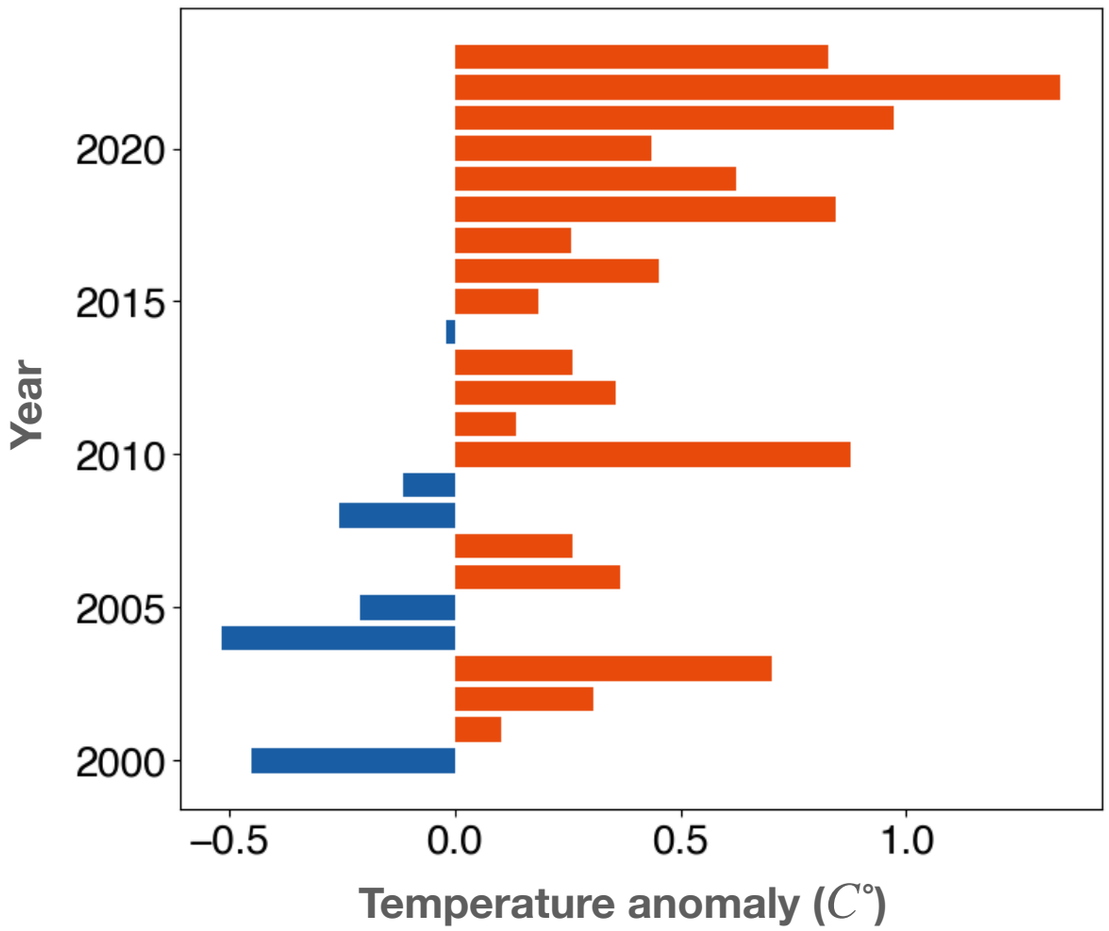
Modelling the immediate and legacy impact of extreme summers on European trees

J.Cale Baguley, Martin De Kauwe

University of BRISTOL

Recent extreme European summers

Summer surface air temperature anomalies across Europe



Data source: the Copernicus climate service.

Surface air temperature anomaly, August 2022

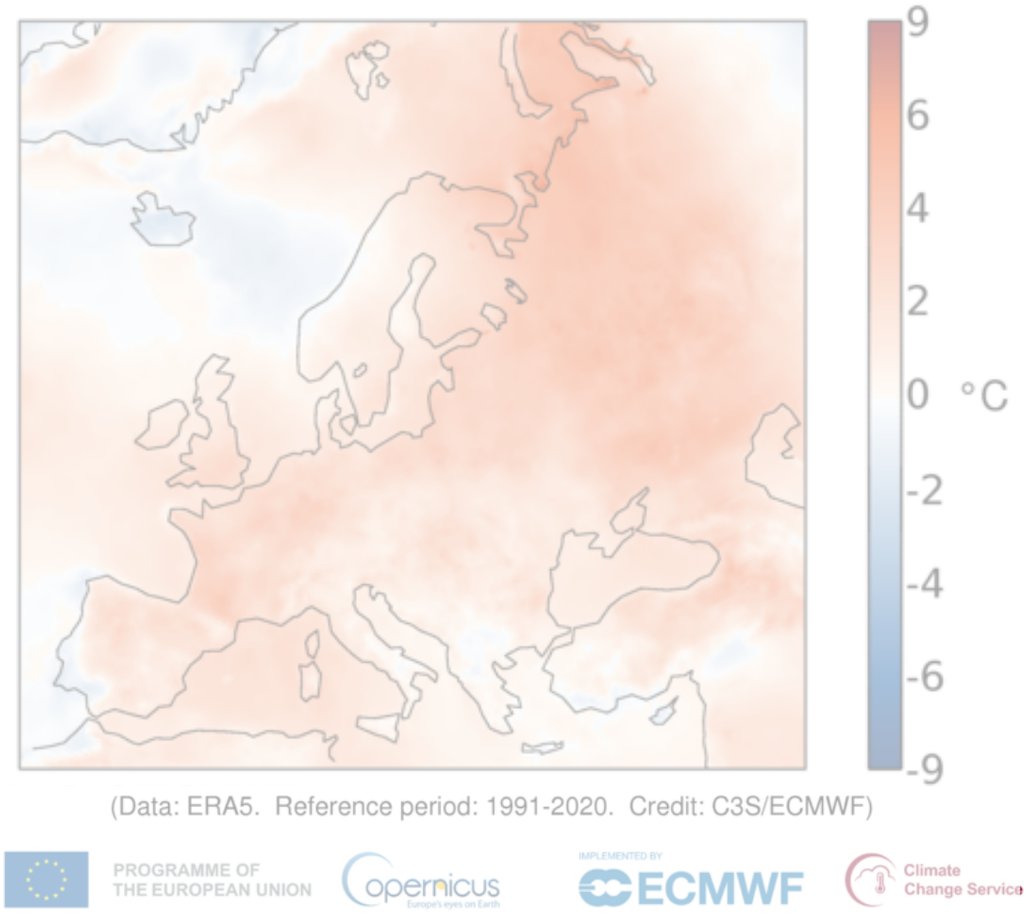
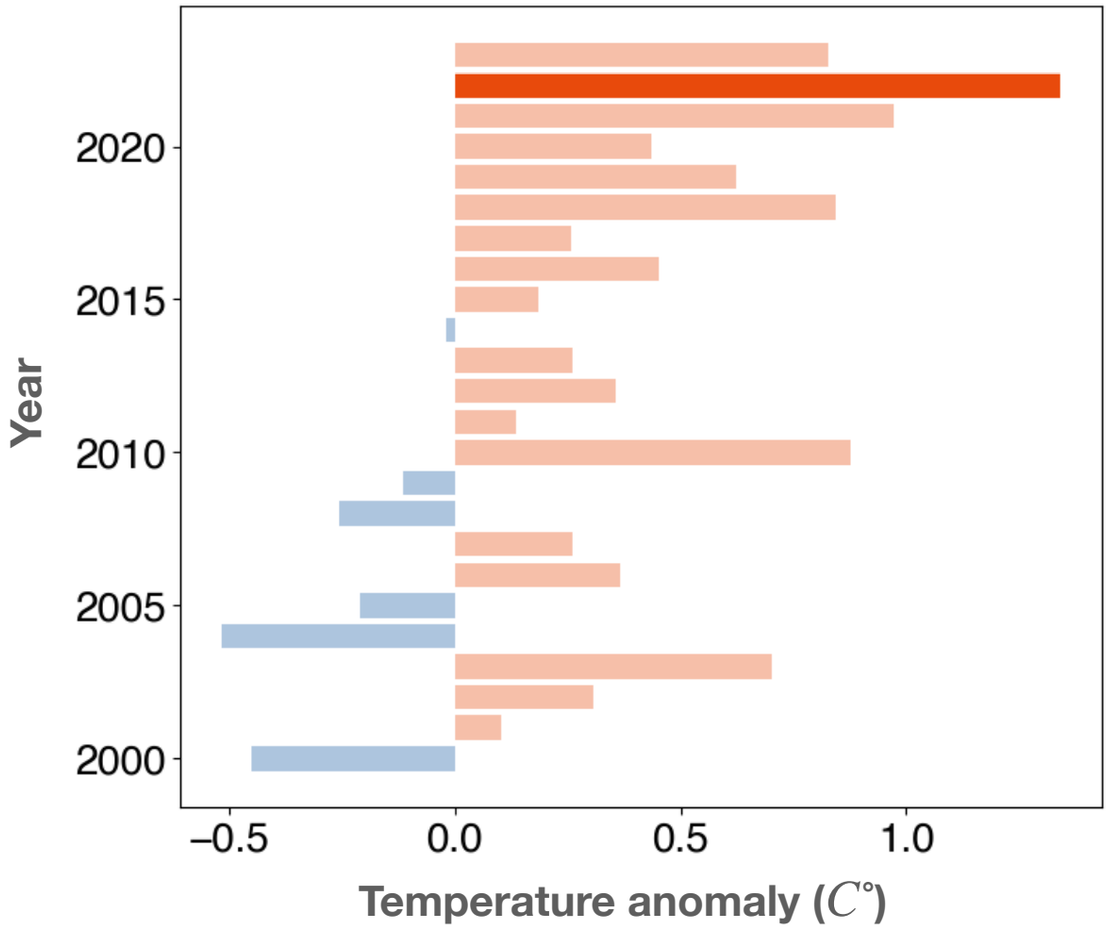


Figure source: the Copernicus climate

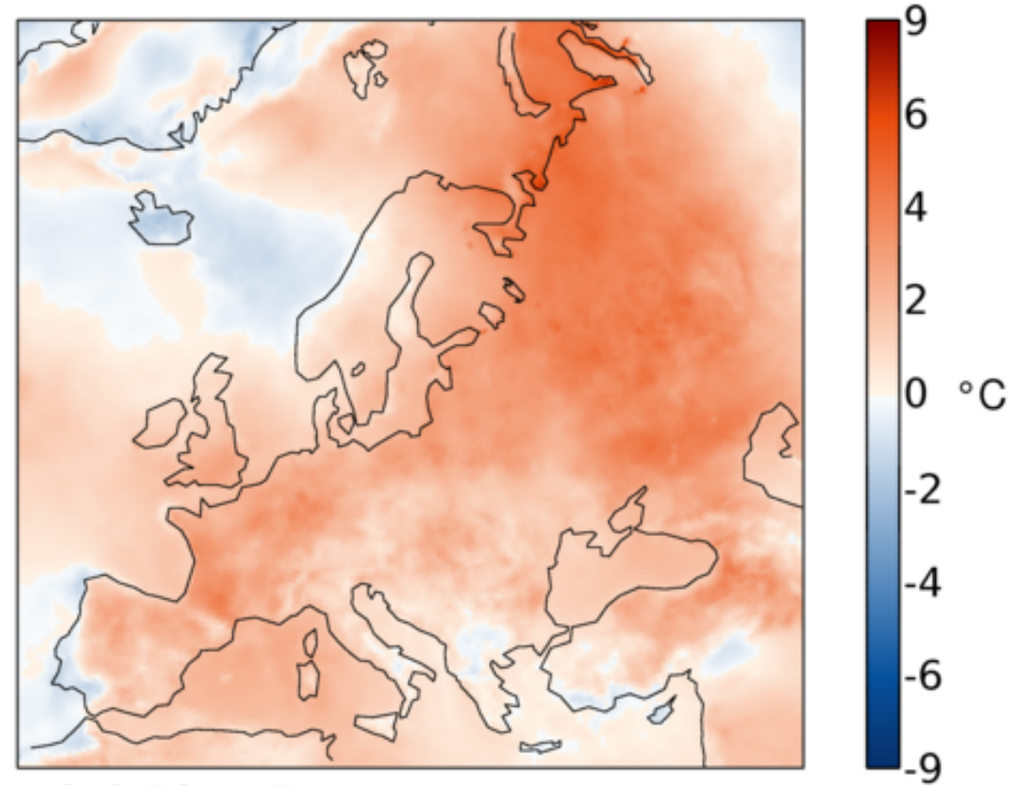
J.C. Baguley, email - jb14389@bristol.ac.uk

Recent extreme European summers

Summer surface air temperature anomalies across Europe



Surface air temperature anomaly, August 2022



(Data: ERA5. Reference period: 1991-2020. Credit: C3S/ECMWF)

PROGRAMME OF THE EUROPEAN UNION
opernicus
IMPLEMENTED BY ECMWF
Climate Change Service

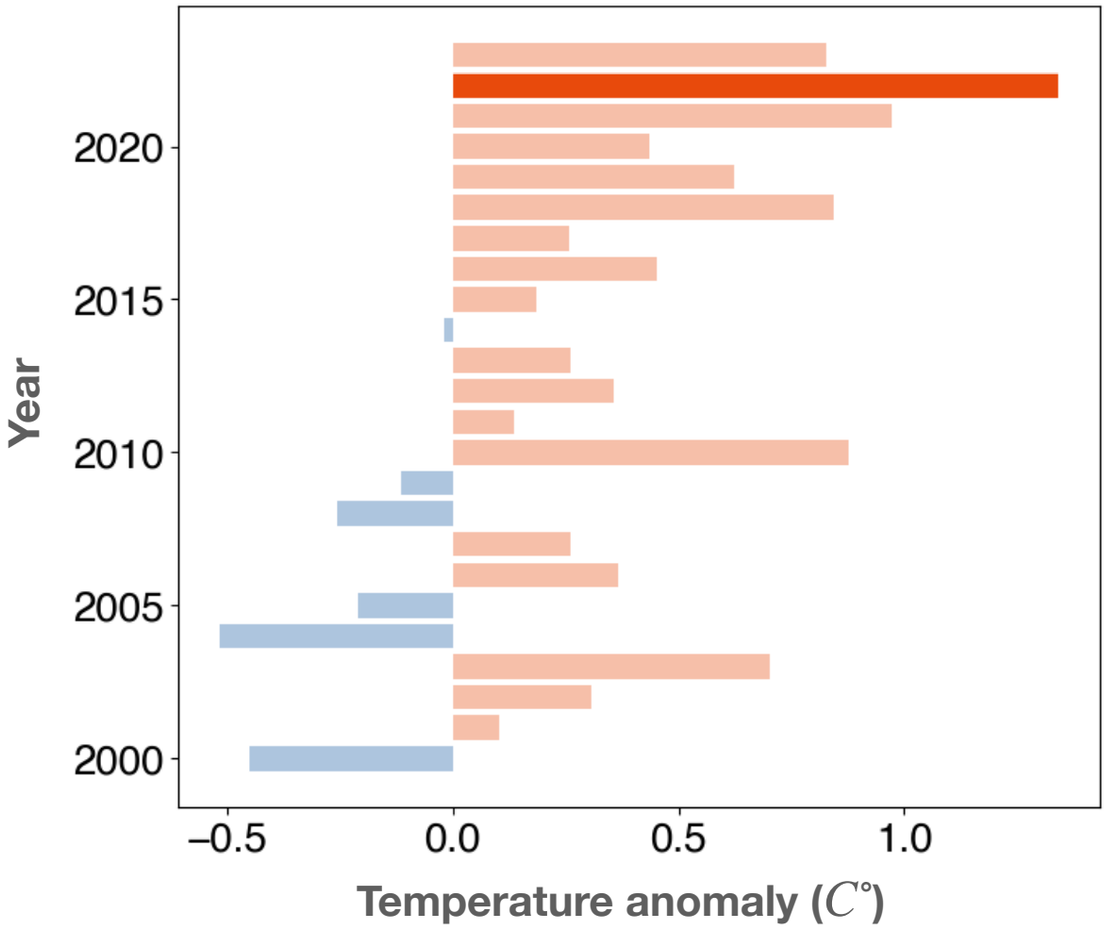
Data source: the Copernicus climate service.

Figure source: the Copernicus climate

J.C. Baguley, email - jb14389@bristol.ac.uk

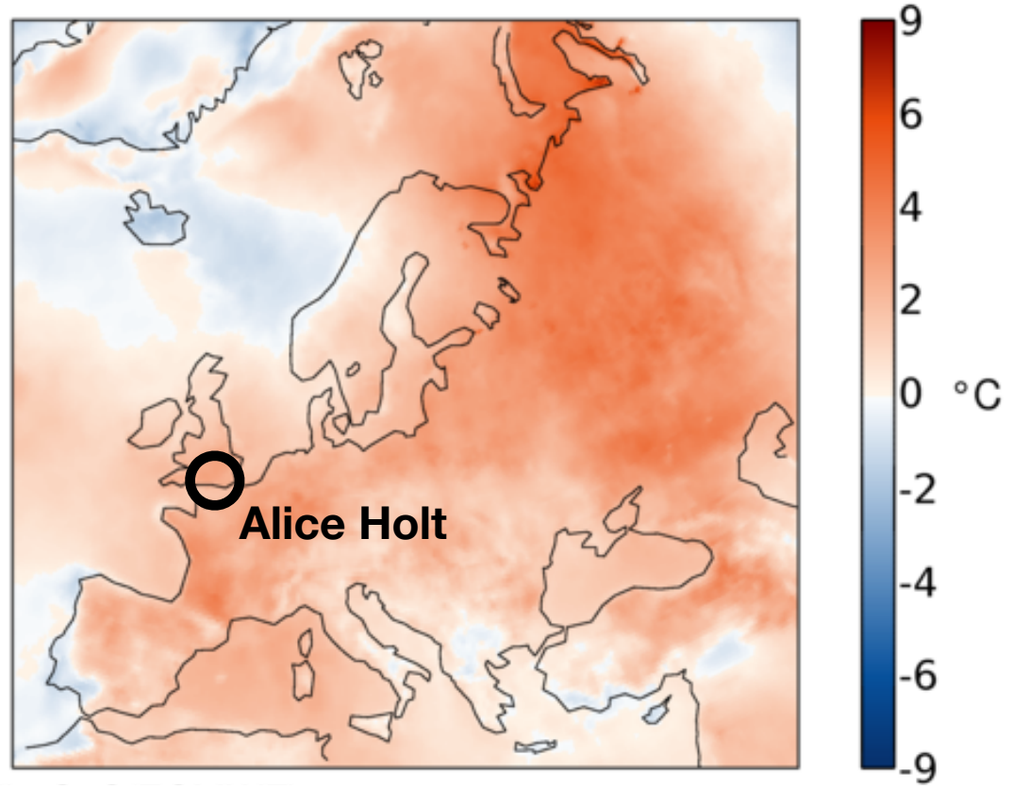
Recent extreme European summers

Summer surface air temperature anomalies across Europe



Data source: the Copernicus climate service.

Surface air temperature anomaly, August 2022



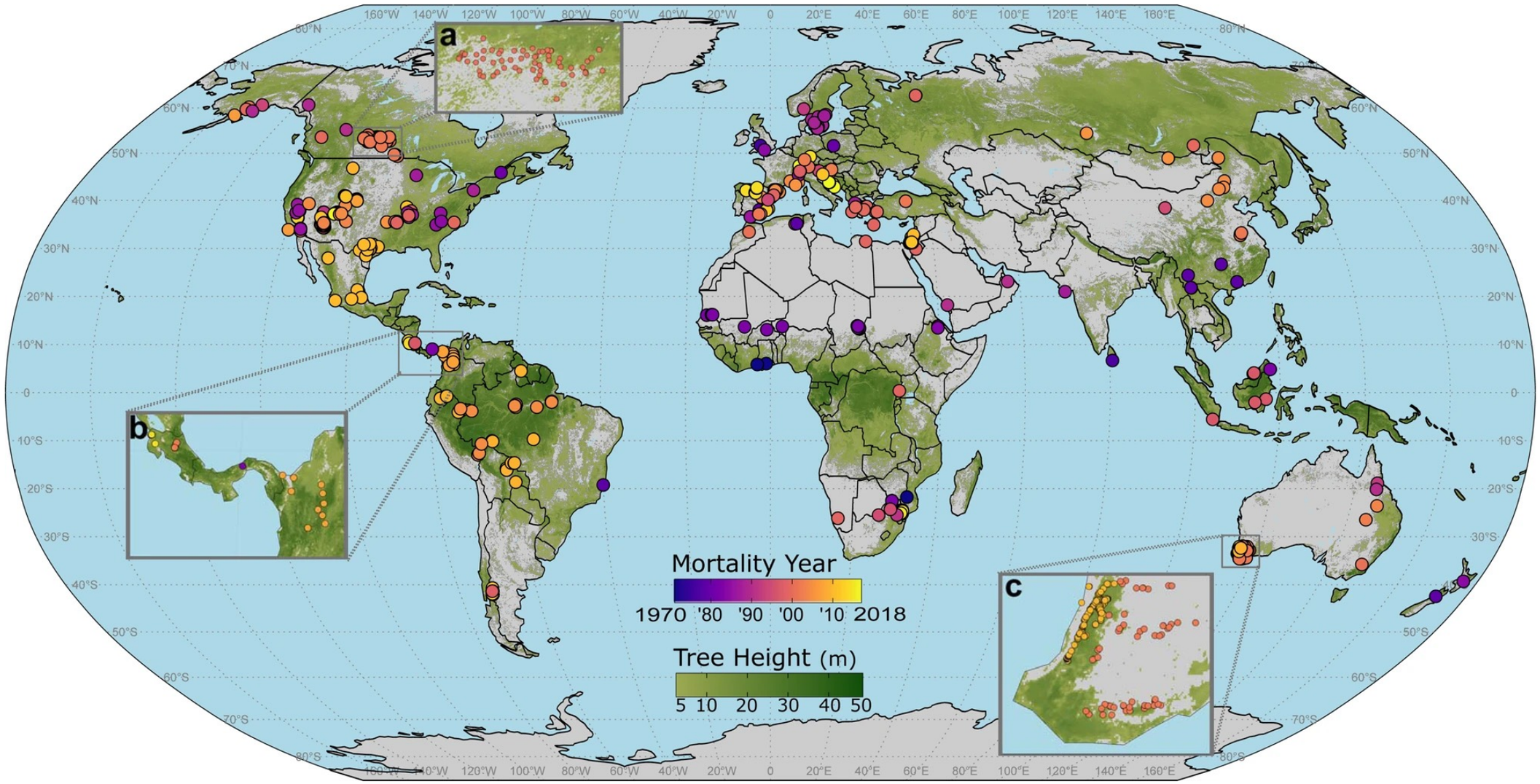
(Data: ERA5. Reference period: 1991-2020. Credit: C3S/ECMWF)

PROGRAMME OF THE EUROPEAN UNION
Copernicus
IMPLEMENTED BY ECMWF
Climate Change Service

Figure source: the Copernicus climate

J.C. Baguley, email - jb14389@bristol.ac.uk

Drought induced tree mortality



Location of tree mortality plots covering the period 1970 to 2018 catalogued by W.M.Hammond et al 2022.

J.C. Baguley, email - jb14389@bristol.ac.uk

Key research questions

- To what extent do stomatal optimisation models improve our predictive capacity during droughts?

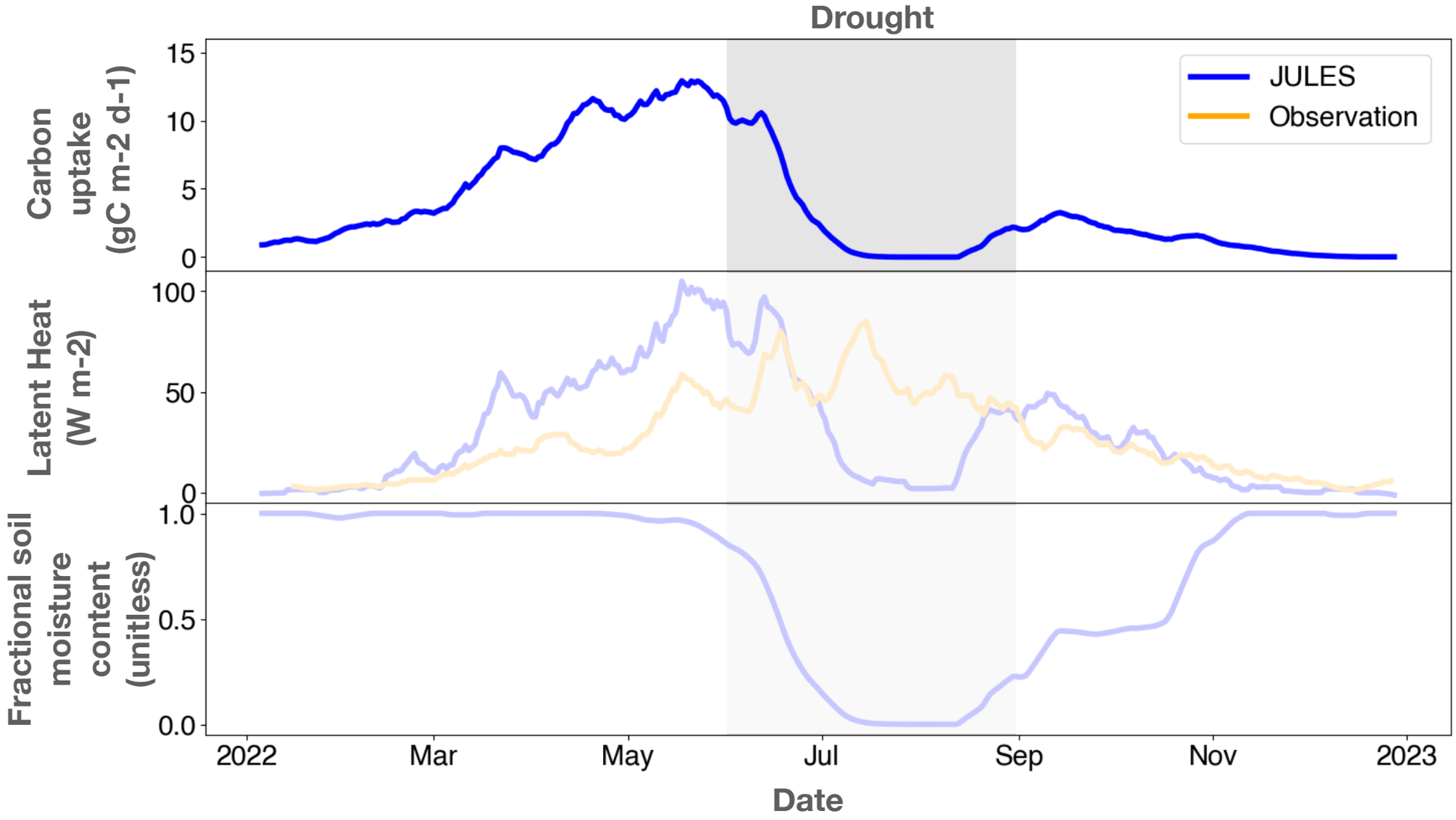
- Drought legacy: Can we extend these optimisation models to capture hydraulic impairment during drought and track the subsequent recovery from drought?

Key research questions

- To what extent do stomatal optimisation models improve our predictive capacity during droughts?

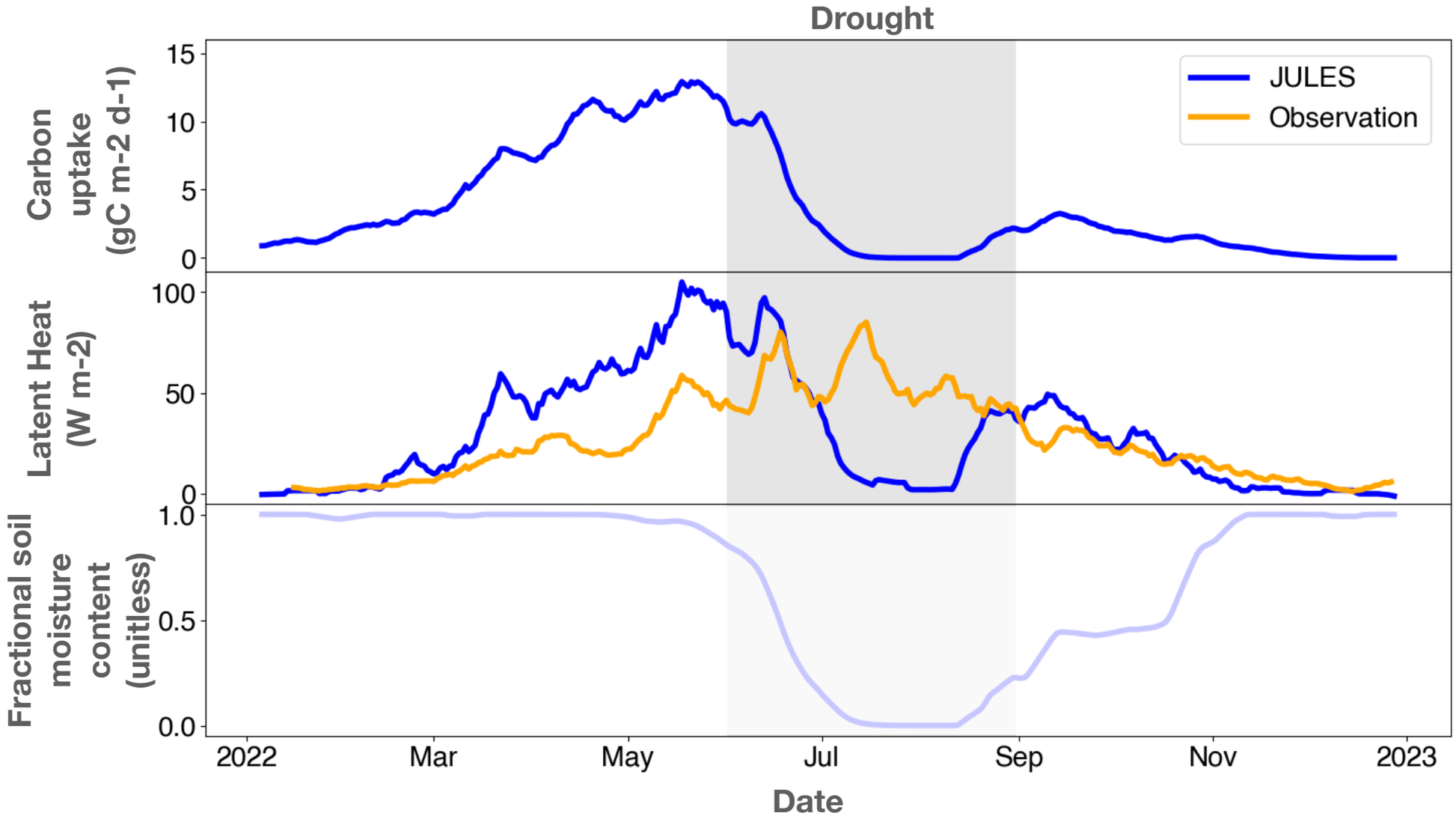
- Drought legacy: Can we extend these optimisation models to capture hydraulic impairment during drought and track the subsequent recovery from drought?

JULES prediction of the 2022 extreme summer at Alice Holt



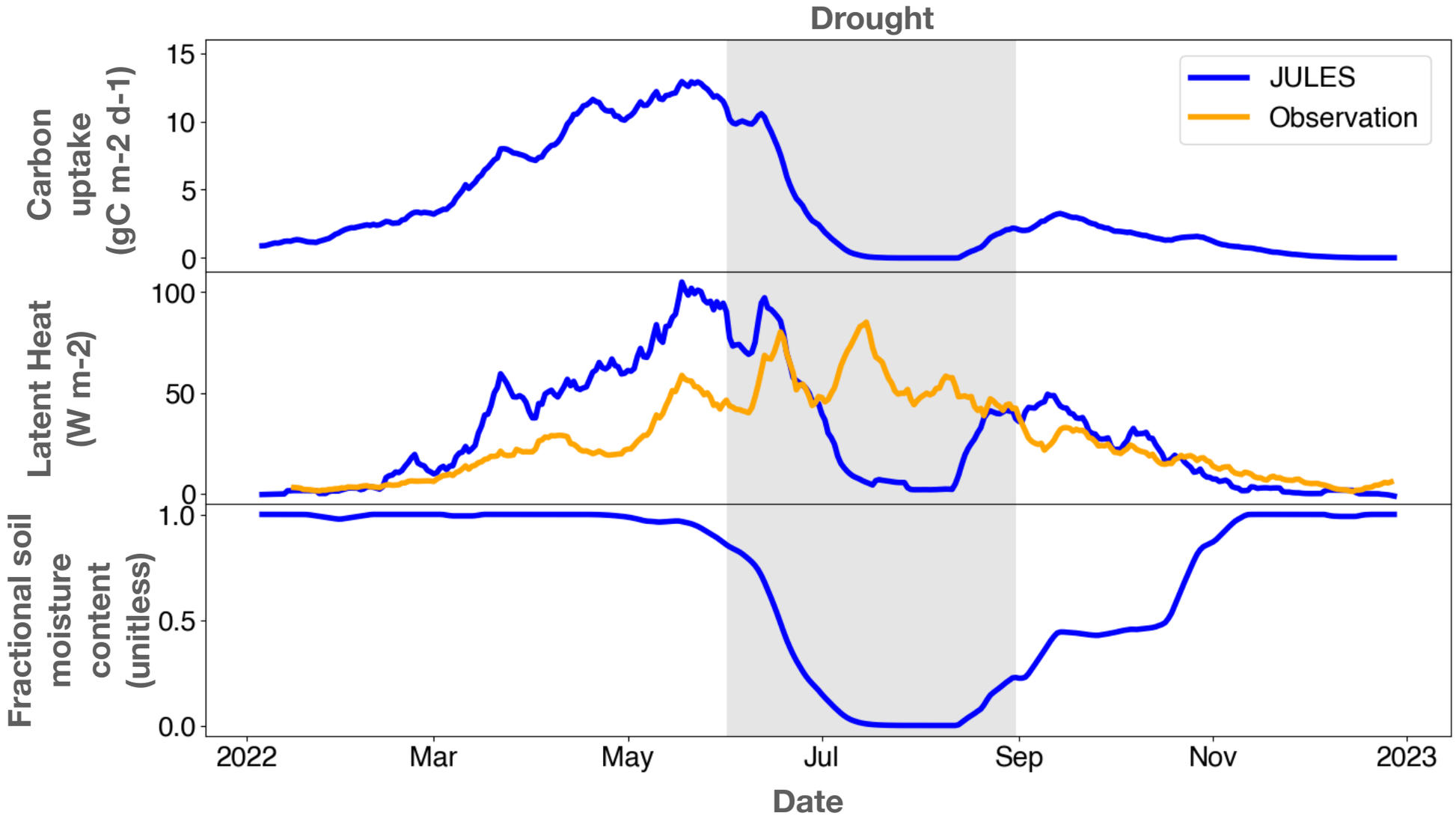
J.C. Baguley, email - jb14389@bristol.ac.uk

JULES prediction of the 2022 extreme summer at Alice Holt



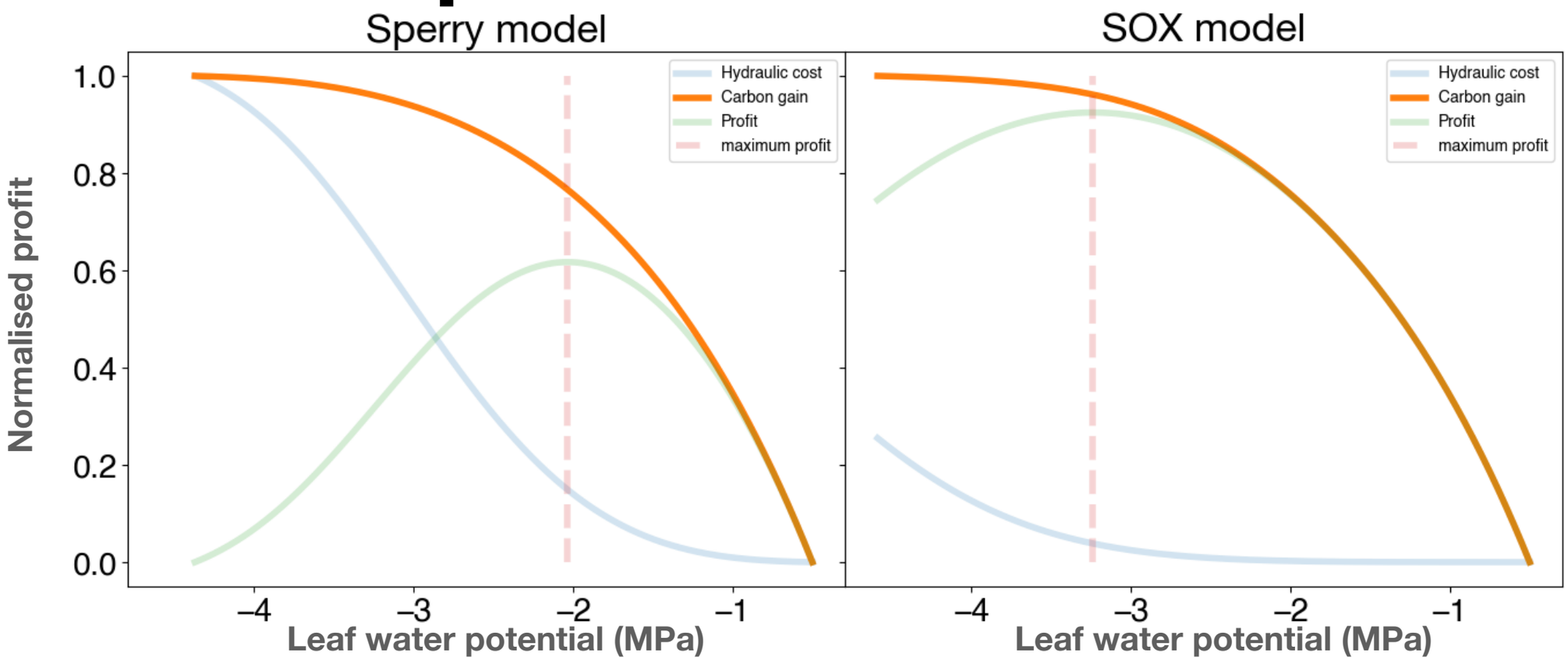
J.C. Baguley, email - jb14389@bristol.ac.uk

JULES prediction of the 2022 extreme summer at Alice Holt



J.C. Baguley, email - jb14389@bristol.ac.uk

Stomatal optimisation models



$$Profit = Gain - Cost$$

$$Gain = \frac{A_n}{A_{max}}, \quad Cost = \frac{k_{max} - k}{k_{max} - k_{crit}}$$

$$k(\psi) = k_{max} e^{-(\frac{\psi}{b})^c}, \quad \psi = \psi_{leaf}$$

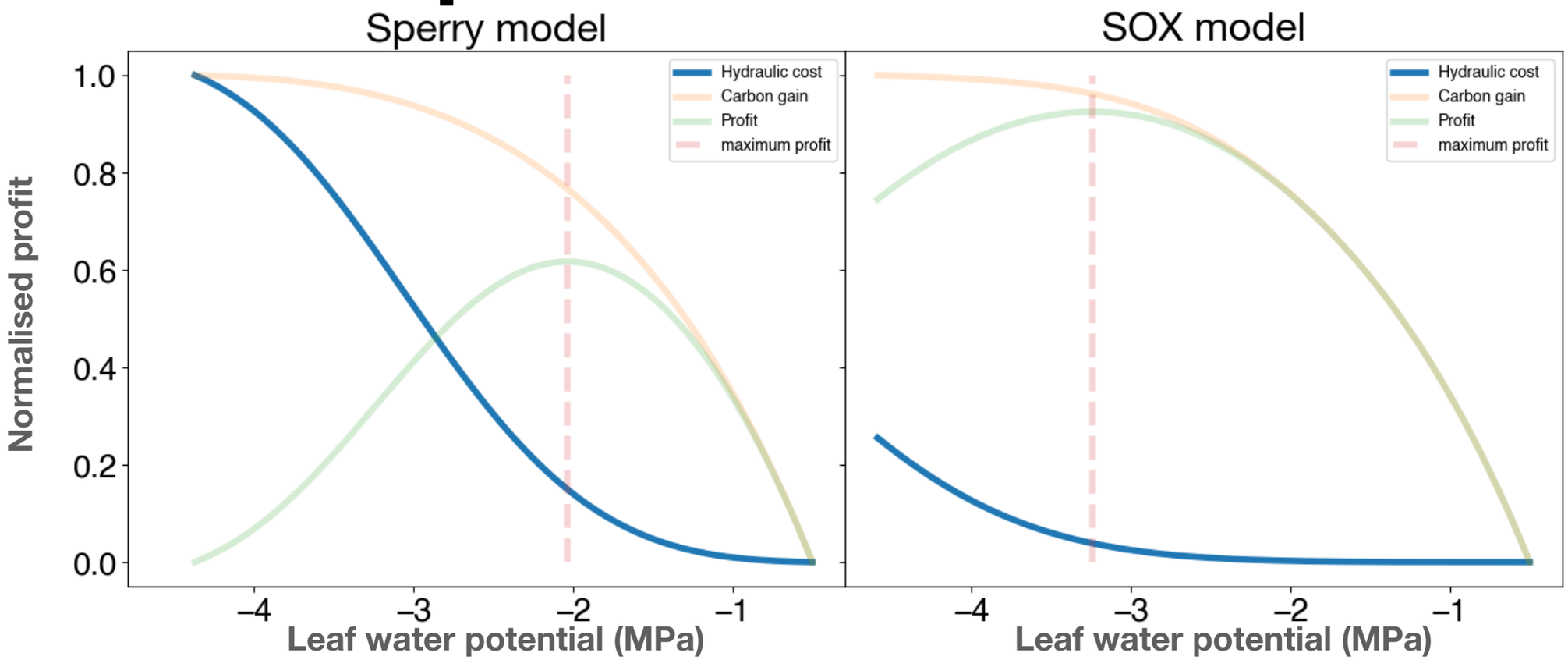
$$Profit = Gain(1 - Cost)$$

$$Gain = A_n, \quad Cost = 1 - \frac{k - k_{crit}}{k_{max} - k_{crit}}$$

$$k(\psi) = k_{max} \frac{1}{1 + (\psi/\psi_{50})^c}, \quad \psi = \frac{\psi_{leaf} + \psi_{root}}{2}$$

J.C. Baguley, email - jb14389@bristol.ac.uk

Stomatal optimisation models



$$Profit = Gain - Cost$$

$$Gain = \frac{A_n}{A_{max}}, \quad Cost = \frac{k_{max} - k}{k_{max} - k_{crit}}$$

$$k(\psi) = k_{max} e^{-(\frac{\psi}{b})^c}, \quad \psi = \psi_{leaf}$$

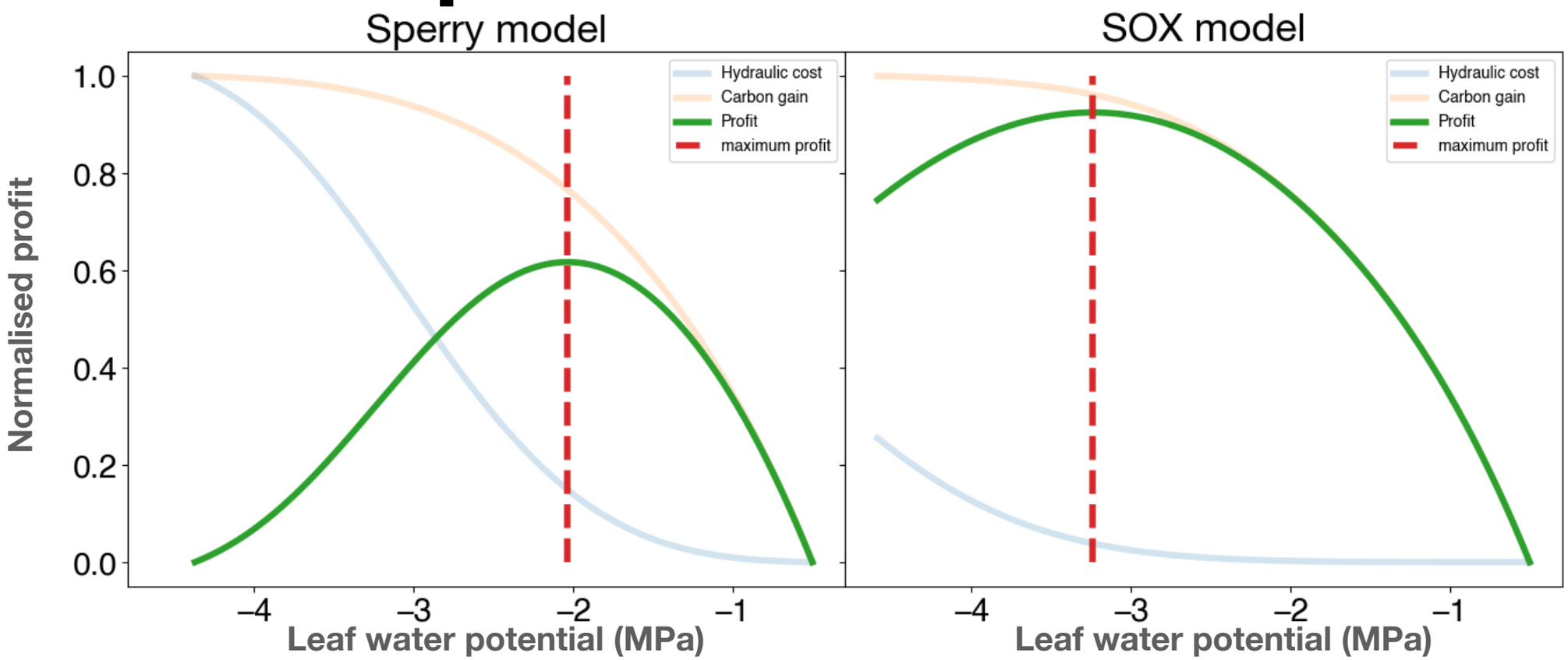
$$Profit = Gain(1 - Cost)$$

$$Gain = A_n, \quad Cost = 1 - \frac{k - k_{crit}}{k_{max} - k_{crit}}$$

$$k(\psi) = k_{max} \frac{1}{1 + (\psi/\psi_{50})^c}, \quad \psi = \frac{\psi_{leaf} + \psi_{root}}{2}$$

J.C. Baguley, email - jb14389@bristol.ac.uk

Stomatal optimisation models



$$Profit = Gain - Cost$$

$$Gain = \frac{A_n}{A_{max}}, \quad Cost = \frac{k_{max} - k}{k_{max} - k_{crit}}$$

$$k(\psi) = k_{max} e^{-(\frac{\psi}{b})^c}, \quad \psi = \psi_{leaf}$$

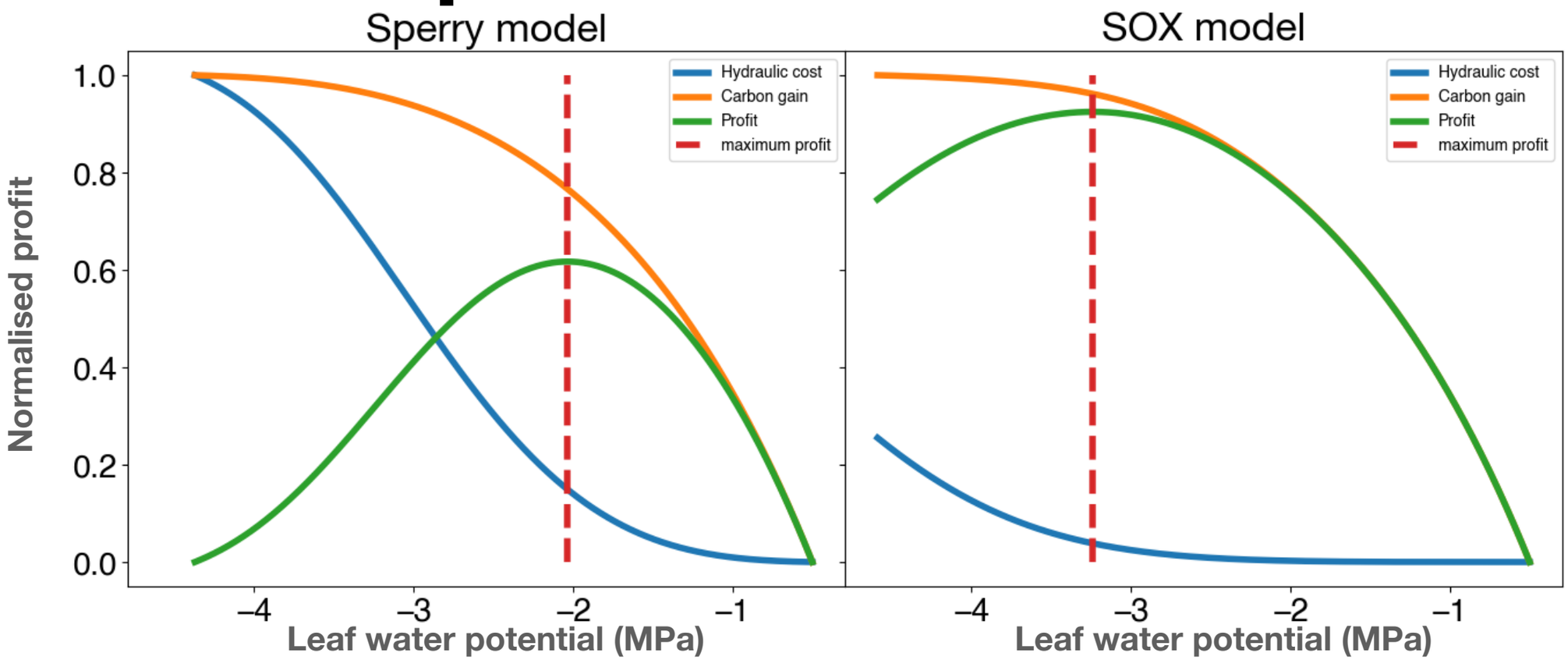
$$Profit = Gain(1 - Cost)$$

$$Gain = A_n, \quad Cost = 1 - \frac{k - k_{crit}}{k_{max} - k_{crit}}$$

$$k(\psi) = k_{max} \frac{1}{1 + (\psi/\psi_{50})^c}, \quad \psi = \frac{\psi_{leaf} + \psi_{root}}{2}$$

J.C. Baguley, email - jb14389@bristol.ac.uk

Stomatal optimisation models



$$Profit = Gain - Cost$$

$$Gain = \frac{A_n}{A_{max}}, \quad Cost = \frac{k_{max} - k}{k_{max} - k_{crit}}$$

$$k(\psi) = k_{max} e^{-(\frac{\psi}{b})^c}, \quad \psi = \psi_{leaf}$$

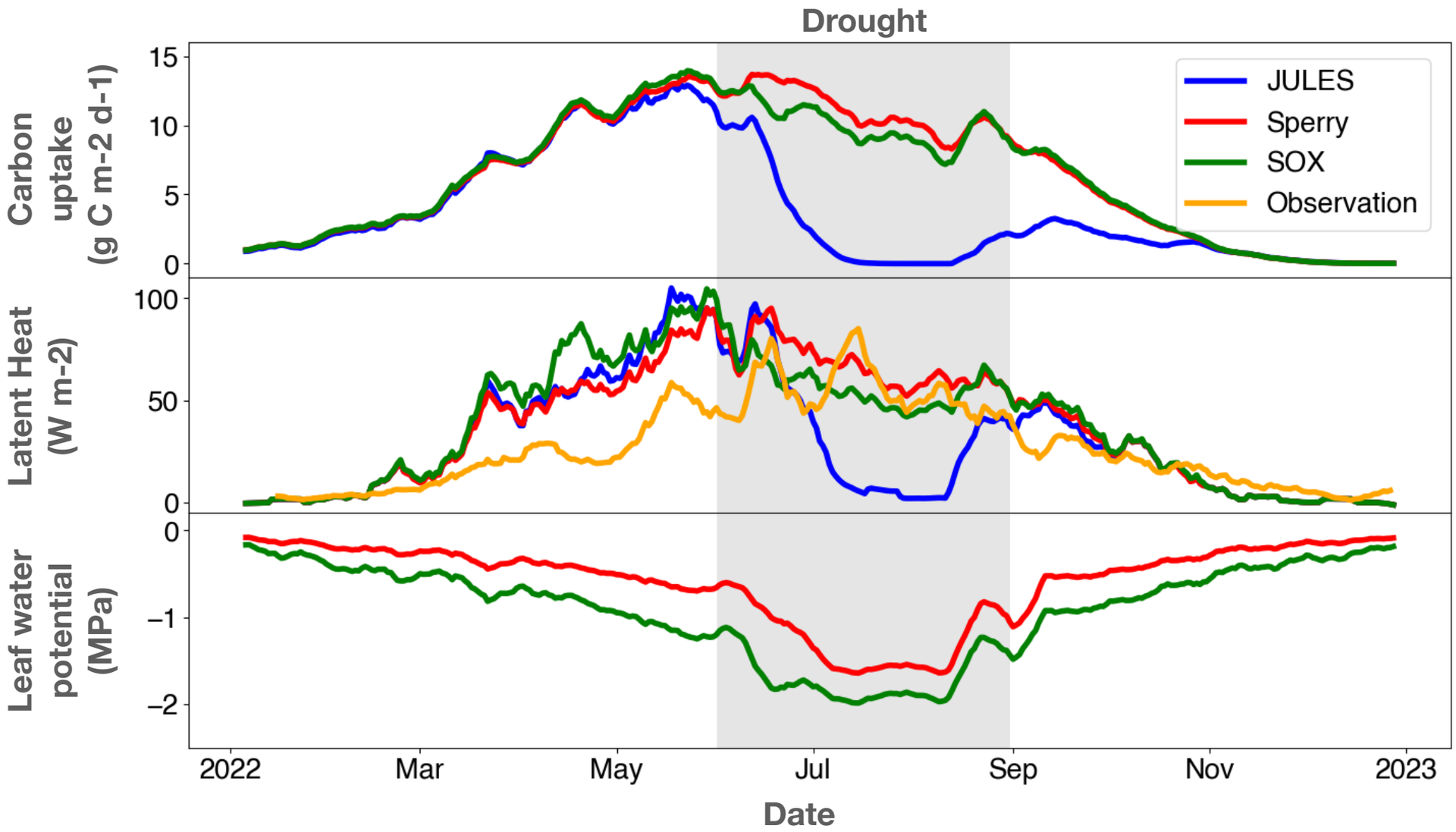
$$Profit = Gain(1 - Cost)$$

$$Gain = A_n, \quad Cost = 1 - \frac{k - k_{crit}}{k_{max} - k_{crit}}$$

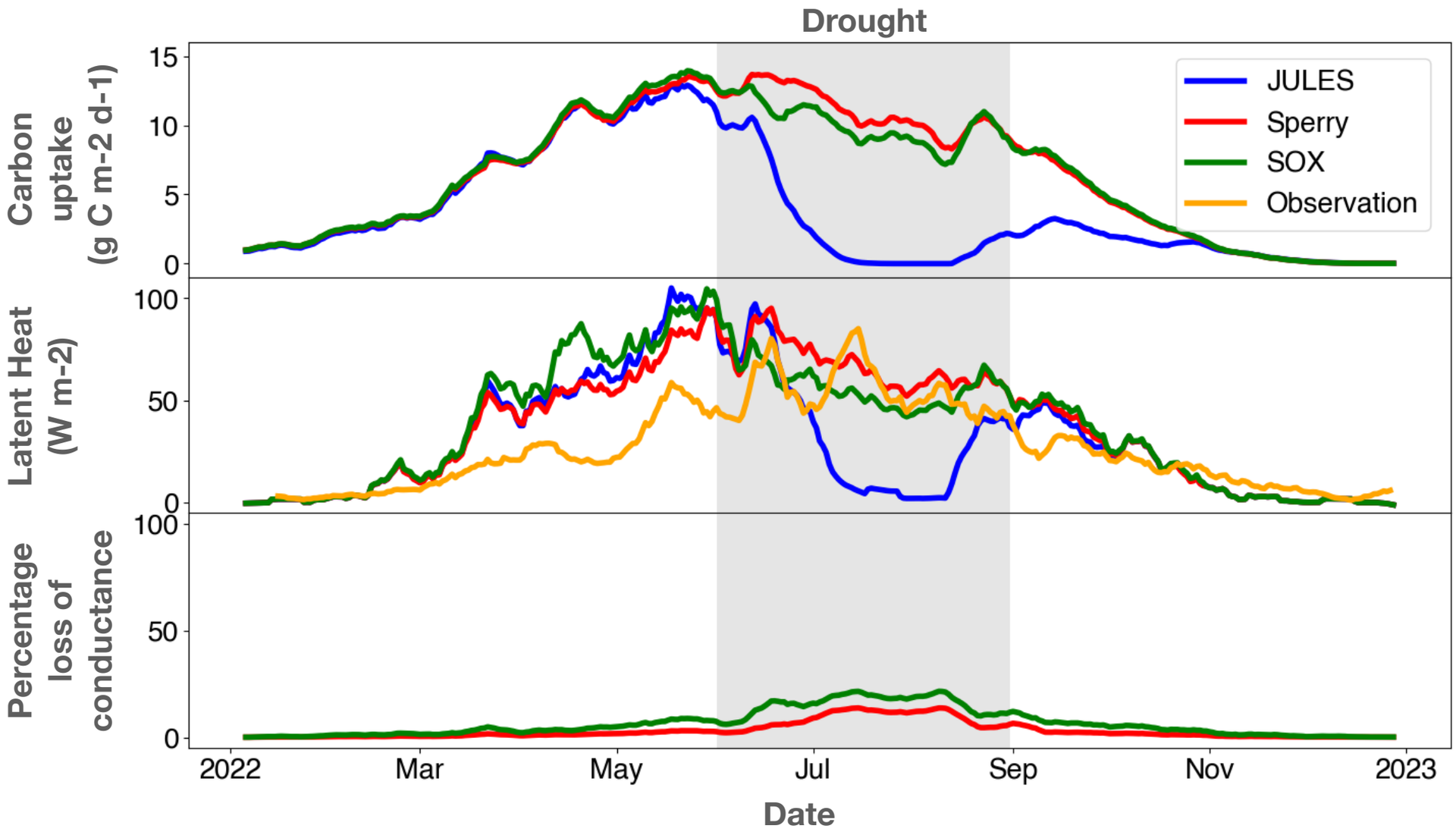
$$k(\psi) = k_{max} \frac{1}{1 + (\psi/\psi_{50})^c}, \quad \psi = \frac{\psi_{leaf} + \psi_{root}}{2}$$

J.C. Baguley, email - jb14389@bristol.ac.uk

Stomatal optimisation model predictions

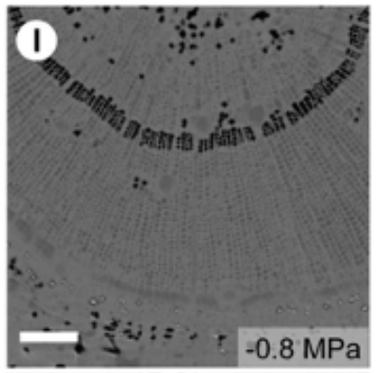


Conductance loss

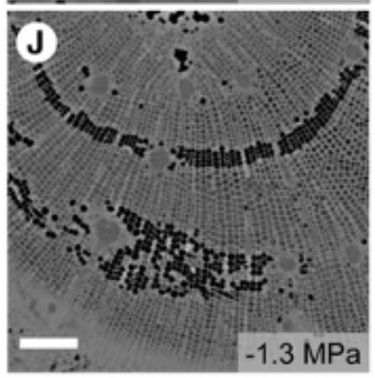


Modelling the longterm impact of conductance loss

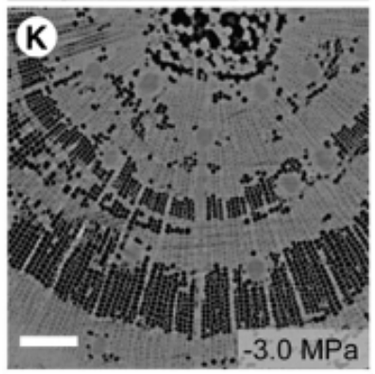
Healthy xylem



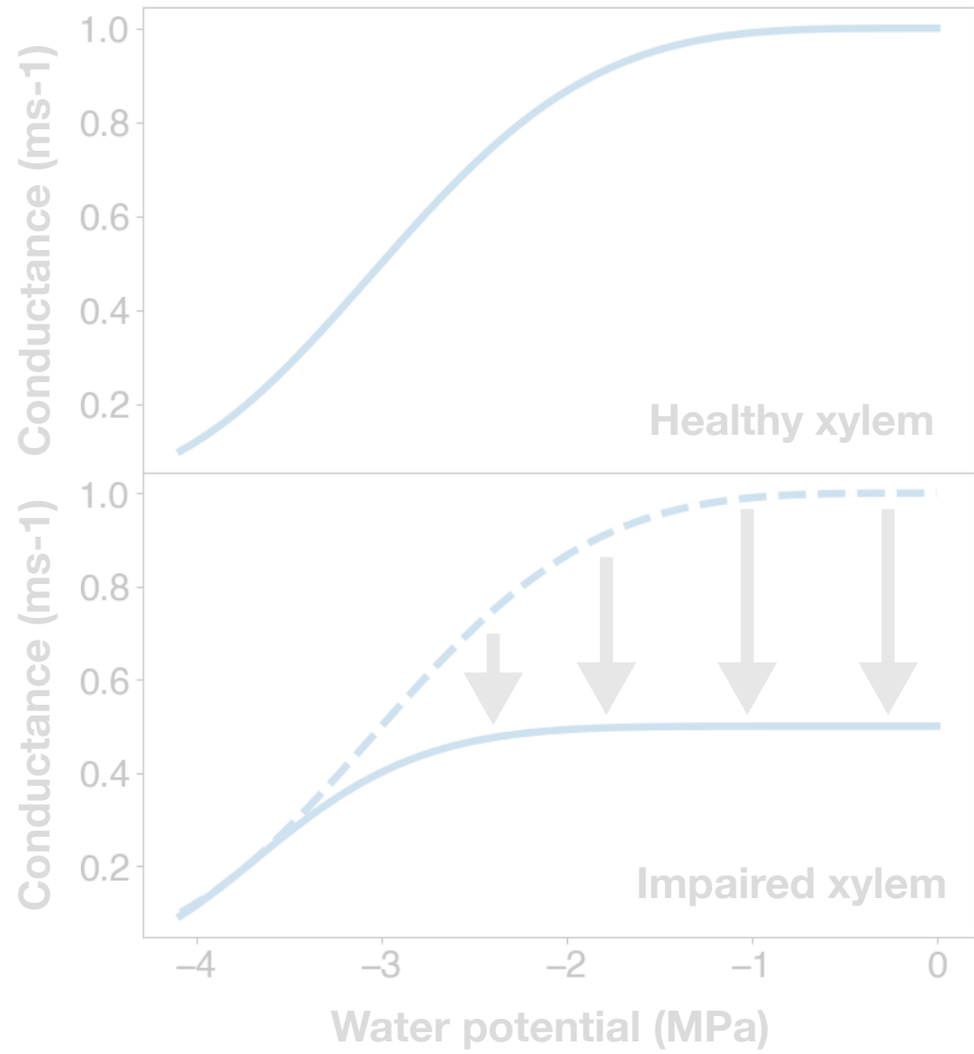
A large negative pressure draws air into the xylem.



Impaired xylem



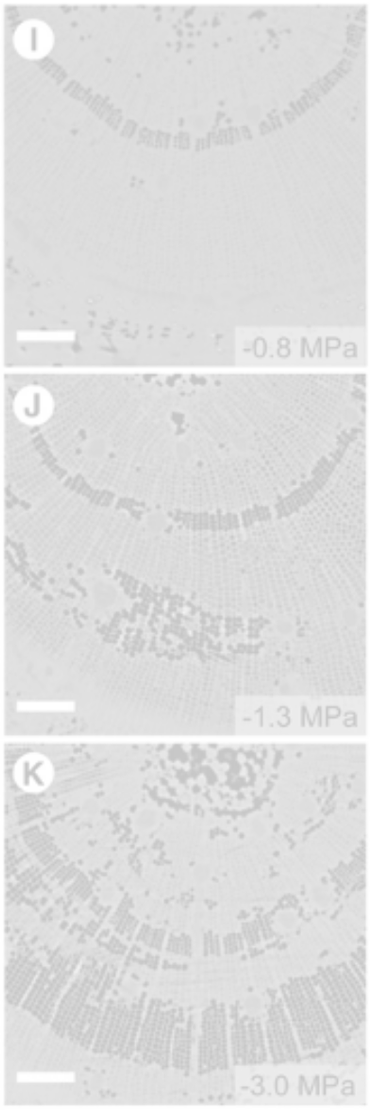
- Drought induce cavitation impairs the xylem's ability to conduct water.
- How does xylem impairment effect water transport?
- Over what time scale are trees able to recover?



Source:
B.Choat et. al. 2015

J.C. Baguley, email - jb14389@bristol.ac.uk

Modelling the longterm impact of conductance loss

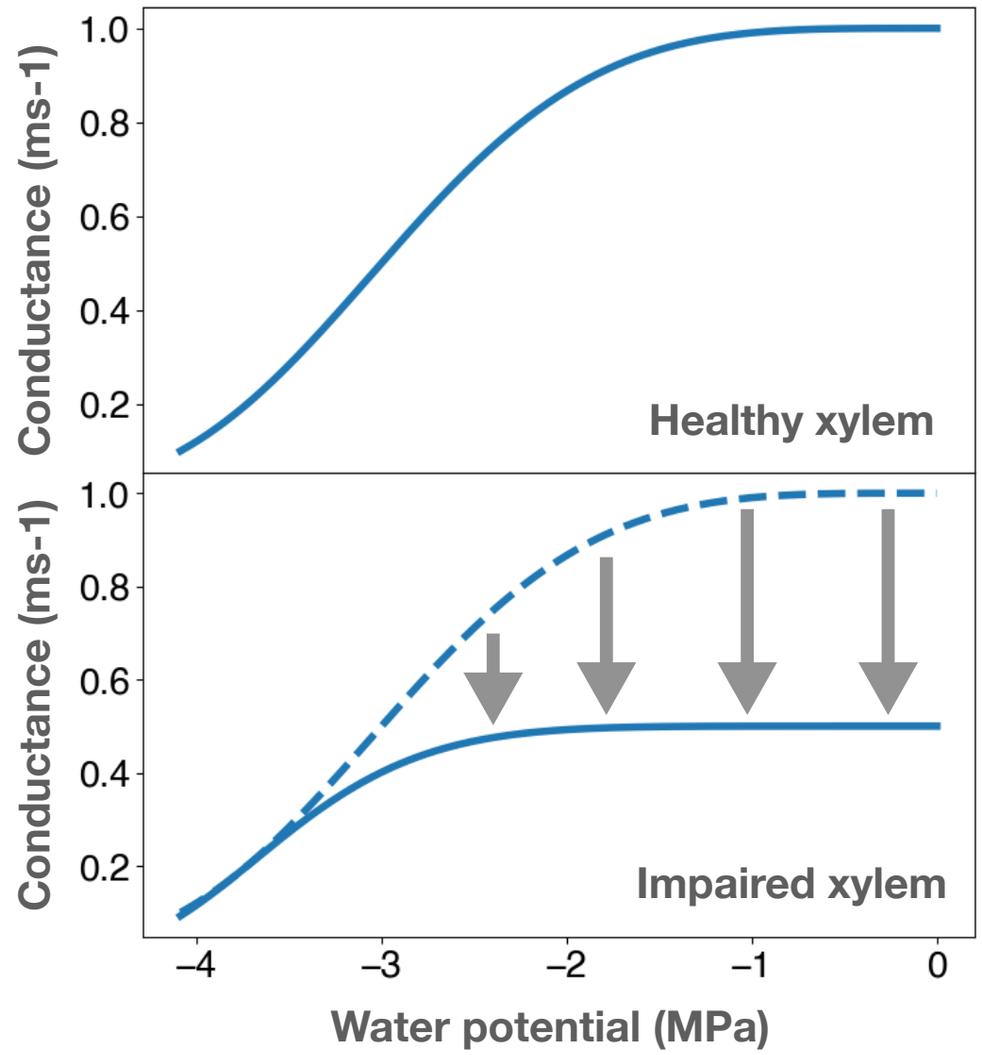


Healthy xylem

A large negative pressure draws air into the xylem.

Impaired xylem

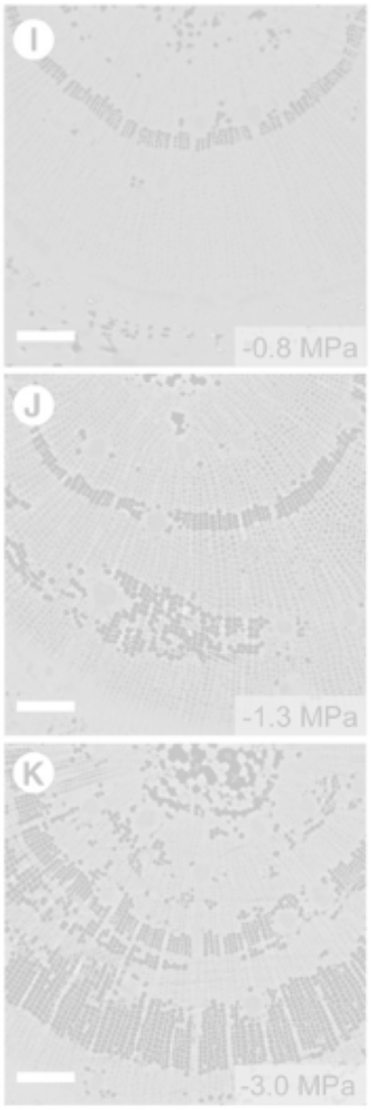
- Drought induce cavitation impairs the xylem's ability to conduct water.
- How does xylem impairment effect water transport?
- Over what time scale are trees able to recover?



Source:
B.Choat et. al. 2015

J.C. Baguley, email - jb14389@bristol.ac.uk

Modelling the longterm impact of conductance loss

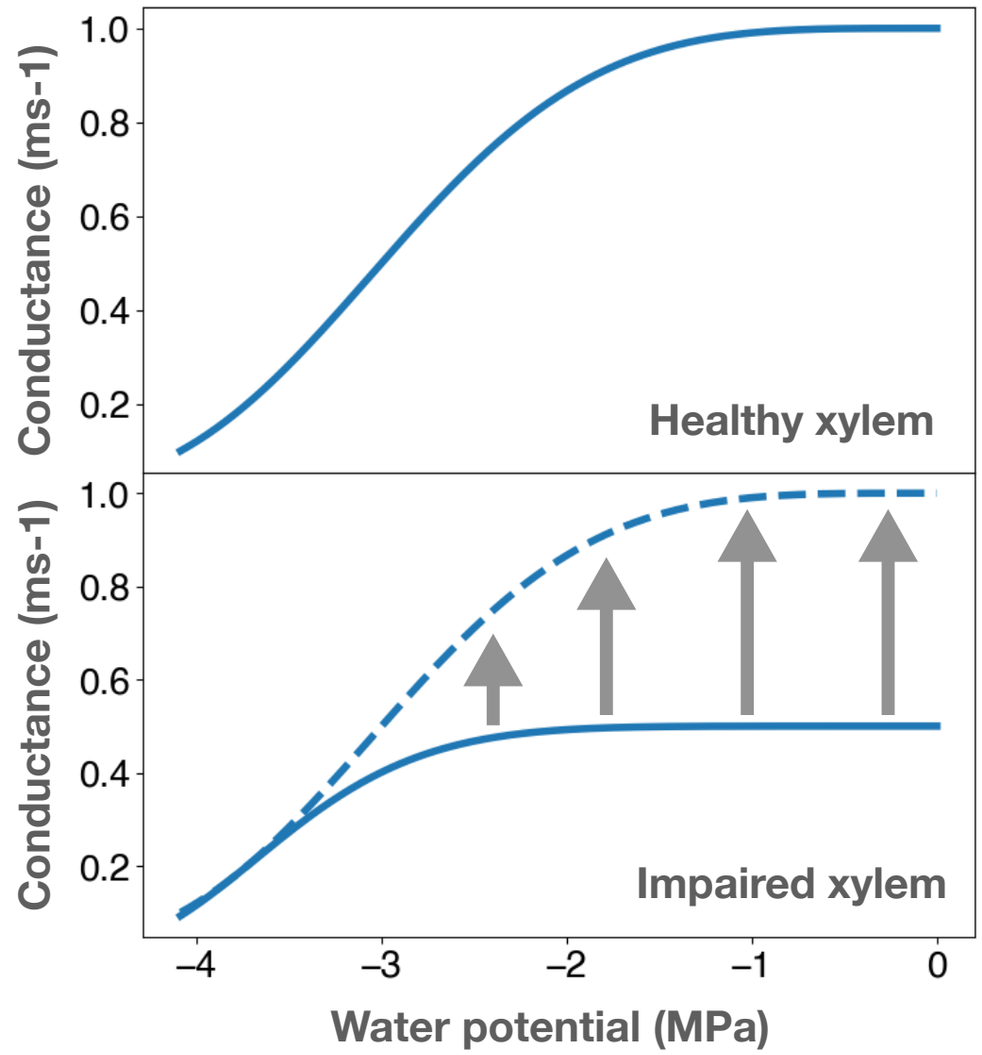


Healthy xylem

A large negative pressure draws air into the xylem.

Impaired xylem

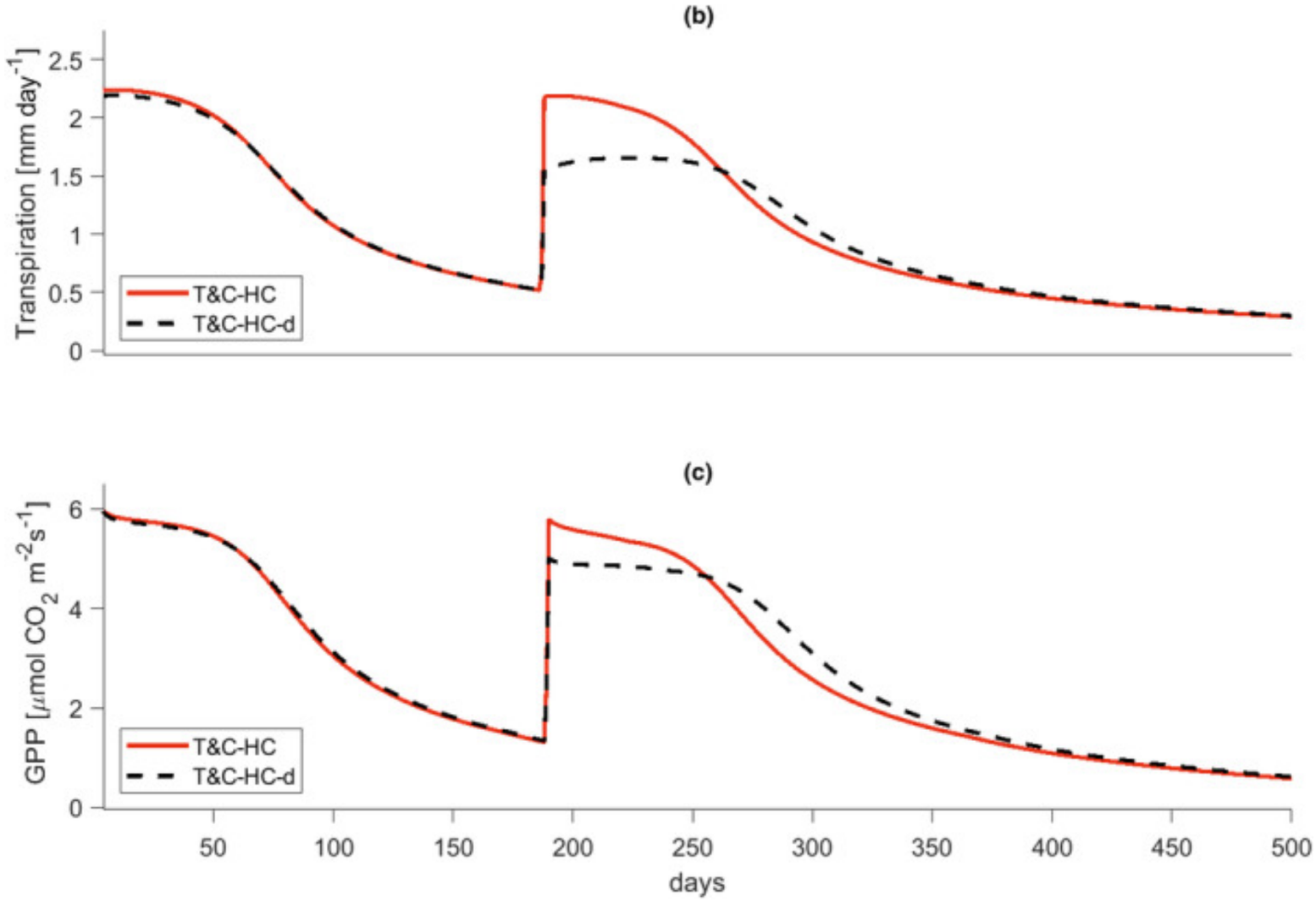
- Drought induce cavitation impairs the xylem's ability to conduct water.
- How does xylem impairment effect water transport?
- Over what time scale are trees able to recover?



Source: B.Choat et. al. 2015

J.C. Baguley, email - jb14389@bristol.ac.uk

Legacy impact of conductance loss



Comparison of immediate recovery (solid red line) and legacy impairment (dashed black line) of xylem following a drought. Source Athanasios Paschalis et al.

Future work

- Predict the legacy impacts of xylem impairment across European tree species. Further investigate differing models of xylem impairment and recovery.

- This will require refining our model of xylem impairment and recovery.

- Optimise the model parameters to better predict the observed flux tower data in collaboration with Tris and Natalie.

- Work to incorporate non-stomatal limitations within the optimisation framework to better capture biochemical and mesophyll limitations during drought.

Thanks for listening. Any questions?

- Thanks to Tris, Patrick & Lucy

Natural Environment Research Council

University of BRISTOL

Legacy impact of conductance loss