Non-radiative heat dissipation across scales in a water stressed pine forest: From the leaf to the planetary boundary layer

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Boundary layer scale: The ‘convector effect’

With suppressed latent heat flux (*LE*) because of lack of water, the forest is transformed into an effective “convector” that exploits the low tree density and open canopy and, consequently, high canopy-atmosphere aerodynamic coupling.

Contribution of Semi-Arid Forests to the Climate System

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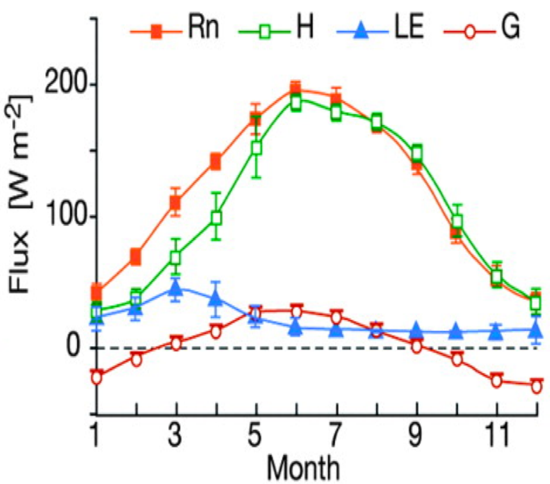
Water-cooled canopy…

Air-cooled canopy…

Forest cooling -5C annual mean



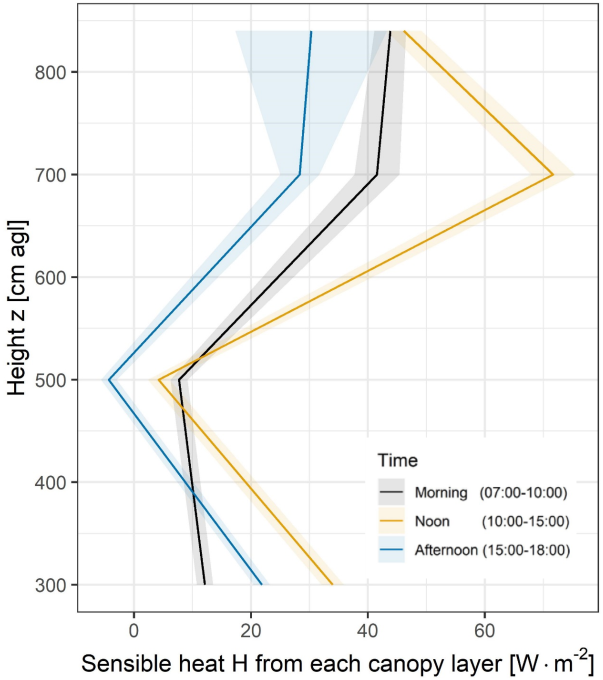
- Latent heat flux (LE) is minor
- Sensible heat (H) balance net radiation Rn

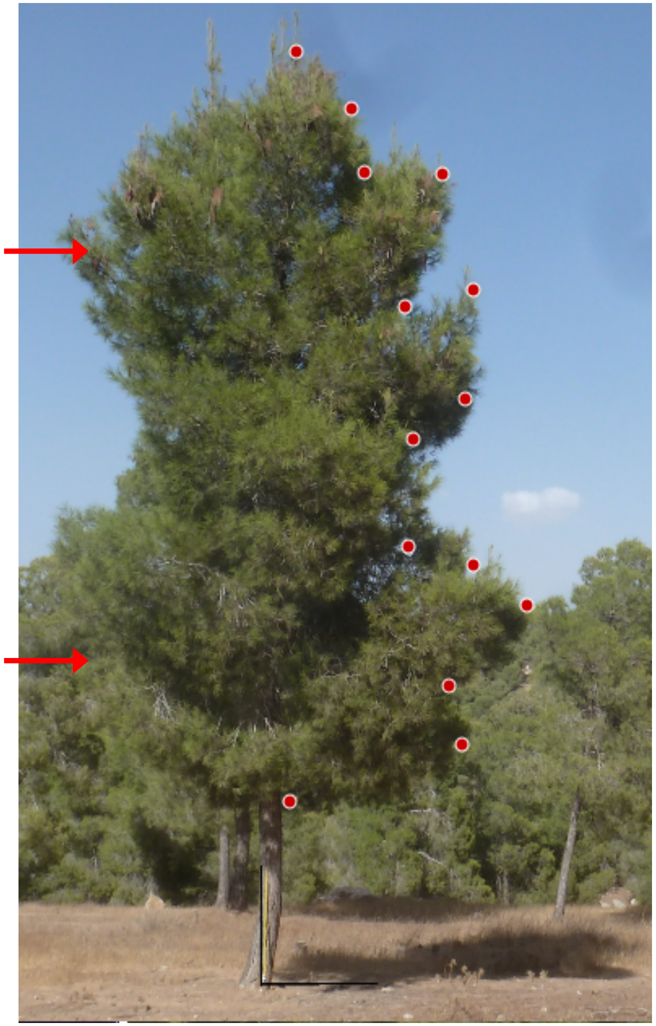
High roughness->low r_h

$$H = \rho_a C_a \frac{(T - T_a)}{r_h}$$

Tree scale 1: Sensible heat from the hottest part of the canopy

Jonathan Muller

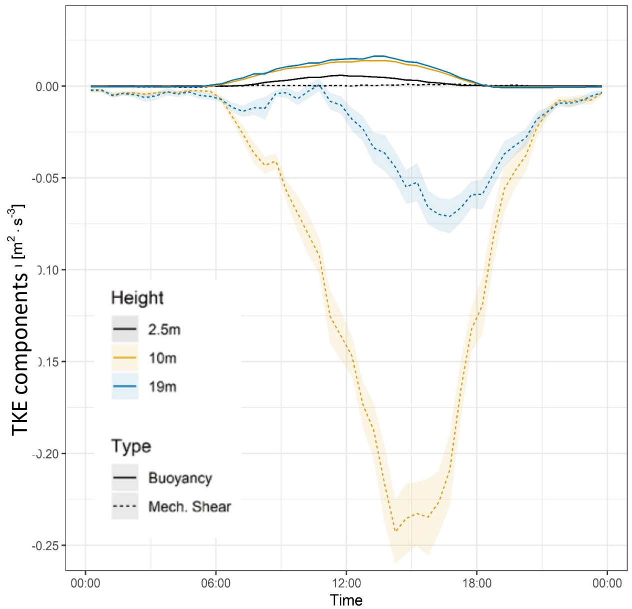


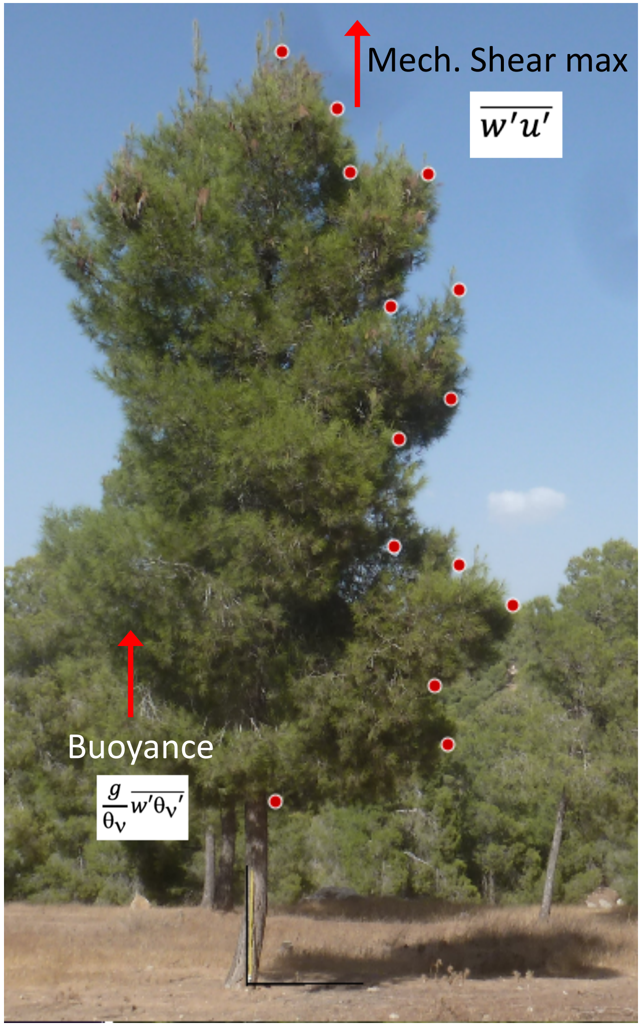


Sensible heat (H) production peak where leaf to air temperature difference is maximal

Tree scale 2: Buoyancy below canopy, mech. shear at the top

Measuring flux profiles



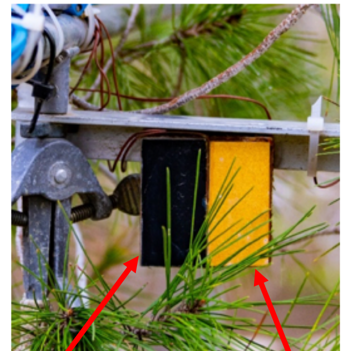


The main components of TKE: Mech. shear is dominant at the top of canopy (yellow); decreasing up (blue), and down (black) where Buoyancy becomes relatively more significant

Leaf scale 1: High precision leaf temperature measurements

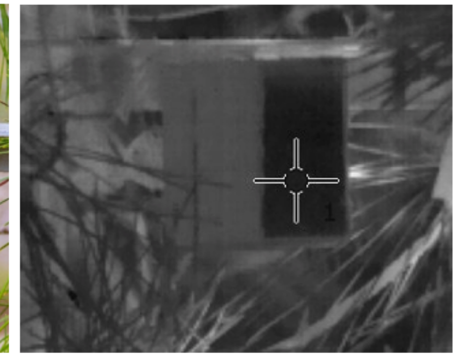
IR camera

IR camera

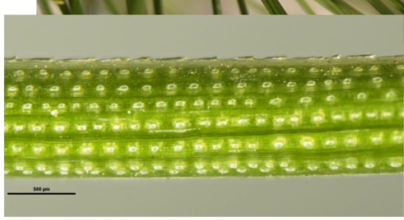


Low Refl. T calibration

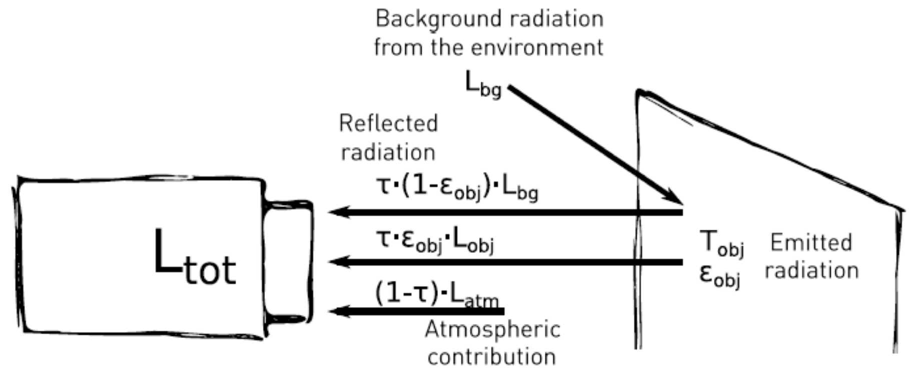
High Refl. Background correction



IR image



Measurement methods for leaf temperature



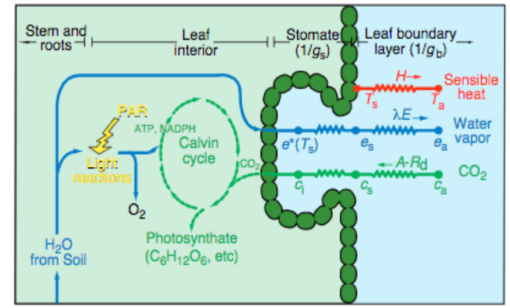
$$L_{tot} = \tau \cdot \varepsilon_{obj} \cdot L_{obj} + \tau \cdot (1-\varepsilon_{obj}) \cdot \underbrace{L_{bg}}_{\text{Reference plate with high reflectivity}} + \underbrace{(1-\tau) \cdot L_{atm}}_{\text{Ignored due to small distance}}$$

Quantity of interest

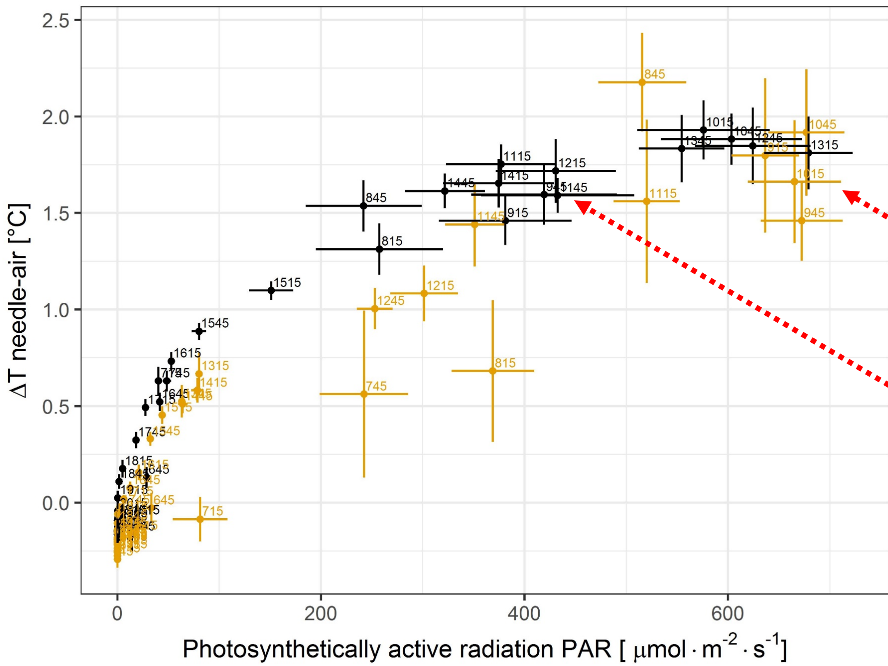
Leaf scale 2: Leaf temperature independent of evaporation

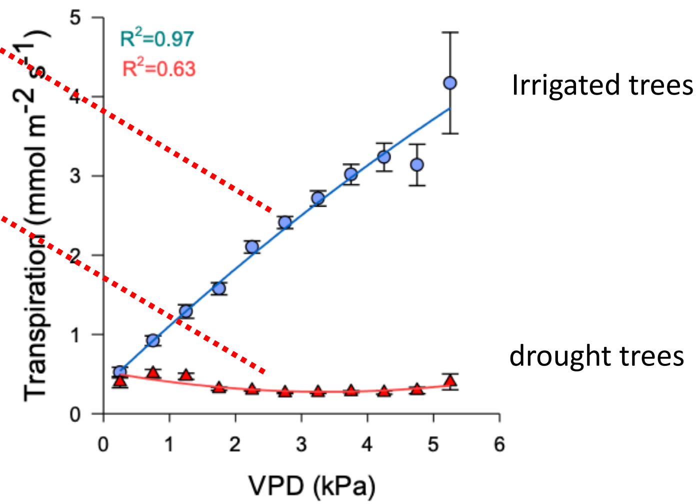
- Leaf temperature similar with x10 rate of evaporation
- Efficient sensible heat production at the leaf scale
- Needle leaf: low heat capacity, large surface area, low density

Leaf temp management to protect the biochemistry



Leaf to air temperature difference

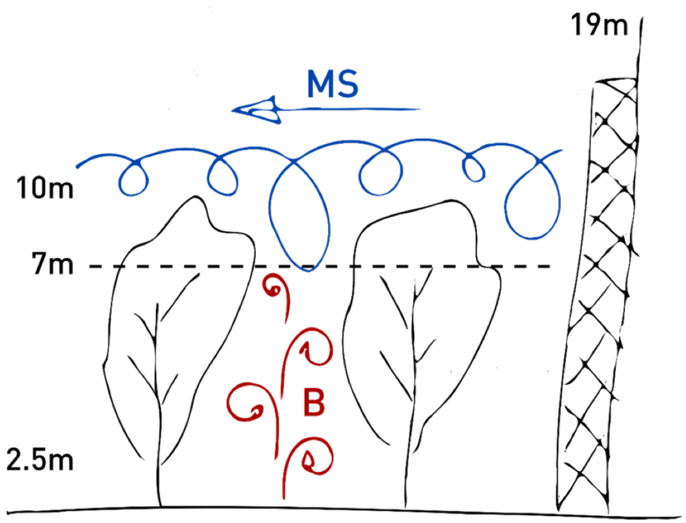




$$H = -c_p \cdot \rho \cdot \frac{T_a - T_s}{R_H},$$ also at the leaf scale

Conclusions

- The ”convector effect” evolves from the leaf, though tree, to the canopy scale
- Main source of sensible heat below top of canopy, with Buoyancy (B) production of turbulence below and Mech. Shear (MS) production above
- Leaf temperature can be controlled independently of evaporation rate
- At all scales, heat is dissipated via non evaporative and non-radiative processes
- Such processes infer resilience to forests under dry dry conditions
- Indicating potential adjustments in forest in regions undergoing drying and warming climatic trends



B, Buoyancy; MS, mechanical shear