Incorporating Thermal Acclimation of Photosynthesis in JULES

(UKESM and PORCELAIN)

Becky Oliver, Lina Mercado, Doug Clark

Thermal Acclimation

- Photosynthesis is sensitive to temperature – typically follows peaked relationship with an optimum temperature for photosynthesis (Topt) between 15 – 35 oC.

- In ESM's this is commonly represented as a fixed relationship – Topt does not move.

- Empirical studies show plants have a degree of plasticity in temperature sensitivity related to prevailing temperature – this occurs on short timescales (days, months, seasons) – Topt can move.

- This fast temporal response to temperature driven by changes in temperature plants have recently been exposed to is **thermal acclimation**.

Thermal Acclimation

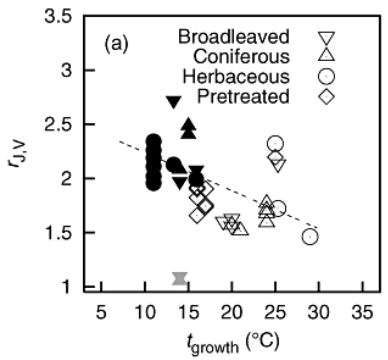
Plant, Cell & Environment

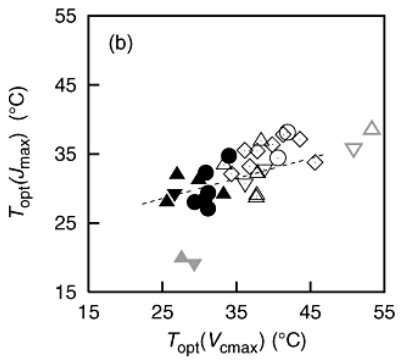
Temperature acclimation in a biochemical model of photosynthesis: a reanalysis of data from 36 species

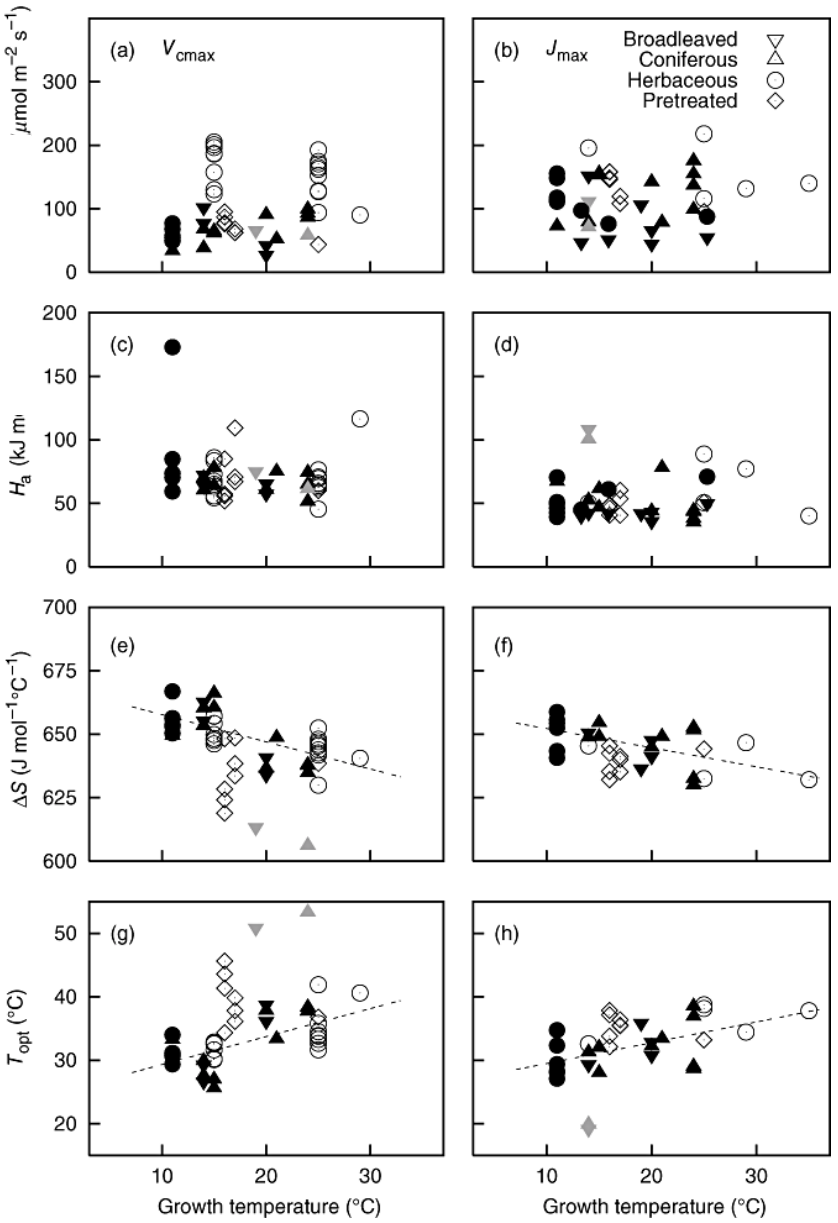
JENS KATTGE & WOLFGANG KNORR https://doi.org/10.1111/j.1365-3040.2007.01690.x

$$x_i = a_i + b_i \times t_{growth}$$

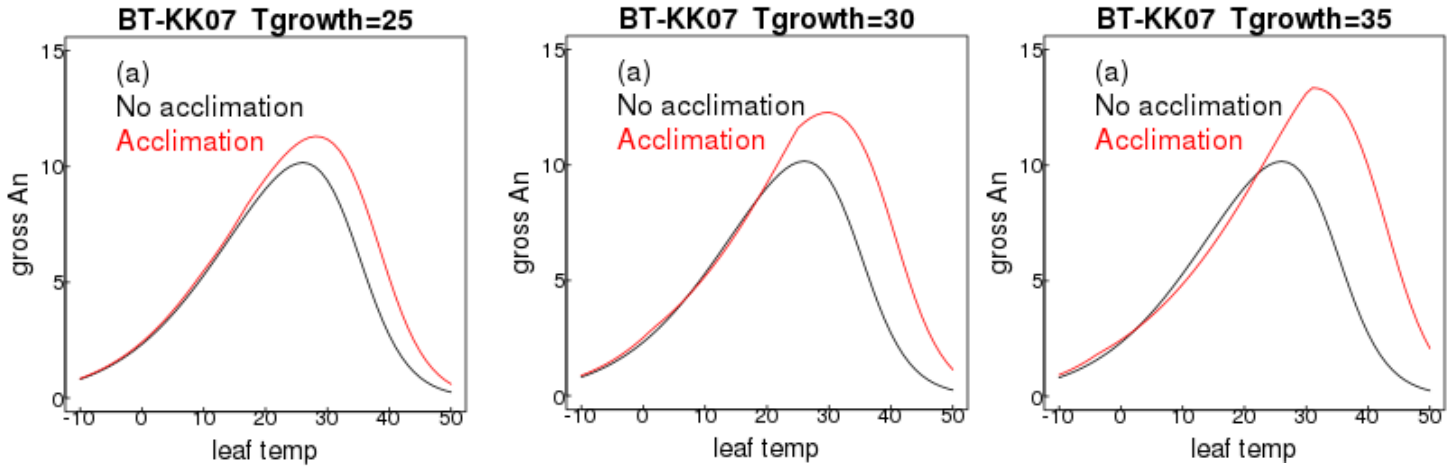
$$k_T = k_{25} \exp[H_a(T_l - T_{ref})/(T_{ref} R T_l)] \frac{1 + \exp\left(\frac{T_{ref}\Delta S - H_d}{T_{ref} R}\right)}{1 + \exp\left(\frac{T_l \Delta S - H_d}{T_l R}\right)}$$





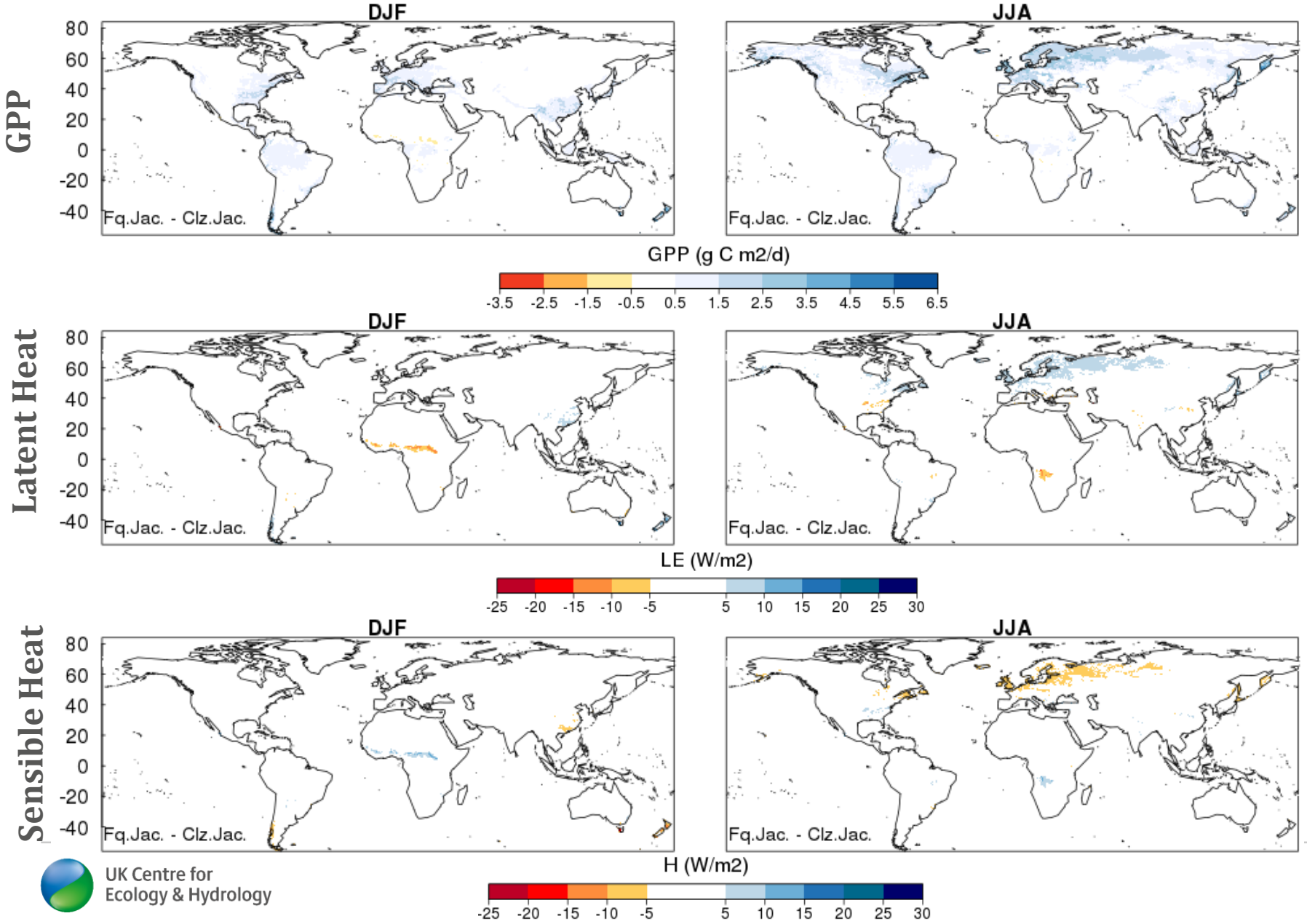


Thermal Acclimation



Farquhar Photosynthesis

Seasonal mean 2002 to 2012



UK Centre for Ecology & Hydrology

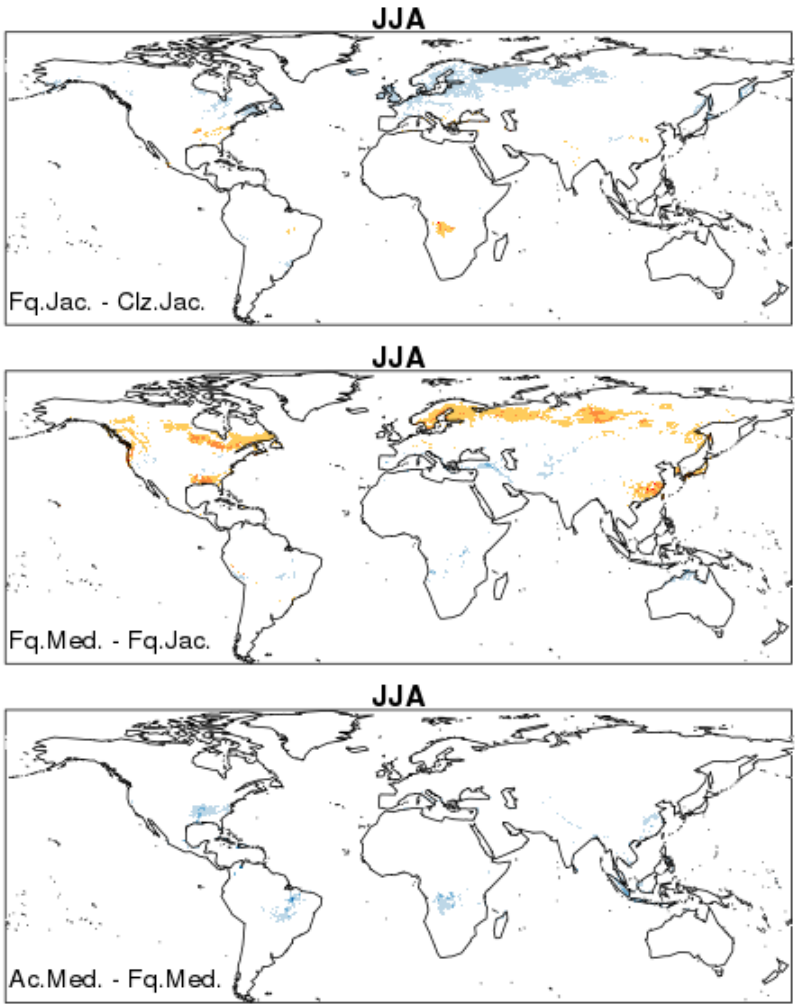
GPP latitude bands (mean 2002 to 2012)

Seasonal mean GPP (2002 to 2012)

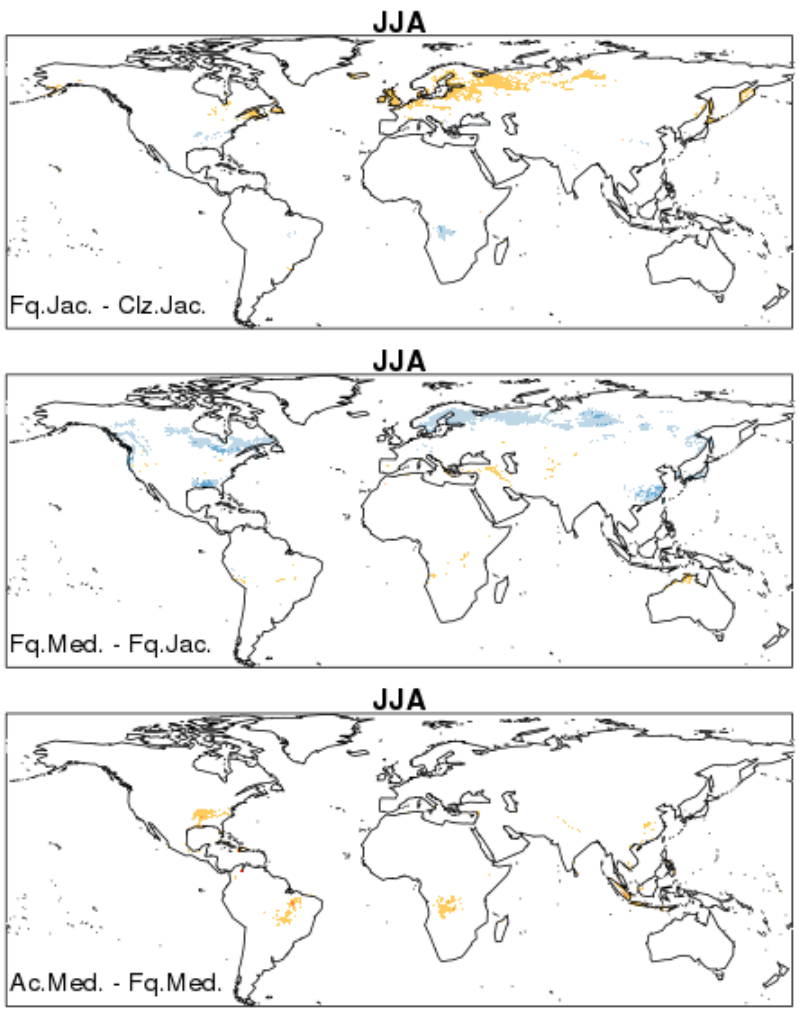
	JJA (Pg C)	MAM (Pg C)	SON (Pg C)	DJF (Pg C)
FLUXCOM	44.68	32.46	29.40	25.67
Collatz	42.22	28.82	34.53	24.82
Farquhar	48.35	33.59	39.24	28.36
Farquhar + Medlyn	48.61	34.02	39.42	28.70
Acclimation + Medlyn	49.93	35.91	40.36	29.77

Thermal Acclimation

Latent Heat



Sensible Heat



W/m2

Seasonal mean (2002 to 2012)

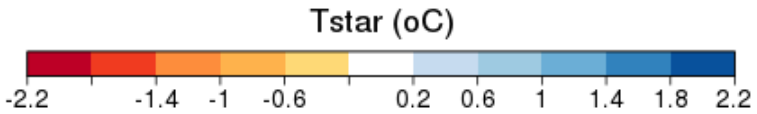
Thermal Acclimation

- Large differences in surface energy fluxes simulated at midday local time due to changes in plant stomatal behaviour.

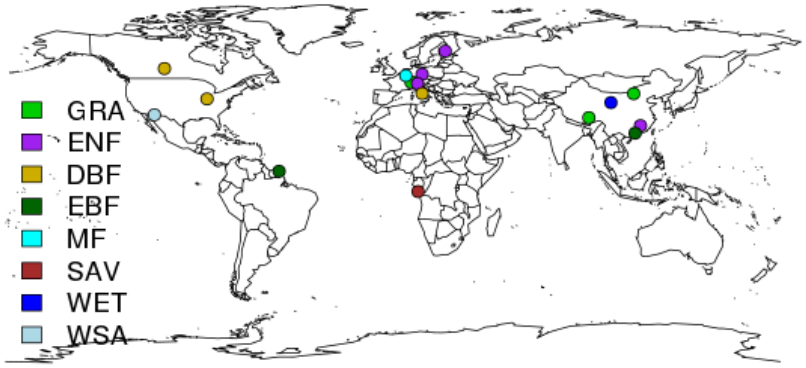
Latent Heat at 12:00 Local Time **Sensible Heat at 12:00 Local Time**

Thermal Acclimation

Land Surface Temperature at 12:00 Local Time



FluxNet Site-level Evaluation



Selection of Fluxnet sites to cover a range of vegetation types.

Relative change in RMSE (JJA) for GPP and evaporative fraction (EF) – yellows/red indicate an improvement.

GPP – biggest improvements at grassland and evergreen needle leaf sites.

EF - biggest improvements at grassland and evergreen needle leaf sites.

Thermal Acclimation: what next……

- For PORCELAIN with colleagues at Reading University (Pier Luigi, Patrick McGuire, Markus Todt) the physiology work is being put into the GCM so we can do some coupled simulation.

- Starting to implement a more recent acclimation model developed by Kumarathunge et al., (2019)(doi: 10.1111/nph.15668) to see how this compares to the Kattge and Knorr model.