Evaluating Divergent Thermoregulatory Strategies of Four Dominant Eastern U.S. Tree Species

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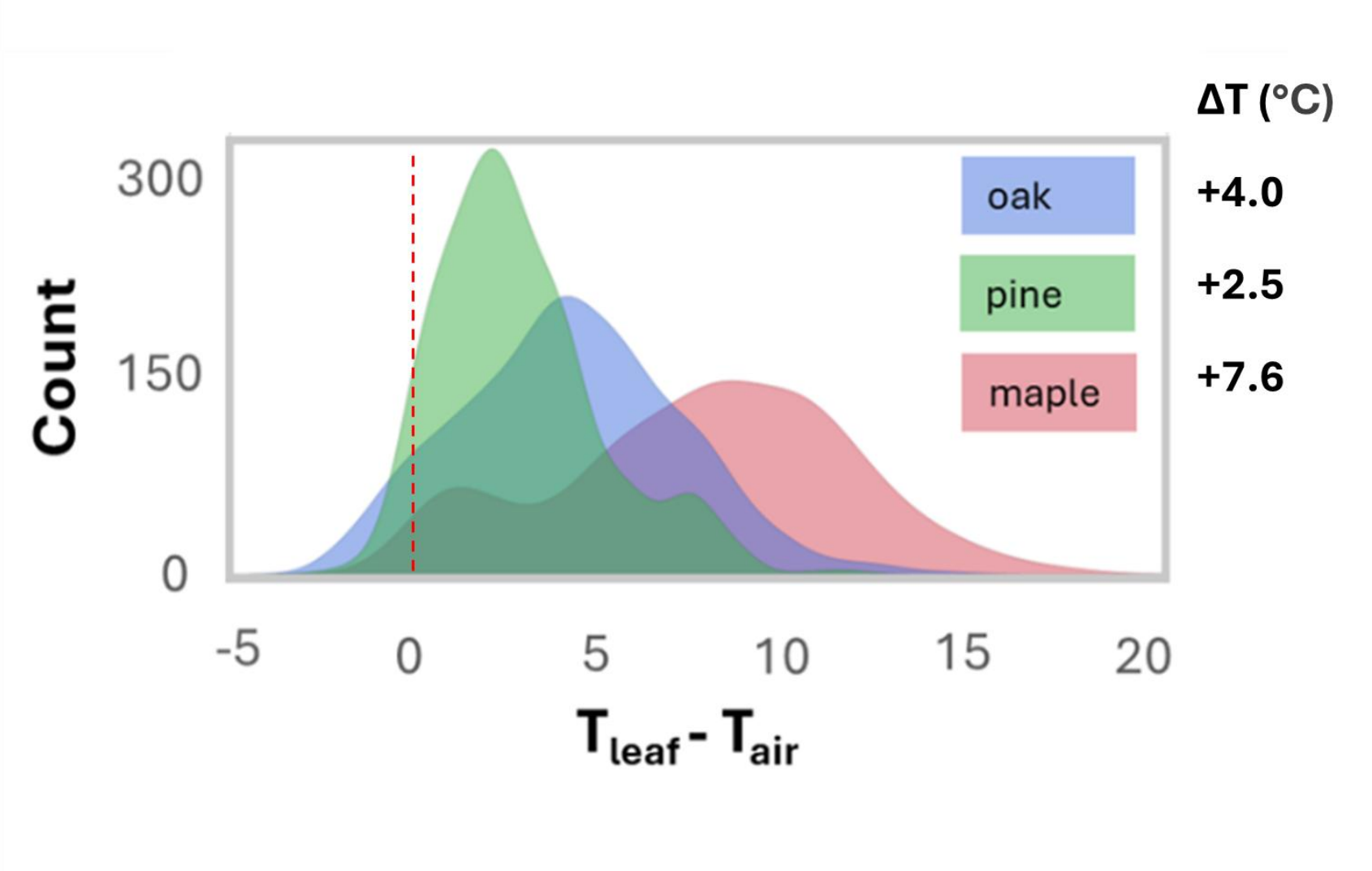
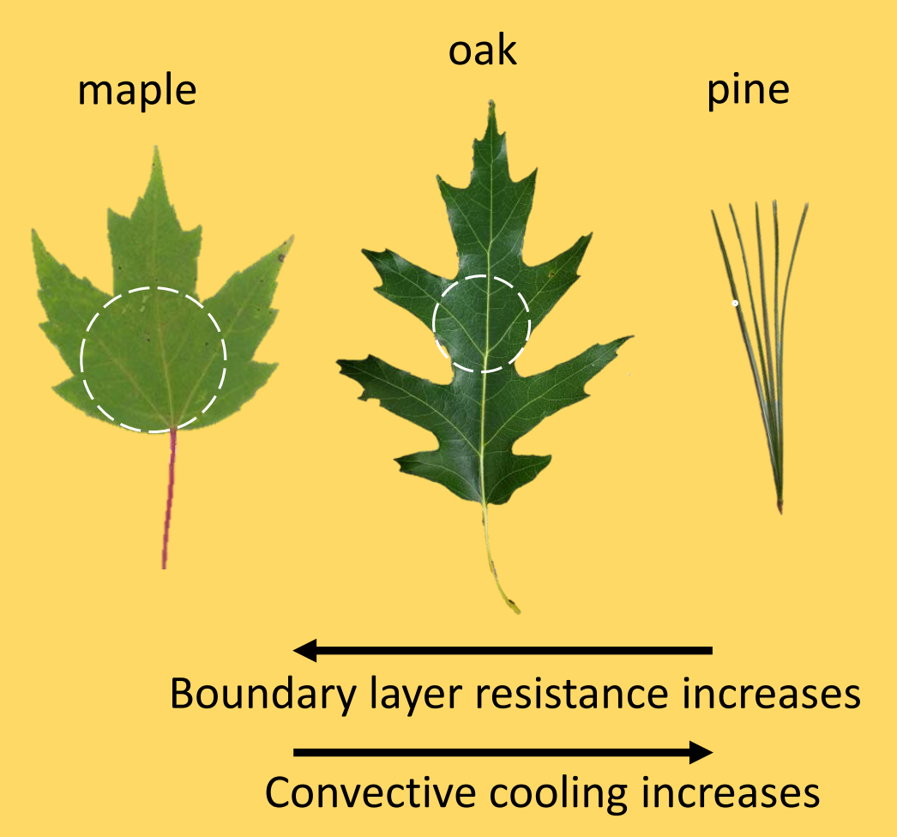
Surveyed leaf temperatures show some species are better at staying cool

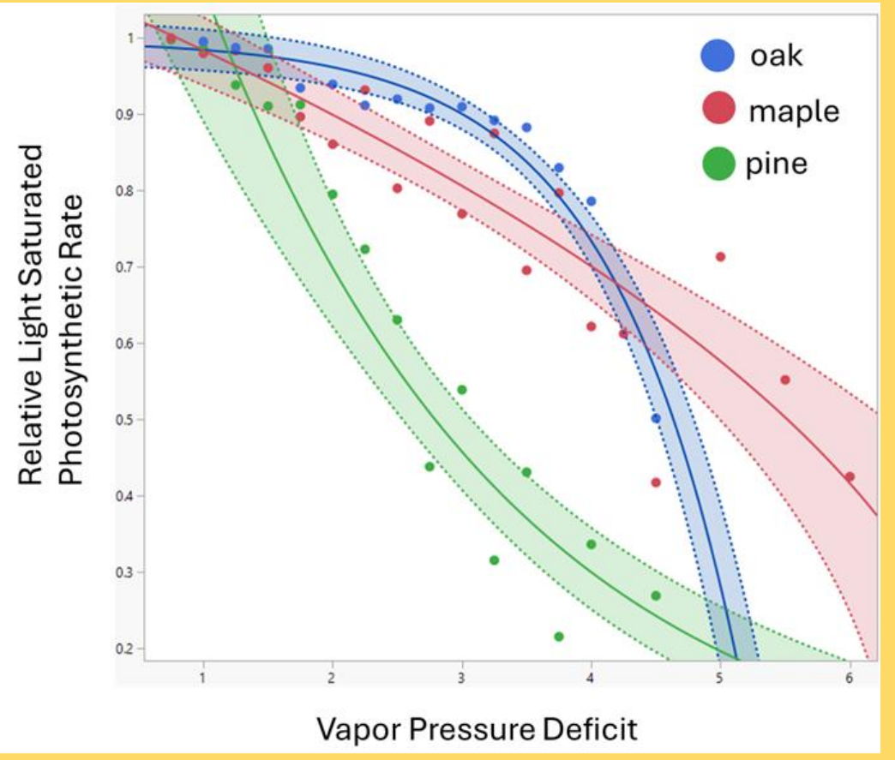


During a hot, dry summer, we surveyed more than 2000 upper-canopy leaf temperatures at the Thompson Farm Forest in southeastern NH, USA. Shade leaves closely tracked air temperature, while sunlit leaves were consistently hotter than air temperature, with clear species difference. (**Left**) Distribution of sunlit leaf-air temperature difference for our three focal species: **red oak** (*Quercus rubra*), **white pine** (*pinus strobus*) and **red maple** (*Acer rubrum*).

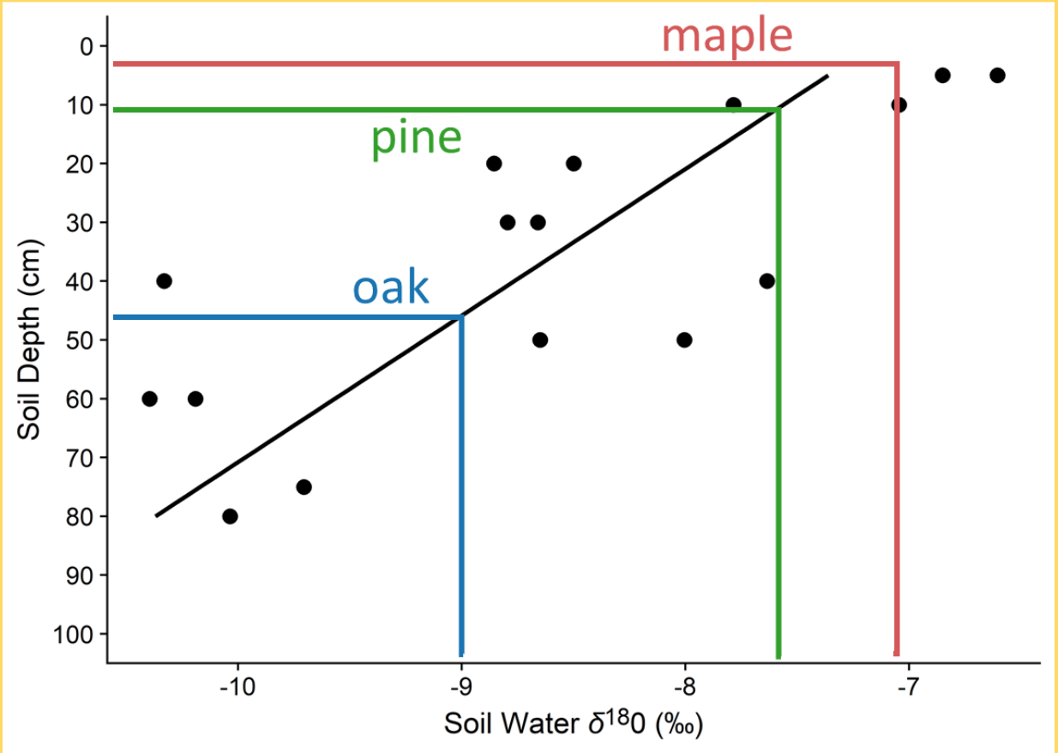
We have been measuring traits influencing how leaves stay cool



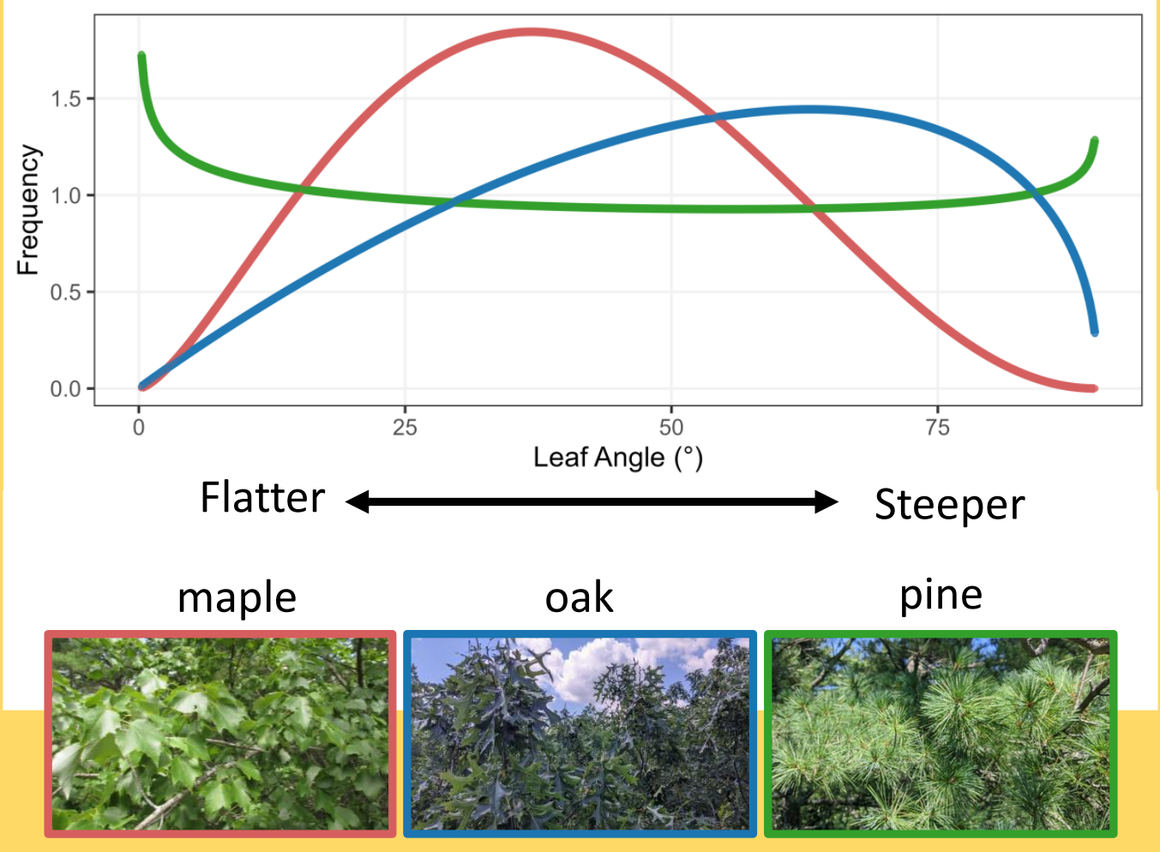
Leaf shape influencings convective cooling.
(**Left**) Example upper canopy leaves with circles illustrating the *characteristic dimension*, the effective width that governs boundary layer thickness and convective heat loss. The small needles of pine make them well suited for convective cooling.



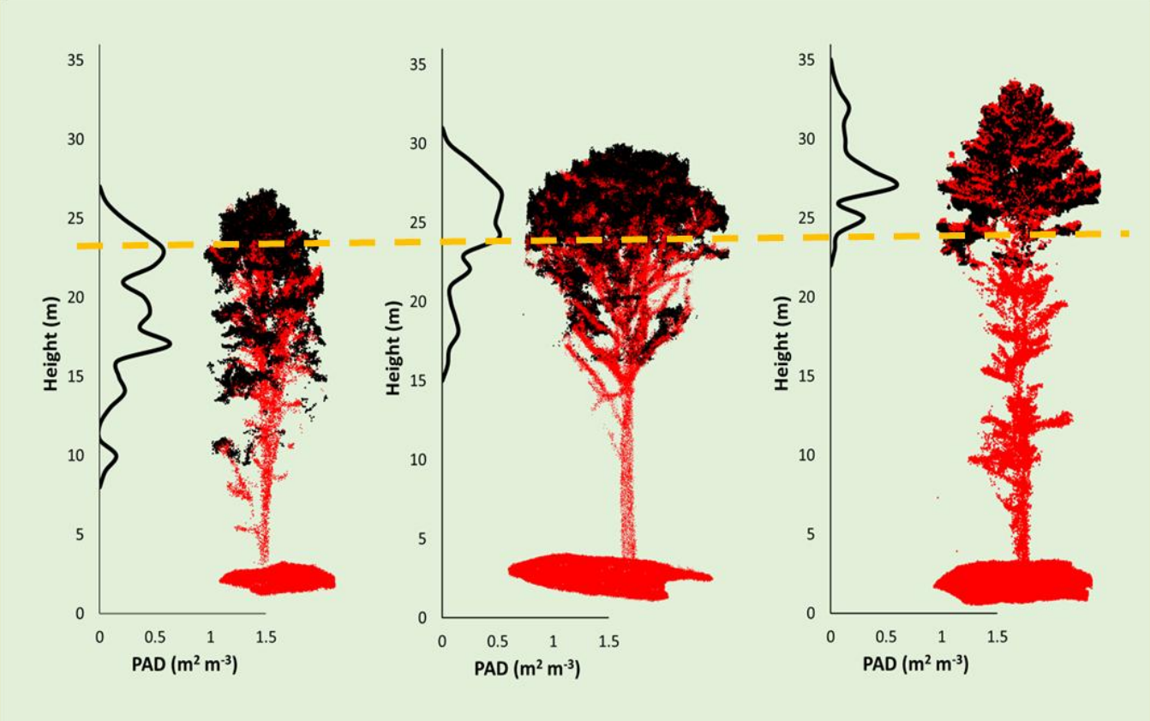
Stomatal sensitivity reflects reliance on convective vs transpirational cooling.
(**Left**) Photosynthetic vapor pressure deficit (VPD) response curves illustrate stomatal sensitivity to dryness: pine (isohydric) closes stomata at low VPD, relying more on convective cooling, while oak (anisohydric) maintains transpiration even as VPD rises.



Access to water is needed to support transpirational cooling.
(**Left**) Water uptake depths estimated from tree core and soil water oxygen isotopes. Oaks have access to deep water enabling sustained transpiration even during drought. Figure courtesy of Tumber-Dávila et al. *In Prep.*



Leaf angle controls solar loading.
(**Above**) Beta distribution fitted to hundreds of upper-canopy leaf angle measurements showing typical leaf orientation at our site. Flatter maple leaves face the sun and absorb more energy than oak and pine.

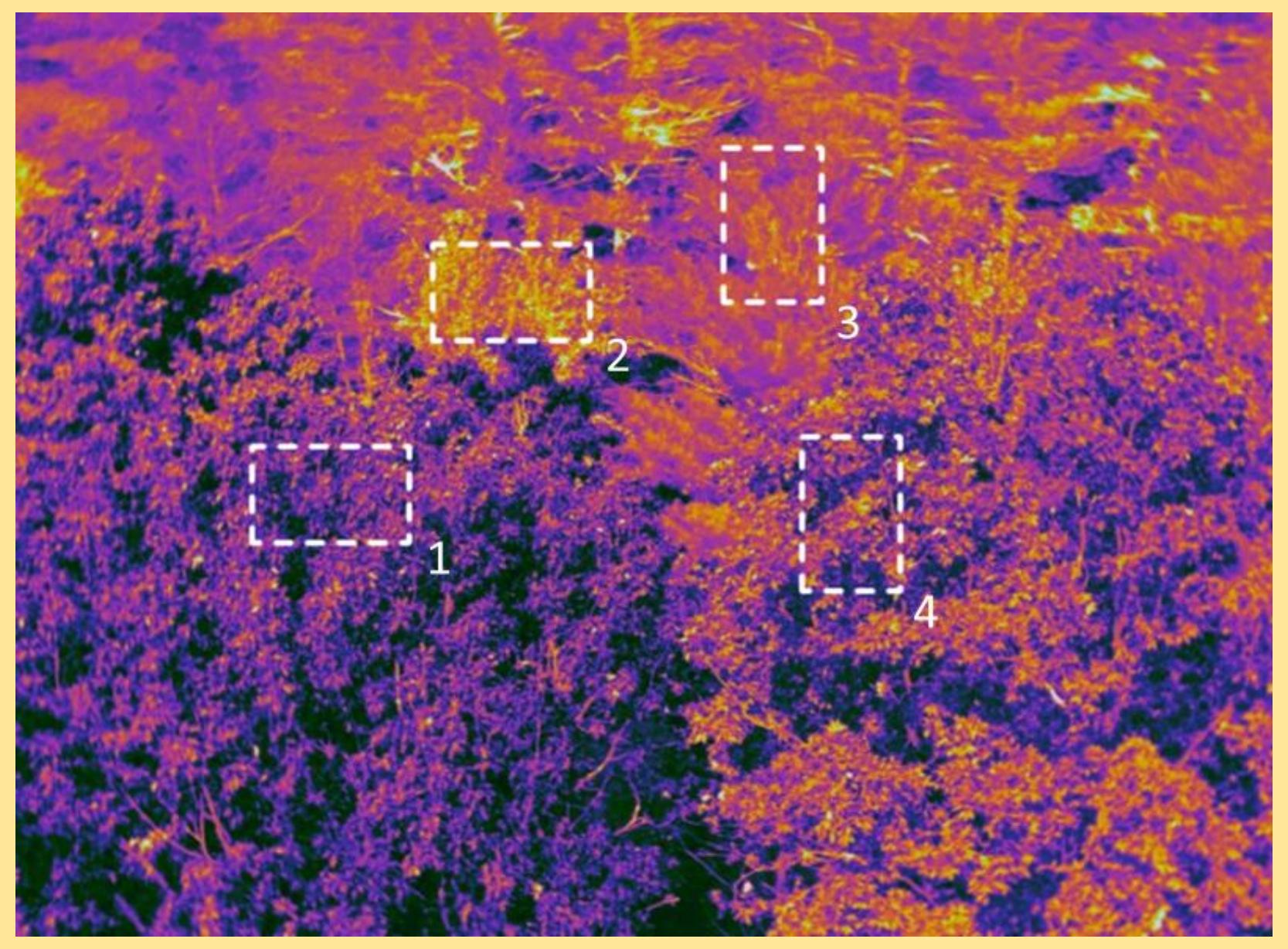


Canopy position drives differences in leaf exposure and microclimate.
(**Above**) Plant area density (PAD) profiles derived from UAV LiDAR. Yellow dashed line indicates mean canopy height. Pine are emergent crowns, oak dominates the main canopy, and maple is intermediate.

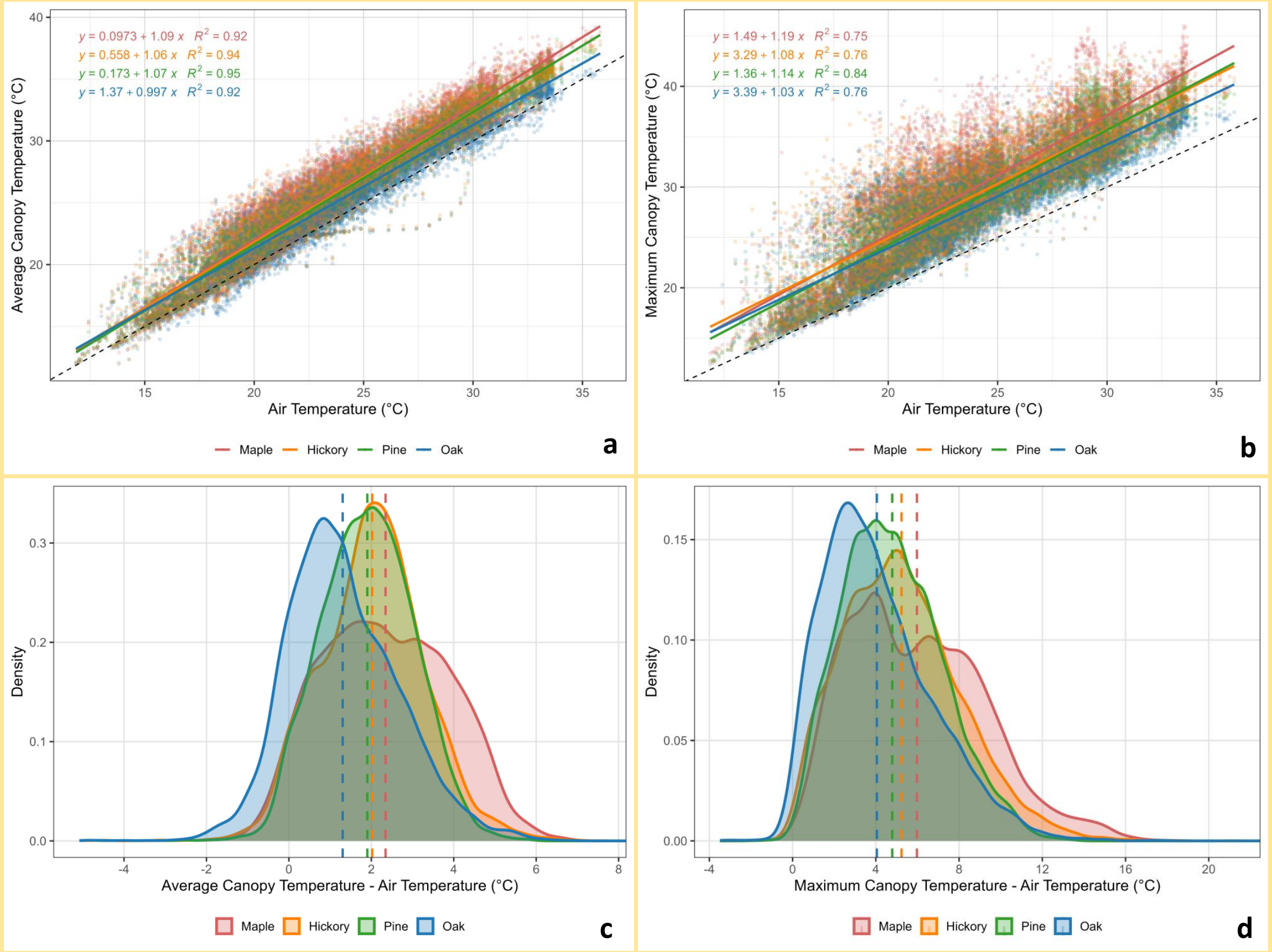
Our measurements suggest pine relies primarily on convective cooling, oak on transpirational cooling, and maple attempts transpirational cooling but struggles under dry conditions, instead relying on a third strategy: heat avoidance by occupying the middle canopy rather than the upper canopy.

Understanding the thermoregulatory strategy of different tree species in the eastern U.S. is critical for forecasting their response to projected increases in average annual temperature and more frequent severe heat and drought events.

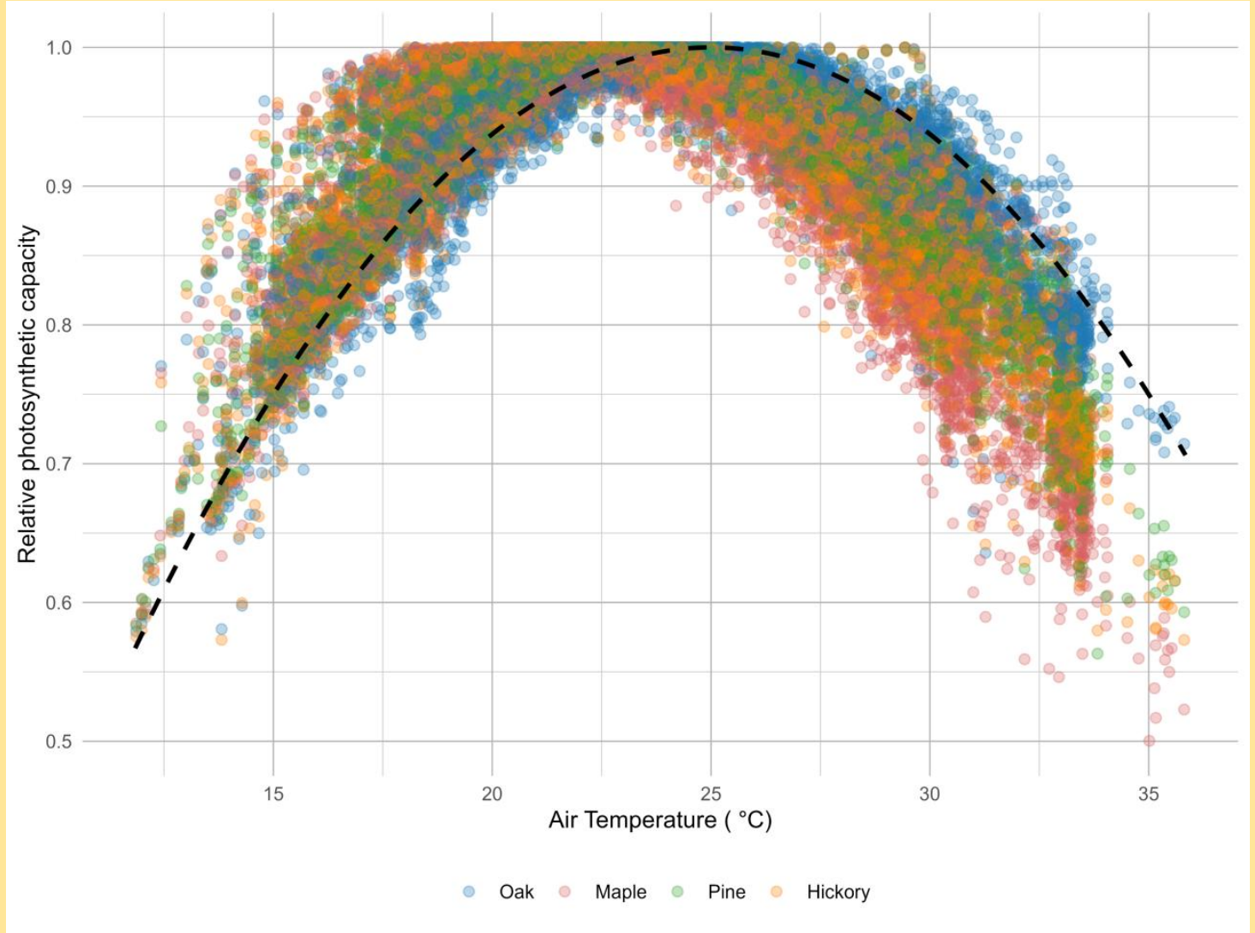
We installed a thermal camera to understand how four species regulate canopy temperature



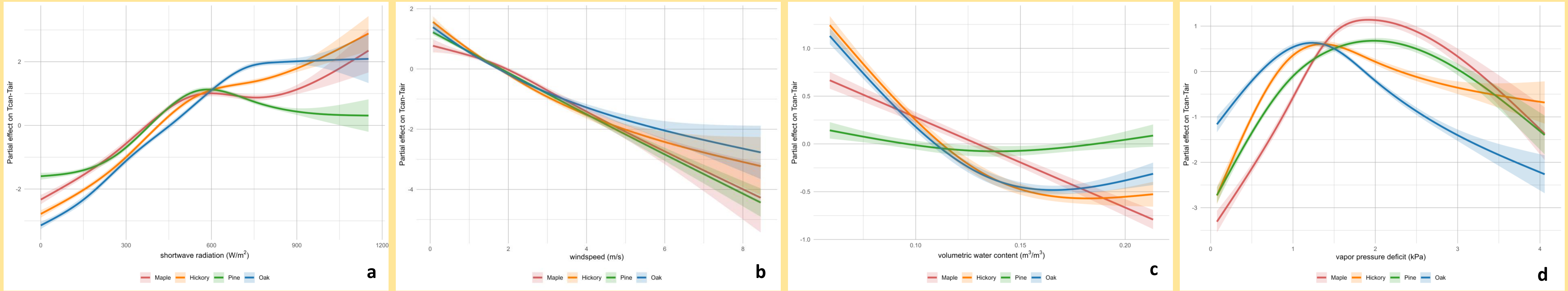
(**Left, above):** We installed a FLIR A655sc thermal camera on top of our flux tower (US-TFF) in late May of 2024. It has collected images every 15 minutes continuously for the last two growing seasons. Four different species are in the camera FOV: 1.) **red oak**, 2.) **red maple**, 3.) **white pine**, 4.) **shagbark hickory** (*Carya ovata*).



(**Above**) Daytime (9am – 5pm) growing season (June – September) thermal camera data. Panels **a** and **b** show mean (**a**) and maximum (**b**) canopy temperature versus air temperature. Panels **c** and **d** show the distributions of mean (**c**) and maximum (**d**) canopy temperature relative to air temperature.



(**Above**) Hypothetical temperature effect on gross photosynthesis calculated using a parabolic equation from the PnET ecosystem model. The dashed line shows temperature effect of air temperature and species points show effect of mean canopy temperature, including all daytime summer values.



(**Above**) Partial effect plots showing how **a**) shortwave radiation, **b)** windspeed, **c)** volumetric water content, and **d)** vapor pressure deficit influence the difference between canopy temperature and air temperature. These panels show maximum temperature differences, but results are similar for mean temperature.

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