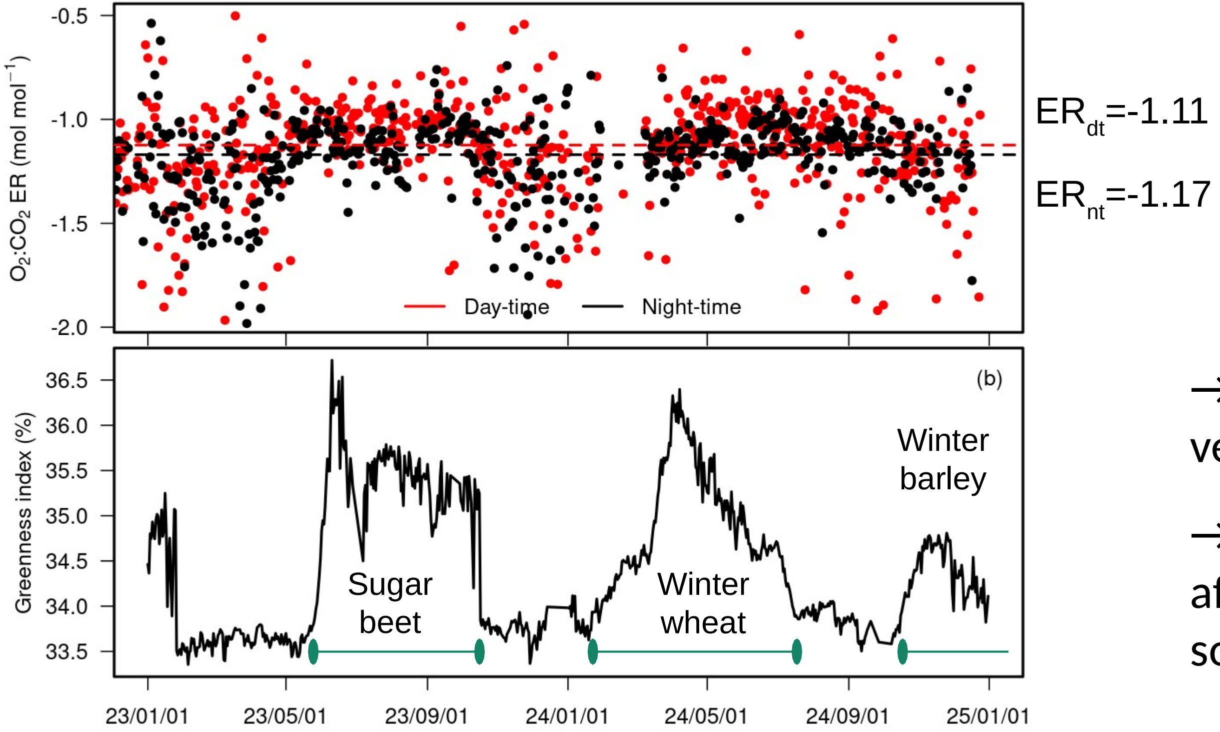
‘Blue-box’ with calibration cylinders

FC-2 Differential Oxygen Analyzer (Oxzilla)

LI-820 CO_2 gas analyser (LI-COR)

- Air dried < 1 ppm H_2O_v
- Flow rate: 0.1 lpm
- Each height measured for a duration of 10 minutes

Daily O_2:CO_2 exchange ratios and greenness index

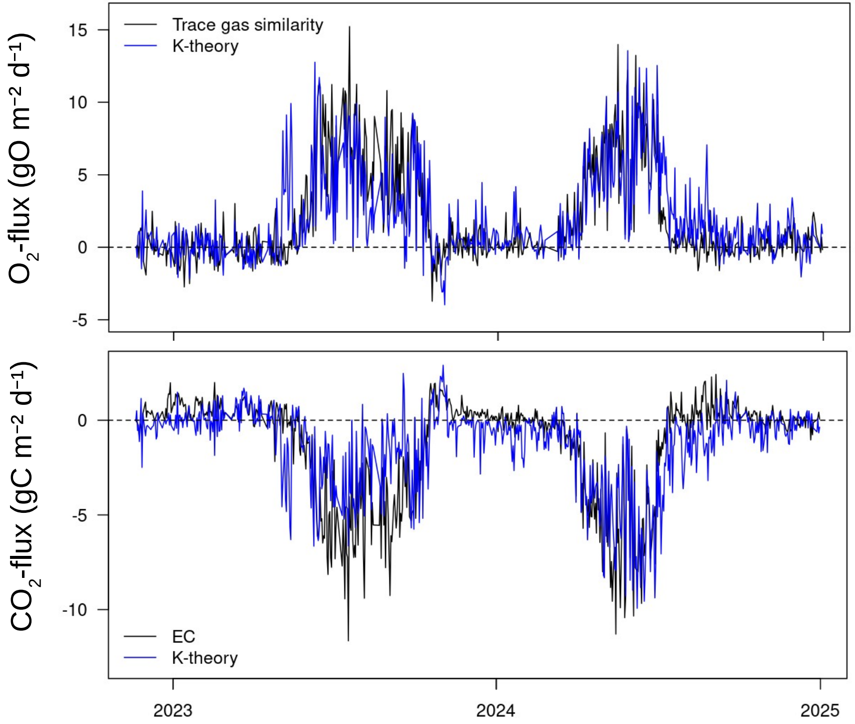


ER based on **slope** between mole fractions (top height)

→ ER ~ -1.0 during vegetation period

→ winter time ER probably affected by fossil fuel sources

Daily O_2 and CO_2 flux estimates



→ O_2- and CO_2 fluxes are negatively correlated

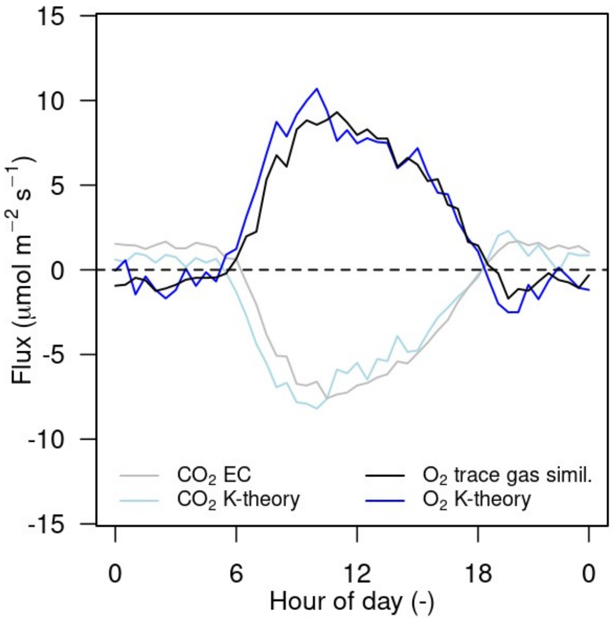
→ O_2-flux from K-theory shows lower O_2 fluxes than O_2-flux from trace gas similarity (Slope=0.88, R^2=0.61)

→ CO_2-flux from K-theory indicates lower CO_2 uptake than EC (Slope=0.74, R^2=0.61)

Mean diel cycles of fluxes and ER

Entire study period: 2023 and 2024

fluxes



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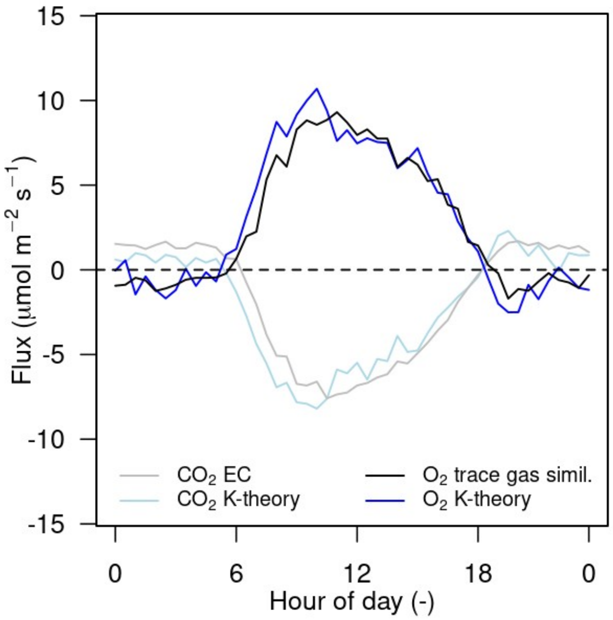
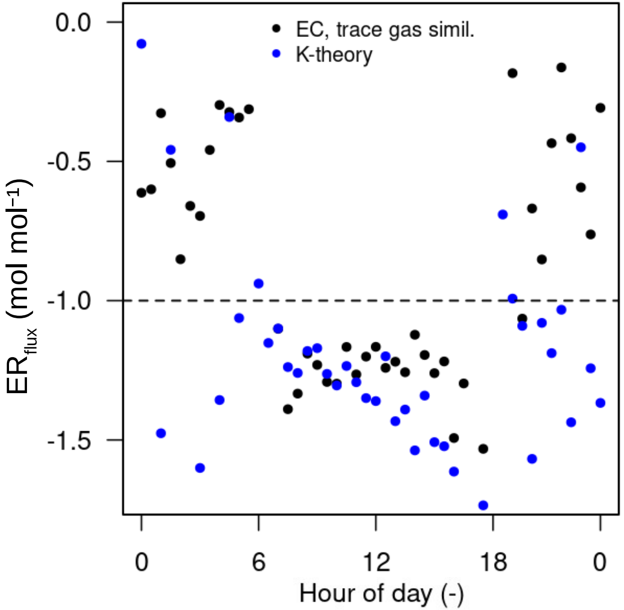
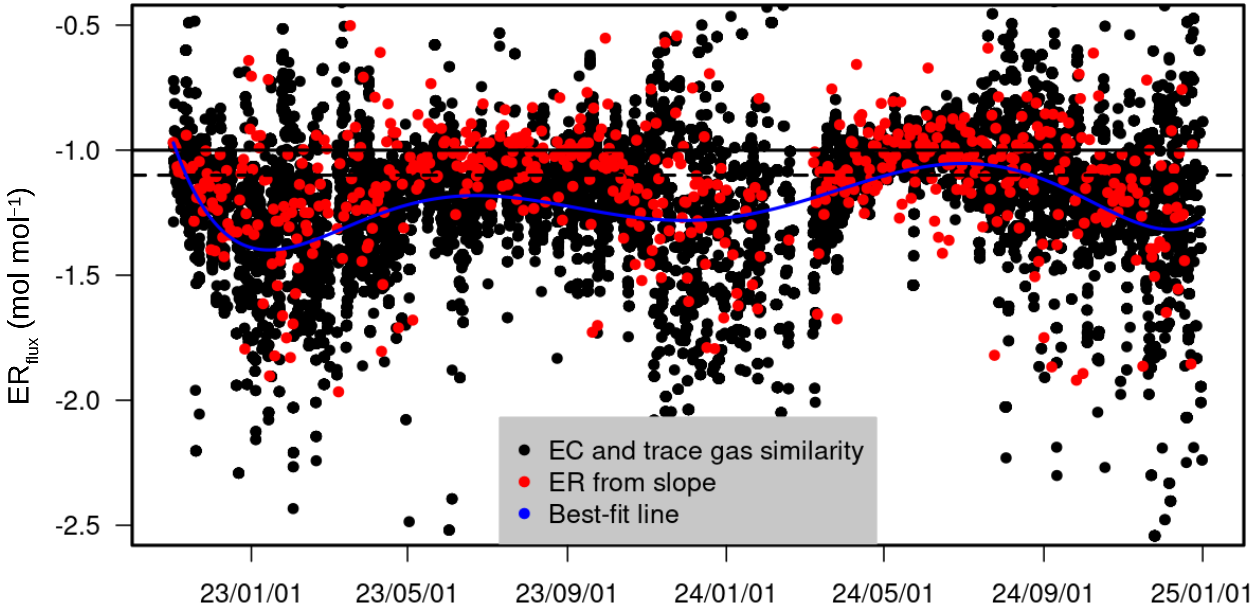


ER_{flux}



Half-hourly O_2:CO_2 flux exchange ratios

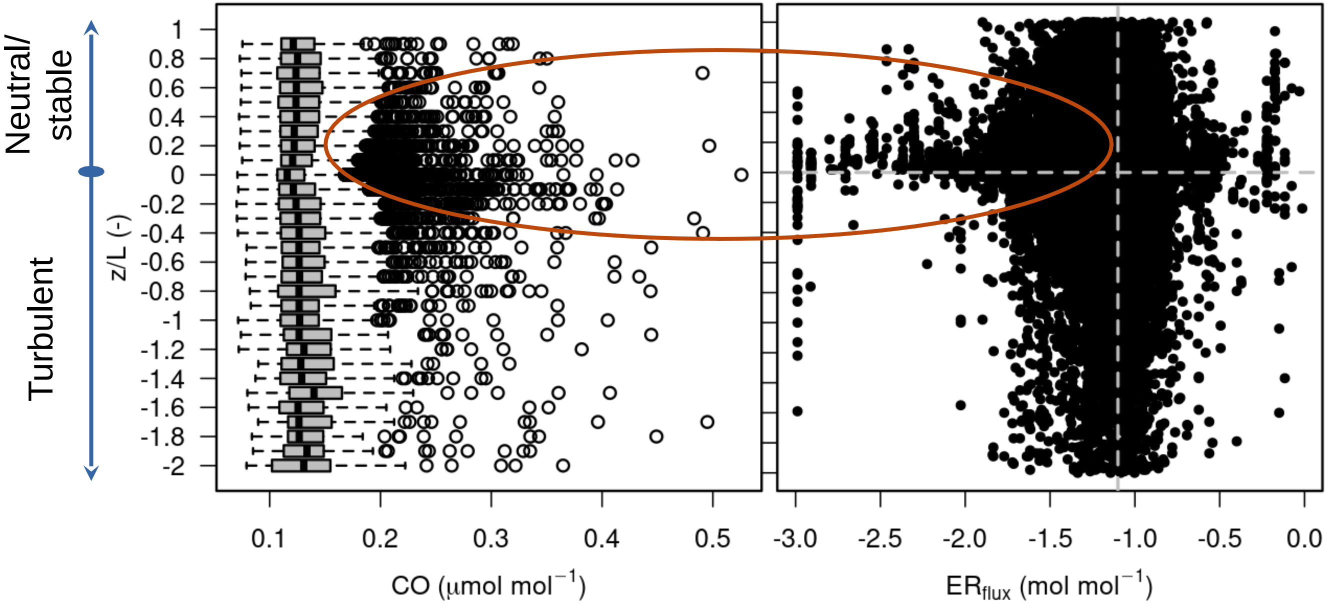


ER based on **flux** estimates (running median) and **slope**

→ ER_{flux} and ER show similar trend

→ But, what about low negative ER?

Stability vs. CO mole fraction and ER measurements



→ CO mole fraction highest during neutral/ stable stratification

→ ER_{flux} < -1.5 corresponds to near neutral/ stable conditions

=> measurements were potentially influenced by anthropogenic emissions and/or low fluxes

Conclusions

- High-precision O_2 continuous measurement are possible at agricultural field
- O_2 and CO_2 fluxes anticorrelated
- Obtained ER comparable to literature for forests
- Summertime ER more robust and at an expected range
- Wintertime ER has large scatter and potentially affected by fossil fuel sources and/or low fluxes

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Acknowledgements

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GEFÖRDERT VON

Niedersächsisches Ministerium für Wissenschaft und Kultur

European Research Council
Established by the European Commission

ERC CoG Oxyflux

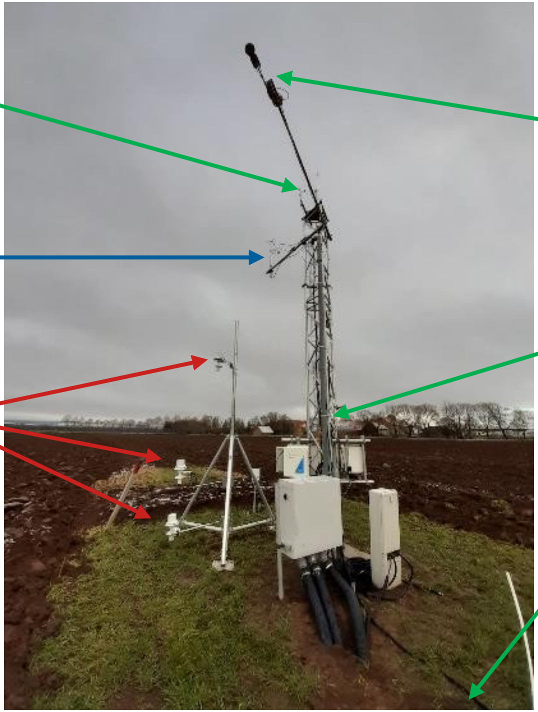
Measurements

Air-conditioned trailer

wind speed and wind direction

eddy covariance of N_2O, CO_2, H_2O, water isotopes and energy fluxes

O_2, CO_2 and H_2O mole fractions at 0.5, 1 and 3 m

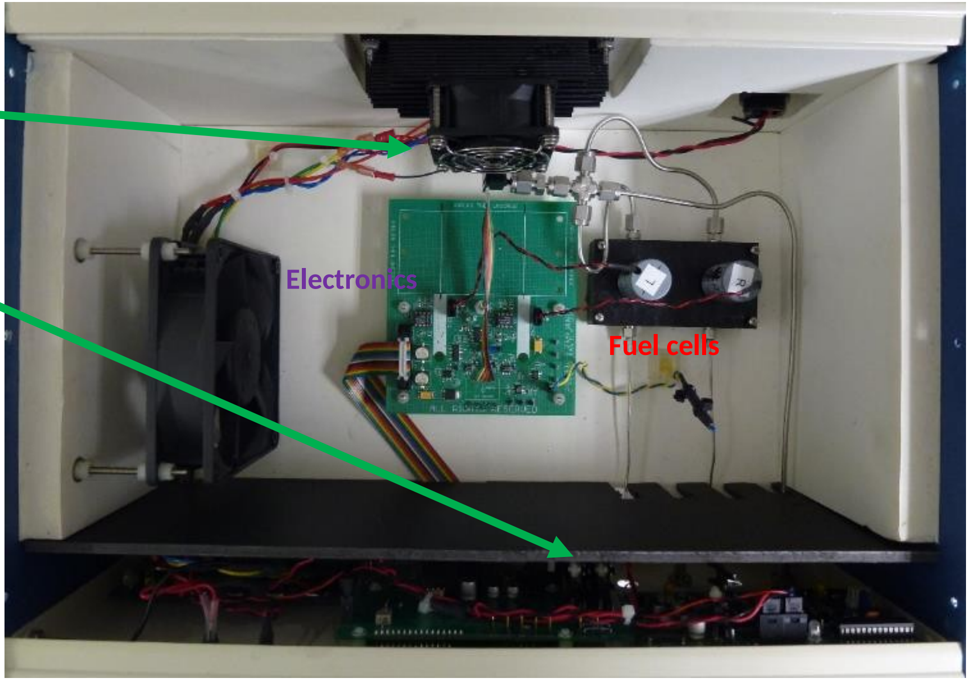


radiation (LW, SW, diffuse, PPFD)

air temperature, humidity and pressure

soil temperature, moisture and heat flux

O_2 fuel cell analyser measuring principle



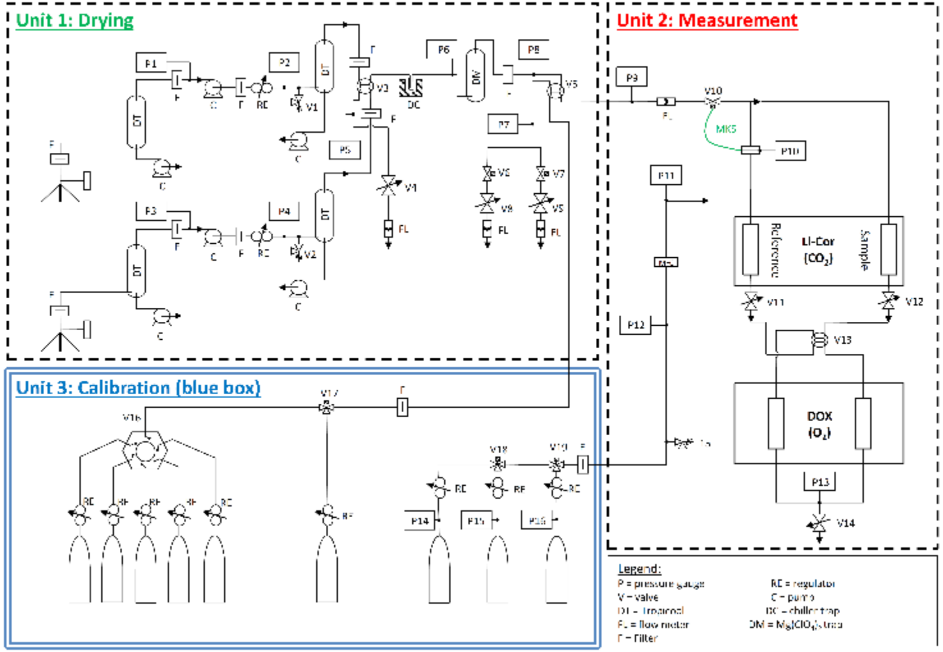
The analyser uses **<u>fuel cell</u>** technology to measure **<u>O_2 mole fraction</u>** via **<u>electrochemical reactions</u>** within the cells:

$O_2 + 4H^+ + 4e \rightarrow 2H_2O$ [cathode]

$2Pb + 2H_2O \rightarrow 2PbO + 4H^+ + 4e$ [anode]

where the change in potential difference between the anode and cathode is proportional to the partial pressure of O_2 in the air stream.

O_2 and CO_2 complete measurement system



Three units
- Drying unit
- Measurement unit
- Calibration unit

O_2 ‘per meg’ unit

We report O_2 concentrations as O_2/N_2 ratios

- assume N_2 is constant
- introduce a new unit: ‘per meg’

per meg is defined as:

$$\delta(O_2/N_2) = \left(\frac{(O_2/N_2)_{sample} - (O_2/N_2)_{ref}}{(O_2/N_2)_{ref}} \right) \times 10^6$$

Why do we use this?

- because O_2 mole fraction is affected by variability in other trace constituents

‘Zero’ per meg defined arbitrarily as O_2/N_2 value in an air sample in 1988.

For comparison purposes (to compare per meg O_2 with ppm CO_2),

4.8 per meg O_2 1 ppm CO_2

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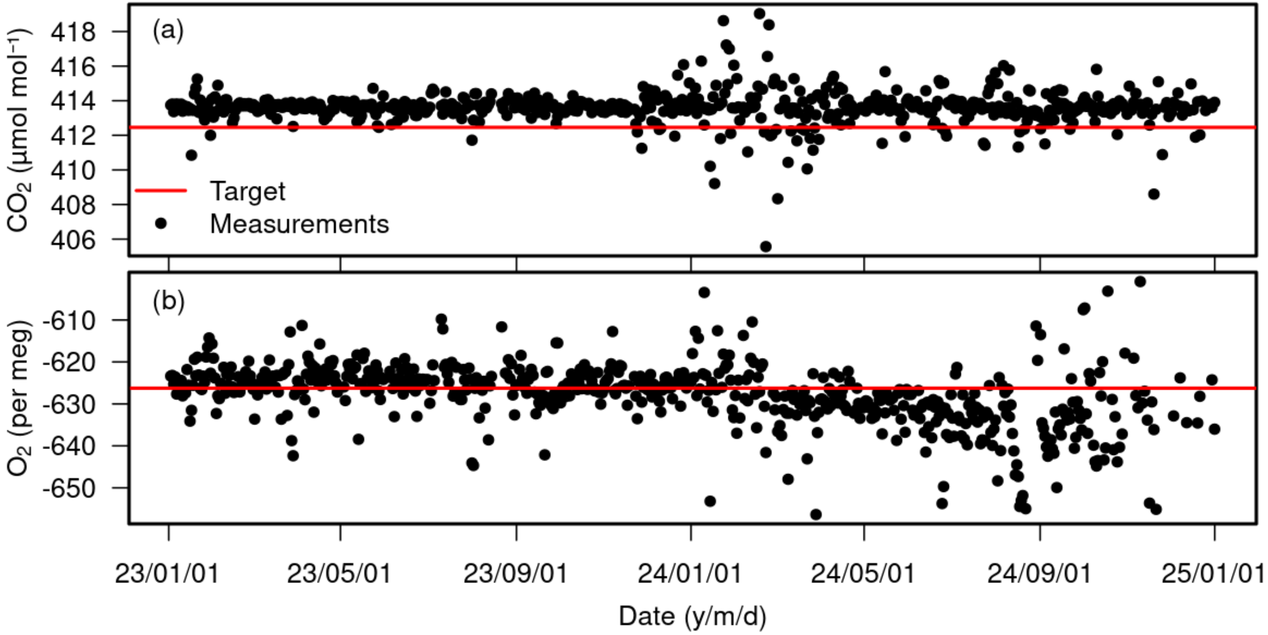
Instrument performance

Target tank measured every 26 hours



target tank

CO_2

Precision: 0.44 ppm

Accuracy : 1.12 ppm

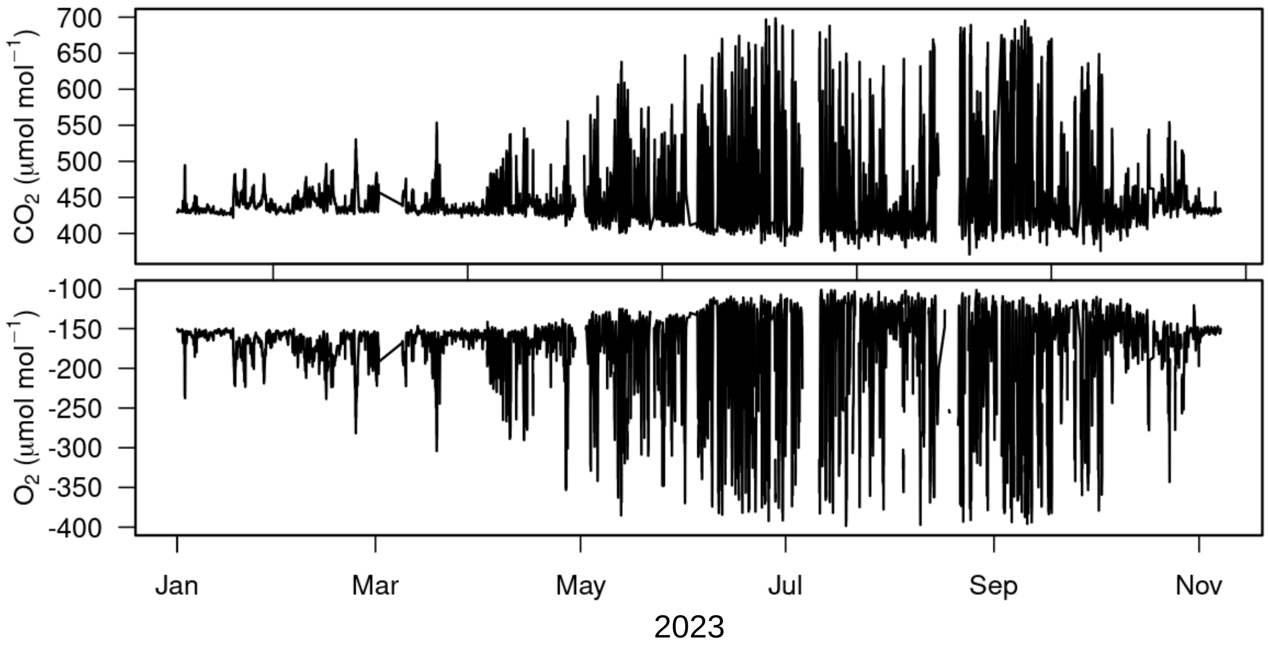
target tank

O_2

Precision: 0.67 ppm eq.

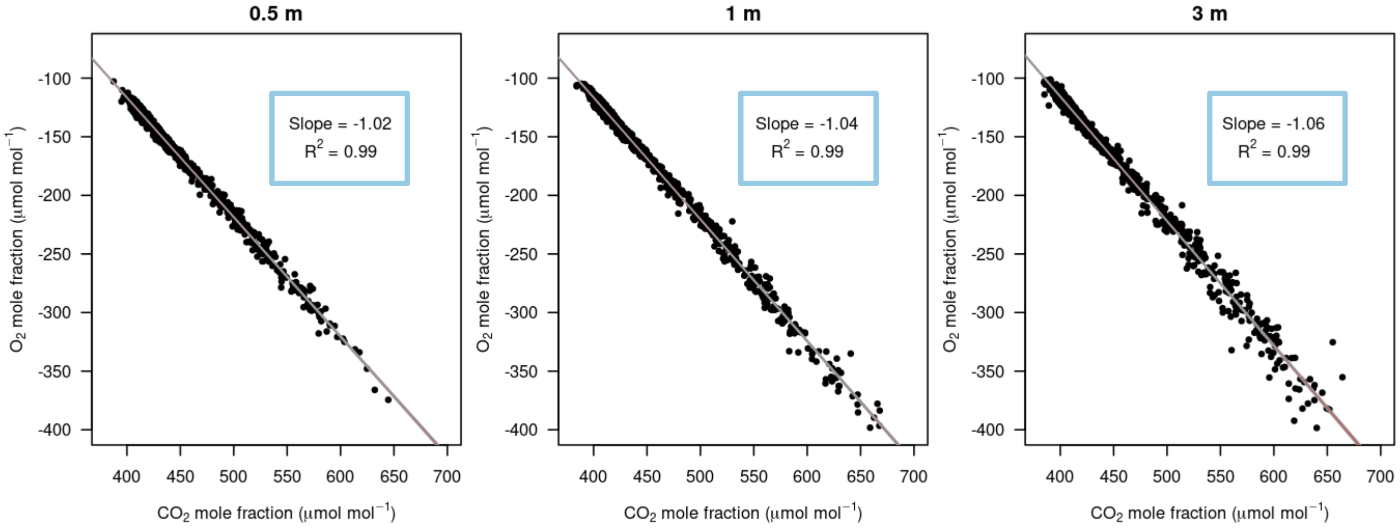
Accuracy : 0.27 ppm eq.

Timeseries of O_2 and CO_2 mole fractions



→ O_2 and CO_2 mole fractions are anticorrelated

Exchange ratios from O_2 and CO_2 mole fraction July 2023

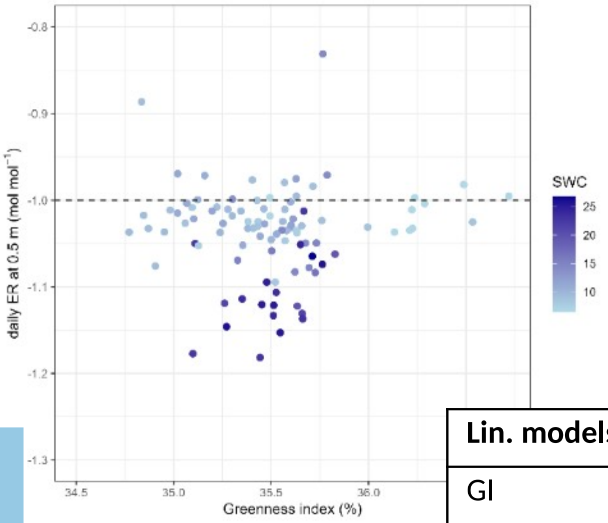


ER based on **slope** between mole fractions

→ O_2:CO_2 exchange ratio of -1.02 to -1.06 mol mol^{-1},
similar to other studies in forests (Ishidoya et al. 2013, Battle et al. 2019, Faassen et al. 2023)

Daily O_2:CO_2 exchange ratios during the vegetation period

ER – Jun-Sep



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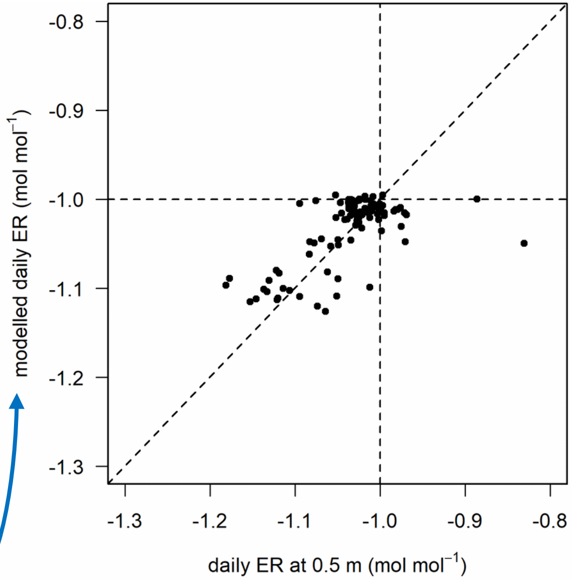
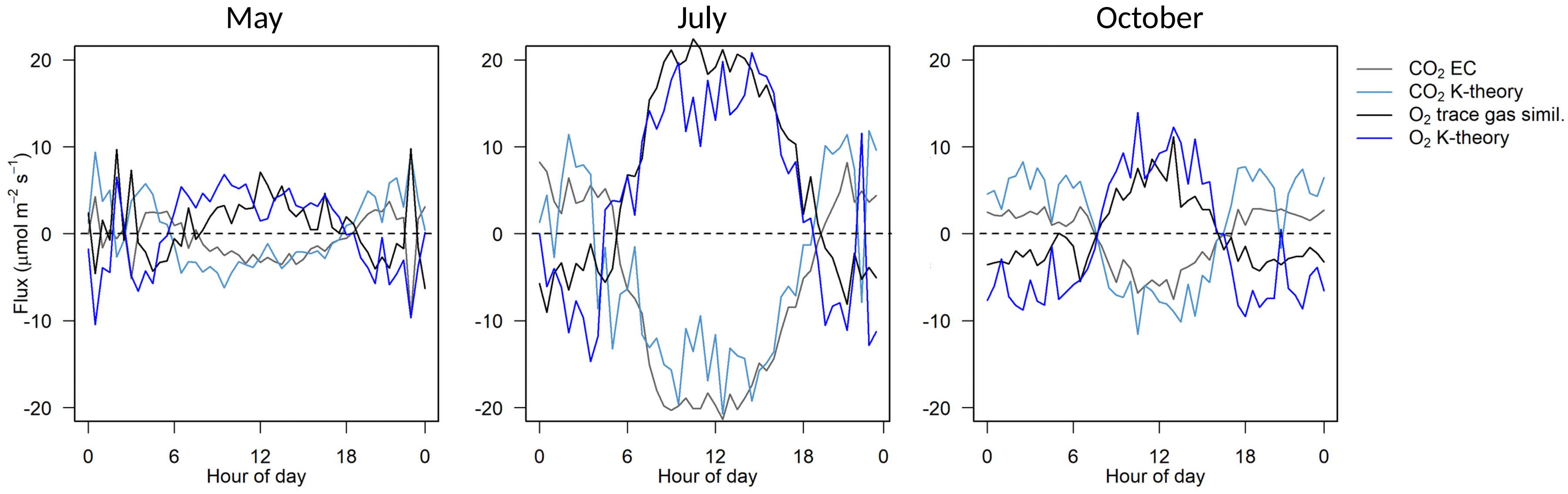


ER based on **slope** between mole fractions

Lin. models	**R^2**
GI	0.004
SWC	0.307
GI + SWC	0.317

GI : greenness index
SWC: soil water content

Mean diel cycles of fluxes for various months



Mean diel cycles of O_2:CO_2 exchange ratios for various months