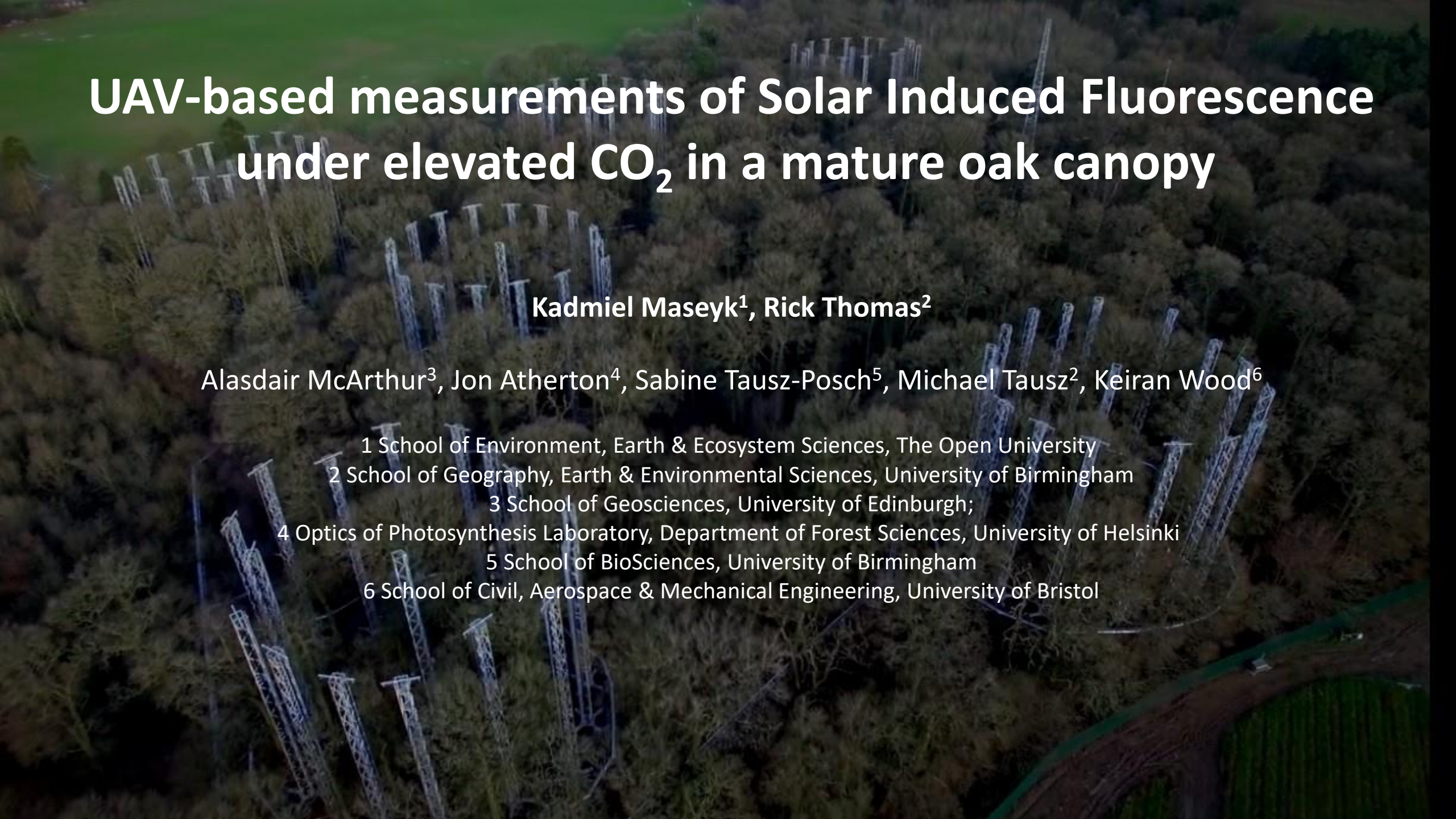

UAV-based measurements of Solar Induced Fluorescence under elevated CO_2 in a mature oak canopy

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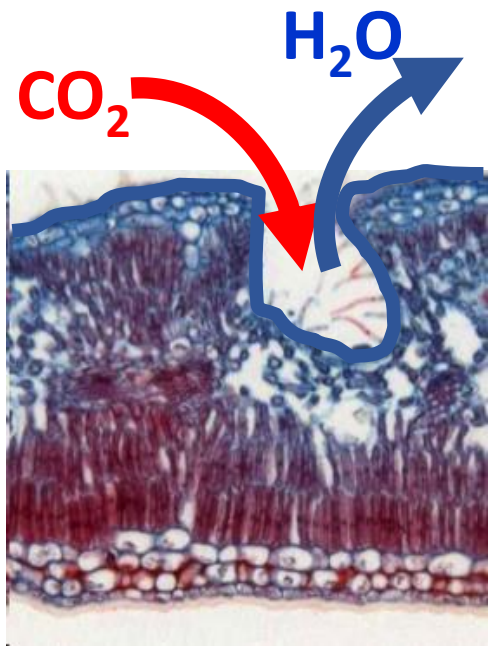
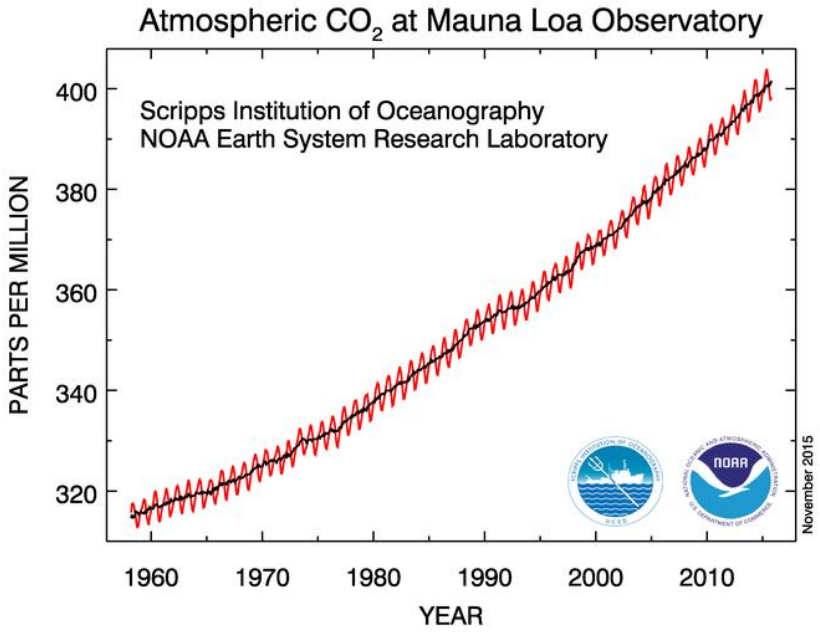
Motivation

The photosynthetic responses to elevated CO_2 is key in the cascade of responses across ecosystem carbon, water and nutrient cycles under elevated CO_2

How much, when, impacts of climatic extremes

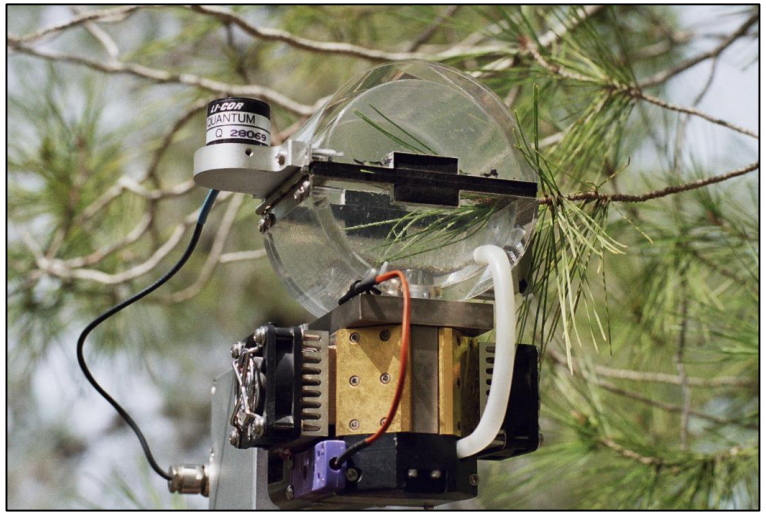




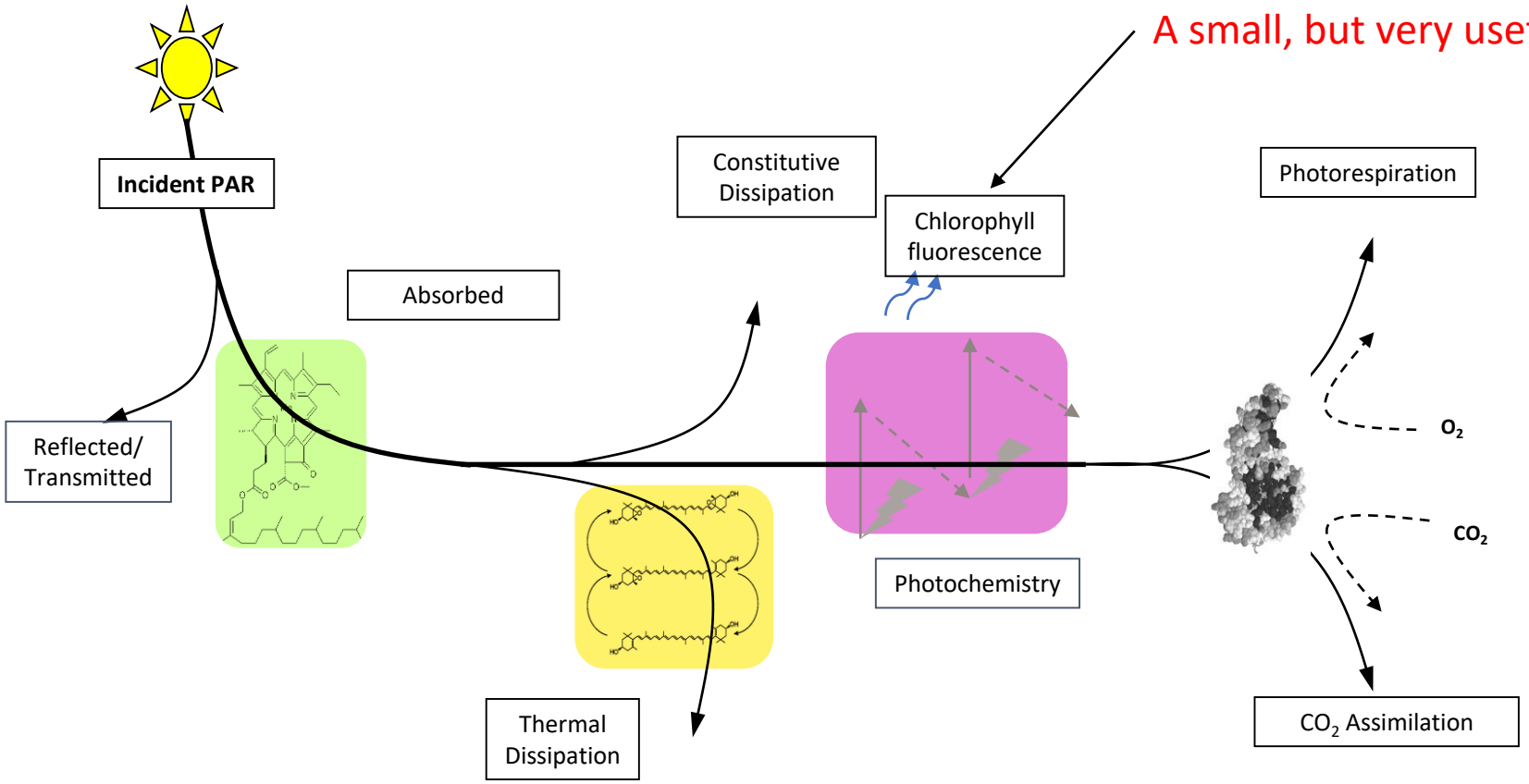
Challenge

Obtaining an integrated, canopy-level measure of photosynthesis at the ‘array’ scale

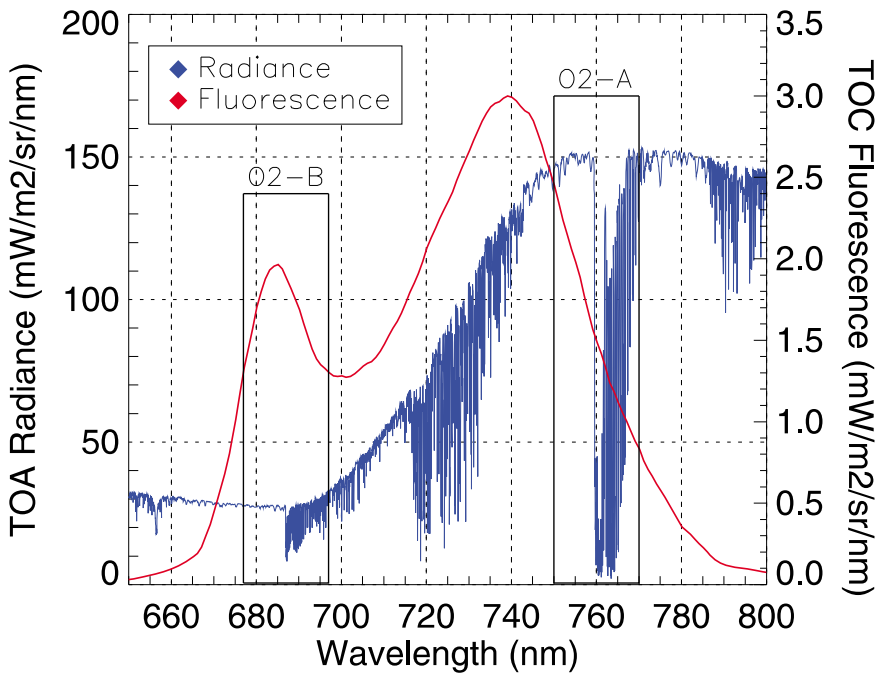
- Link the detailed process information from leaf scale to the canopy scale



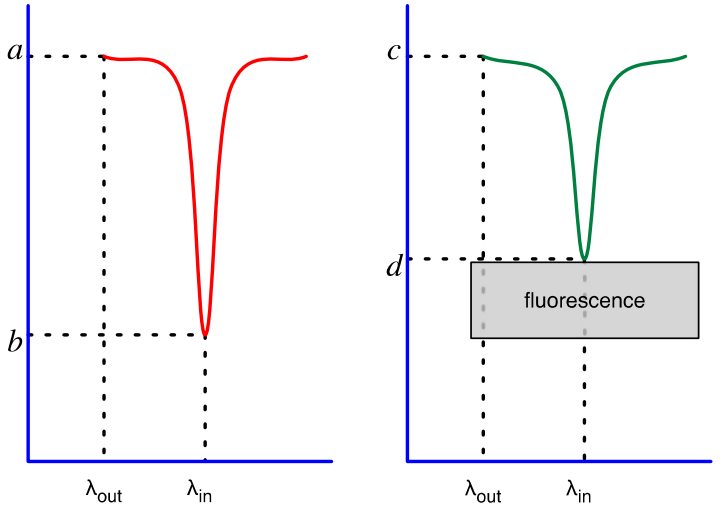
The process of photosynthesis



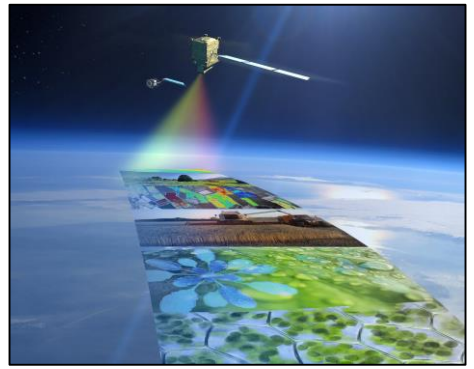
Fluorescence emission spectrum adds to surface reflectance signal



Guanter et al 2010



Gomez Chova et al 2006

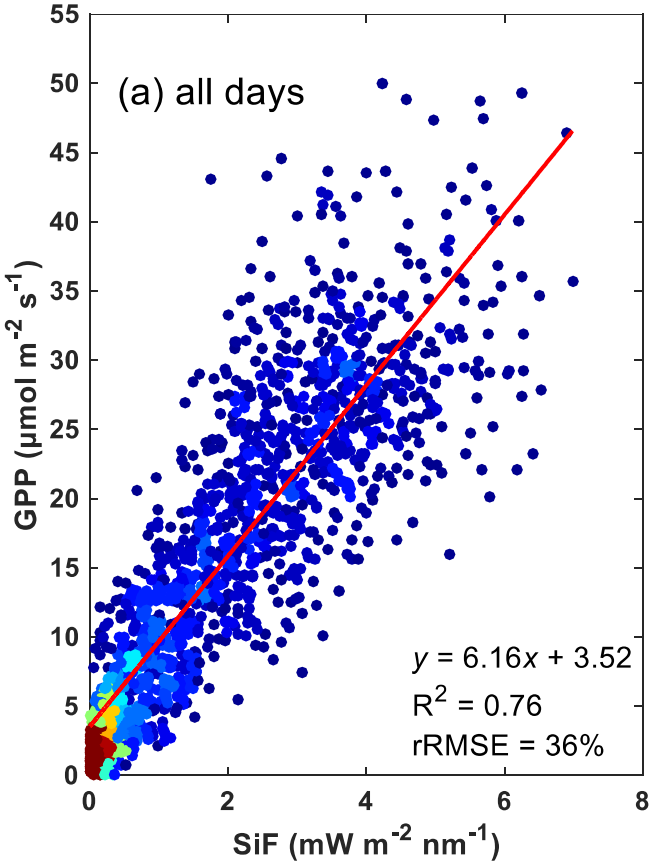


Spectral infilling of the spectrum by Solar Induced Fluorescence

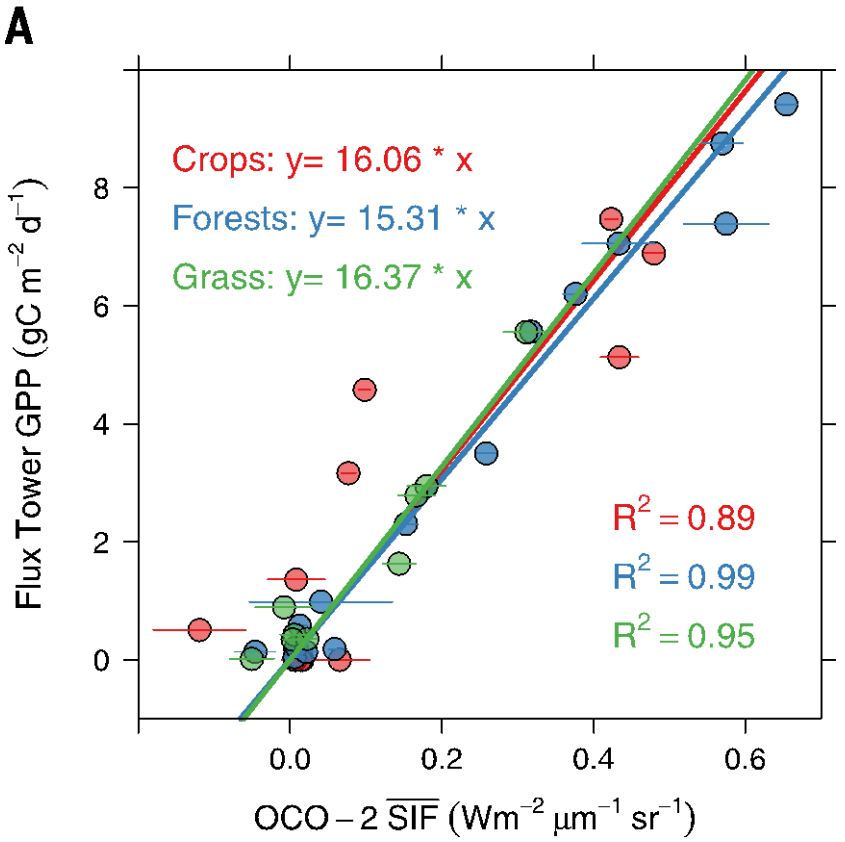
Measure of photosynthesis across scales

Use SIF to estimate photosynthesis (GPP) across scales

GPP ~ SIF x ΦF



Yang et al 2018 RSE



Sun et al 2017 Sci

Canopy scale, rice paddies

Ecosystem scale, satellite data

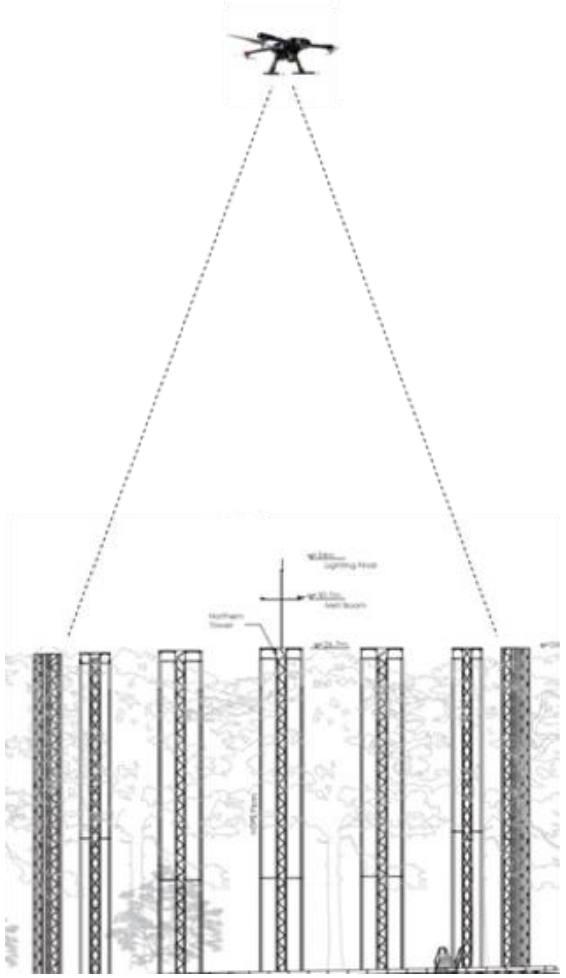
Goal

Can we get canopy-level photosynthesis information at ‘ring-level’ from UAV-based measurements of Solar Induced Fluorescence?

Can we detect SIF from a UAV platform?

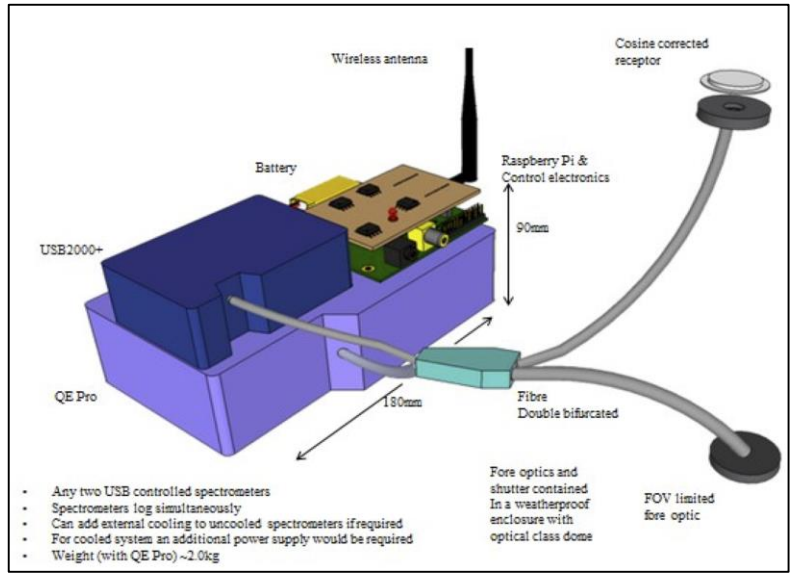
Do we see diurnal/environmentally driven changes?

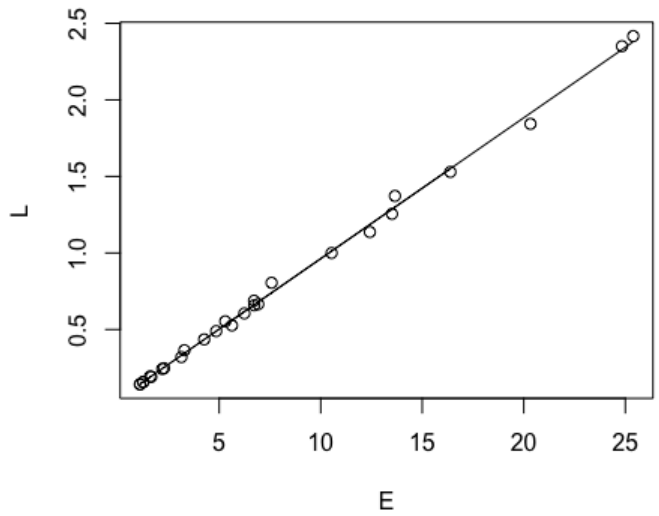
Do these differ between treatments?



Measurement set-up

- Piccolo Doppio dual-field-of view spectrometer system (QEPro: 0.1 nm band width, 0.3 nm FWHM, 640 – 800 nm)
- Matrice 600 Pro UAV
- Three flight campaigns (June, August, October).
- Height of 35m above the canopy
- SIF calculated in the 760 O_2-A band following Meroni et al (2006) spectral fitting approach





Campaigns between Sept ‘17 – Oct ‘18

Sept 2017 – first trials. Measured all rings at least once in the day

June 2018 – 8 flights of all rings over two days*

July 2018 – two complete flights on one day

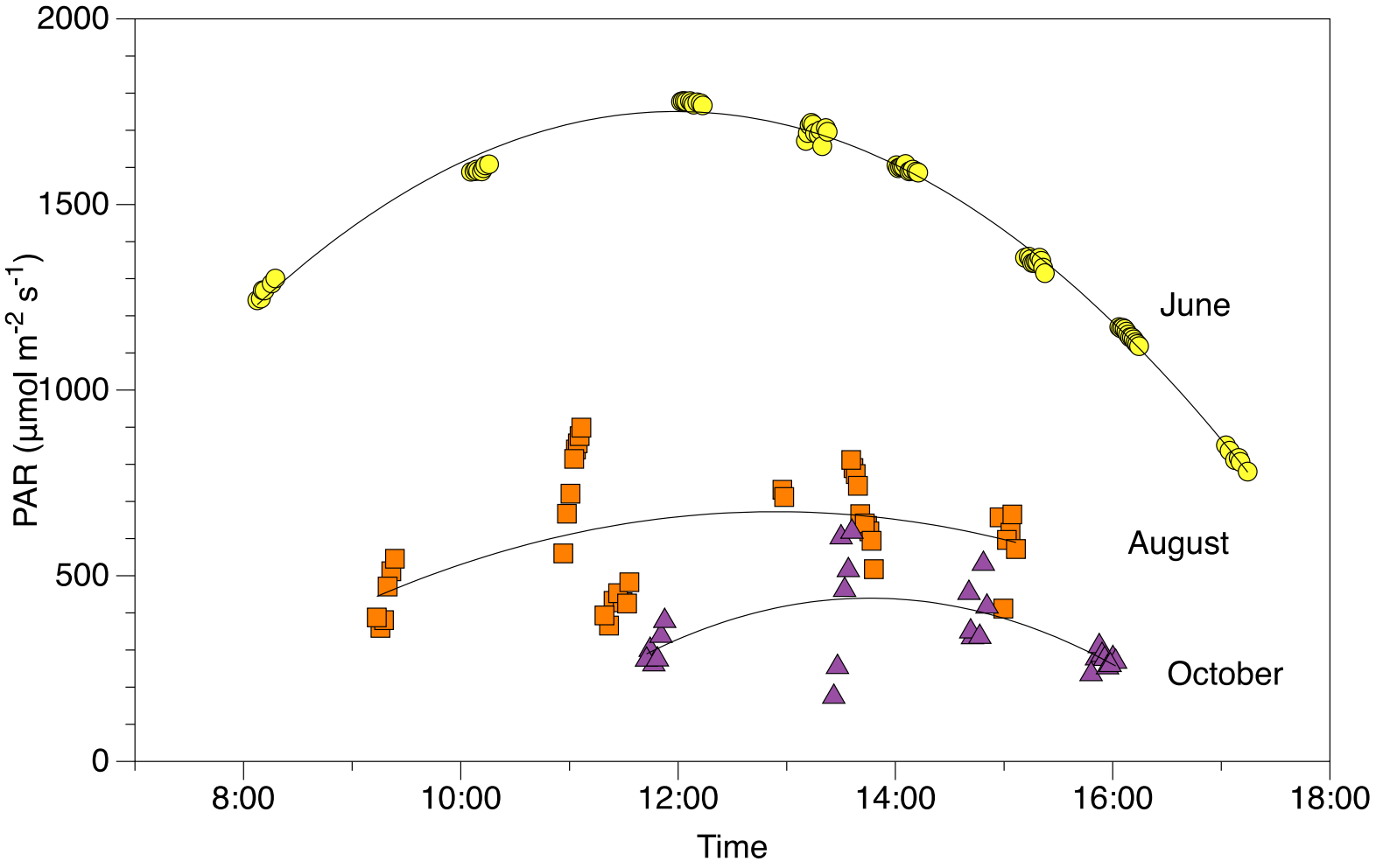
Aug 2018 – 5-6 flights over two days*

Oct 2018 – 9 flights of all rings over two days*

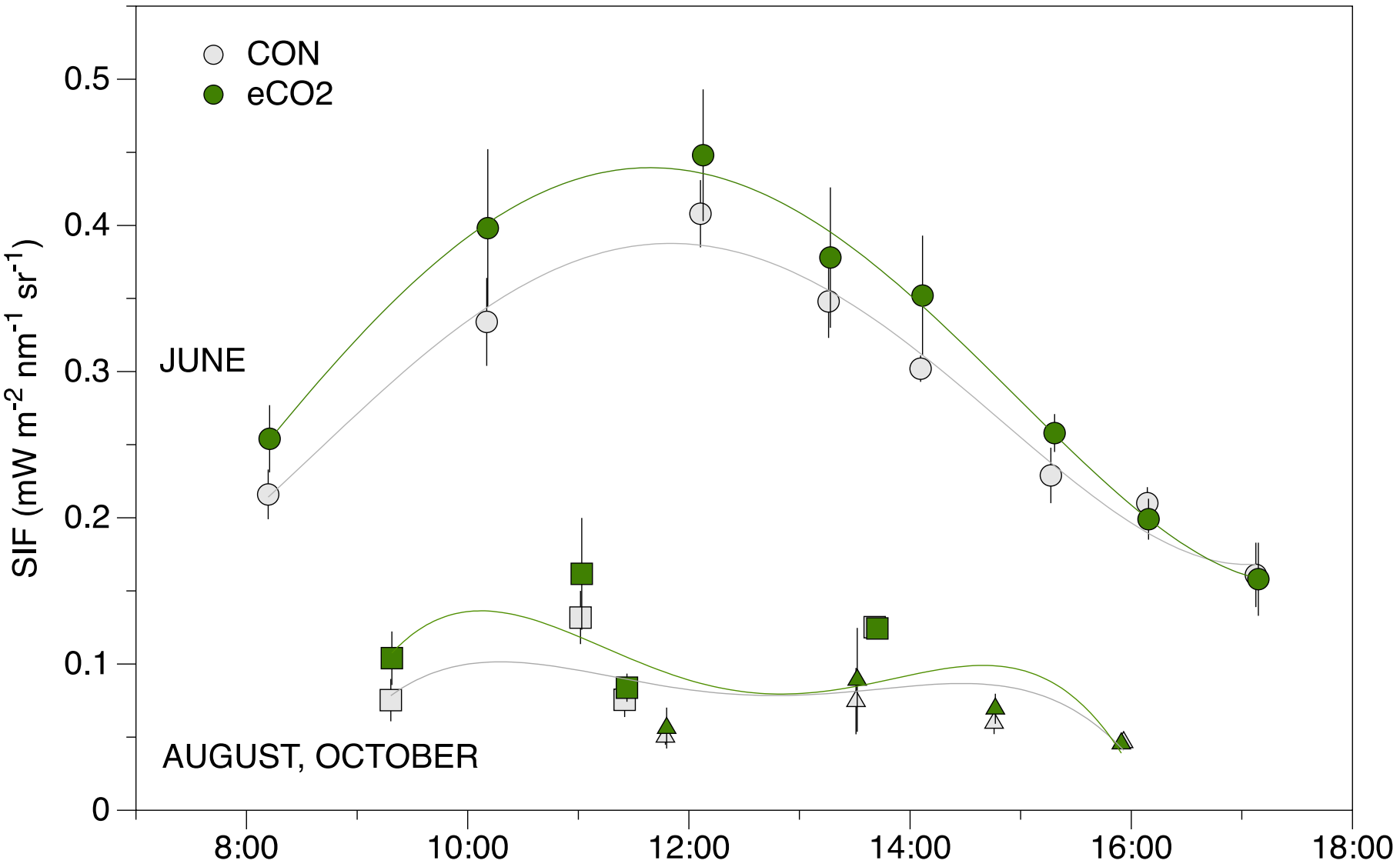
* Data shown here

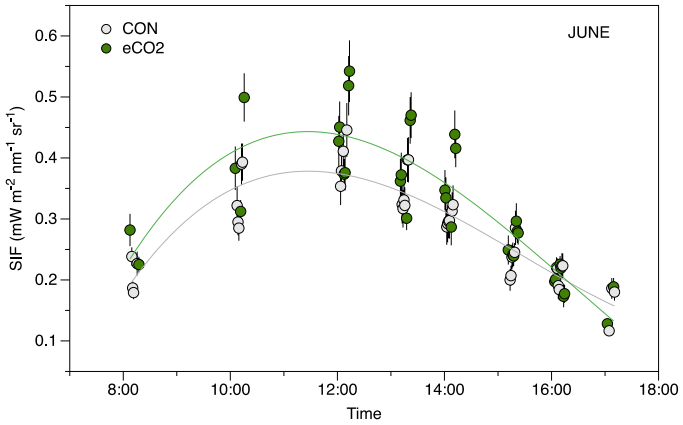
Total flight time ~ 16 mins

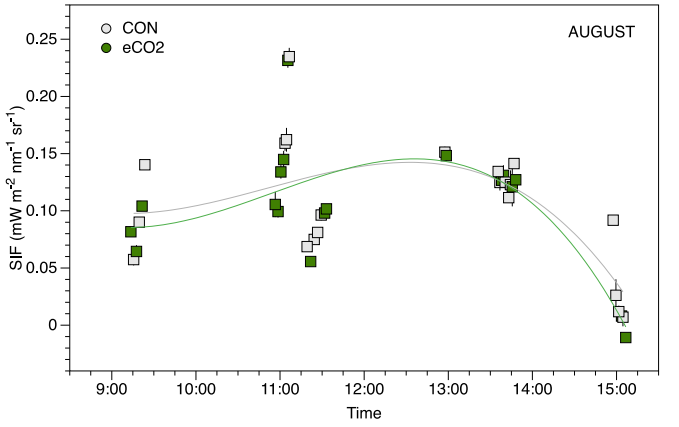
Range of light levels across the campaigns

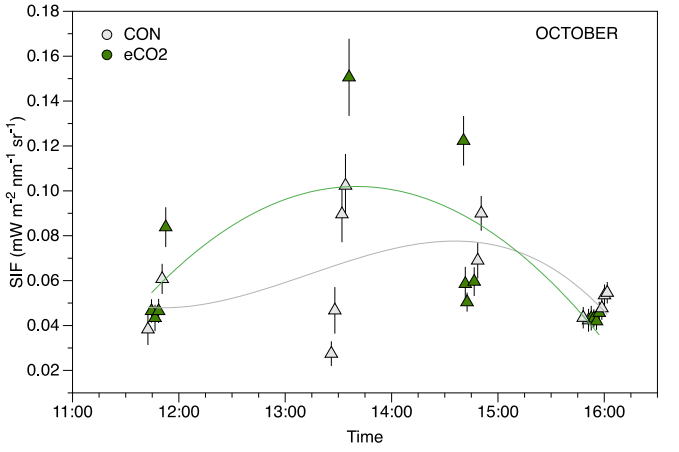


Diurnal SIF patterns



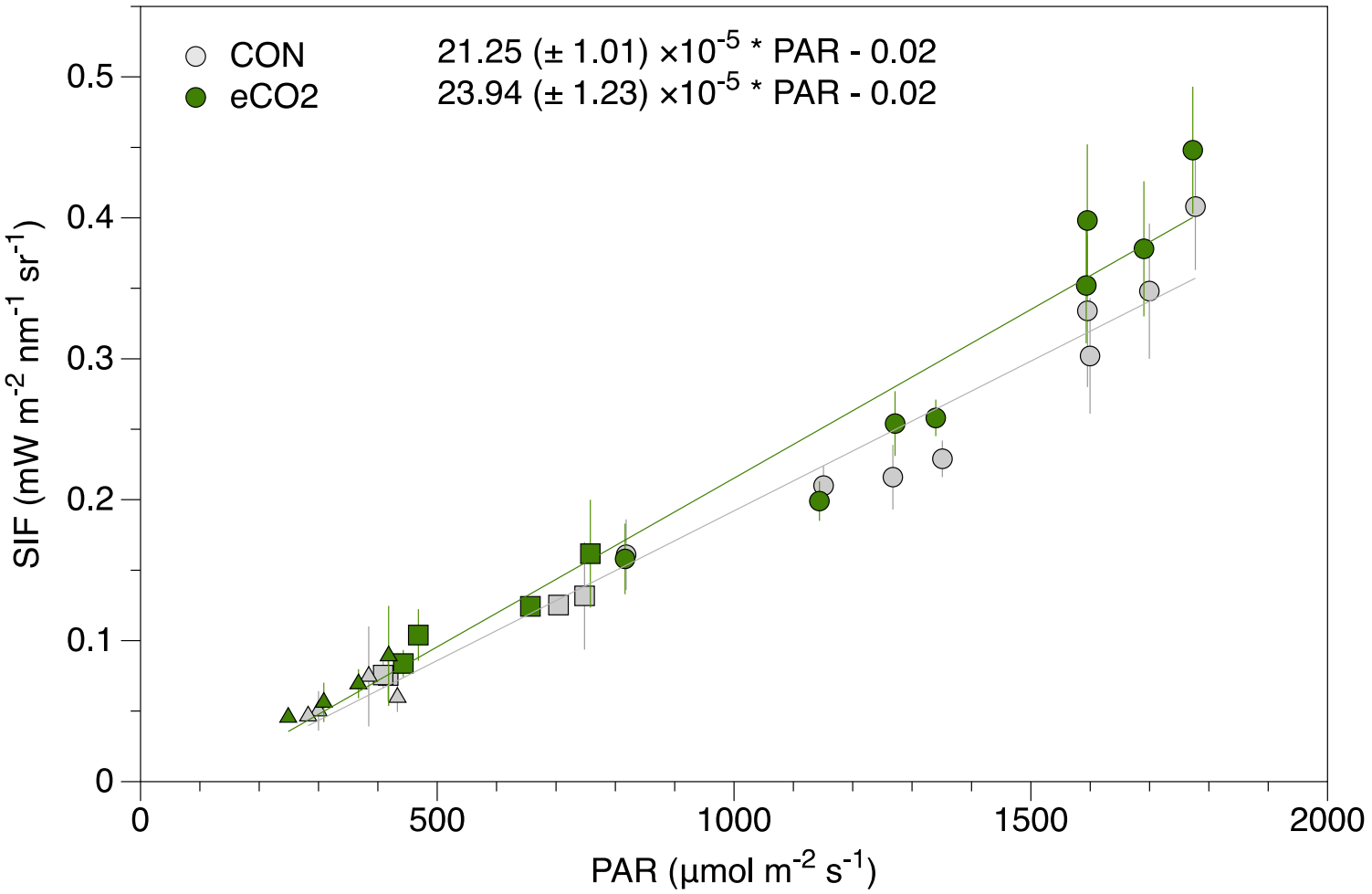


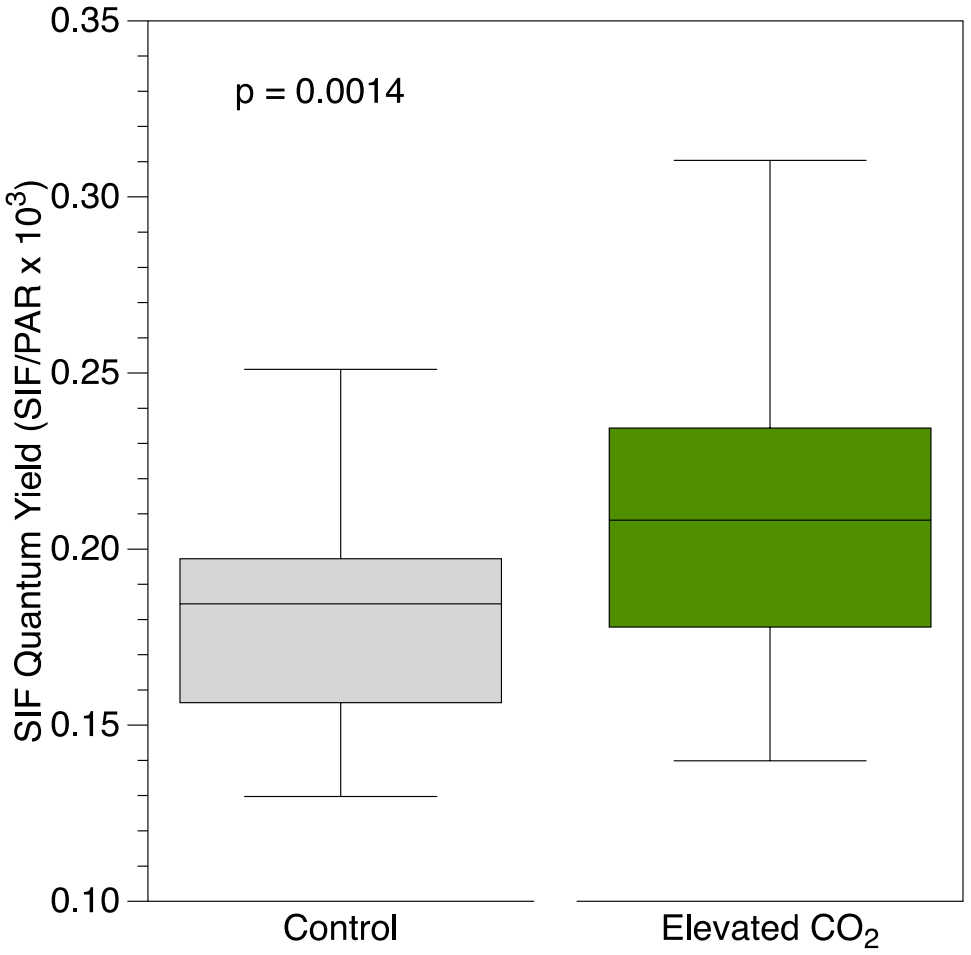




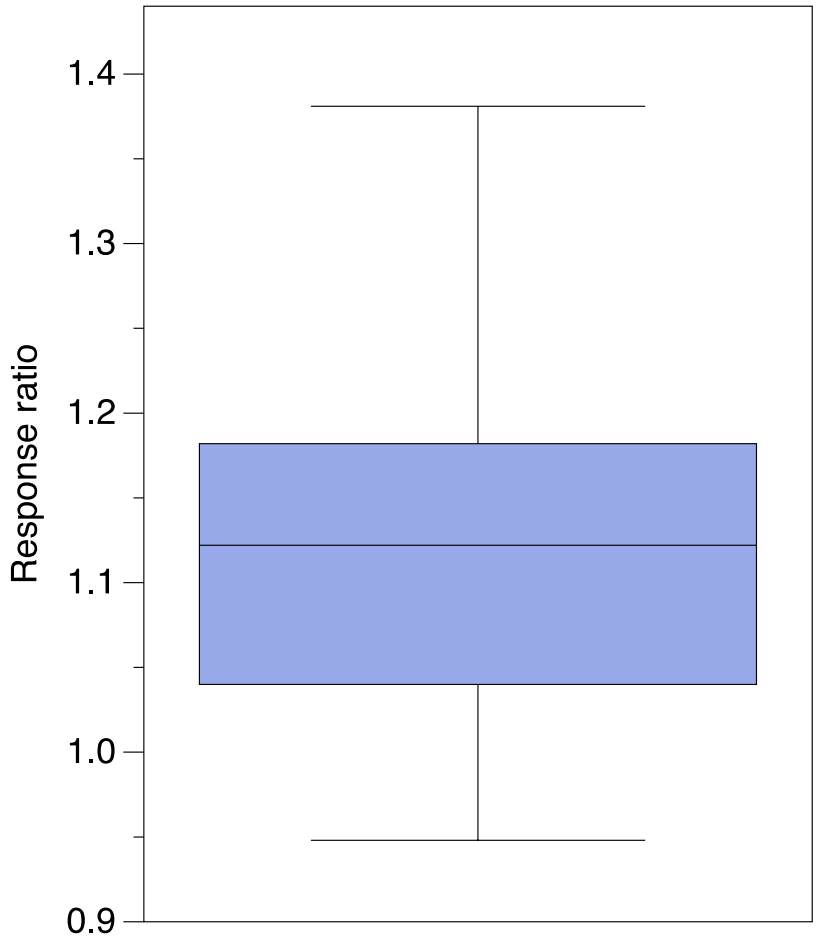
Increase in SIF yield under elevated CO_2

Constant relationship with PAR across time scales

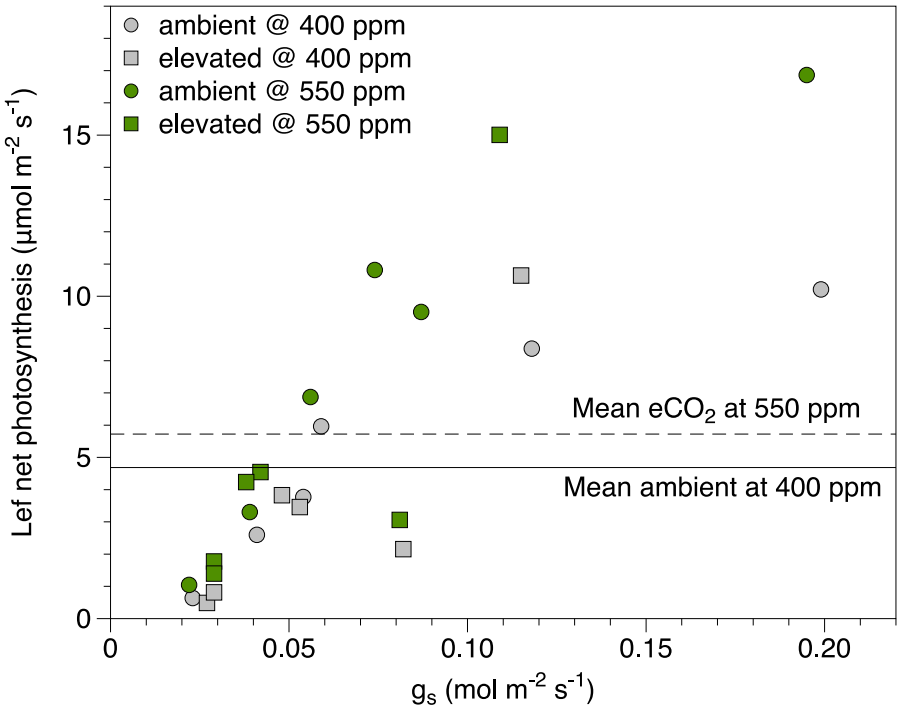




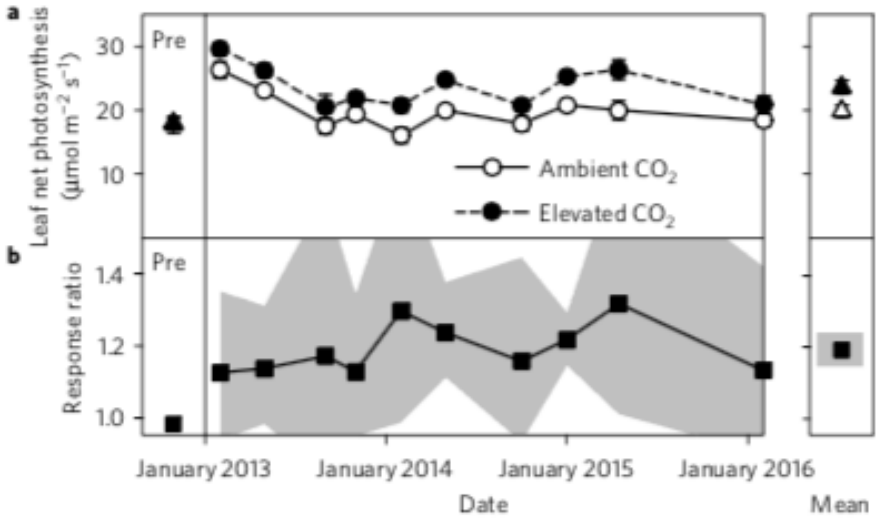
SIF response ratio consistent with gas exchange data



Response ratio = eCO2/control



Response ratio of 1.2



Ellsworth et al 2017 NCC EucFACE

See Anna and her poster for more complete gas exchange information

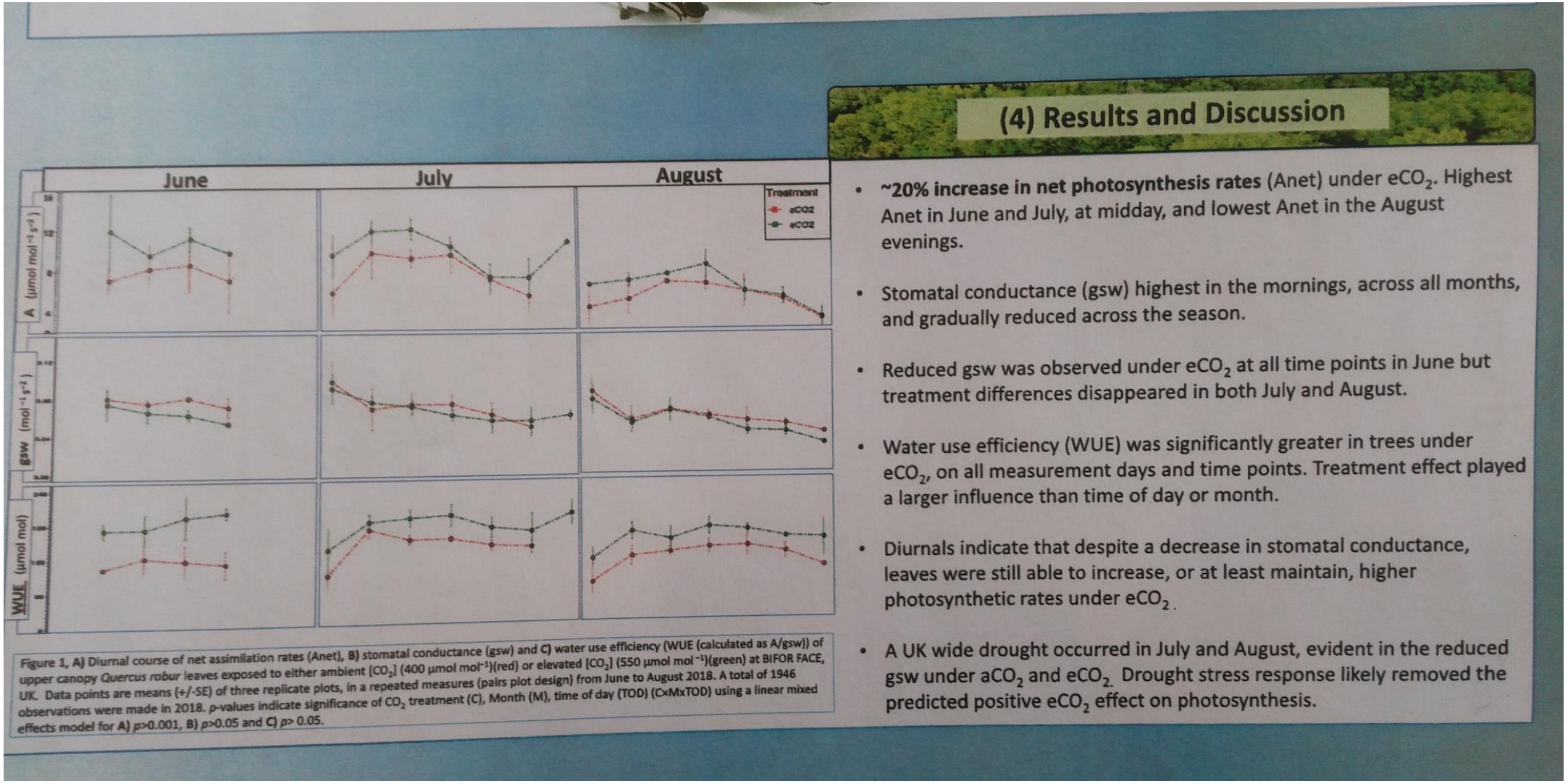
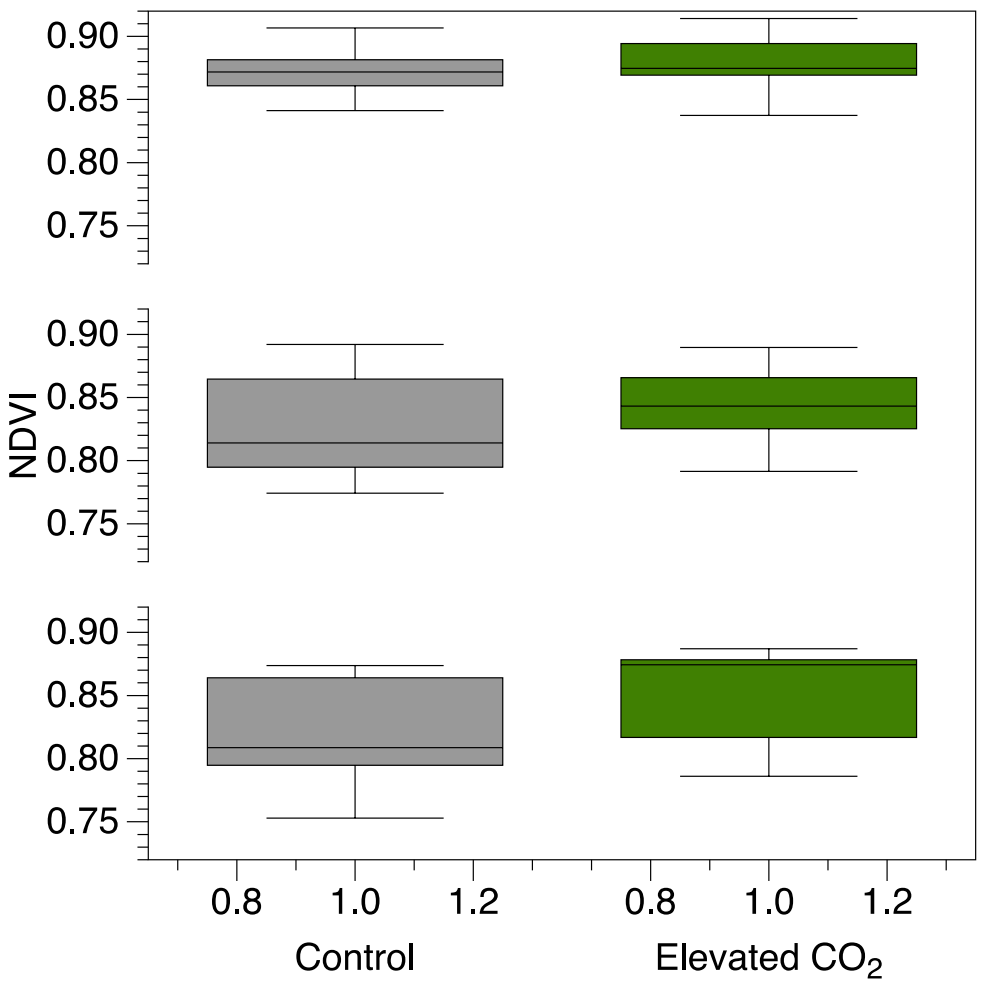


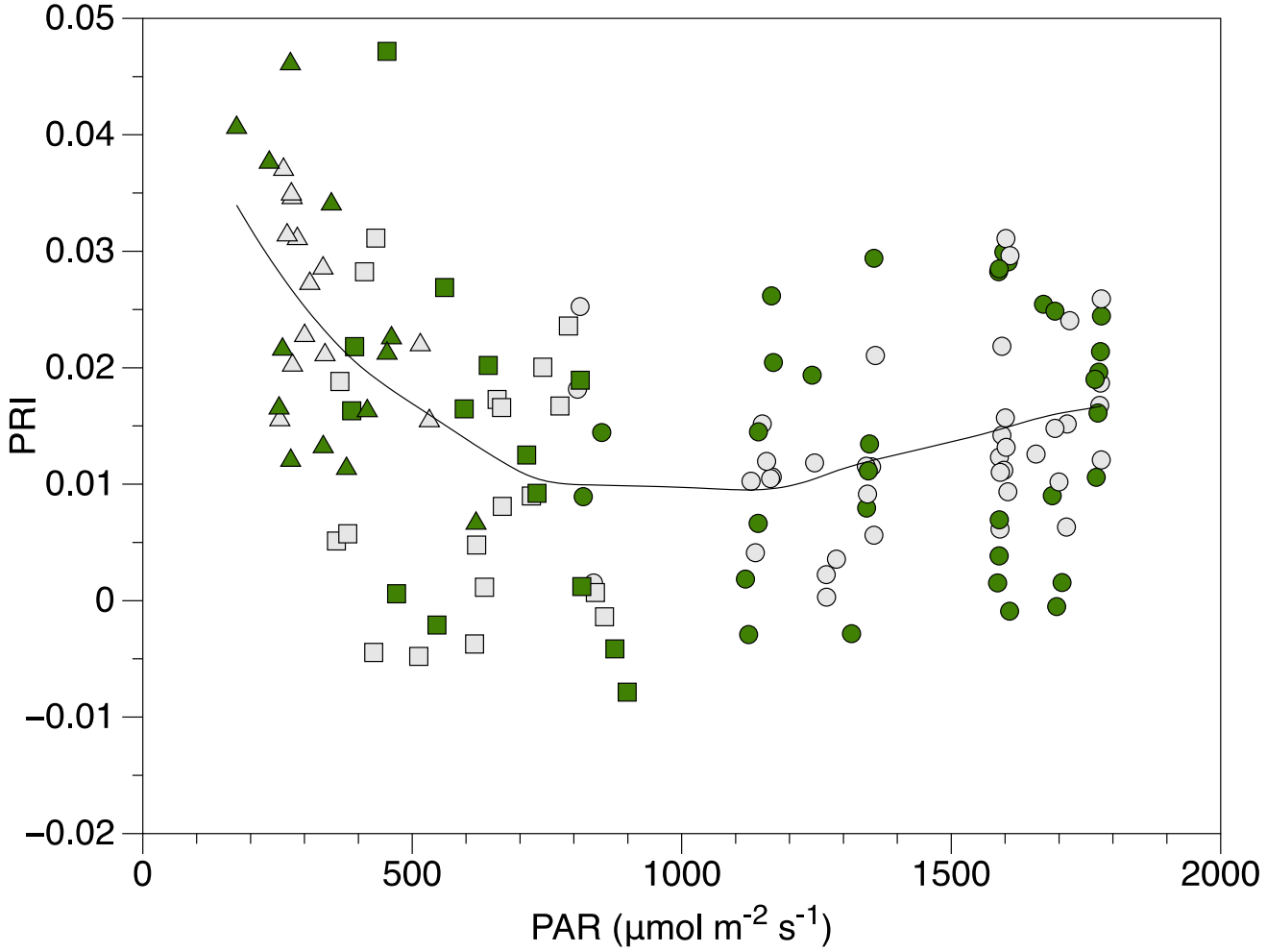
Figure 1, A) Diurnal course of net assimilation rates (Anet), B) stomatal conductance (gsw) and C) water use efficiency (WUE (calculated as A/gsw)) of upper canopy *Quercus robur* leaves exposed to either ambient (CO_2) (400 μmol mol^{-1})(red) or elevated (CO_2) (550 μmol mol^{-1})(green) at BIFOR FACE, UK. Data points are means (+/-SE) of three replicate plots, in a repeated measures (pairs plot design) from June to August 2018. A total of 1946 observations were made in 2018. *p*-values indicate significance of CO_2 treatment (C), Month (M), time of day (TOD) (C×M×TOD) using a linear mixed effects model for A) $p>0.001$, B) $p>0.05$ and C) $p> 0.05$.

(4) Results and Discussion

- **~20% increase in net photosynthesis rates** (Anet) under eCO_2. Highest Anet in June and July, at midday, and lowest Anet in the August evenings.
- Stomatal conductance (gsw) highest in the mornings, across all months, and gradually reduced across the season.
- Reduced gsw was observed under eCO_2 at all time points in June but treatment differences disappeared in both July and August.
- Water use efficiency (WUE) was significantly greater in trees under eCO_2, on all measurement days and time points. Treatment effect played a larger influence than time of day or month.
- Diurnals indicate that despite a decrease in stomatal conductance, leaves were still able to increase, or at least maintain, higher photosynthetic rates under eCO_2.
- A UK wide drought occurred in July and August, evident in the reduced gsw under aCO_2 and eCO_2. Drought stress response likely removed the predicted positive eCO_2 effect on photosynthesis.

SIF variations not linked to NDVI or PRI





Summary

UAV-based SIF measurements can be used gain insight into responses to elevated CO_2 at a FACE site

First measurements show higher SIF under elevated CO_2: higher photochemical activity associated with higher CO_2 fixation

SIF relationship with PAR appears similar across diurnal and seasonal time scales

Canopy structural and leaf ecophysiological information is required to further understand the what underlies the differences in SIF between treatments