Leaf transpiration compared with tree stem sap flux and water usage of old growth Quercus robur under elevated CO2

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Baseline 2015/16

eCO_2 2017-2026

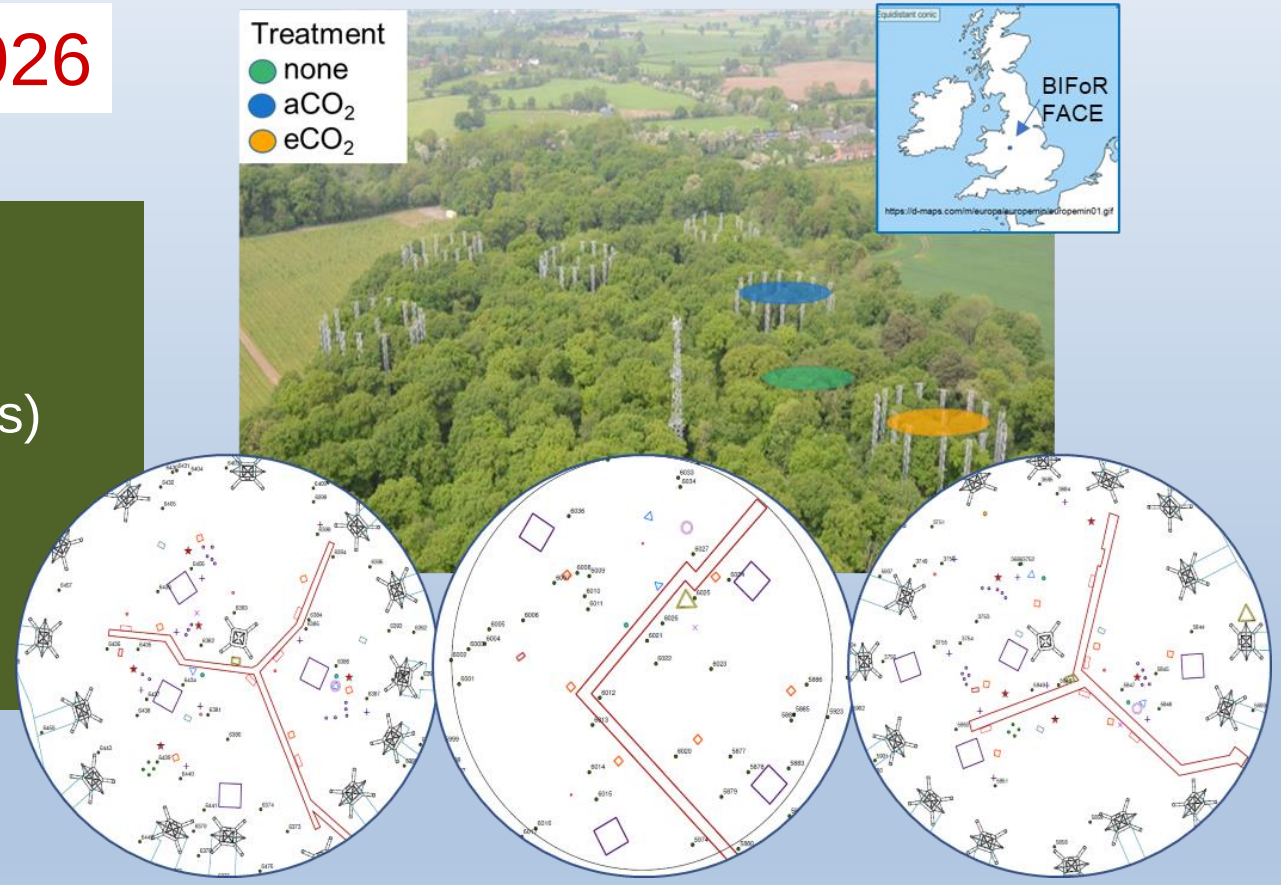
Free-Air Carbon-dioxide Enrichment (FACE)

3 no-infrastructure ambient-air (natural/ ghost arrays)

3 ambient-air infrastructure FACE rings

3 FACE treatments of +150 ppmv CO_2

https://www.birmingham.ac.uk/research/bifor/face/index.aspx



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Acknowledgements:
BIFoR FACE Operations Team and colleagues.

Research Questions

Q1: How does elevated CO_2 influence daily leaf level transpiration?

Q2: Is peak daily leaf transpiration synchronised between oak trees and with stem sap flux dynamics?

Key Measurements

Leaf temperature & transpiration

Sap flow & canopy transpiration

Soil moisture & temperature

Winter

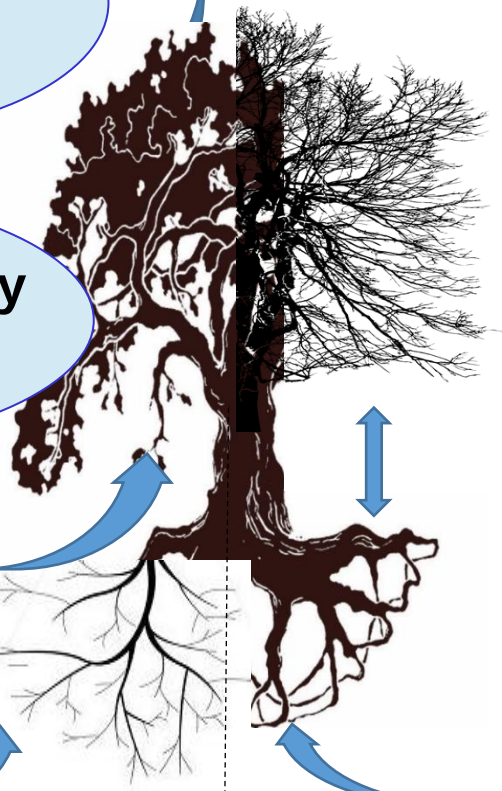

Photo K M Hart

Summer

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Sharing is encouraged

Leaf transpiration measurements - Method

Canopy Access System (CAS) used to access top canopy of selected oaks throughout the treatment season April to October using:

Infrared thermometer
-Leaf temperature

Porometer - stomatal conductance

***Porometer benefits*:**

- Short time per measurement (30s)
- Lightweight

Toro et al (2019)

***Porometer limitations*:**

- RH >80%
- Large differences in leaf and air temperatures
- No auto capture of environmental factors

***Infra-red gas analyzer (IRGA) limitations*:**

g_s in the enclosed chamber may be much reduced under high VPD

Longer measurement time

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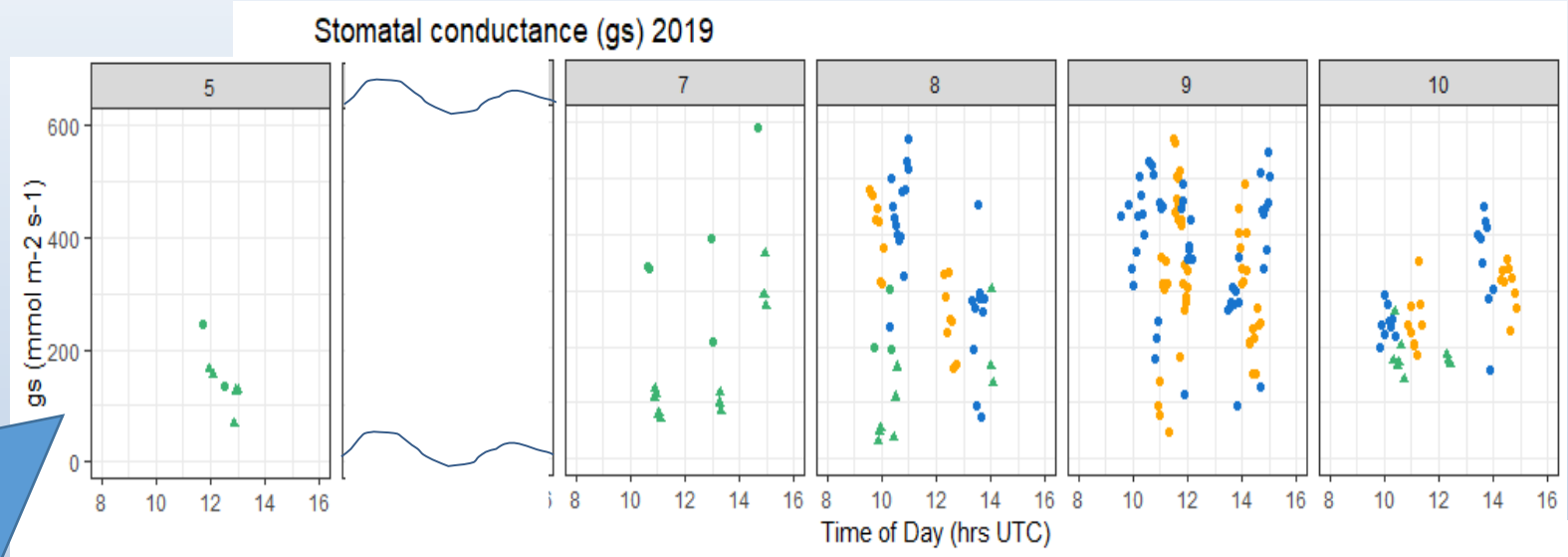
1. Data visualization of stomatal conductance (g_s) 2019, 2020

Data visualisation :

Stomatal conductance peaks around midday

Light levels, air temperature and relative humidity in top canopy vary widely giving a range of results

Cut twig measurement mostly lower than in-situ



Outdoor Lab notes:

We cannot control the natural environment in this FACE experiment, only the eCO_2.

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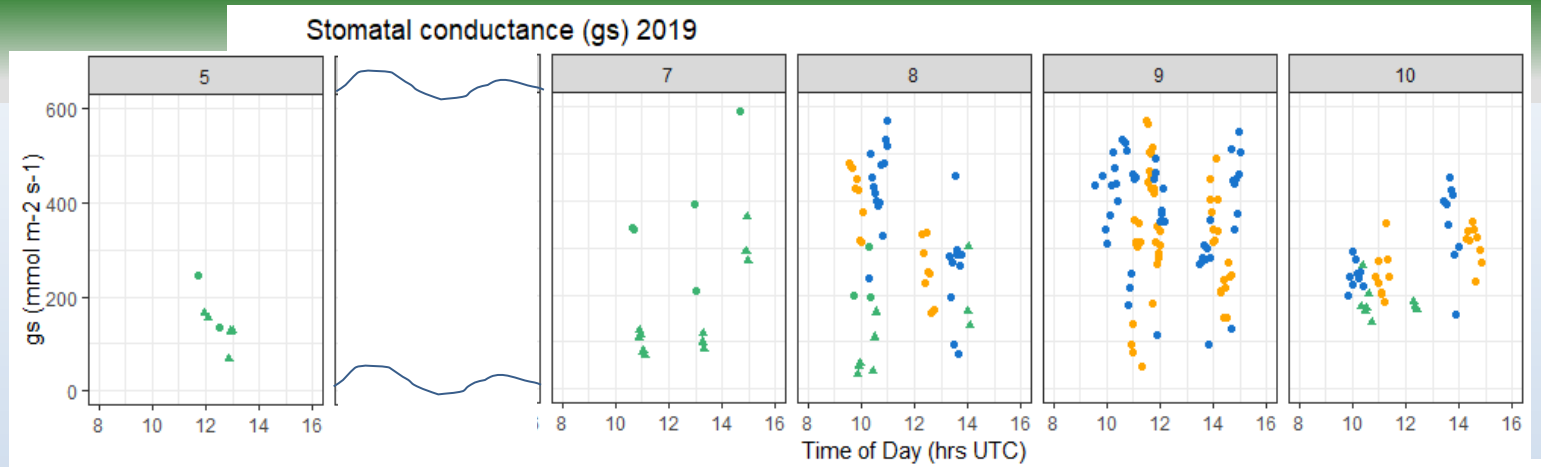
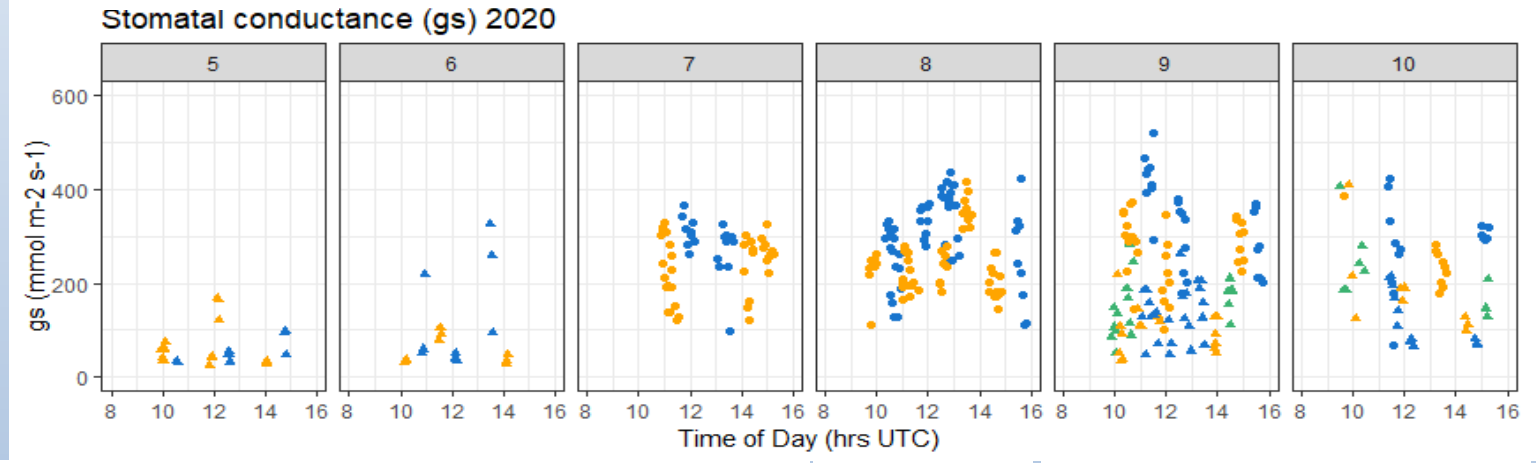
2. Data visualization of stomatal conductance (g_s) 2019- 2021

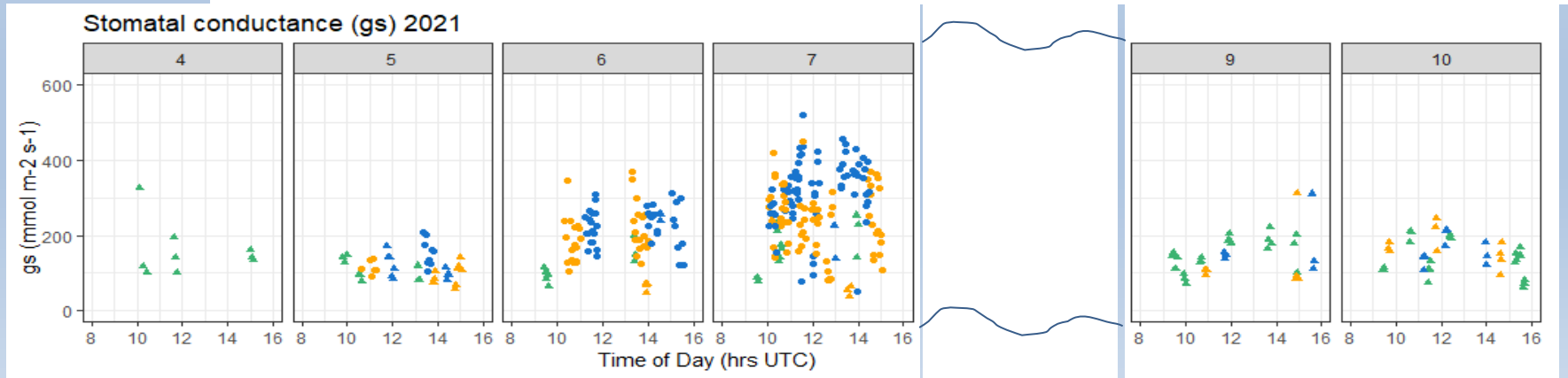
Annual and season variation

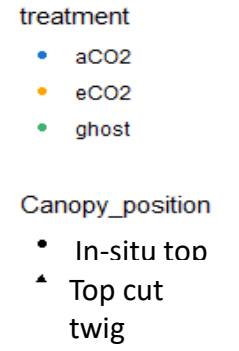
Stomatal conductance max- min range similar for infrastructure treatments (eCO_2 and aCO_2)

Highest stomatal conductance during months of July (2021), August (2019) and September (2019, 2020)



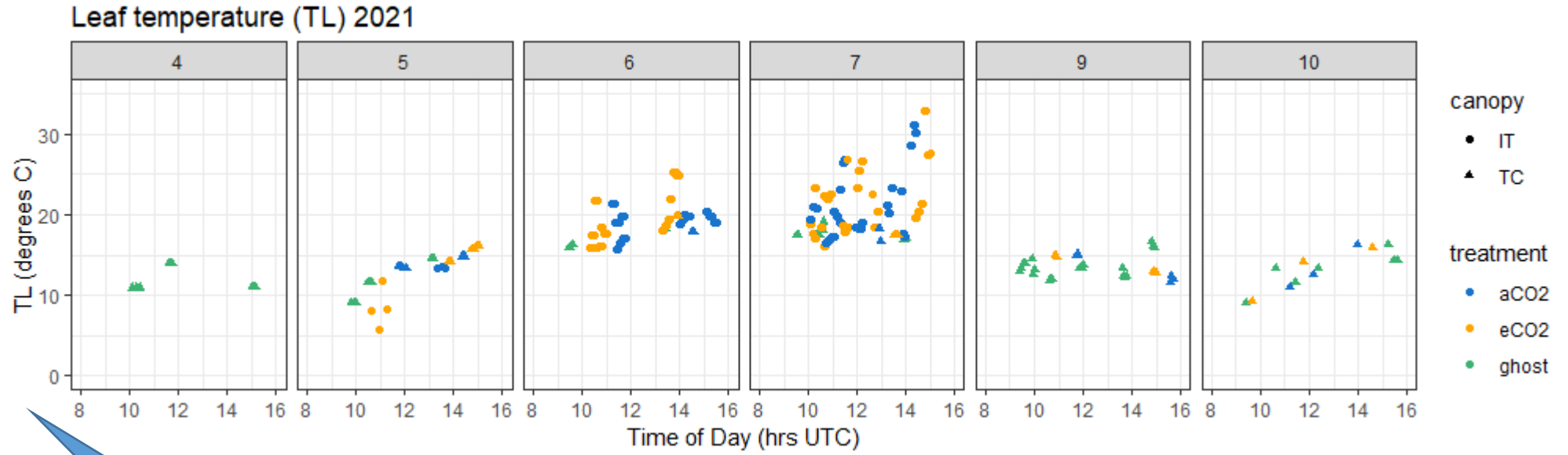






Outdoor Lab note 2:
The cut twigs experience different light levels and air temperature/ RH.

3.Leaf temperature treatment comparisons – example 2021



Is this an example of thermoregulation? Further data analysis & air v. leaf temp comparisons for data 2019- 2021 for oaks & other species …

Annual and season variation

Leaf temperature during the middle of the day does not vary widely across the treatment season April to October (example 2021). On a daily basis it increases with time of day during no precipitation periods.

Values are similar for all treatments (eCO_2, aCO_2 and no infrastructure – ambient air (ghosts)) circa 9 to 35 degrees C) peaking in July for 2021.

N.B. no August 2021 measurements

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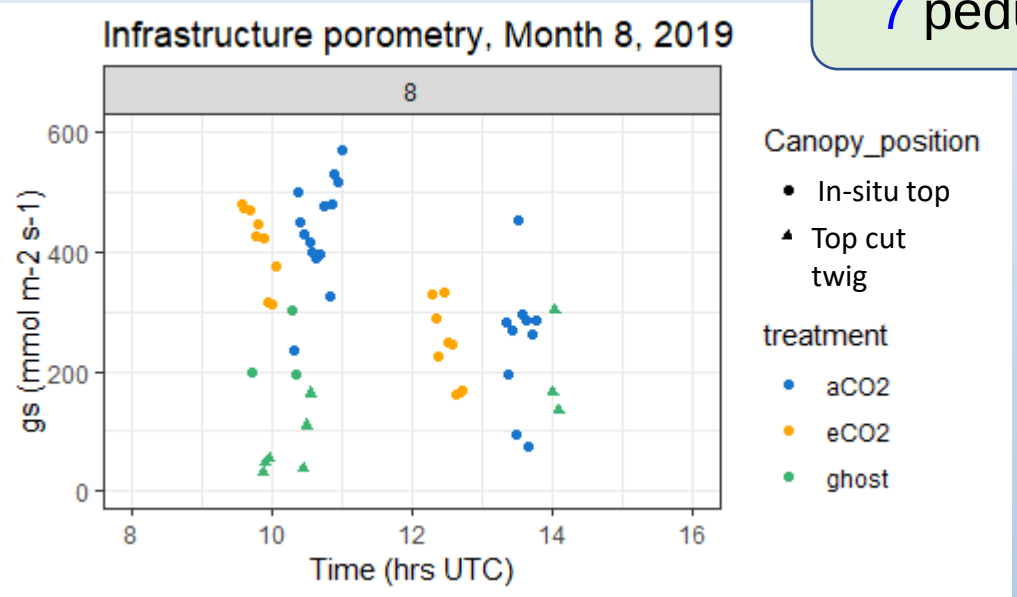
4. Stomatal conductance in mores detail and tree sap flux/ water usage comparisons

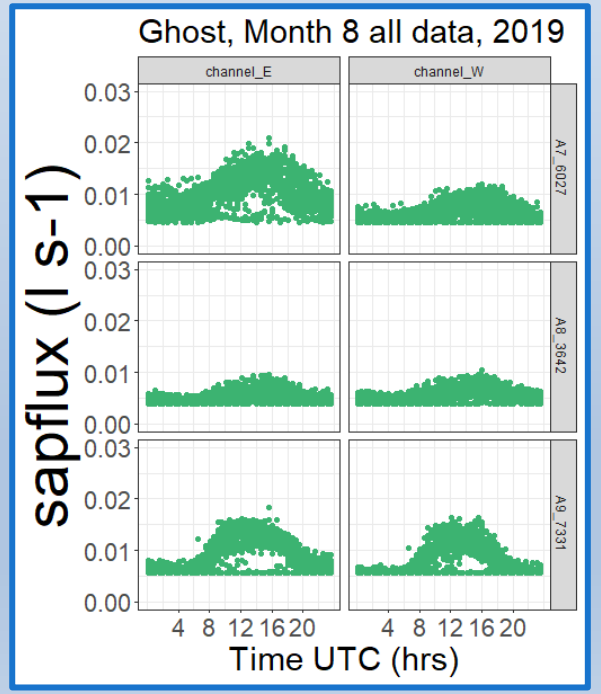
Quick et al. (in prep)

Leaf stomatal conductance – all August 2019 measurements superimposed .

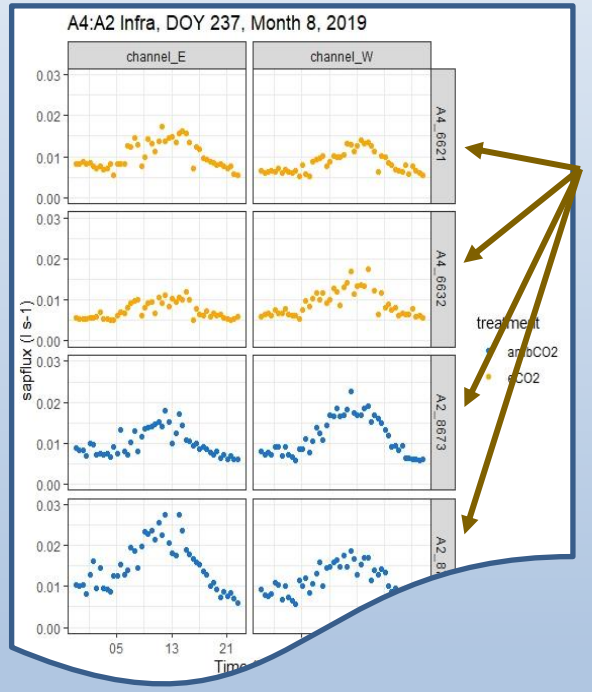


Porometry data from 7 pedunculate oak

One month Superimposed



Single day.



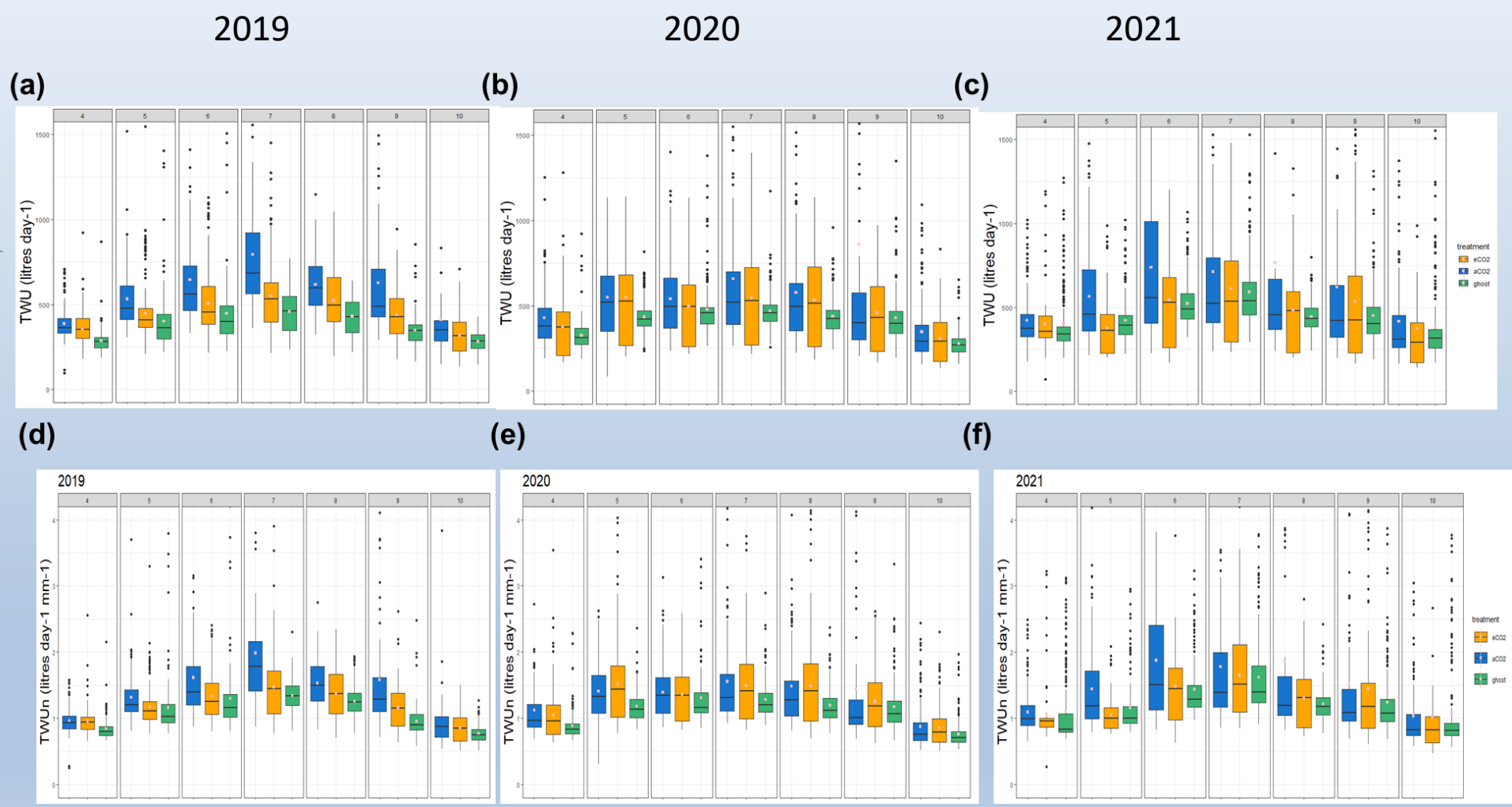
Sap flux data examples

Recap – Tree water usage (TWU) treatment comparisons 2019 to 2021

Annual / seasonal whole tree water usage / tree transpiration

Stomatal conductance / leaf transpiration?

Canopy density, leaf number, leaf temperature, incident radiation and VPD will vary by season and year across all trees.



Tree water usage -normalised by tree radius

Quick et al. (in prep)

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Leaf transpiration calculations from stomatal conductance g_s.

Calculation 1

Leaf transpiration [E] = **stomatal conductance** (g_s) x **differential molecular water vapour** ($C_{VS} - C_{VA}$)

g_s total conductance of water from inside the leaf into the ambient air
C_{VS} intercellular water vapour mole fraction
C_{VA} ambient (in air) water vapour mole fraction

Refs. Keenan et al. (2013), Meter Group (metergroup.com) (2023)

Calculation 2

Leaf transpiration [E] = g_s * VPD_L

Leaf vapour pressure deficit (VPD_L) = LSVP – (AVSP * RH /100)

AVSP air saturated vapour pressure
LSVP leaf saturated vapour pressure
RH is relative humidity in %

FACE Met Towers Measurements:

- *RH, air_temp*

From which we calculate SVP(at air temp), AVP: (i.e. saturated and actual air vapour pressure)

Other measurements:

- T_L – leaf temperature (using an infrared thermometer IRT)
- T_a – air temperature (measured at top canopy each INF array)

NEXT STEPS
Further data analysis & transpiration calcs. in progress from data 2019-2021 for oaks & other species.

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Why is this important? Interim results and conclusions Q1

Quick et al. (in prep)

Q1: How does elevated CO_2 influence daily leaf level transpiration?

We explored variation of stomatal conductance and leaf temperature across the eCO_2 treatment season – the diurnal cycles imply a likely effect of eCO_2 on stomatal conductance measured by porometry.

We will now do leaf transpiration calculations and analysis using leaf VPD to make scientific correlative comparisons between treatments.

'For DAF (*deciduous trees*) we found…no effect (of leaf-air VPD)… on the response of g_s (to eCO_2)'
Gardner, A. et al (2023) New Phytologist

'Stomatal responses are similar whether leaf water status is altered via evaporative demand (a) or water supply (b)…'
Buckley, T. N. (2016) Plant, Cell & Environment

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Why is this important? Interim results and conclusions Q2

Quick et al. (in prep)

Q2: Is peak daily leaf transpiration synchronised between oak trees and with stem sap flux dynamics?

We explored our 2019-2021 sap flux and porometry data:
We conclude that… calculating whole tree sap flux from field sap flow presents a better way of averaging the diurnal, seasonal and annual dynamics of canopy level stomatal conductance compared with labour intensive field leaf measurements

'For DAF (*deciduous trees*) we found…no effect (of leaf-air VPD)… on the response of g_s (to eCO_2)'
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Thank you for reading my supplement. Questions welcomed by email or at EGU23.

Photo by Willbee Films

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