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Xylem sapflow at BIFoR FACE: early results of Tree-Soil-Water Relations

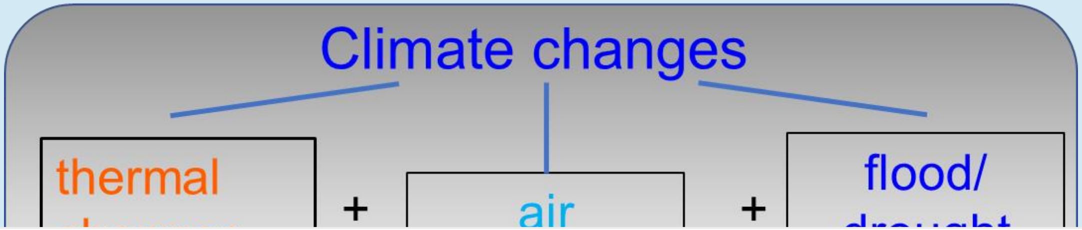
2017-2019

Susan Quick SEQ616@student.bham.ac.uk

Supervisors: Prof. Rob MacKenzie and Prof. Stefan Krause

Acknowledgements: BIFoR Operations Team, Prof. Neil Loader, and others who have reviewed my work.

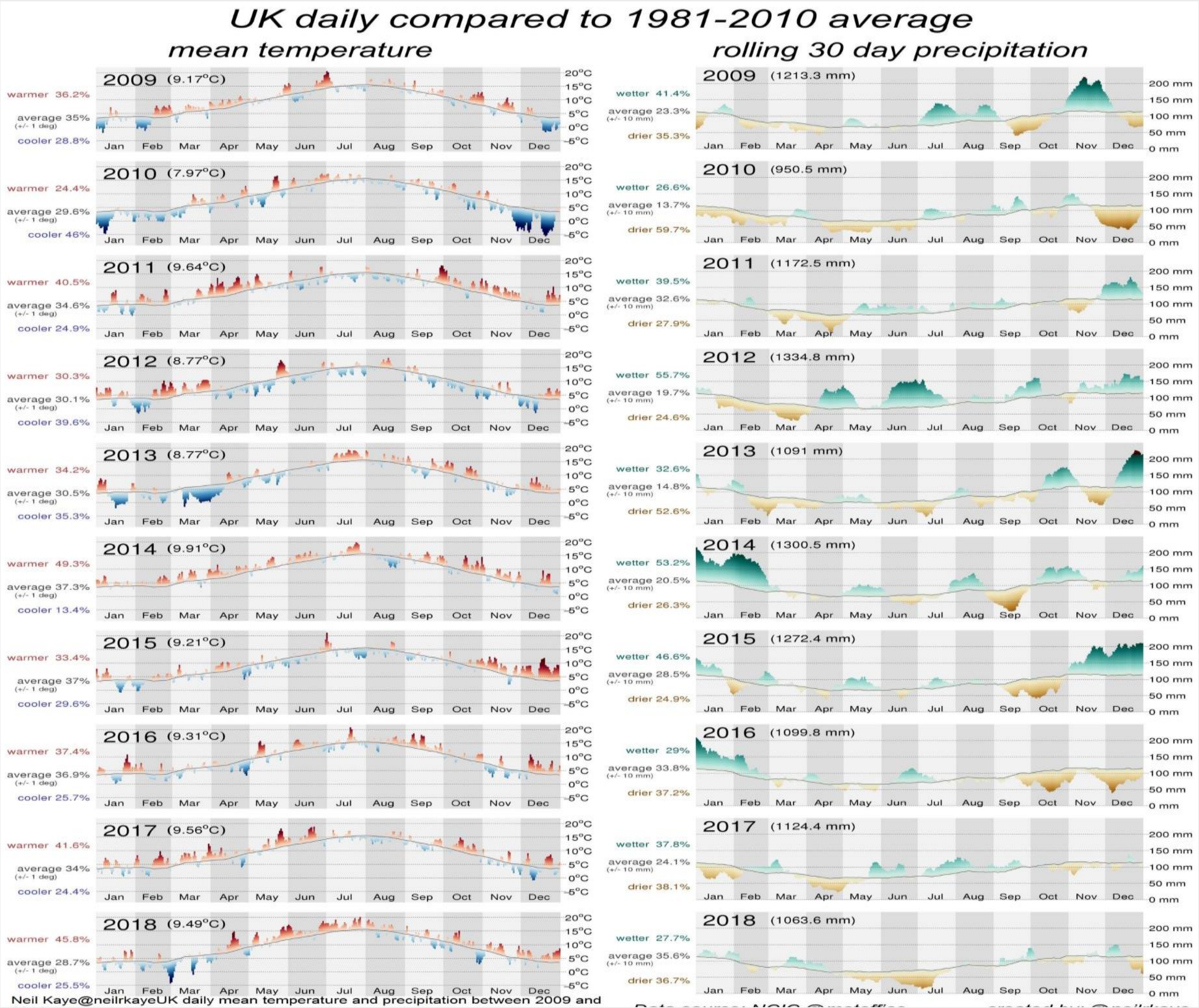
Resilience to Climate Change:



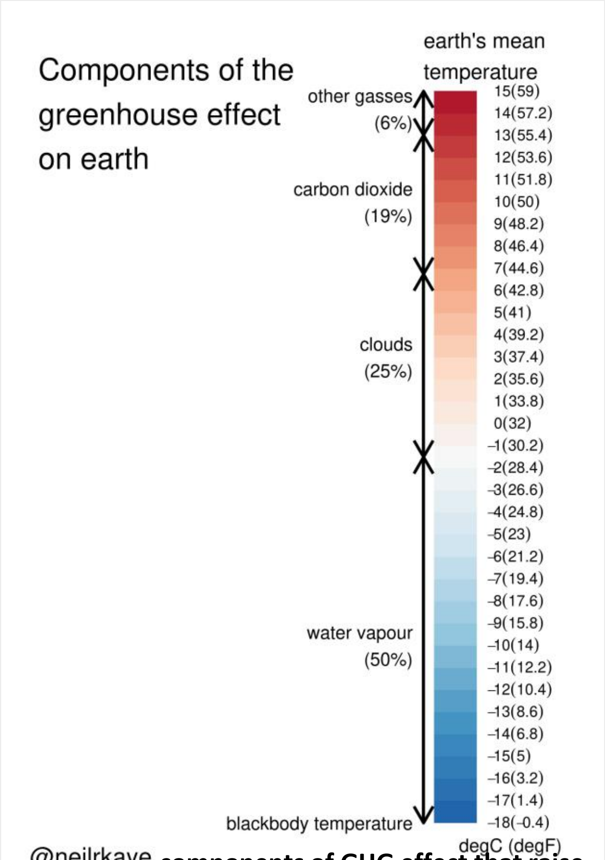
Water –

Carbon –

Energy



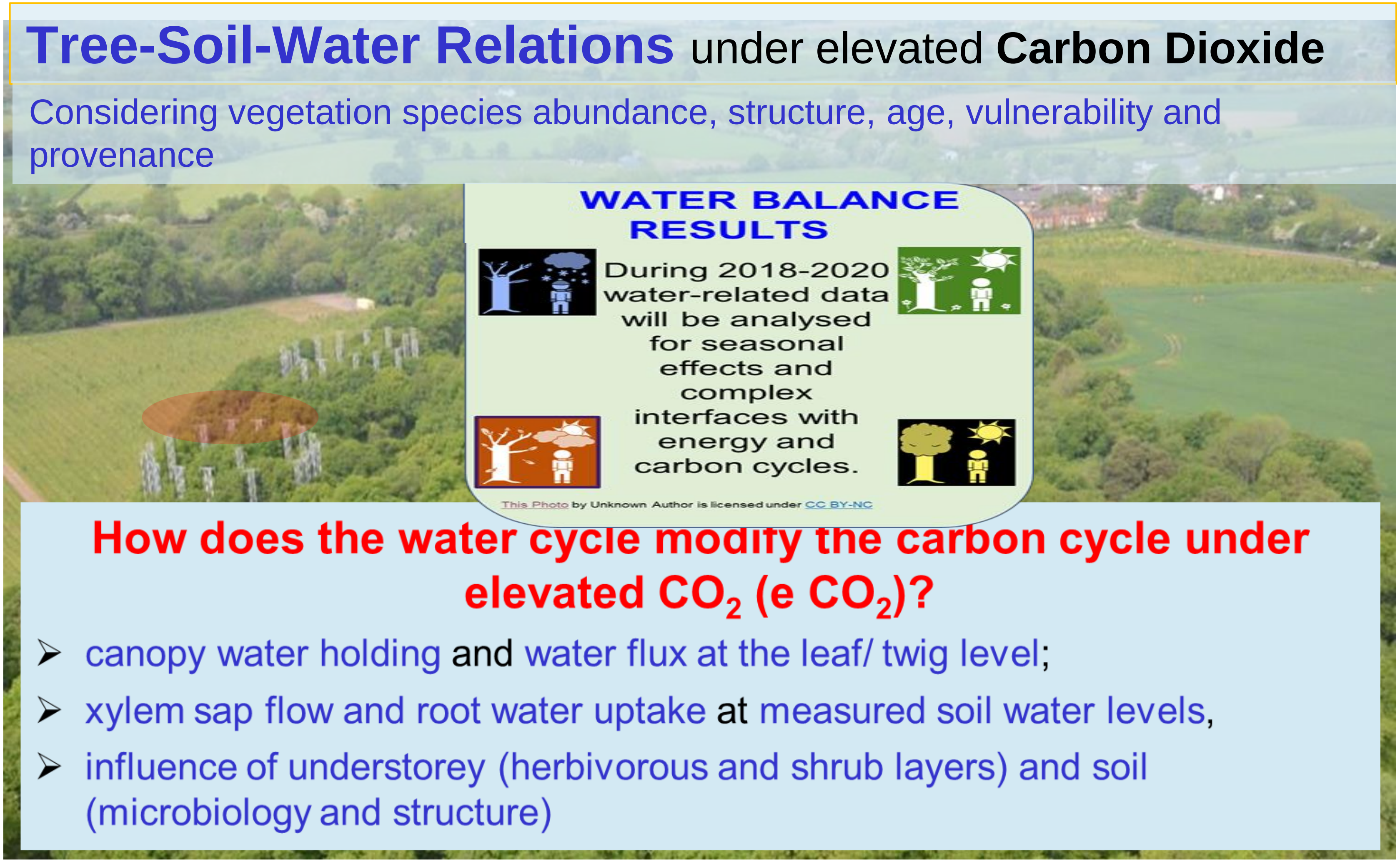
Neil Kaye@neilrkayeUK daily mean temperature and precipitation between 2009 and



components of GHG effect that raise earth's mean temp. from -18° to 15° C.

Tree-Soil-Water Relations under elevated **Carbon Dioxide**

Considering vegetation species abundance, structure, age, vulnerability and provenance



WATER BALANCE RESULTS

During 2018-2020 water-related data will be analysed for seasonal effects and complex interfaces with energy and carbon cycles.

How does the water cycle modify the carbon cycle under elevated CO_2 (e CO_2)?

- canopy water holding and water flux at the leaf/ twig level;
- xylem sap flow and root water uptake at measured soil water levels,
- influence of understorey (herbivorous and shrub layers) and soil (microbiology and structure)

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What do we expect? First hypotheses…

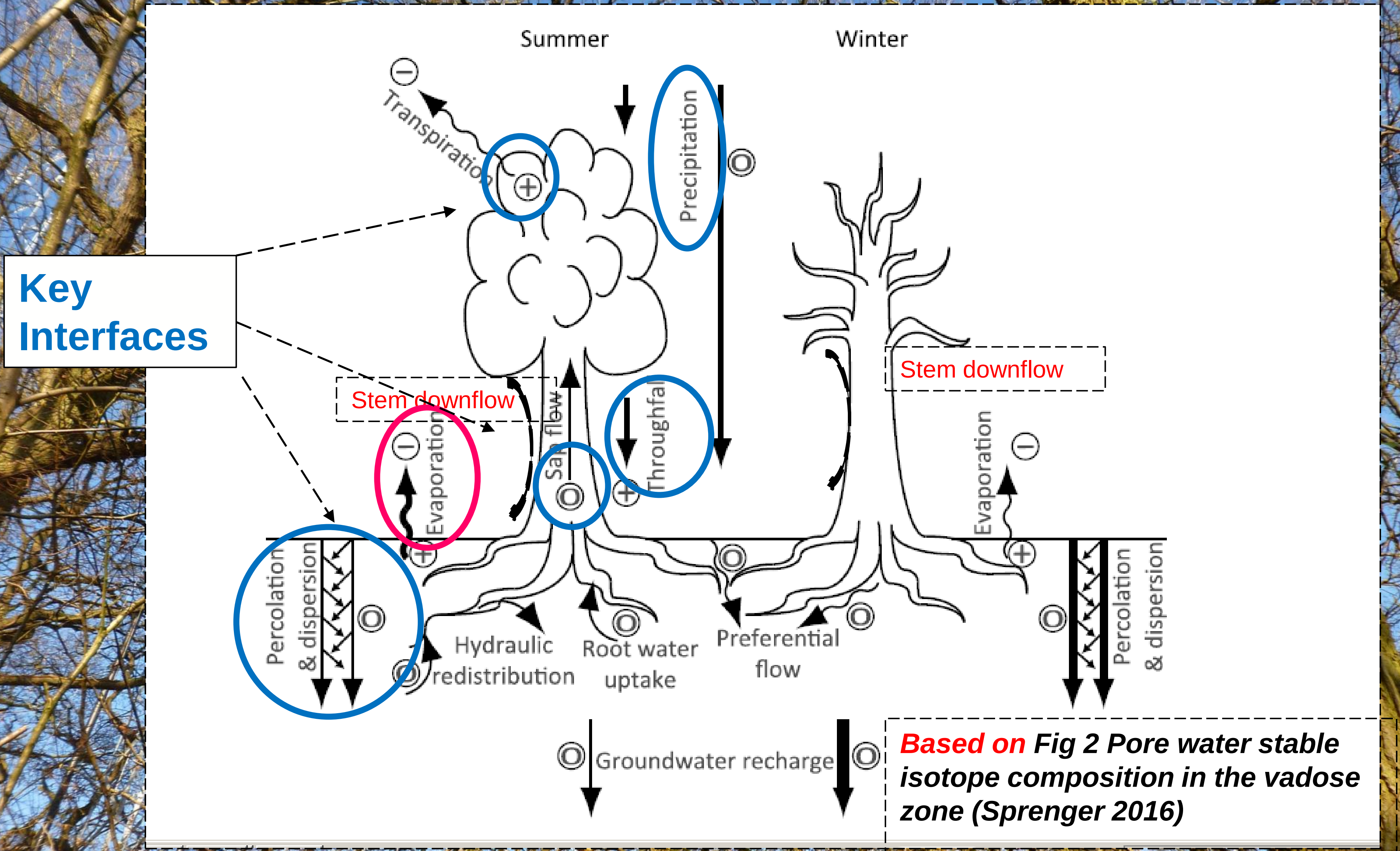
Water availability is the primary switch, governing woodland ecosystems as a net carbon ‘sink’ or net ‘source’

Oak has a more plastic adaptive phenological response to solar radiation effects and temperature than Sycamore, with different water usage strategies

Native oak-dominant woodland with sub-dominant sycamore, hawthorn, hazel and holly, is more resilient to eCO_2 than the oak species alone
e.g. ***Sycamore xylem diffuse porosity means it adapts better than oak, a ring porous species.*** **but is more vulnerable to water shortage;**

Tree-Soil-Water relations

Model of Soil Plant Atmosphere Continuum



Key Interfaces

Stem downflow

Stem downflow

***Based on** Fig 2 Pore water stable isotope composition in the vadose zone (Sprenger 2016)*

Steppe et al (2015)

Tree-Soil-Water relations

Remote monitoring

Transpiration and Sap flow

BIOSPHERE

Canopy extent *

Leaf Area Index *

Sub canopy temperature & humidity

Dendrometry *

Xylem flow* & cavitation

Shrub layer & groundcover vegetation density

Throughfall * & stem flow

ATMOSPHERE

Atmospheric weather* – (rain, solar energy, wind, temperature, relative humidity)

Above canopy fluxes*

H_2O*

CO_2 *

Light levels*

Tower measures

PEDOSPHERE

Soil temperature profile*

Soil moisture profile *

*** Now being measured in research woodland.**

HYDROSPHERE

Soil moisture Content

BIOSPHERE

PEDOSPHERE

Spring & Autumn

Phenology:

Trees + Understorey

+phenocam)

Tree cores, Water isotopes

HYDROSPHERE

ATMOSPHERE

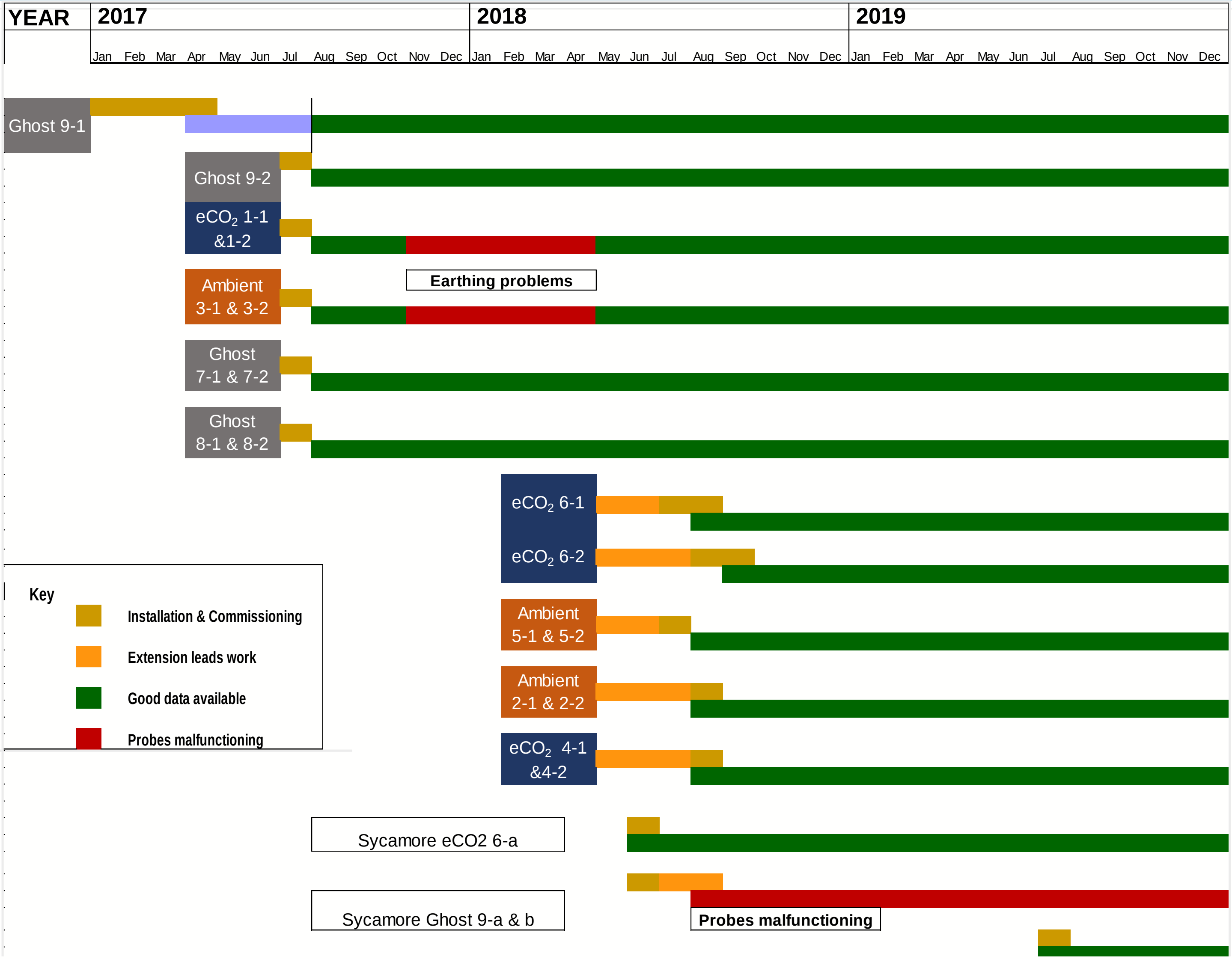
Transpiration

Trees + Understorey

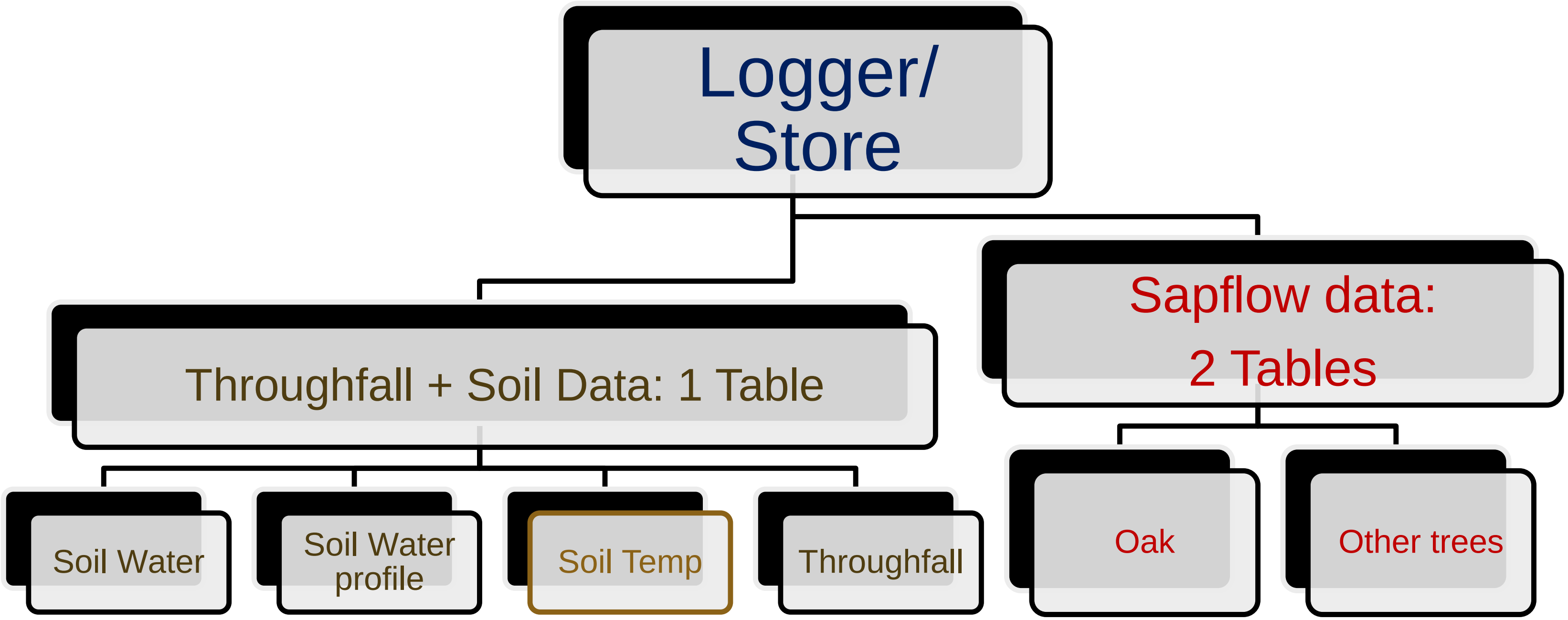
Tree-Soil-Water relations: Spot measures + Citizen Science Records

Sapflow installations
G8
T6
2018
A5
G7
T4
BIFoR
A2
G9
2017
A3
T1
Google Earth
N
200 m

Timeline for sapflow installations and data 2017- 2019



Types of Remote Data for Analysis



Logger/ Store

Throughfall + Soil Data: 1 Table

Soil Water

Soil Water profile

Soil Temp

Throughfall

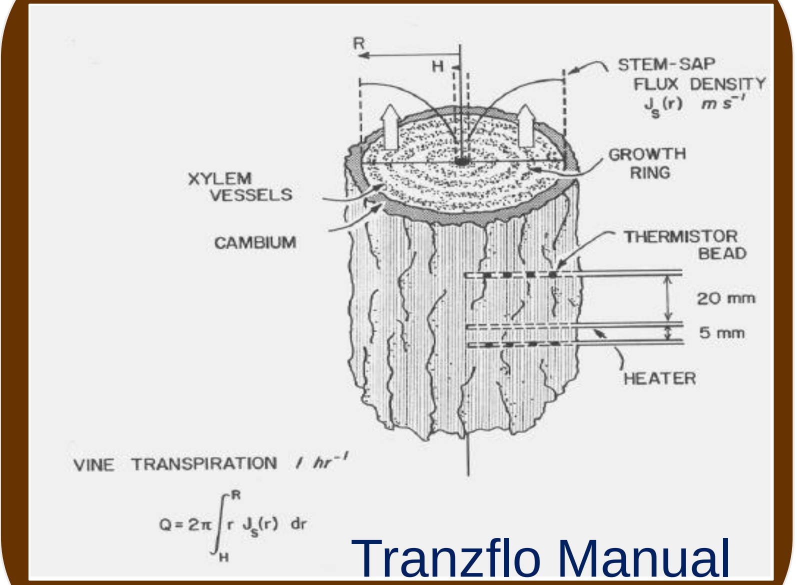
Sapflow data:

2 Tables

Oak

Other trees

Xylem Sapflow CHP Measurement



Tranzflo Manual

Smith & Allen (1996) JExpBot

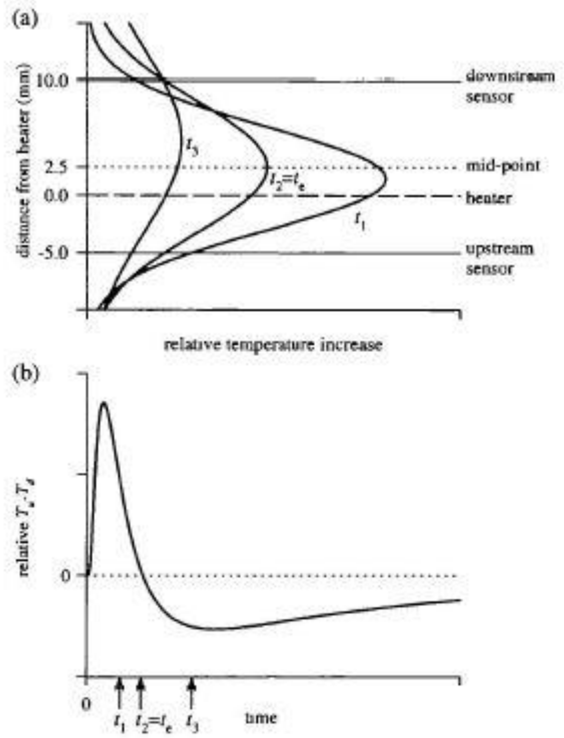
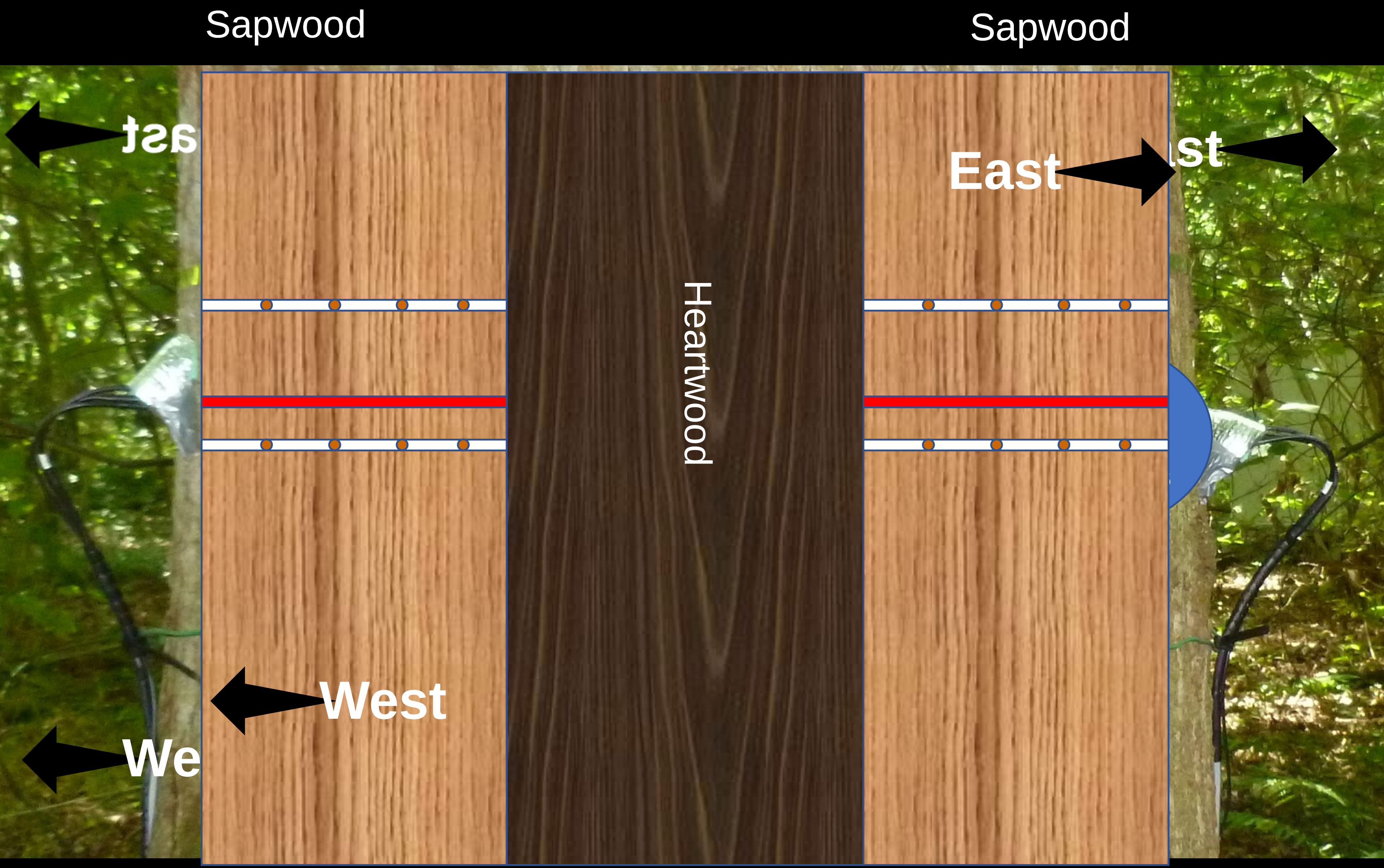
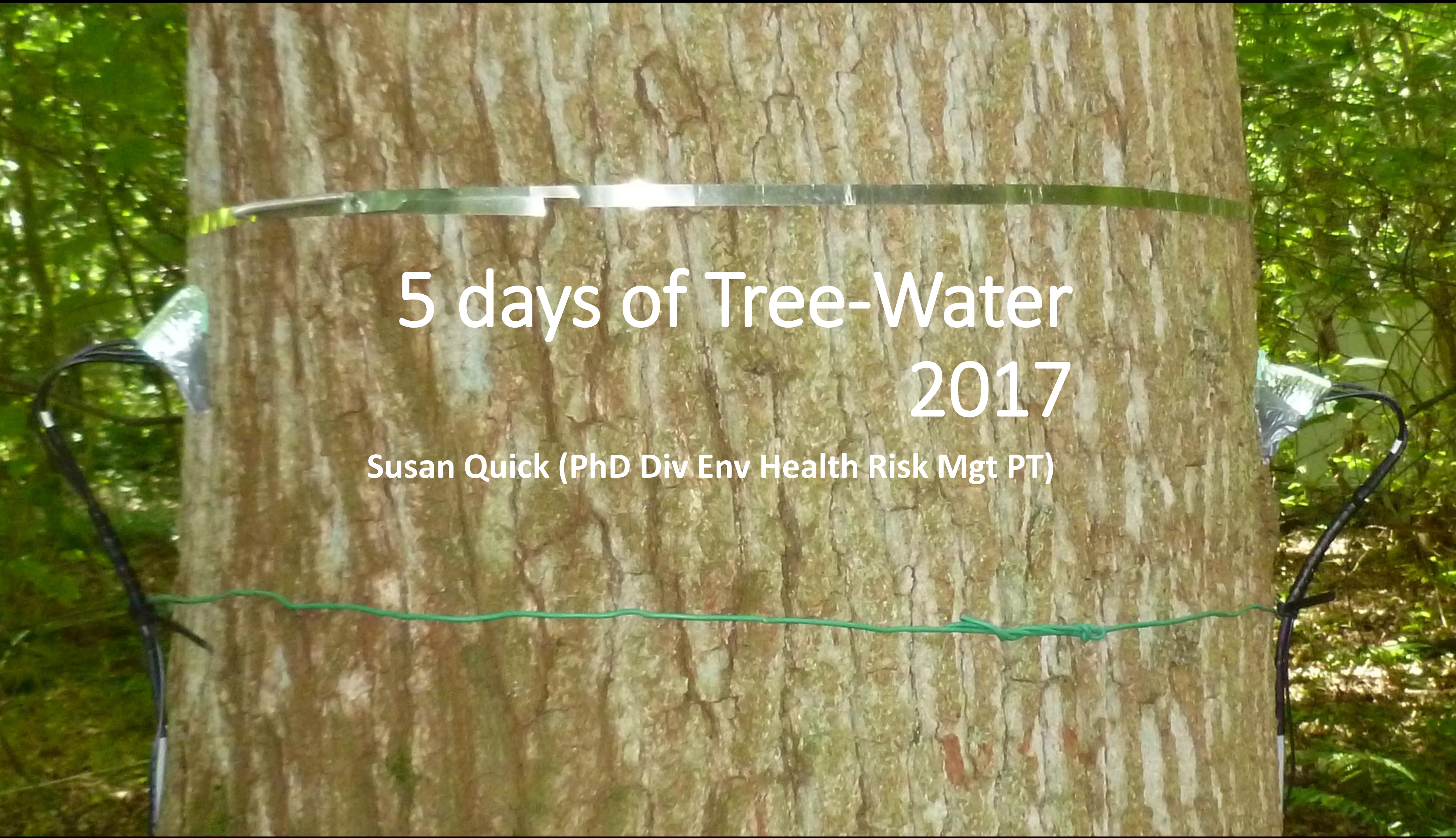


Fig. 4. Dissipation of a heat pulse released from a line heater into a stem containing moving sap and upstream and downstream sensor probes in the configuration shown in Fig. 3. (a) The distribution of relative temperature at times t_1, t_2 and t_3 after release of the heat pulse; the temperature of the upstream and downstream sensor probes are equal at time t_e. (b) Change with time in the temperature difference between the upstream and downstream temperature sensors ($T_u - T_d$) after release of the heat pulse.

Need baseline results

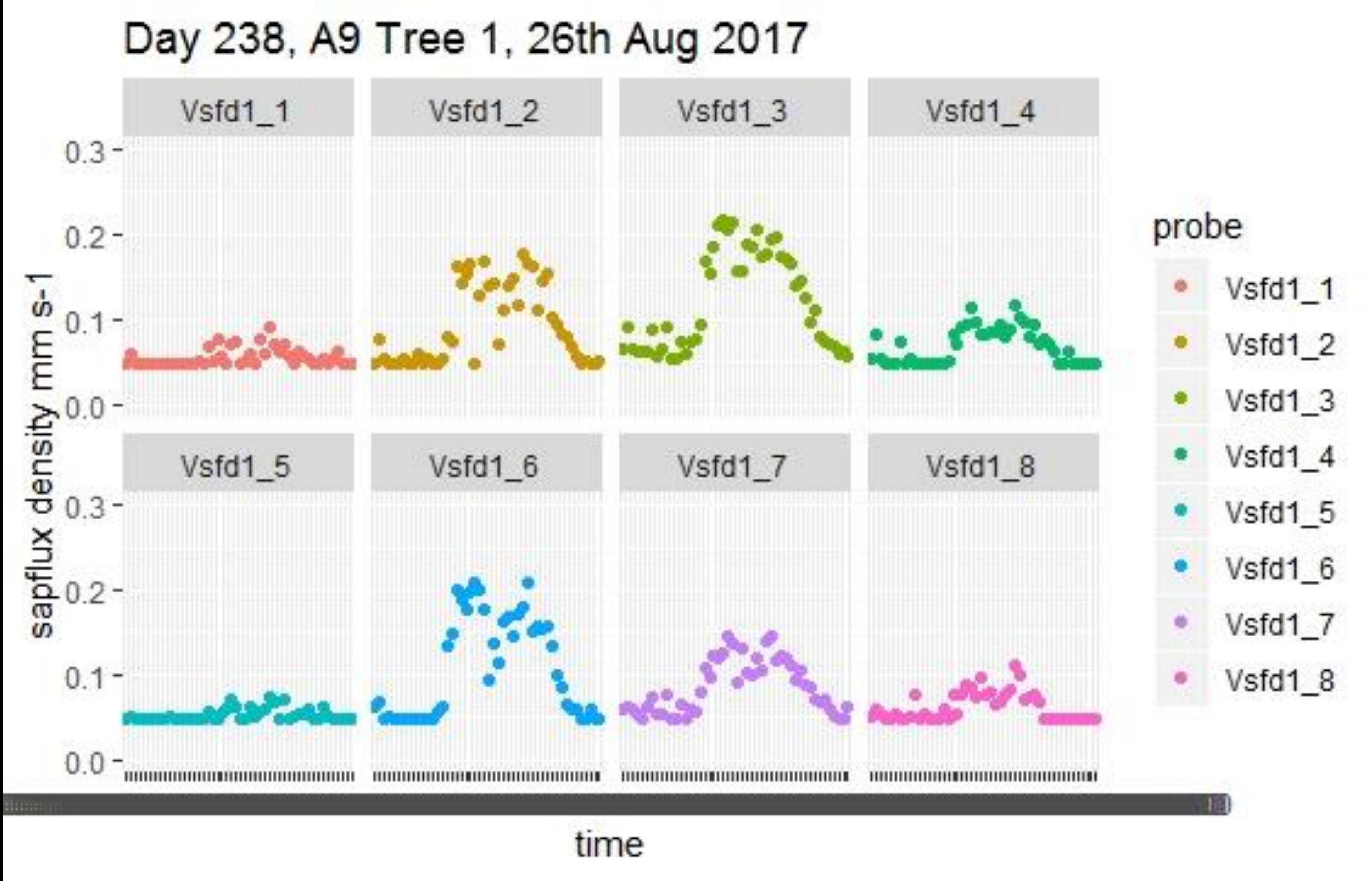
Will evapotranspiration will go up or down?

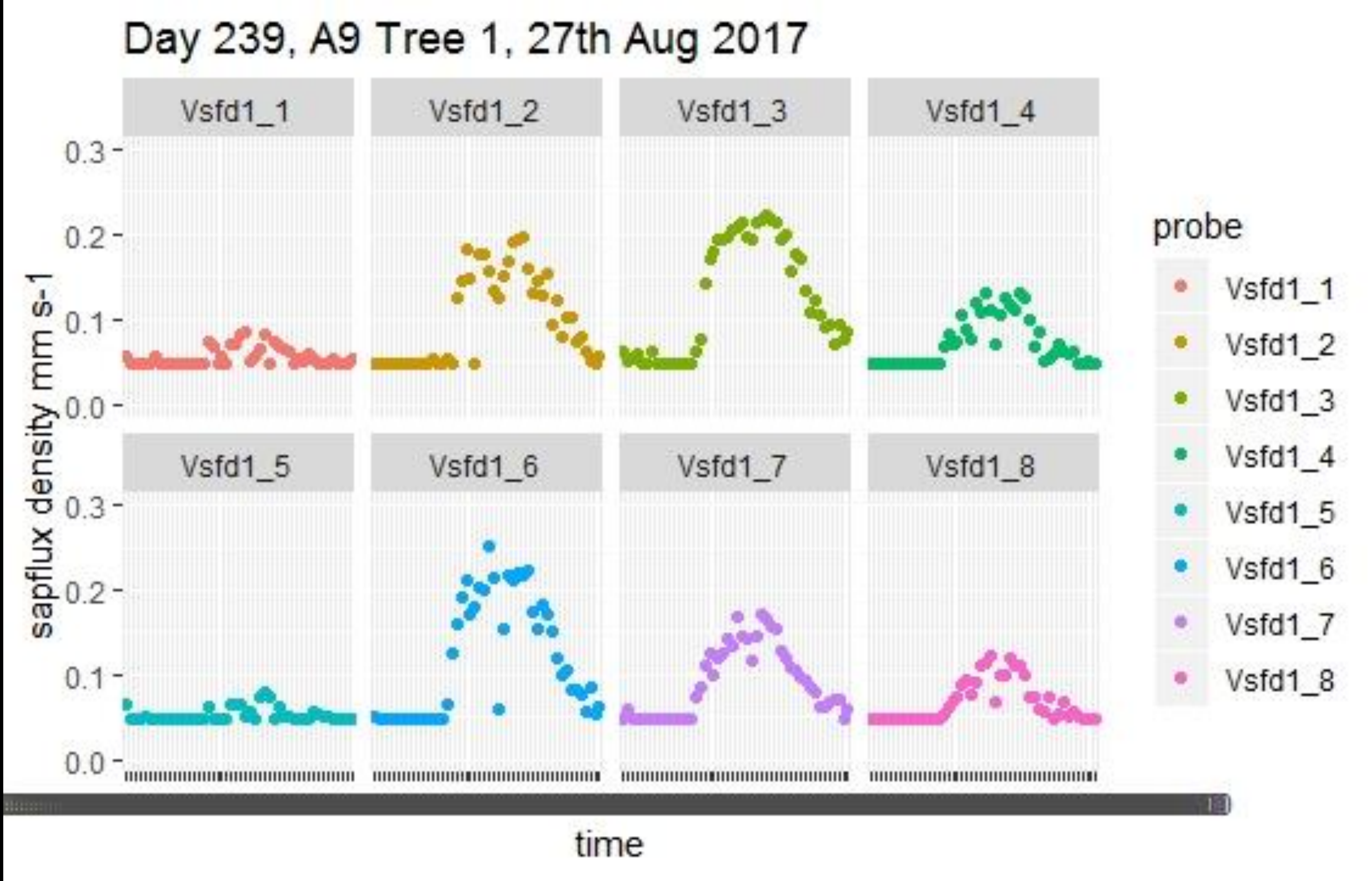

Sapwood
Sapwood
ast
East
Heartwood
West
We

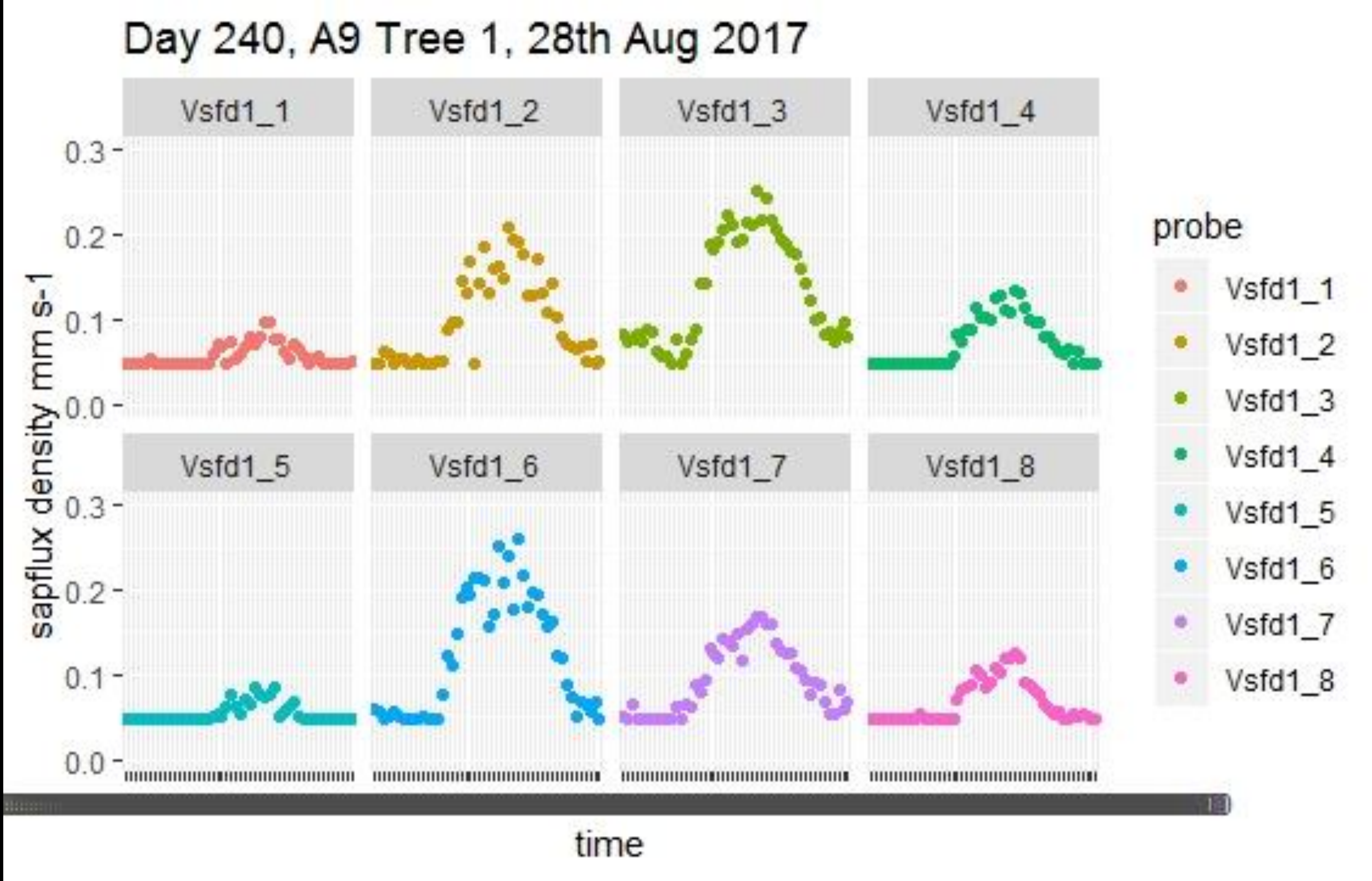


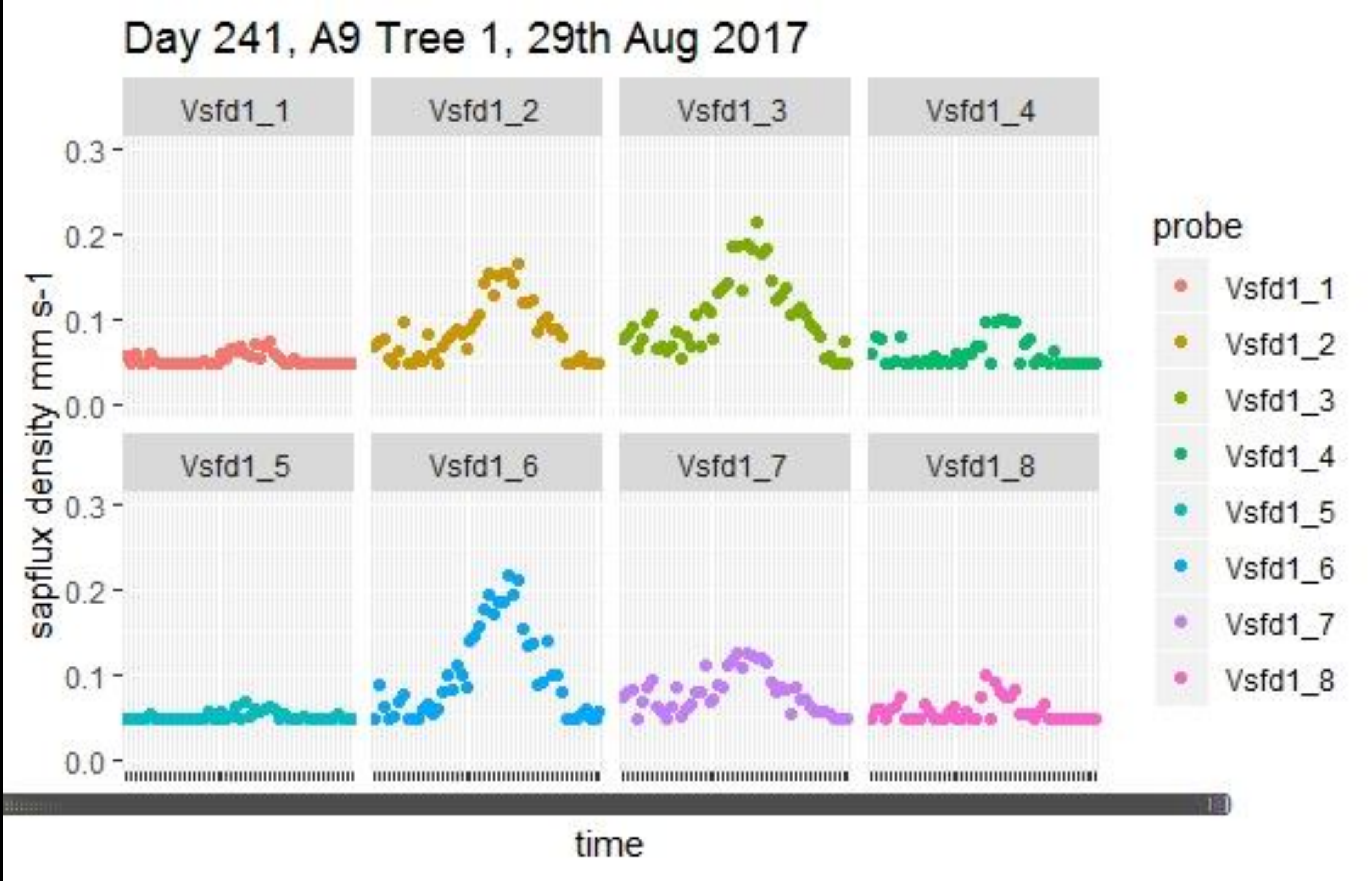
5 days of Tree-Water 2017

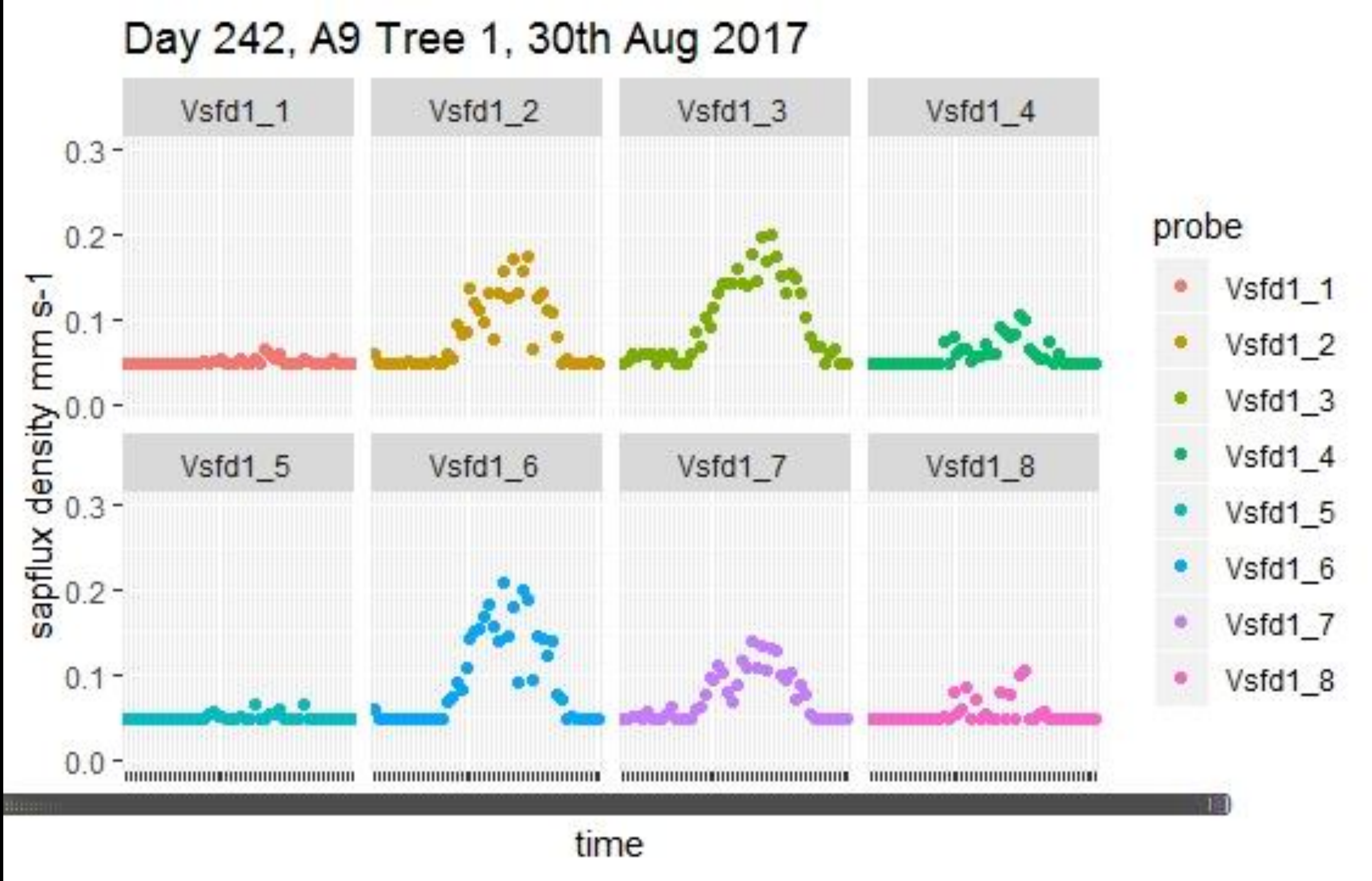
Susan Quick (PhD Div Env Health Risk Mgt PT)


Day 238, A9 Tree 1, 26th Aug 2017
Vsfd1_1
Vsfd1_2
Vsfd1_3
Vsfd1_4
Vsfd1_5
Vsfd1_6
Vsfd1_7
Vsfd1_8
0.3
0.2
0.1
0.0
sapflux density mm s-1
time
probe
Vsfd1_1
Vsfd1_2
Vsfd1_3
Vsfd1_4
Vsfd1_5
Vsfd1_6
Vsfd1_7
Vsfd1_8

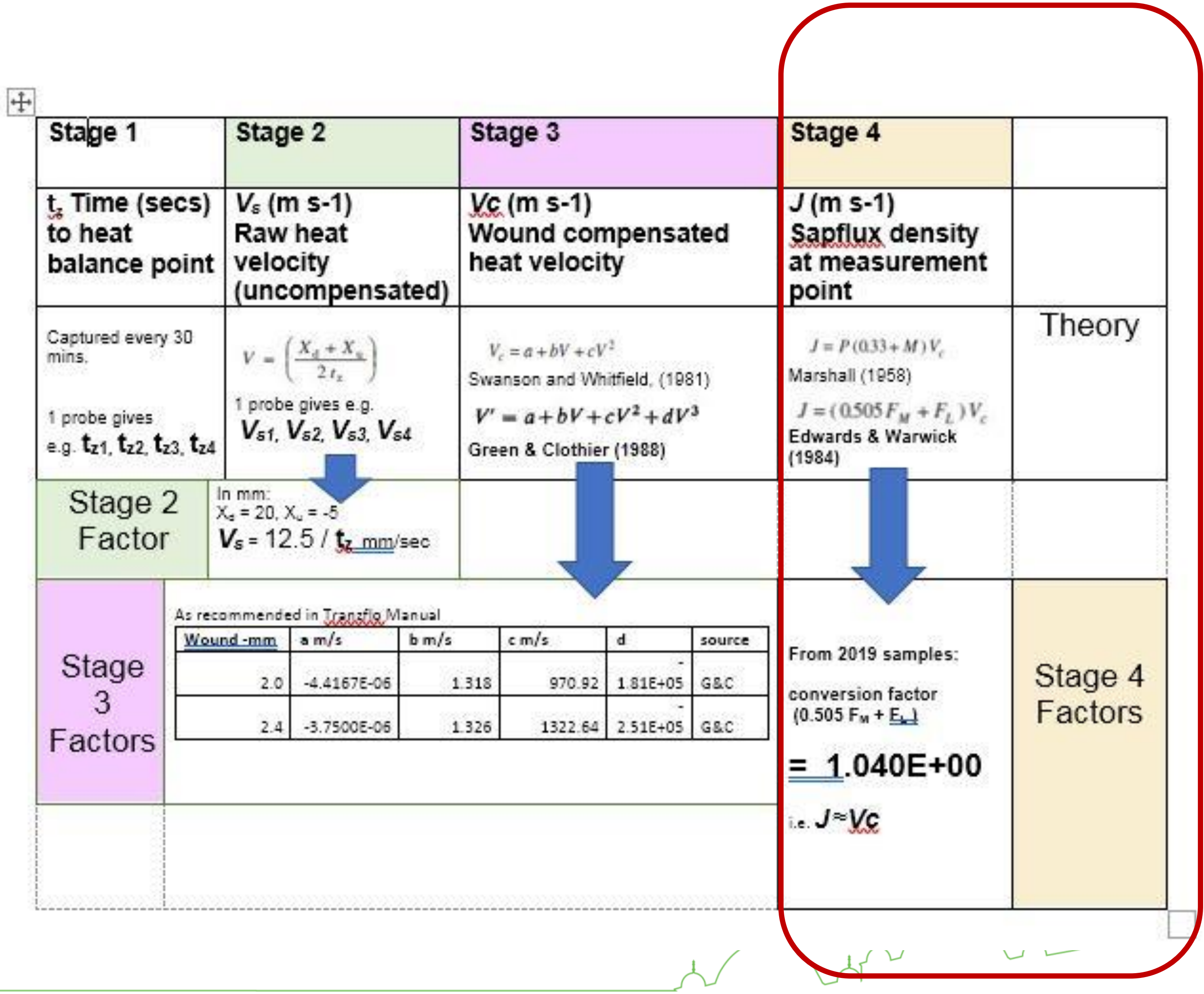

Day 239, A9 Tree 1, 27th Aug 2017
Vsfd1_1
Vsfd1_2
Vsfd1_3
Vsfd1_4
Vsfd1_5
Vsfd1_6
Vsfd1_7
Vsfd1_8
0.3
0.2
0.1
0.0
sapflux density mm s-1
time
probe
● Vsfd1_1
● Vsfd1_2
● Vsfd1_3
● Vsfd1_4
● Vsfd1_5
● Vsfd1_6
● Vsfd1_7
● Vsfd1_8


Day 240, A9 Tree 1, 28th Aug 2017
Vsfd1_1
Vsfd1_2
Vsfd1_3
Vsfd1_4
Vsfd1_5
Vsfd1_6
Vsfd1_7
Vsfd1_8
0.3
0.2
0.1
0.0
sapflux density mm s-1
time
probe
● Vsfd1_1
● Vsfd1_2
● Vsfd1_3
● Vsfd1_4
● Vsfd1_5
● Vsfd1_6
● Vsfd1_7
● Vsfd1_8


Day 241, A9 Tree 1, 29th Aug 2017
Vsfd1_1
Vsfd1_2
Vsfd1_3
Vsfd1_4
Vsfd1_5
Vsfd1_6
Vsfd1_7
Vsfd1_8
sapflux density mm s-1
0.3
0.2
0.1
0.0
time
probe
Vsfd1_1
Vsfd1_2
Vsfd1_3
Vsfd1_4
Vsfd1_5
Vsfd1_6
Vsfd1_7
Vsfd1_8


Day 242, A9 Tree 1, 30th Aug 2017
Vsfd1_1
Vsfd1_2
Vsfd1_3
Vsfd1_4
Vsfd1_5
Vsfd1_6
Vsfd1_7
Vsfd1_8
0.3
0.2
0.1
0.0
sapflux density mm s-1
time
probe
Vsfd1_1
Vsfd1_2
Vsfd1_3
Vsfd1_4
Vsfd1_5
Vsfd1_6
Vsfd1_7
Vsfd1_8

Stages 1-4 of Sapflow Data Calculation



Stage 1	Stage 2	Stage 3	Stage 4	
t_z Time (secs) to heat balance point	**V_s (m s-1) Raw heat velocity (uncompensated)**	**V_c (m s-1) Wound compensated heat velocity**	**J (m s-1) Sapflux density at measurement point**	
Captured every 30 mins. 1 probe gives e.g. $t_{z1}, t_{z2}, t_{z3}, t_{z4}$	$V = \left(\frac{X_d + X_u}{2 t_z}\right)$ 1 probe gives e.g. $V_{s1}, V_{s2}, V_{s3}, V_{s4}$	$V_c = a + bV + cV^2$ Swanson and Whitfield, (1981) $V' = a + bV + cV^2 + dV^3$ Green & Clothier (1988)	$J = P(0.33 + M)V_c$ Marshall (1958) $J = (0.505 F_M + F_L)V_c$ Edwards & Warwick (1984)	Theory

Stage 2 Factor

In mm:
$X_d = 20$, $X_u = -5$
$V_s = 12.5 / t_z$ mm/sec

Stage 3 Factors

As recommended in Tranzflo Manual

Wound -mm	a m/s	b m/s	c m/s	d	source
2.0	-4.4167E-06	1.318	970.92	-1.81E+05	G&C
2.4	-3.7500E-06	1.326	1322.64	-2.51E+05	G&C

Stage 4 Factors

From 2019 samples:

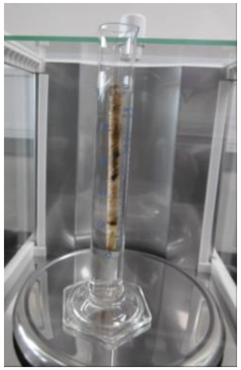
conversion factor
(0.505 F_M + F_L)

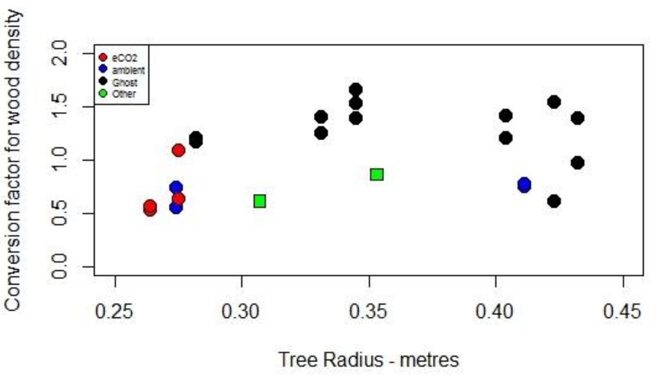
= 1.040E+00

i.e. $J \approx Vc$

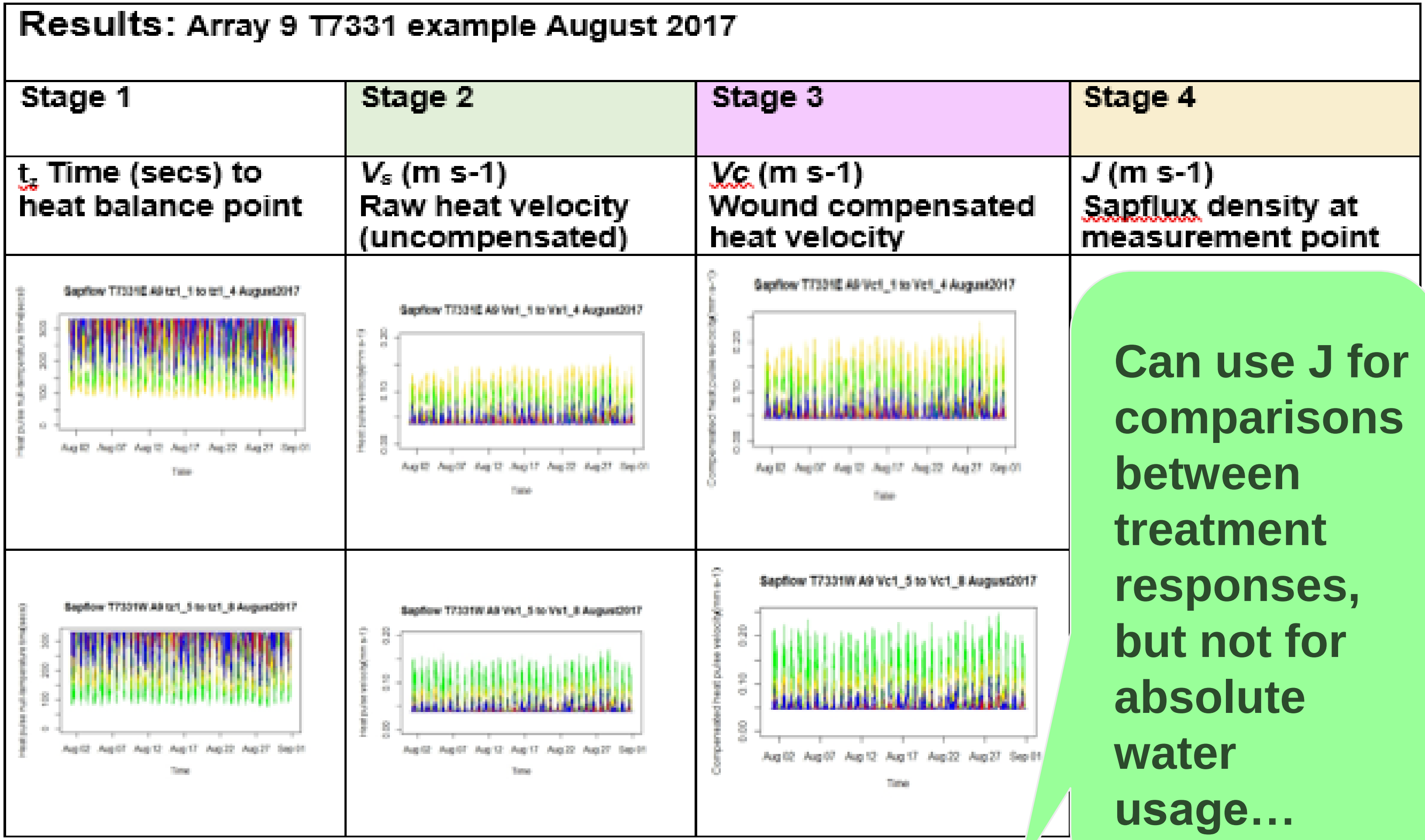
Stage 4: Volume fraction for oak woody matrix: mini – cores G7,8,9 + T1, A3 + 2 incremental. cores

treeNumber	TreeRadius	facing_dir	array	species	coreType	volFract Water	volFract Wood	heattoSapvelFactor	
7476	0.345	N	9	Oak	mini	1.083333	0.626362	1.399645969	
7476	0.345	SW	9	Oak	mini	1.333333	0.653595	1.663398693	
7476	0.345	SE	9	Oak	mini	1.238095	0.591348	1.536725801	
7331	0.404	W	9	Oak	mini	0.857143	0.684718	1.202925615	
7331	0.404	E	9	Oak	mini	1.052632	0.722394	1.41744066	
6021	0.423	W	7	Oak	mini	0.510204	0.213419	0.617980526	
6021	0.423	E	7	Oak	mini	1.222222	0.653595	1.552287582	
6027	0.331	W	7	Oak	mini	1.045455	0.713012	1.405525847	
6027	0.331	E	7	Oak	mini	0.925926	0.653595	1.255991285	
3634	0.432	W	8	Oak	mini	1.076923	0.628457	1.394293615	
3634	0.432	E	8	Oak	mini	0.625	0.694444	0.975694444	
3642	0.282	W	8	Oak	mini	0.862069	0.676133	1.203515889	
3642	0.282	E	8	Oak	mini	0.827586	0.676133	1.16903313	
9301	0.411	W	3	Oak	mini	0.6	0.300654	0.751830065	
9301	0.411	E	3	Oak	mini	0.632653	0.293451	0.780845672	
8351	0.274	W	3	Oak	mini	0.55	0.375817	0.739787582	
8351	0.274	E	3	Oak	mini	0.389974	0.329851	0.556549358	
8468	0.275	W	1	Oak	mini	0.490196	0.294758	0.639049084	
8468	0.275	E	1	Oak	mini	0.848485	0.475342	1.088532383	
8467	0.264	W	1	Oak	mini	0.403509	0.252265	0.530902419	
8467	0.264	E	1	Oak	mini	0.368421	0.395597	0.568197454	
8606	0.353	W	0	Oak	incr	0.689024	0.352702	0.867138929	
3176	0.307	W	0	Oak	incr	0.435927	0.346615	0.610967156	





Stages 1-4 of Sapflow Data Examples: Array 9 2017



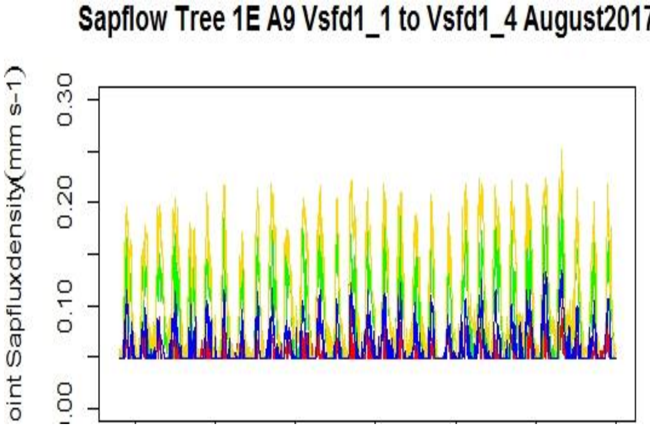
Results: **Array 9 T7331 example August 2017**

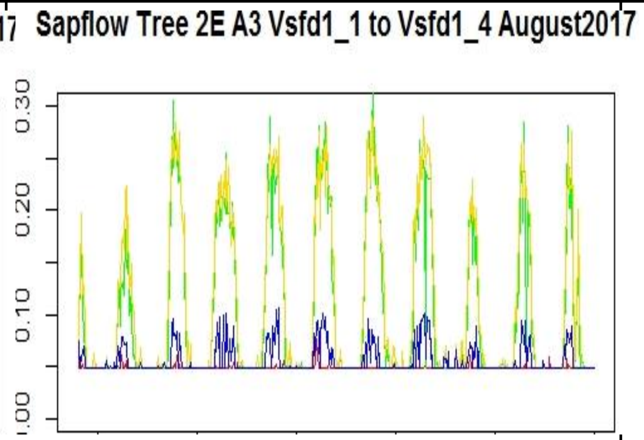
Stage 1	**Stage 2**	**Stage 3**	**Stage 4**
t_z Time (secs) to heat balance point	V_s (m s-1) Raw heat velocity (uncompensated)	Vc (m s-1) Wound compensated heat velocity	J (m s-1) Sapflux density at measurement point

Can use J for comparisons between treatment responses, but not for absolute water usage…

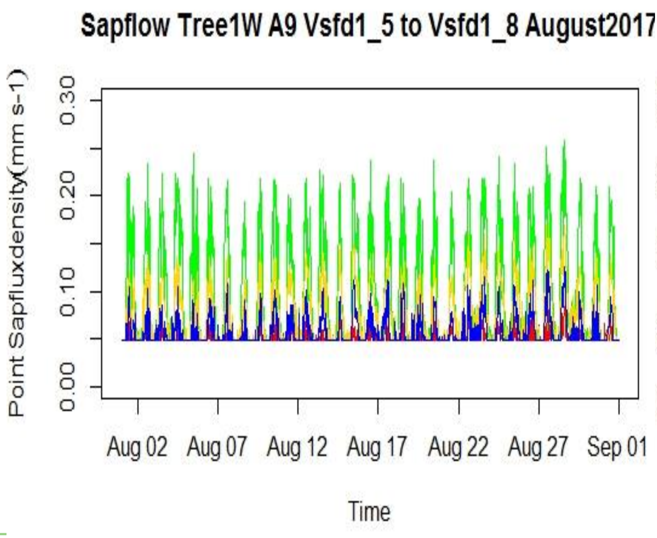
Comparing sapflux density 2017 – trees are all different

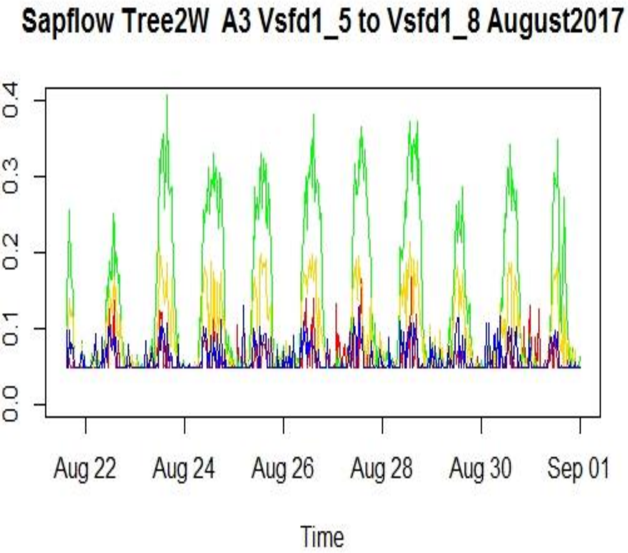
Ghost G9	Ambient A3	eCO_2 T1

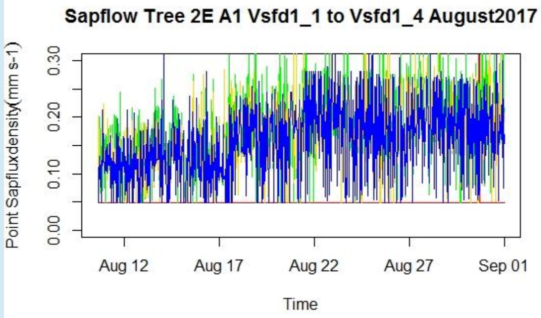




Earthing problems

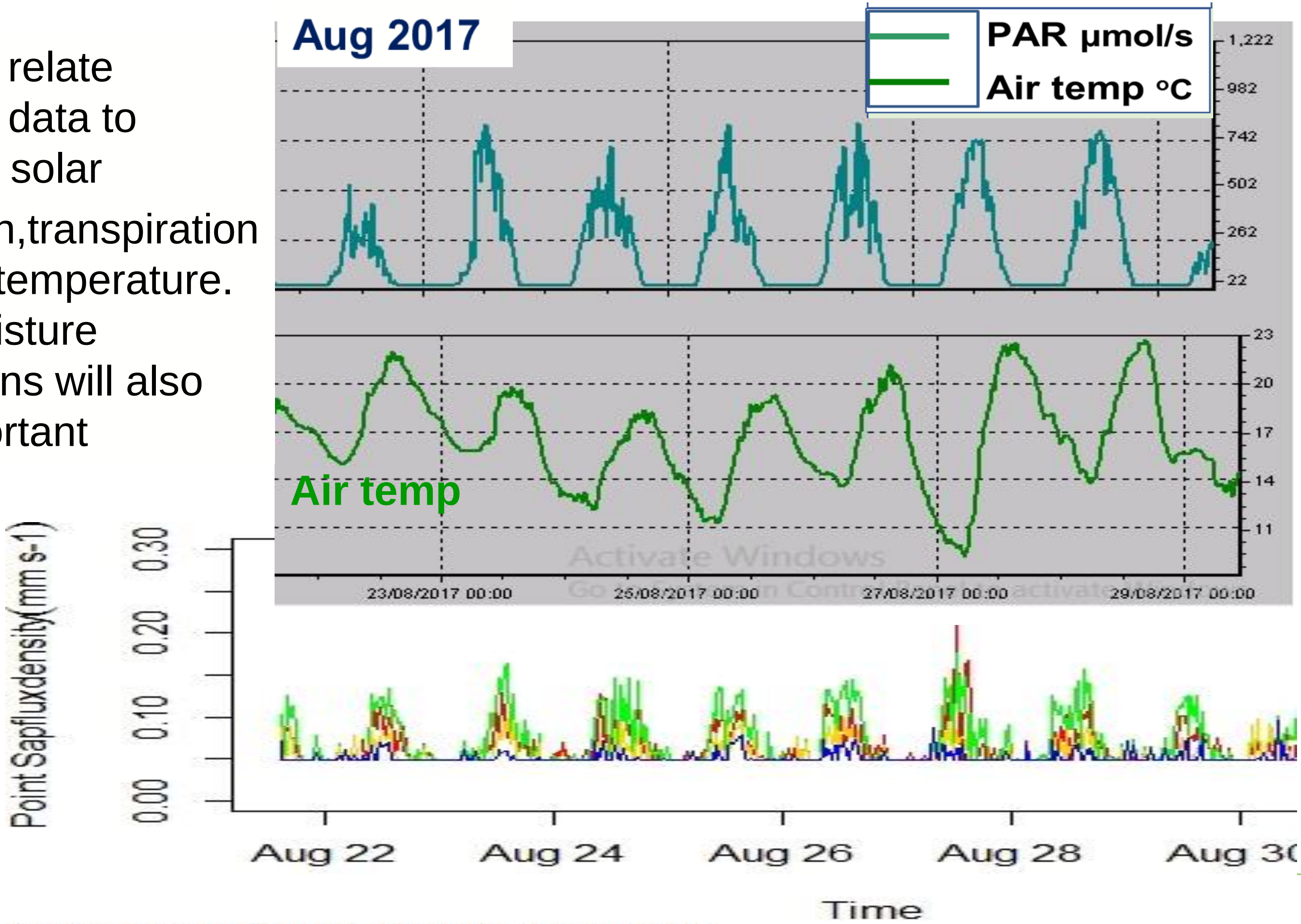






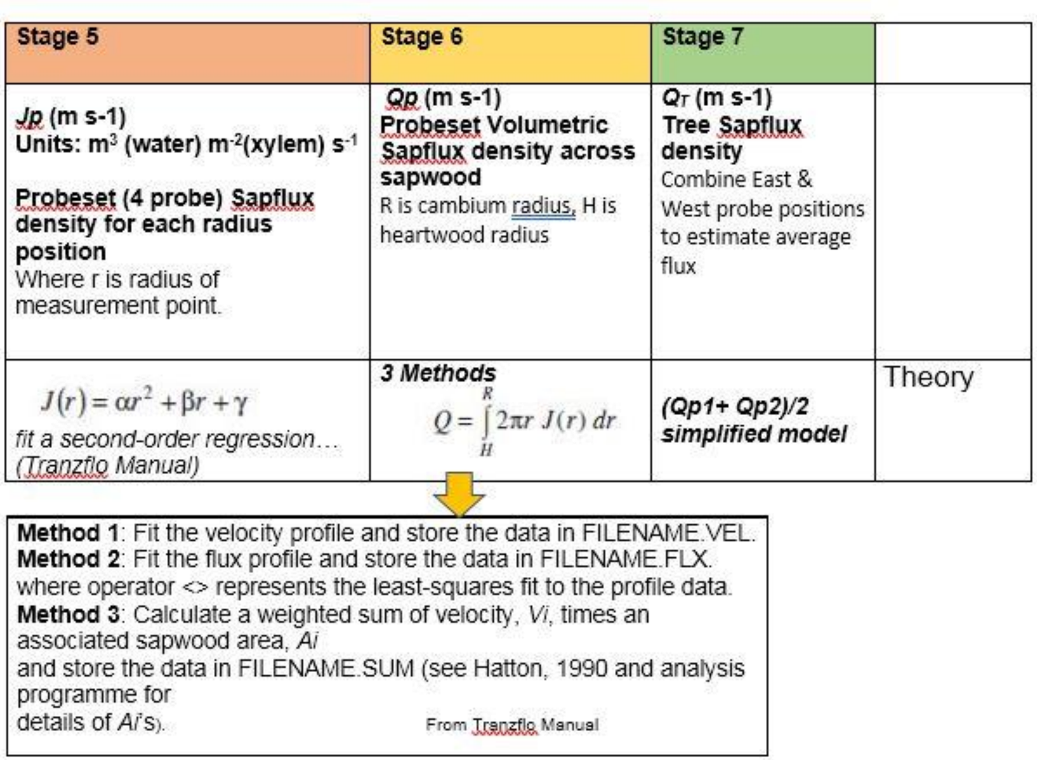
Sapflow Data analysis: Next steps

We can relate sapflow data to incident solar radiation,transpiration and air temperature. Soil moisture conditions will also be important



Sapflow Tree 1E A3 Vsfd1_1 to Vsfd1_4 August2017

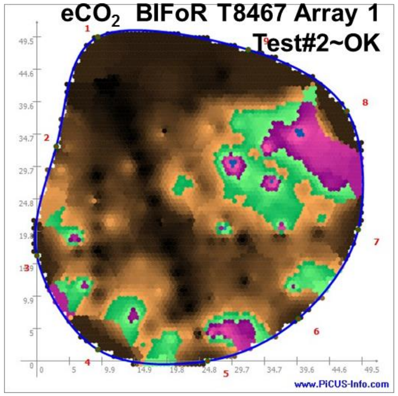
Stages 5-7 of Sapflow Data Calculation – to be done

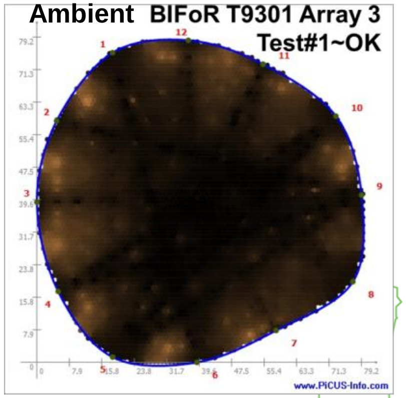


Stage 5	Stage 6	Stage 7	
Jp (m s-1) **Units: m^3 (water) m^{-2}(xylem) s^{-1}** **Probeset (4 probe) Sapflux density for each radius position** Where r is radius of measurement point.	**Qp (m s-1)** **Probeset Volumetric Sapflux density across sapwood** R is cambium radius, H is heartwood radius	**Q_T (m s-1)** **Tree Sapflux density** Combine East & West probe positions to estimate average flux	
$J(r) = \alpha r^2 + \beta r + \gamma$ *fit a second-order regression… (Tranzflo Manual)*	***3 Methods*** $Q = \int_H^R 2\pi r\, J(r)\, dr$	***(Qp1+ Qp2)/2 simplified model***	Theory

Method 1: Fit the velocity profile and store the data in FILENAME.VEL.
Method 2: Fit the flux profile and store the data in FILENAME.FLX.
where operator <> represents the least-squares fit to the profile data.
Method 3: Calculate a weighted sum of velocity, *Vi*, times an associated sapwood area, *Ai*
and store the data in FILENAME.SUM (see Hatton, 1990 and analysis programme for
details of *Ai*'s).

From Tranzflo Manual





PiCUS® 2

SonicTomograph report

Nik Pearson
FdSc Arb MarborA
Keysor Ltd

Summary + Next steps

SUMMARY

- ➢Data for oak xylem sapflow can be analysed and further comparison and calibration steps considered to test hypotheses

NEXT STEPS 2020-2021

- ➢Complete oak xylem sapflow analysis 2017-2019 to test hypotheses & compare treatments. Gather data for 2020 season.
- ➢ Relate to water balance/availability (soil moisture, throughfall + air temperature, humidity, solar radiation) to xylem results
- ➢Analyse *Quercus robur* 2019 canopy transpiration time domain data in all 3 treatment types to correlate with sapflux density. Add May-August data 2020
- ➢ Extend sapflow probes for inter-species comparison
- ➢ Soil Moisture – determine if further variation in treatment patches occurs, extend survey data with Giulio C/ Carolina M

Key References:

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Thank you for your attention

Any questions ?

Susan Quick SEQ616@student.bham.ac.uk,

Prof. Rob MacKenzie and Prof. Stefan Krause

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