UAV-based measurements of Solar Induced Fluorescence under elevated CO\textsubscript{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

- Incident PAR
- Reflected/Transmitted
- Absorbed
- Constitutive Dissipation
- Chlorophyll fluorescence
- Photochemistry
- Thermal Dissipation
- Photorespiration
- CO₂ Assimilation

A small, but very useful signal!

CO₂ → Photosynthesis → O₂

Chlorophyll fluorescence
Fluorescence emission spectrum adds to surface reflectance signal

Guanter et al 2010

Spectral infilling of the spectrum by Solar Induced Fluorescence

Measure of photosynthesis across scales

Gomez Chova et al 2006
Use SIF to estimate photosynthesis (GPP) across scales

GPP $\sim$ SIF $\times$ $\Phi F$

Canopy scale, rice paddies

Ecosystem scale, satellite data

**Graphs:**
- **Yang et al. 2018 RSE:**
  - $y = 6.16x + 3.52$
  - $R^2 = 0.76$
  - rRMSE = 36%

- **Sun et al. 2017 Sci:**
  - Crops: $y = 16.06 \times x$
  - Forests: $y = 15.31 \times x$
  - Grass: $y = 16.37 \times x$
  - $R^2 = 0.89$
  - $R^2 = 0.99$
  - $R^2 = 0.95$
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

[Graph showing the range of light levels across campaigns in June, August, and October, with data points and curves indicating PAR (μmol m⁻² s⁻¹) over time from 8:00 to 18:00.]
Diurnal SIF patterns

- CON
- eCO2

**JUNE**

**AUGUST, OCTOBER**
Increase in SIF yield under elevated CO$_2$

Constant relationship with PAR across time scales

- **CON**: $21.25 \pm 1.01 \times 10^{-5} \times$ PAR - 0.02
- **eCO2**: $23.94 \pm 1.23 \times 10^{-5} \times$ PAR - 0.02

$p = 0.0014$
SIF response ratio consistent with gas exchange data

Response ratio = eCO2/control

Ellsworth et al 2017 NCC EucFACE
See Anna and her poster for more complete gas exchange information.
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.