BIFOR
BIRMINGHAM INSTITUTE OF FOREST RESEARCH

UNIVERSITY OF BIRMINGHAM

Oak Ridge sweetgum FACE forest site 1996-2010

FACE 1.0

FACE 2.0 BIFoR FACE - Global facility for research & science translation

Coordinated with Hawksbury EucFACE, Western Sydney Australia

Top-level research questions

1. Does elevated CO_2 increase the **carbon storage**?
2. Do other **macro- or micro-nutrients** limit the uptake of carbon?
3. What aspects of **biodiversity and ecosystem structure-and-function** alter?
4. How can lessons learnt be **generalised** to other woodlands and forests? (Global Network of second-generation Forest FACE experiments)

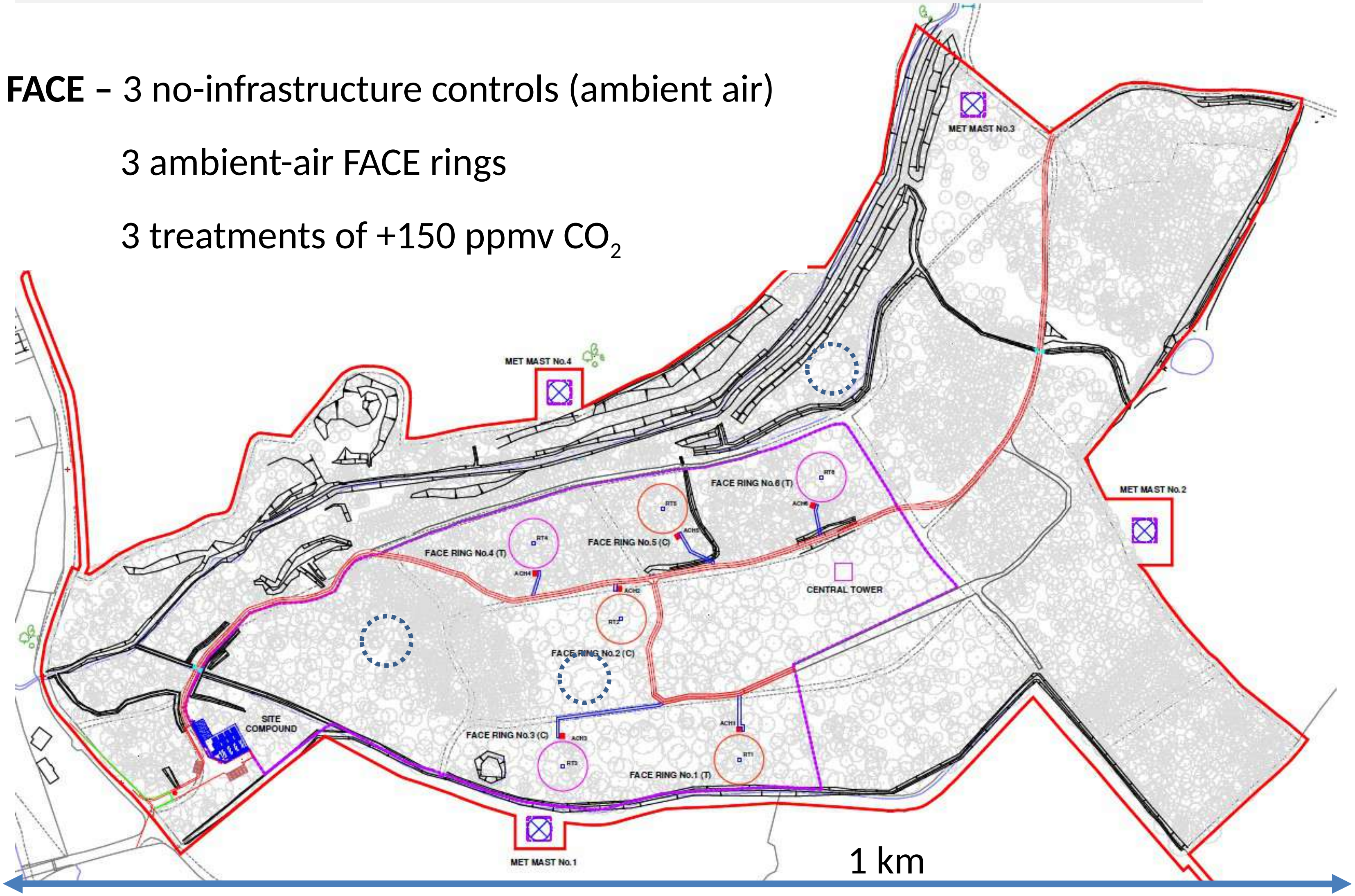
The BIFoR FACE facility- Mill Haft woodland, Staffordshire

A research platform to study the response of a mature temperate deciduous forest ecosystem to elevated CO_2 over 10 years

FACE – 3 no-infrastructure controls (ambient air)

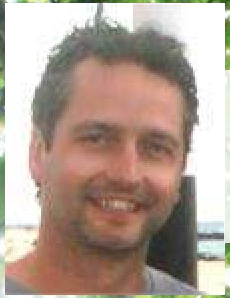
3 ambient-air FACE rings

3 treatments of +150 ppmv CO_2



BIFoR Research Team
Lead – Prof Rob Mackenzie

Theme 1: Ecological – Dr Alex Poynter



Theme 2 (and Baseline lead):
Atmospheric – Dr Rick Thomas

Theme 3: ‘Omics’ – Dr Will Allwood

Theme 4: Hydrological / Hydrogeological – Dr Phil Blaen

Theme 5: Litter and sub-surface systems – TBC

Theme 6: Stable isotopes & links with ecosystem modelling – Dr Debbie Hemming

Core Measurements at Mill Haft - baselining

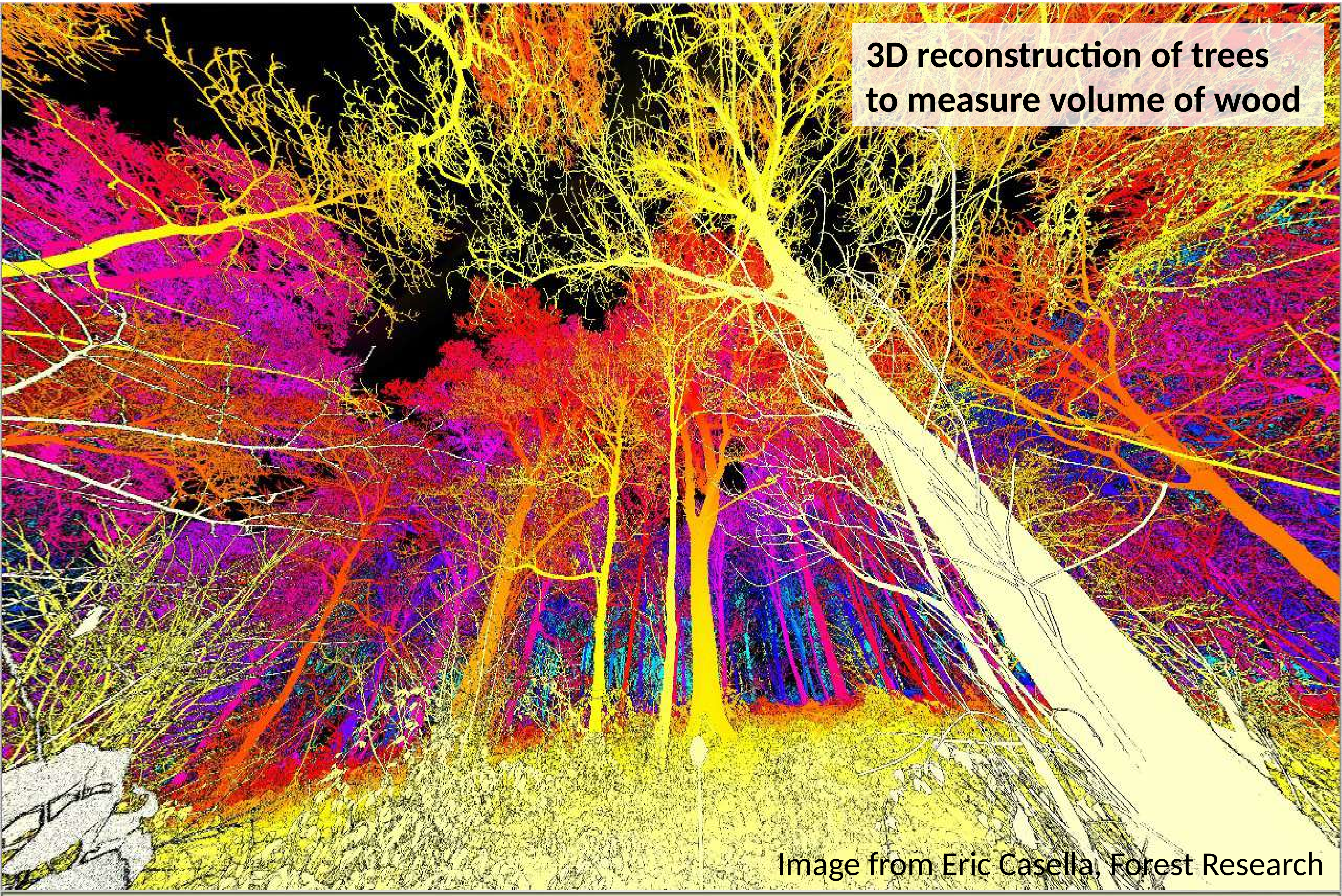
Underway

- Eddy covariance flux measurements ($CO_{2,}H_2O$, CH_4)
- Stream Monitoring (Discharge,Water temperature, pH, Turbidity, Dissolved oxygen, Nitrate & Nitrite, Dissolved organic carbon
- LAI - via hemispherical photography
- Phenocam
- Met kit
- Plant tissue sampling
- Invertebrate sampling
- Litter traps
- Dendrometers
- Soil sampling – inc. soil moisture, temperature, characteristics

Pending

- Leaf gas exchange (Licor 6400 just arrived!)
- Soil gas fluxes (soil chambers in the post)
- Minirhyzotrons (to be installed)

Laser Scanning

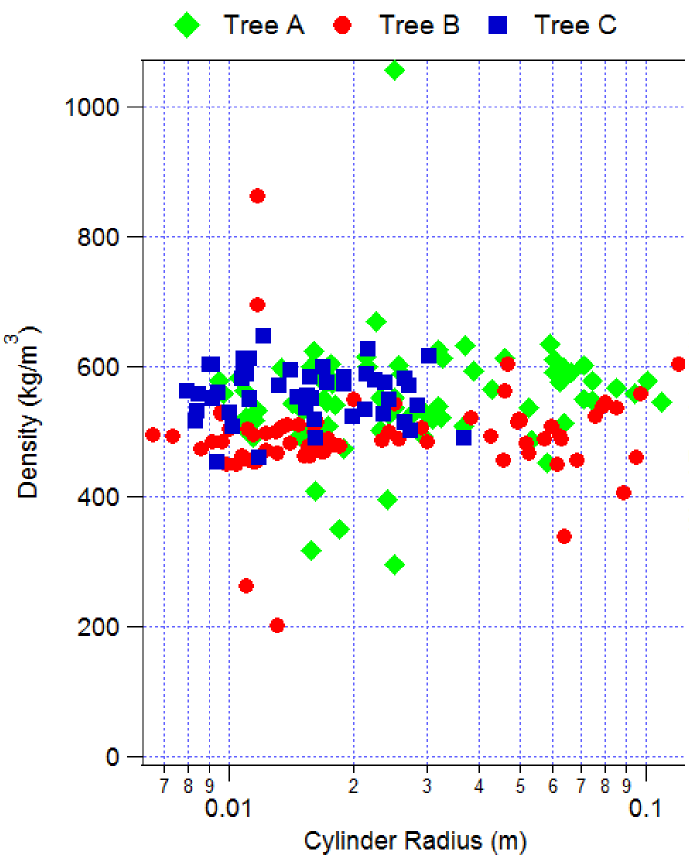


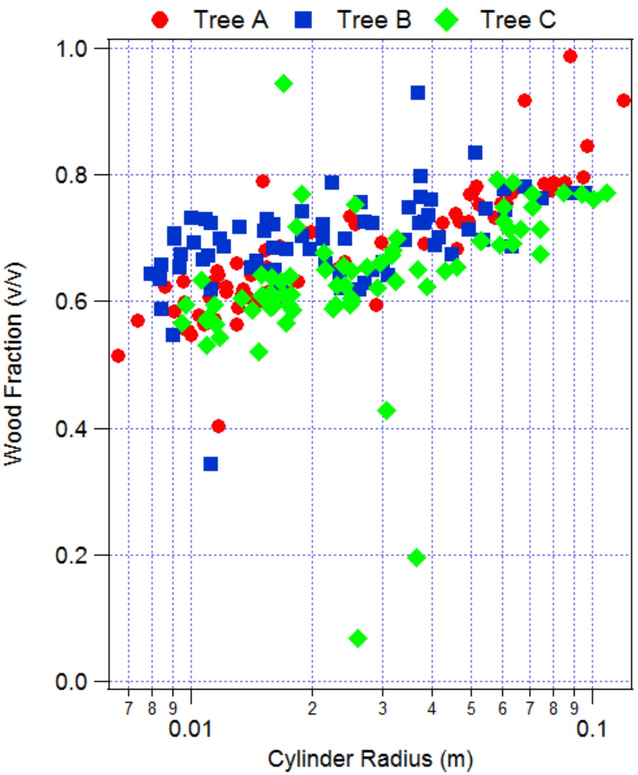
3D reconstruction of trees to measure volume of wood

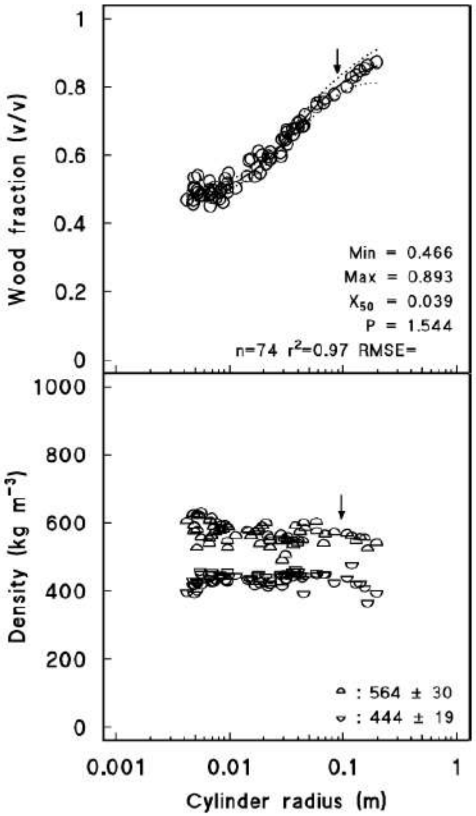
Image from Eric Casella, Forest Research

Tree Allometrics


Weighing entire trees



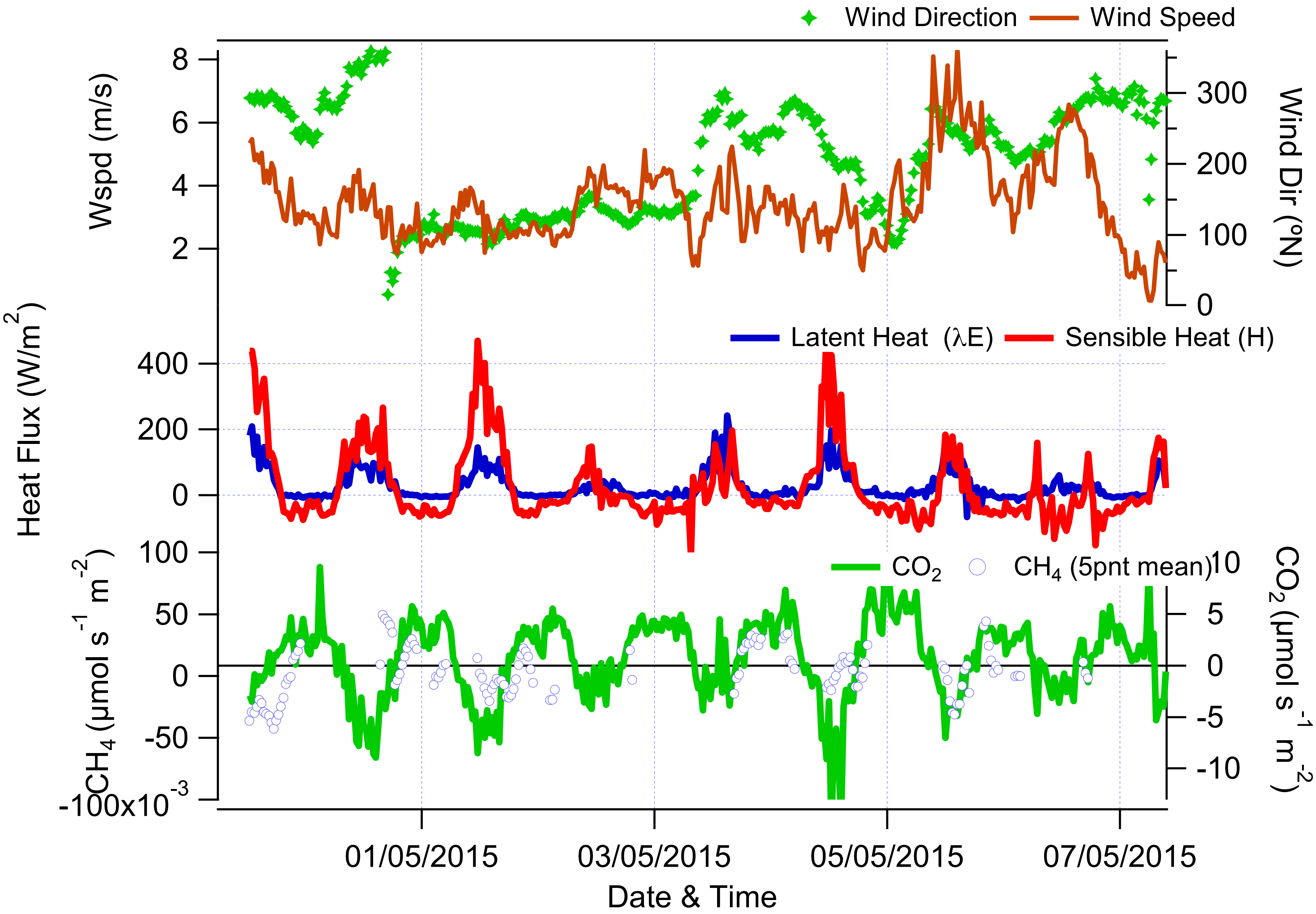




Eddy Covariance Flux System

- Tower height: 30m
- Canopy height: 23m
- Measurements:
- Phenology camera
- CO_2, H_2O, CH_4 fluxes
- PAR profile (30, ~17, ~10m)
- Rainfall
- Long and short wave radiation balance (30m)
- Temperature/Humidity , PAR &Turbulence profile 30, (~17, ~10m)
- Powered by methanol fuel cell, remote access via 3G network

Preliminary Flux results



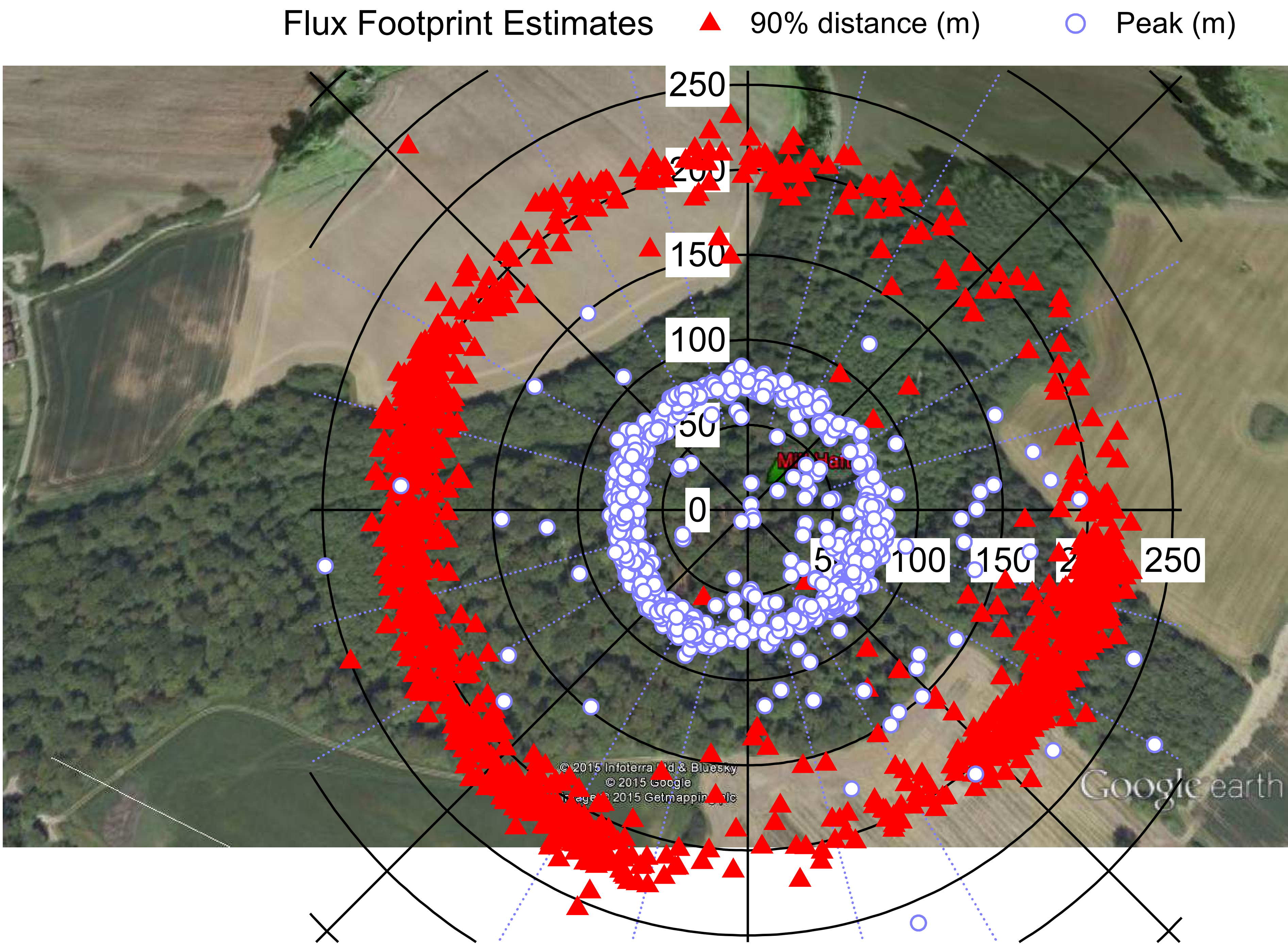

Flux Footprint Estimates
▲ 90% distance (m)
○ Peak (m)
250
200
150
100
50
0
50
100
150
200
250
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Image © 2015 Getmapping plc
Google earth

Phenology Camera

PhenoCam Image Processor v1.1

millhaft_2015_04_25_063006.jpg
millhaft_2015_04_25_070005.jpg
millhaft_2015_04_25_073006.jpg
millhaft_2015_04_25_080005.jpg
millhaft_2015_04_25_083005.jpg

ROI 1

Images 7 to 20 hour

window 1 days

dark thres. 15

☐ 90th perc. ☑ Mean ☐ Median

☑ Gcc ☐ Gcc smooth ☐ Red ☐ Green ☐ Blue

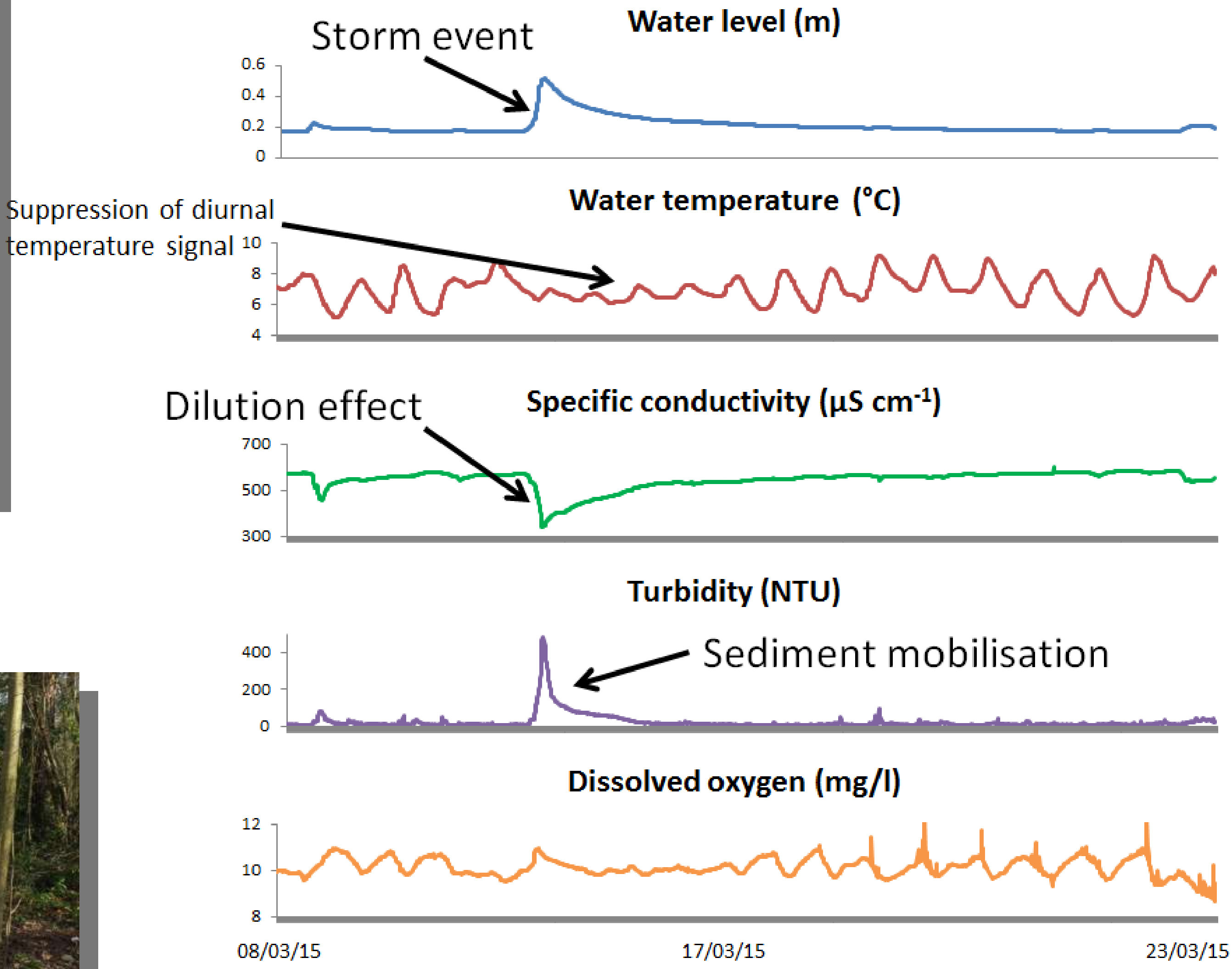
☑ ROI 1 ☐ ROI 2 ☐ ROI 3

14th April

29th April

http://phenocam.sr.unh.edu/data/latest/millhaft.jpg

Stream Monitoring Equipment


Storm event

Suppression of diurnal temperature signal

Dilution effect

Sediment mobilisation

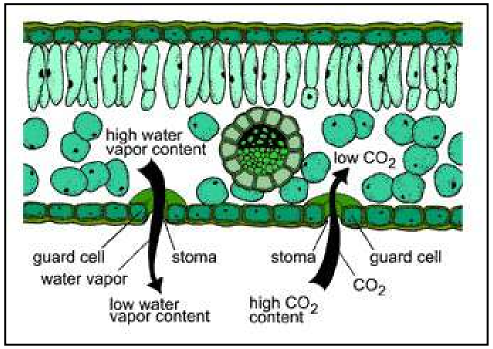
Plant ecophysiology

Leaf-canopy scale research

Two broad topics:

Mechanisms - how plants sense and respond to environmental changes

Scaling - how these responses are coordinated with one another, and how their collective effect on plant growth and gas exchange can be understood and modelled.



Photosynthesis and chlorophyll fluorescence

Dr Kadmiel Maseyk, Open University

Chlorophyll fluorescence can be measured at the leaf-level, and detected from canopy, airborne and satellite platforms

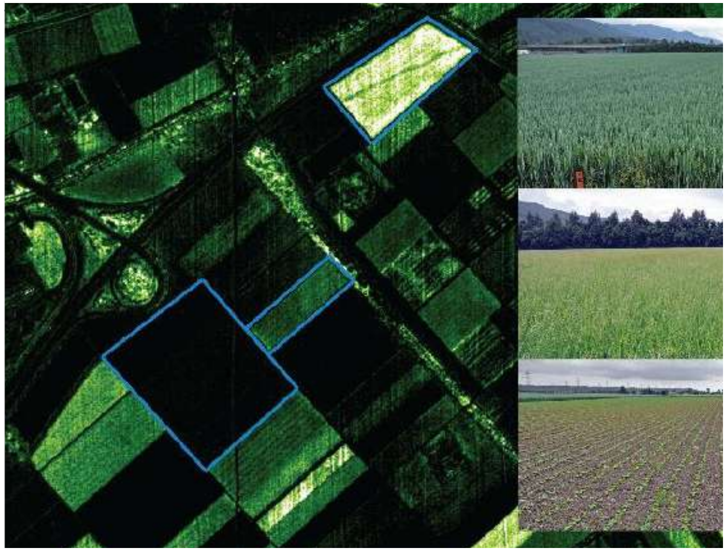
It is an emerging tool for estimating photosynthesis at canopy to global scales

We aim to see if we can detect and monitor photosynthetic differences between eCO_2 rings, control rings and surrounding forest?

Field measurements (June-Sept)
Leaf CO_2 assimilation rate measurements
Leaf-level measurements of chlorophyll fluorescence
Pigment analysis and leaf-CO_2 assimilation rates

Analyses to follow
Compare CO_2, fluorescence and Phenocam images
Ground truthing of remotely sensed fluorescence signals

Fluorescence – remote sensing



Tree ring analyses

Dr Neil Loader, Swansea University

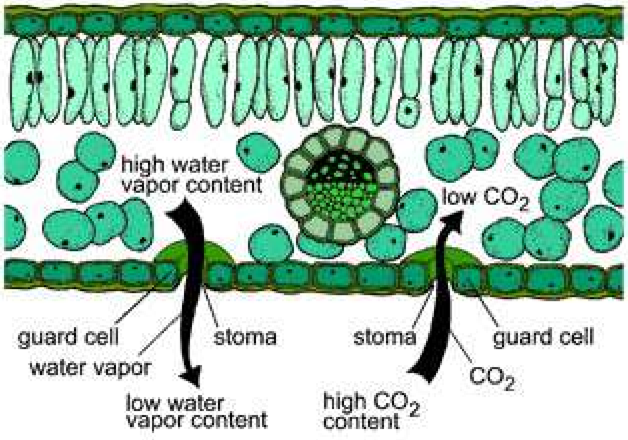
26/03/15 - 5mm diameter cores taken from 23 trees

Laboratory measurements in progress
Ring width measurements for whole core ~150 years
Stable carbon isotope analyses of latewood cellulose
Stable oxygen isotope analyses of latewood cellulose

Analyses to follow
Spatial and temporal variability in ring widths & isotope composition
Intrinsic Water Use Efficiency of trees – from carbon isotopes
Water source for cellulose formation – precip., soil water, leaf water

Tree water-use efficiency

How has the (intrinsic) water-use efficiency (iWUE) of the oak trees changed over the last ~100 years ?



$$\mathbf{iWUE} = c_a \frac{b - [(\delta^{13}C_a - \delta^{13}C_p)/(1 + \delta^{13}C_p/1000)]}{1.6(b - a)}$$

a = isotopic fractionation during diffusion of CO_2 into leaves

b = isotopic fractionation during carboxylation CO_2 into carbohydrates

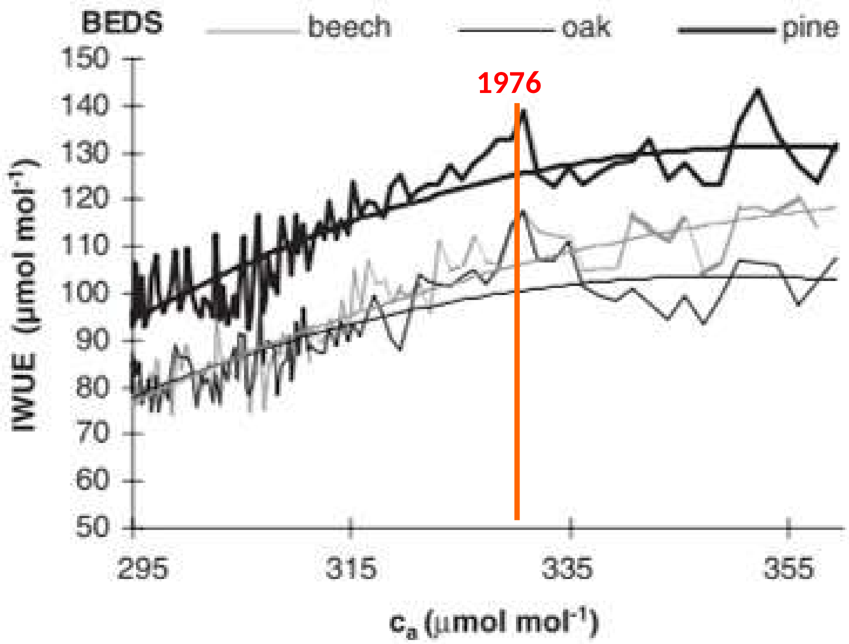
$\delta^{13}C_a$ = carbon isotopic ratio ($^{13}C/^{12}C$) of atmospheric CO_2

$\delta^{13}C_p$ = carbon isotopic ratio of plant material

c_a = atmospheric CO_2 concentration

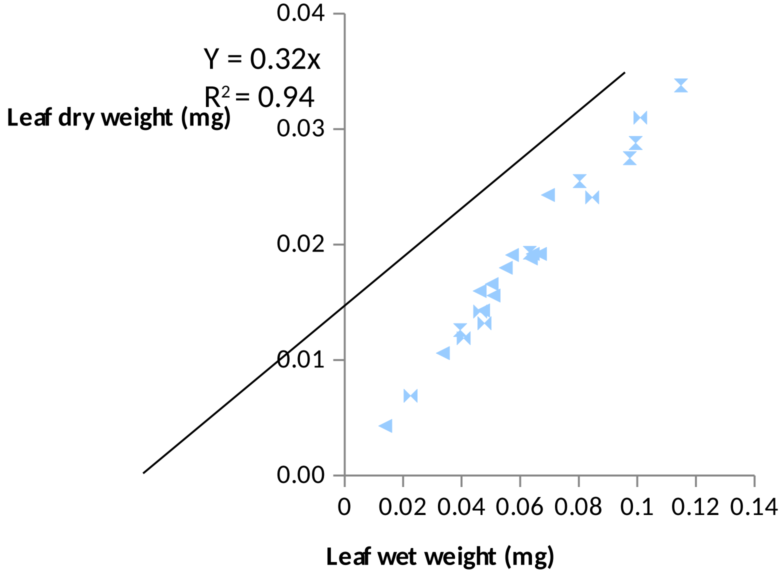
1.6 = difference in diffusivity of CO_2 and water vapour in air

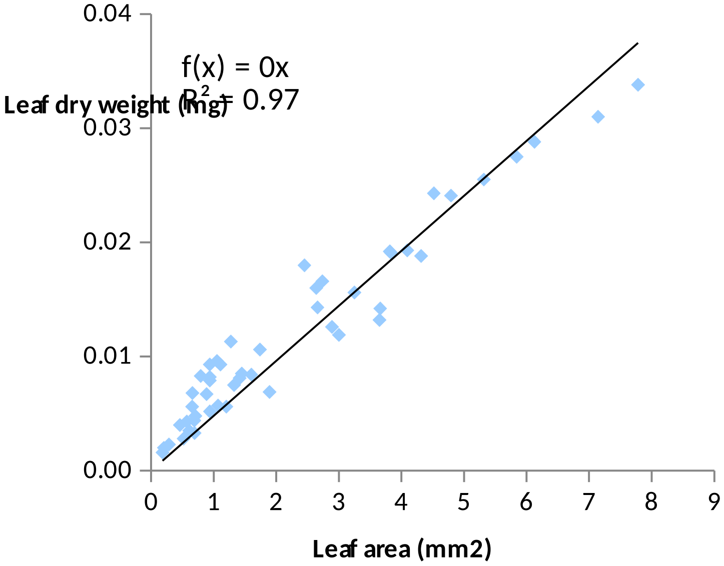
Woburn Abbey, Bedford, UK



Oak leaf traits, C & N measurements

Mill Haft woodland April-June 2015





%Cleaf **~ 45%** +/- 3%

%Nleaf **April ~ 7%** +/- 2%

May ~ 4% +/- 2%

June ~ 2% +/- 1%

%Cstem **~ 40%** +/- 5%

%Nstem **~ 1%** +/- 0.5%

C and N allocation during phenological changes

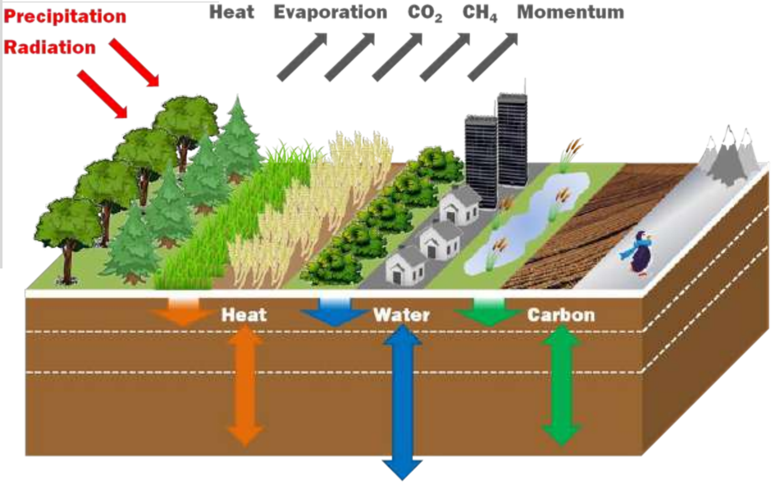
Oak bud burst Mill Haft – 29/04/15

Field sampling
2-weekly twig/bud/leaf samples from top, mid, lower oak canopy
Monthly collection of samples from lower canopy at Wytham wood

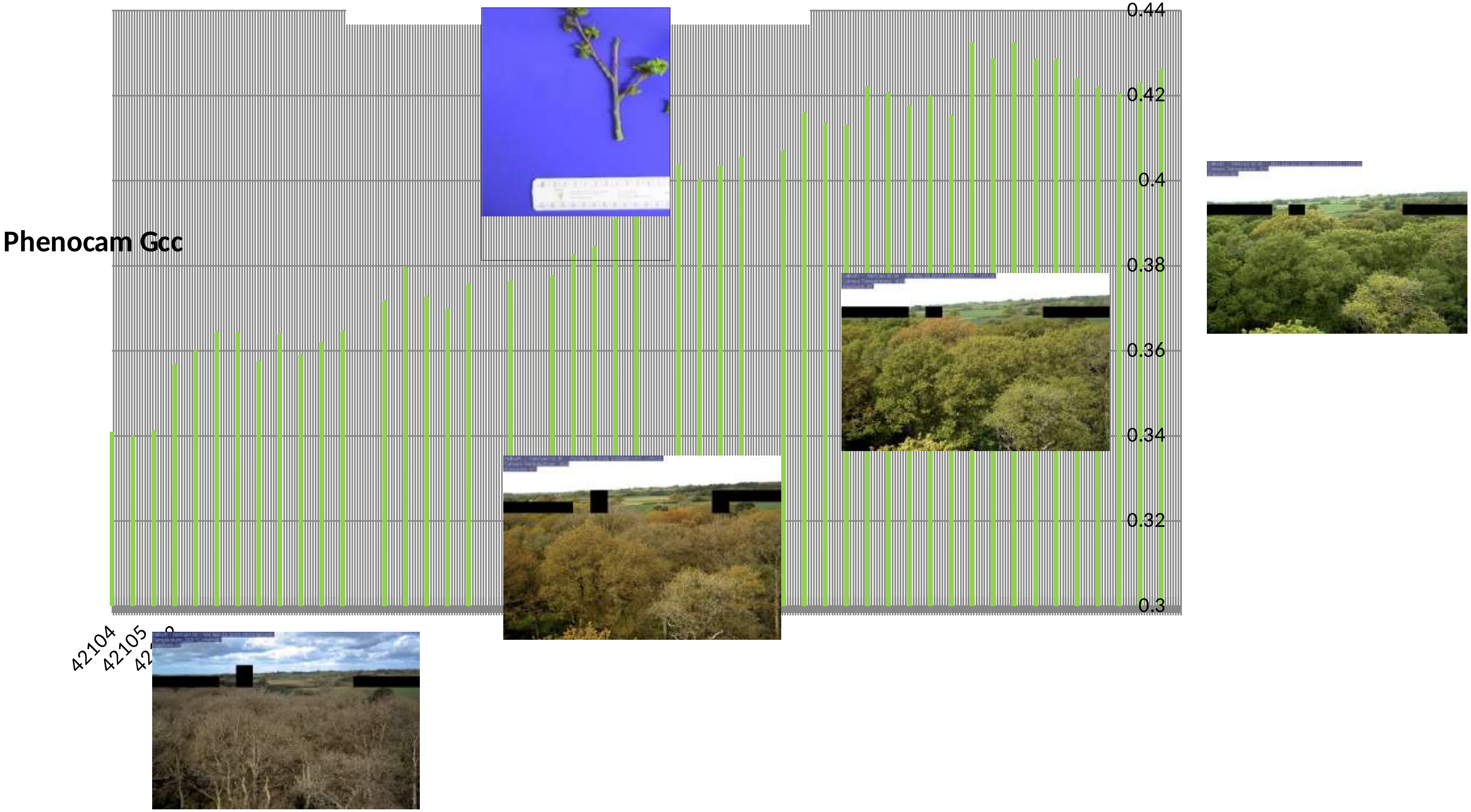
Laboratory measurements in progress
Leaf traits (wet and dry mass, area), stem elongation
% C and N in new twig wood, buds, leaves
Stable carbon and oxygen isotope analyses of samples

Analyses to follow
Comparisons with phenocam vegetation indexes,
flux tower CO_2 and H_2O exchanges
JULES modelling
Responses under enhanced CO_2

Joint UK Land-Environment Simulator



Phenocam – Gcc index Green chromatic coordinate



Oak bud burst Mill Haft – 29/04/15

JULES – Joint UK Land-Environment Simulator

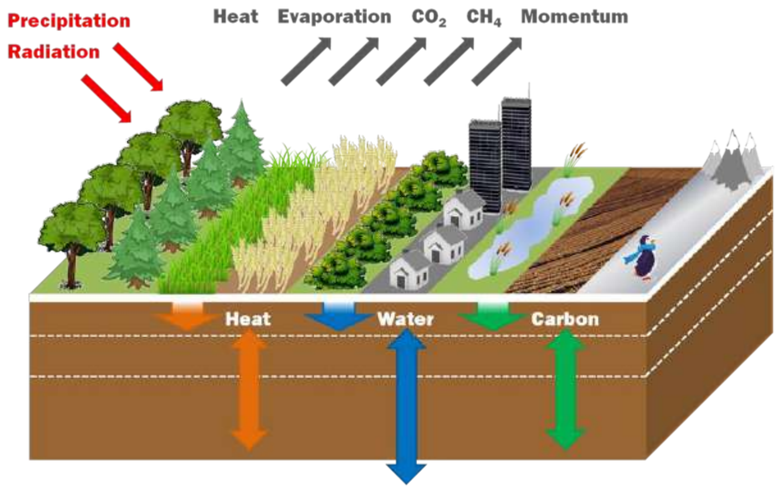
Can JULES simulate the observed fluxes, leaf/twig C, N and phenological changes observed at Mill Haft ?

Run JULES vn4.2 point location forced with hourly Shawbury meteorological station data

Compare timing of leaf development, tower fluxes and leaf C and N for ‘broadleaf tree’ fraction

Change key parameters in JULES (Vcmax, Jmax) based on Mill Haft observations to see if simulations improve

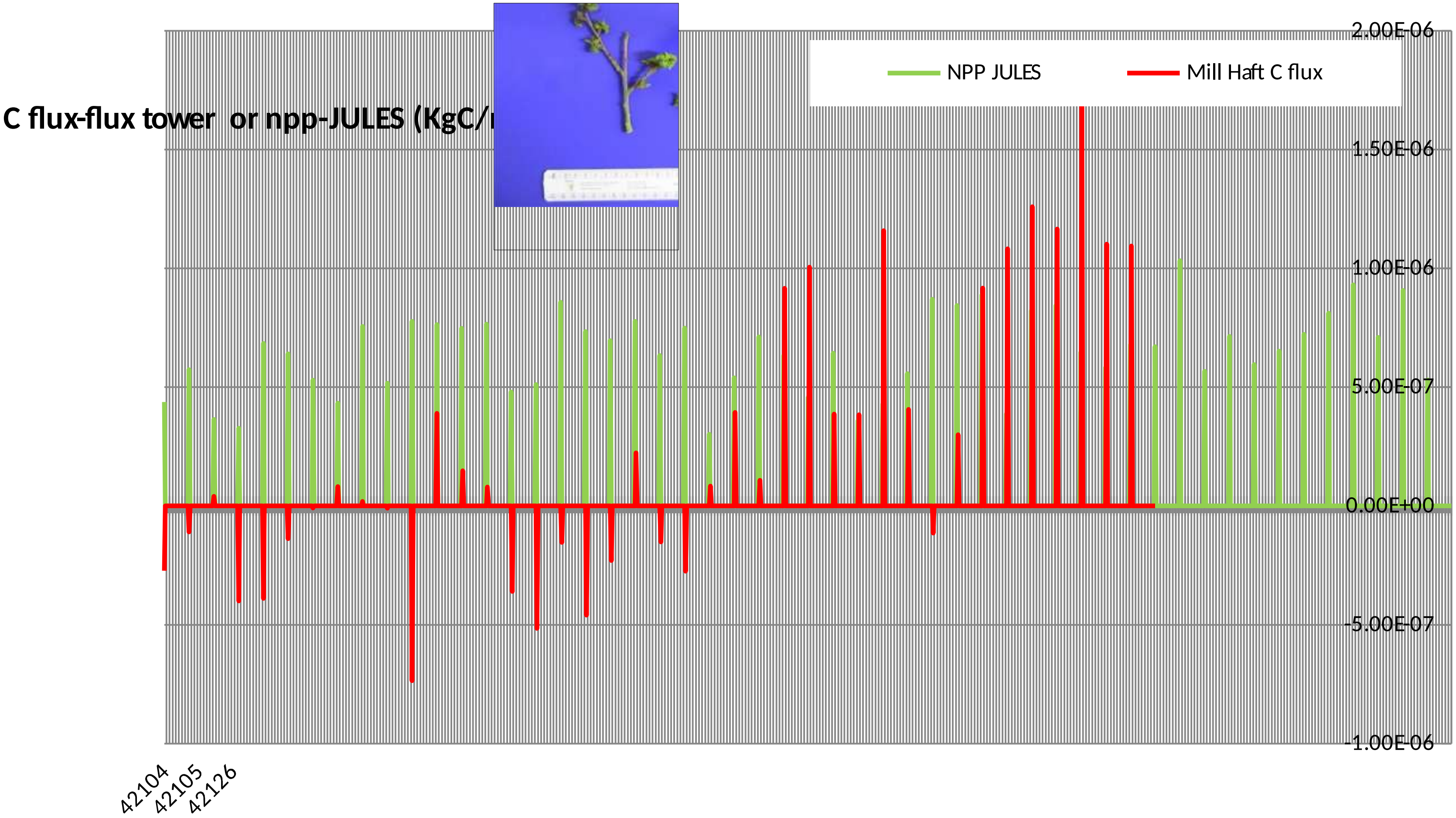
Test a semi-mechanistic phenology model within JULES



JULES – some preliminary results

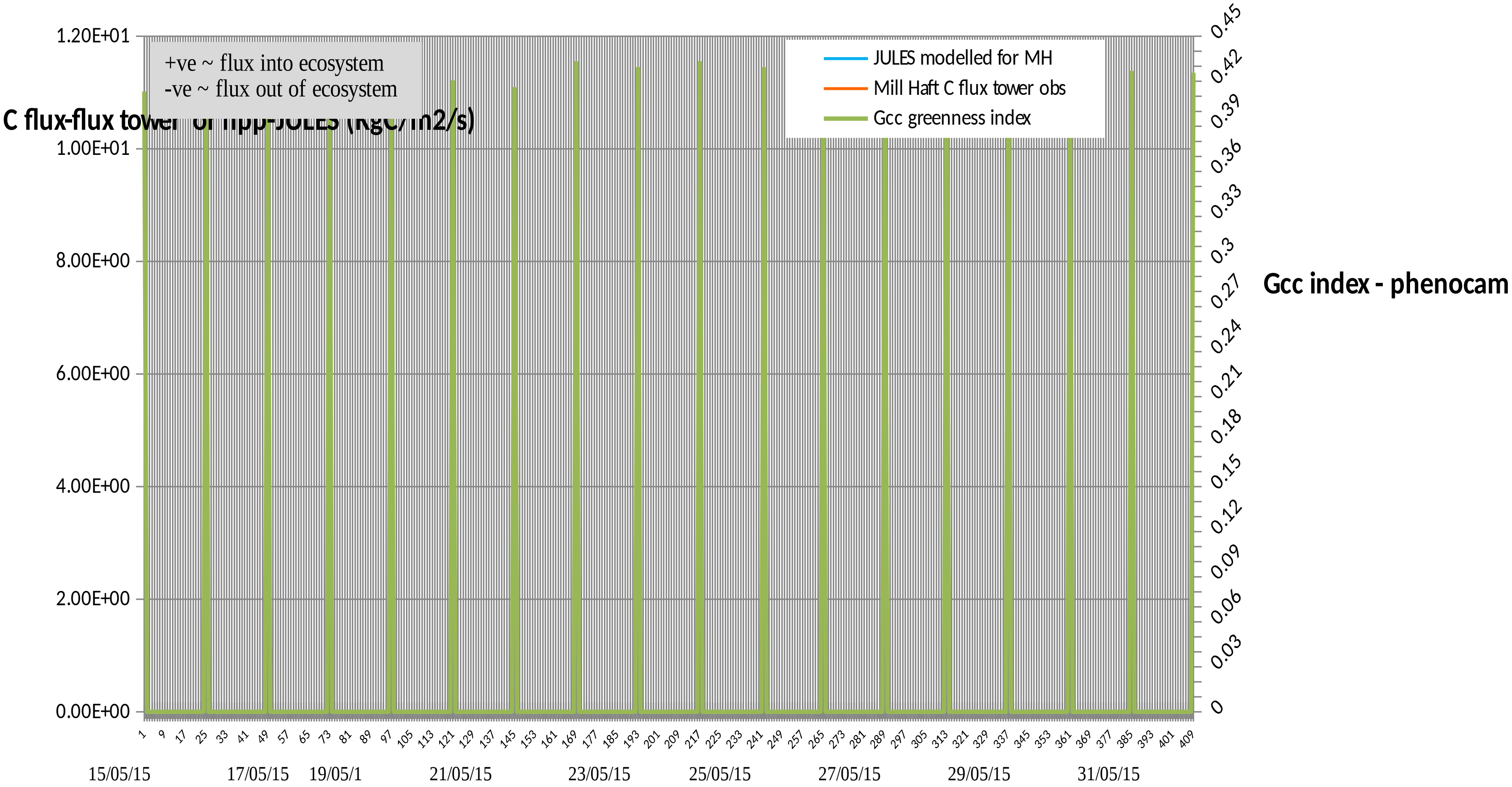
Flux tower C flux and JULES NPP (KgC/m2/day)

Oak bud burst Mill Haft – 29/04/15

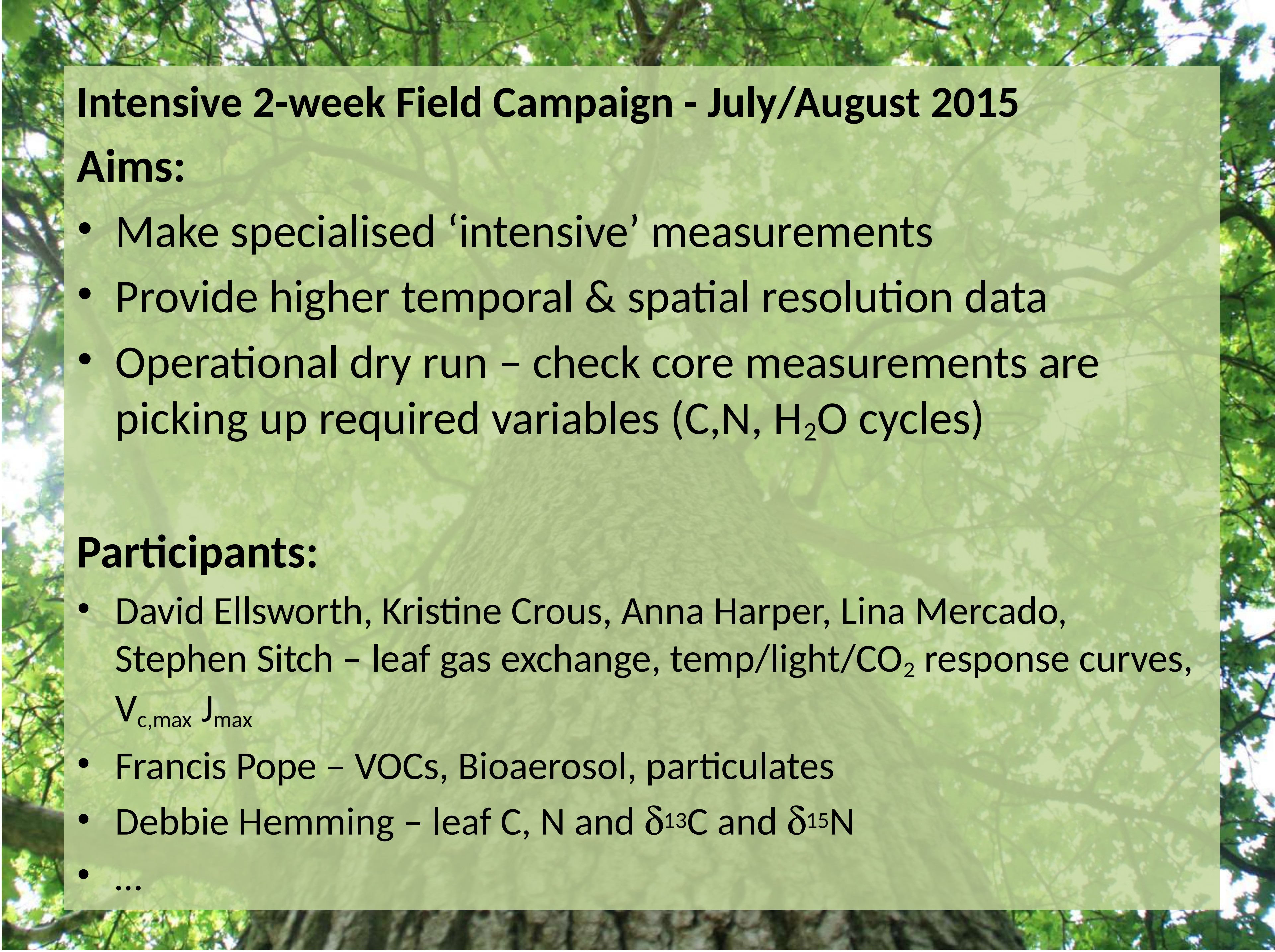


JULES – some preliminary results

Flux tower C flux and JULES NPP (KgC/m2/hour)



+ve ~ flux into ecosystem
-ve ~ flux out of ecosystem



Intensive 2-week Field Campaign - July/August 2015

Aims:

- Make specialised ‘intensive’ measurements
- Provide higher temporal & spatial resolution data
- Operational dry run – check core measurements are picking up required variables (C,N, H_2O cycles)

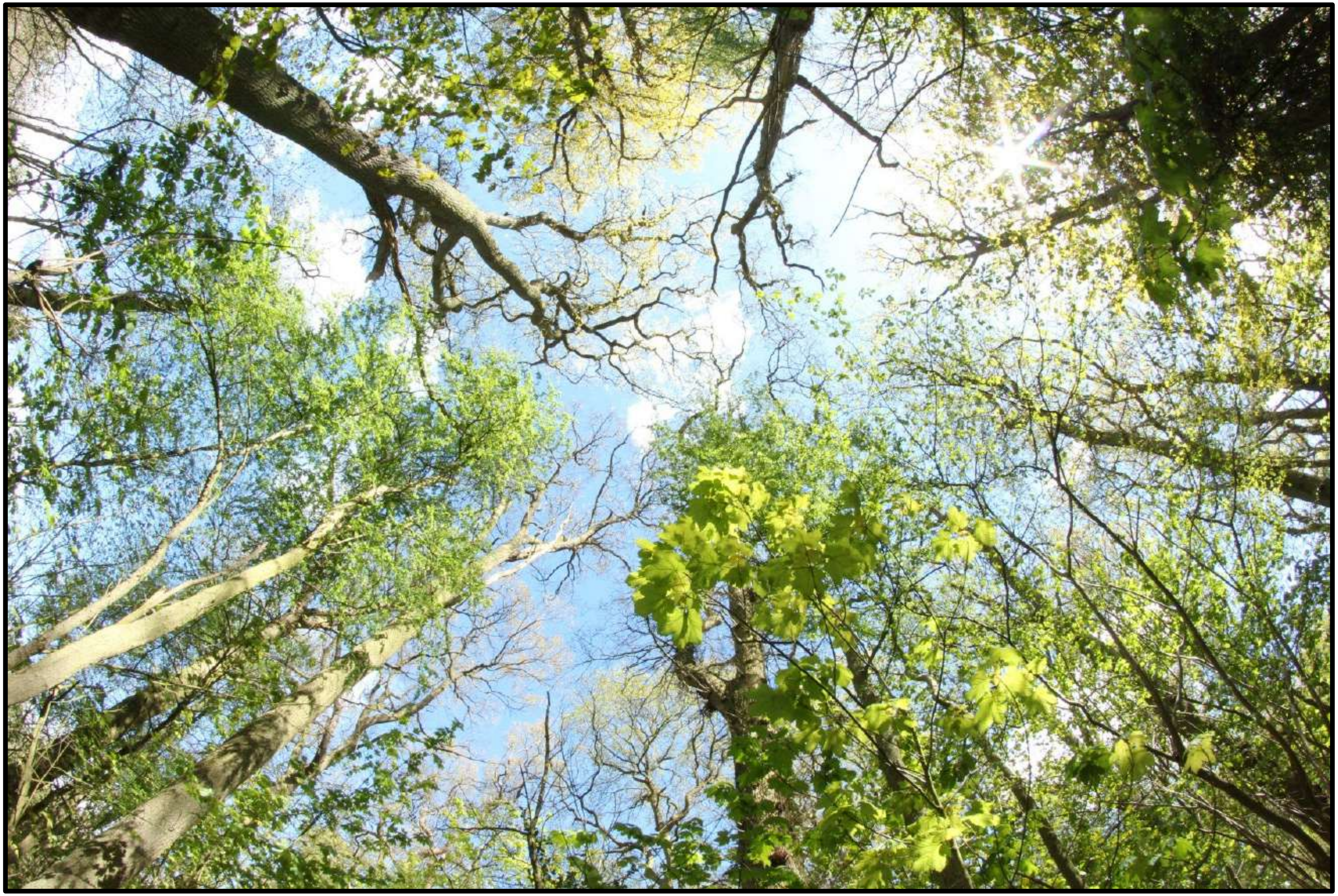
Participants:

- David Ellsworth, Kristine Crous, Anna Harper, Lina Mercado, Stephen Sitch – leaf gas exchange, temp/light/CO_2 response curves, $V_{c,max}$ J_{max}
- Francis Pope – VOCs, Bioaerosol, particulates
- Debbie Hemming – leaf C, N and $\delta^{13}C$ and $\delta^{15}N$
- …

Please contact me if you have ideas for measurements/experiments at Mill Haft

Thank you !

Plant ecophysiology

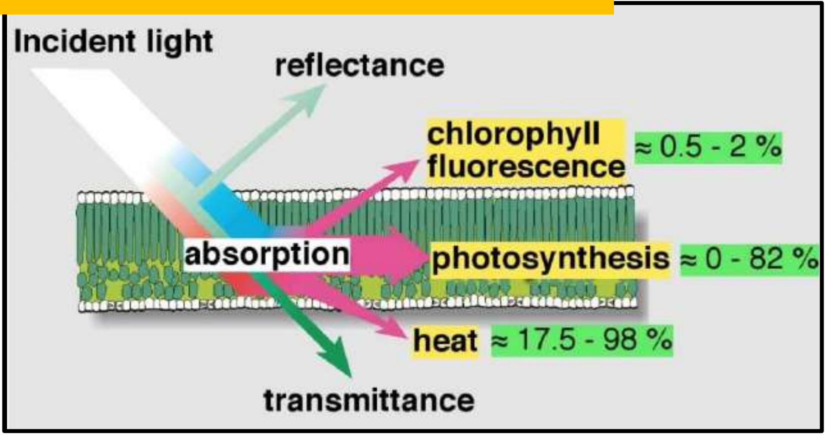


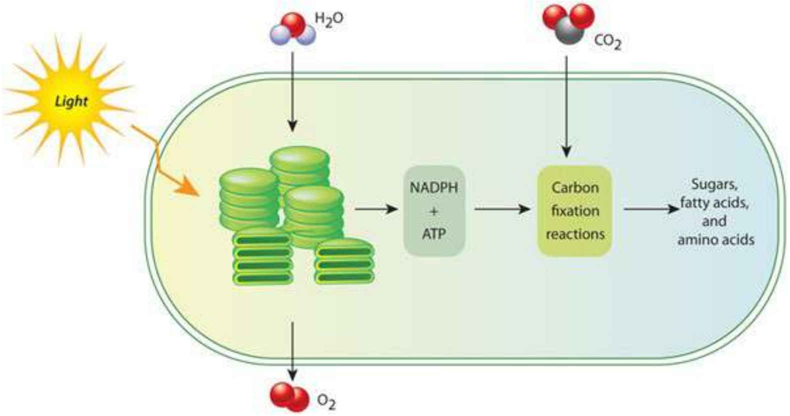
Photosynthesis and chlorophyll fluorescence

How is the development of the photosynthetic apparatus during phenological development affected by eCO_2?

Phenological ‘greening-up’ is related to increases in leaf area, and development of chlorophyll and other pigments associated with photochemistry

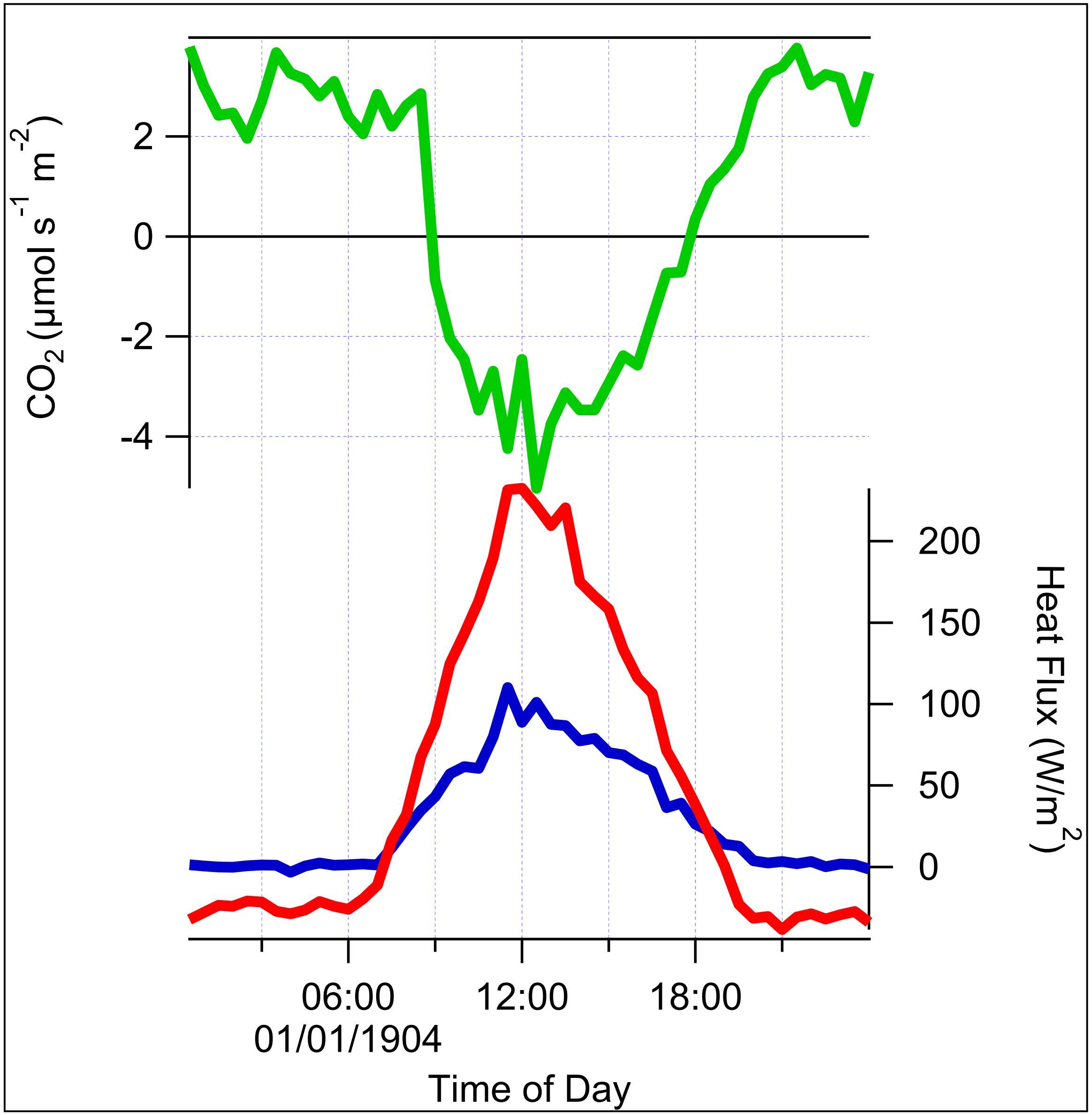
Fluorescence is given off during the photochemical reactions





Fluorescence provides information on the state of photosystems, response to stress and rates of CO_2 fixation

Diurnal Cycles



C and N allocation

What are the seasonal dynamics of C and N allocation in oak ?

Stored carbohydrates (esp. starch) are vital for the resilience of trees to variable environmental conditions and other stresses

Earlywood in oak trees is typically formed from the previous years' carbohydrates

Aviemore, Scotland oak tree ring carbon isotopes
Earlywood and Latewood

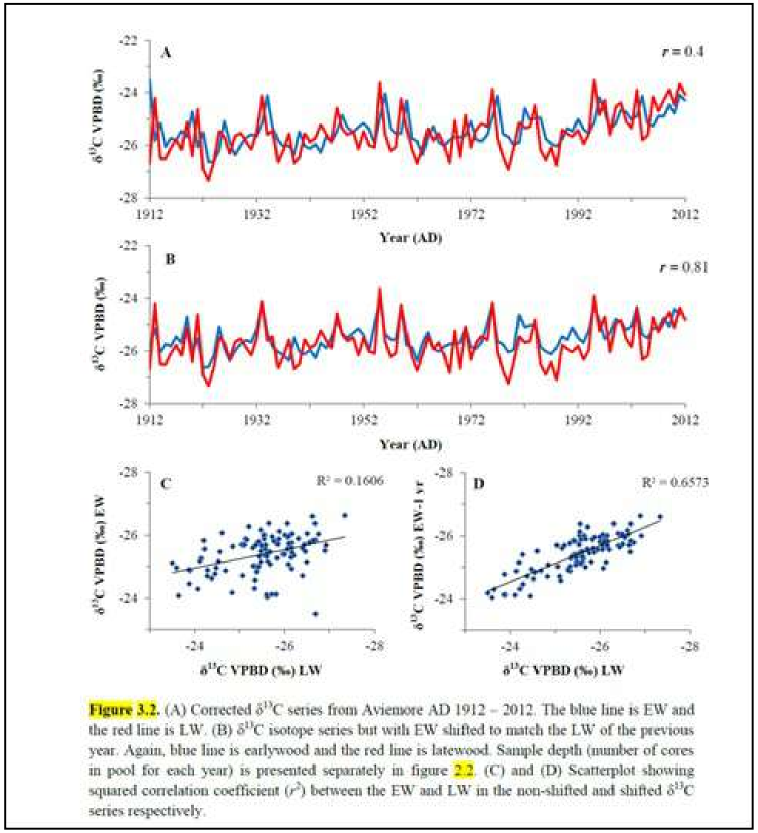


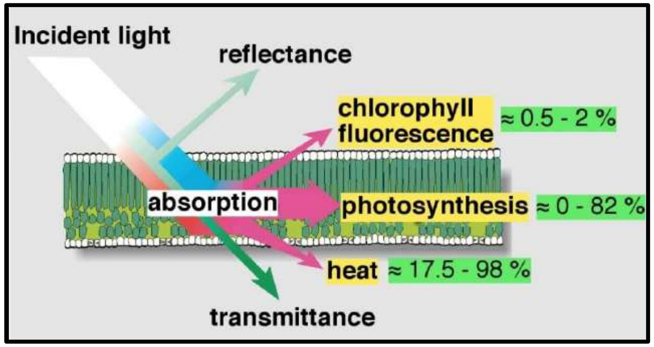
Figure 3.2. (A) Corrected $\delta^{13}C$ series from Aviemore AD 1912 – 2012. The blue line is EW and the red line is LW. (B) $\delta^{13}C$ isotope series but with EW shifted to match the LW of the previous year. Again, blue line is earlywood and the red line is latewood. Sample depth (number of cores in pool for each year) is presented separately in figure 2.2. (C) and (D) Scatterplot showing squared correlation coefficient (r^2) between the EW and LW in the non-shifted and shifted $\delta^{13}C$ series respectively.

Loader, in prep

Overview

- Tree ring analyses

- C and N allocation during phenological changes



- Photosynthesis and chlorophyll fluorescence

Chlorophyll fluorescence - leaf to global scales

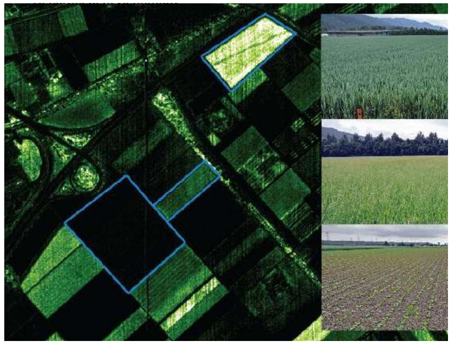
Can we use UAV-based systems to detect chlorophyll fluorescence from the canopy and determine canopy-level effects of eCO_2 on photochemistry and CO_2 assimilation? (with Rick Thomas)

Chl

from canopy, airborne and satellite platforms

It is an emerging tool for estimating photosynthesis at canopy to global scales

We aim to see if we can detect and monitor photosynthetic differences between eCO_2 rings, control rings and surrounding forest?



GOME-2