UAV-based measurements of solar induced fluorescence (SIF) to investigate photosynthetic responses to elevated CO_2

Kadmiel Maseyk[1], Rick Thomas[2], Jon Atherton[3], Alasdair Mac Arthur[4], Rob MacKenzie[2]

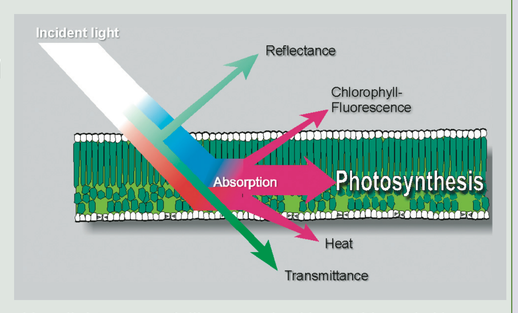
[1]School of Environment, Earth & Ecosystem Sciences, The Open University; [2]School of Geography, Earth & Environmental Sciences, University of Birmingham; [3]Department of Forest Sciences, University of Helsinki; [4]School of Geosciences, University of Edinburgh University of Birmingham;

Background

- A primary challenge in Free-Air CO_2 Enrichment (FACE) studies is obtaining array-level estimates of canopy photosynthesis
- UAV-based measurements of Solar Induced Fluorescence provide a unique opportunity to address this challenge
- We are conducting flights at BIFoR FACE to investigate the use of SIF to explore photosynthetic responses to eCO_2

Solar Induced Fluorescence

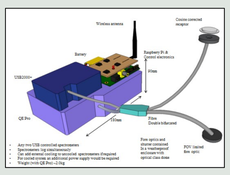
- An emerging remote sensing approach to investigate the photochemical component of photosynthesis
- During photosynthesis, a portion of absorbed solar energy is emitted as fluorescence.
- Provides a signal directly linked to photosynthesis that can be detected from proximal and remote platforms.



How light energy falling on a leaf is partitioned. About 78% of the incident radiation is absorbed, while the rest is either transmitted or reflected at the leaf's surface. About 20% is dissipated through heat and only 2% emitted as fluorescence, as a by-product of photosynthetic reactions occurring within the leaf itself. Mapping Photosynthesis from Space - a new vegetation-fluorescence technique. ESA Bulletin 11/2003 116:34-37.

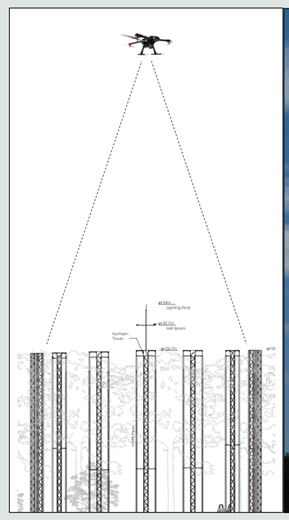
Instrumentation

- Piccolo Doppio dual-field-of view spectrometer system (Ocean Optics FLAME + QEPro)
- Matrice 600 Pro UAV
- Parrot Sequoia multispectral sensor
- 360˚ and GoPro cameras
- Total weight ~15 kg

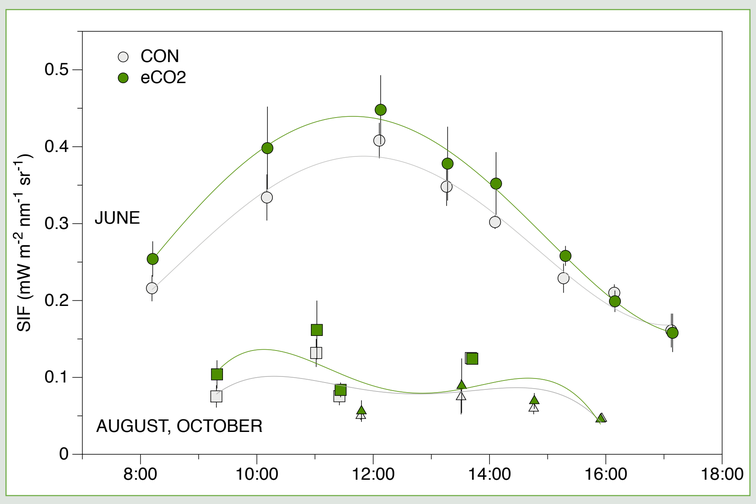


Flight campaigns

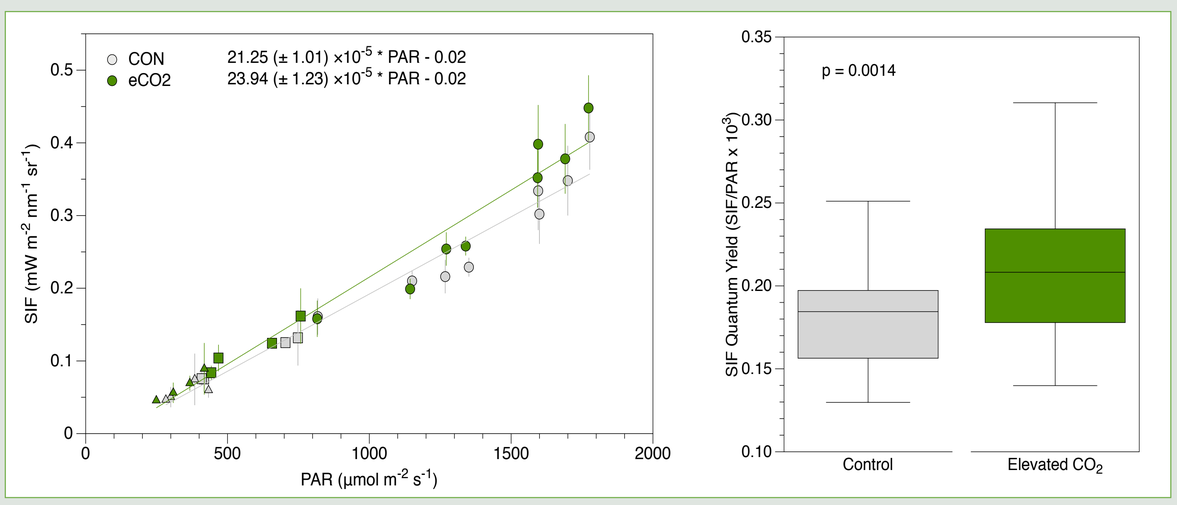
- Three flight campaigns (June, Aug, Oct. 2018)
- 35 m above canopy
- Fly-and-hover
- Multiple flights in the day



Results

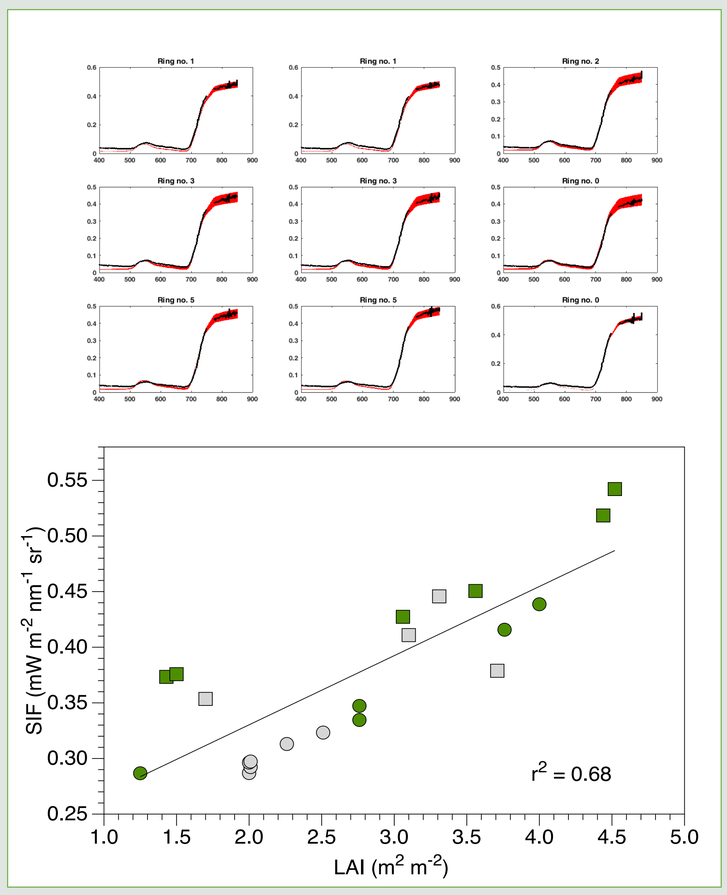


- SIF reliably determined from the UAV platform
- SIF shows diurnal and seasonal variation
- Higher values in SIF seen from the eCO_2 treatments



- SIF is related incident Photosynthetically Active Radiation (PAR)
- Similar relationship across diurnal and seasonal scales
- SIF Quantum Yield (SIF/PAR) is higher under eCO_2

- Inverse modelling of full reflectance spectra using PROSAIL model to estimate canopy properties
- Estimates of Lear Area Index show strong relationship with SIF for June midday measurements



Outlook

- We provide first canopy level measurements of photosynthetic activity under elevated CO2 treatment using UAV-based SIF measurements
- Differences in SIF yields between ambient and eCO2 treatments are detected, but whether this difference relates to leaf-level (e.g. Vcmax) or canopy-level (e.g. LAI) properties remains to be determined
- SIF and hyperspectral reflectance measurements are promising approach for investigating canopy physiology at BIFoR FACE

The Open University · University of Birmingham · Helsingin Yliopisto Helsingfors Universitet University of Helsinki · The University of Edinburgh · BIFoR Birmingham Institute of Forest Research

kadmiel.maseyk@open.ac.uk