

Trees are Cool!

Dexter H. Locke

Chesapeake Bay Program, Forestry Working Group

March 4, 2026

USDA Forest Service, Northern Research Station, Baltimore Field Station

dexter.locke@usda.gov

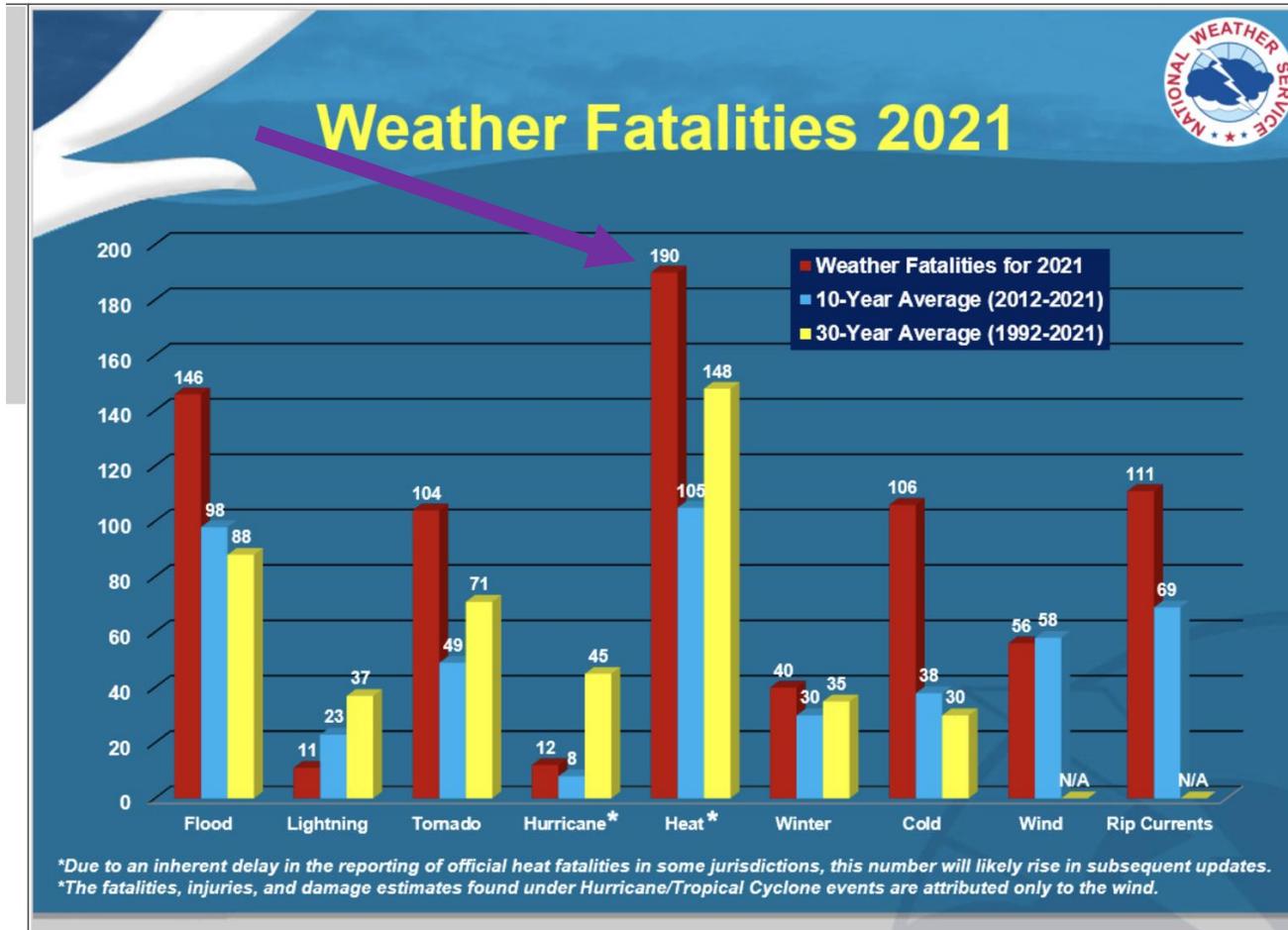
<http://dexterlocke.com/>



outline

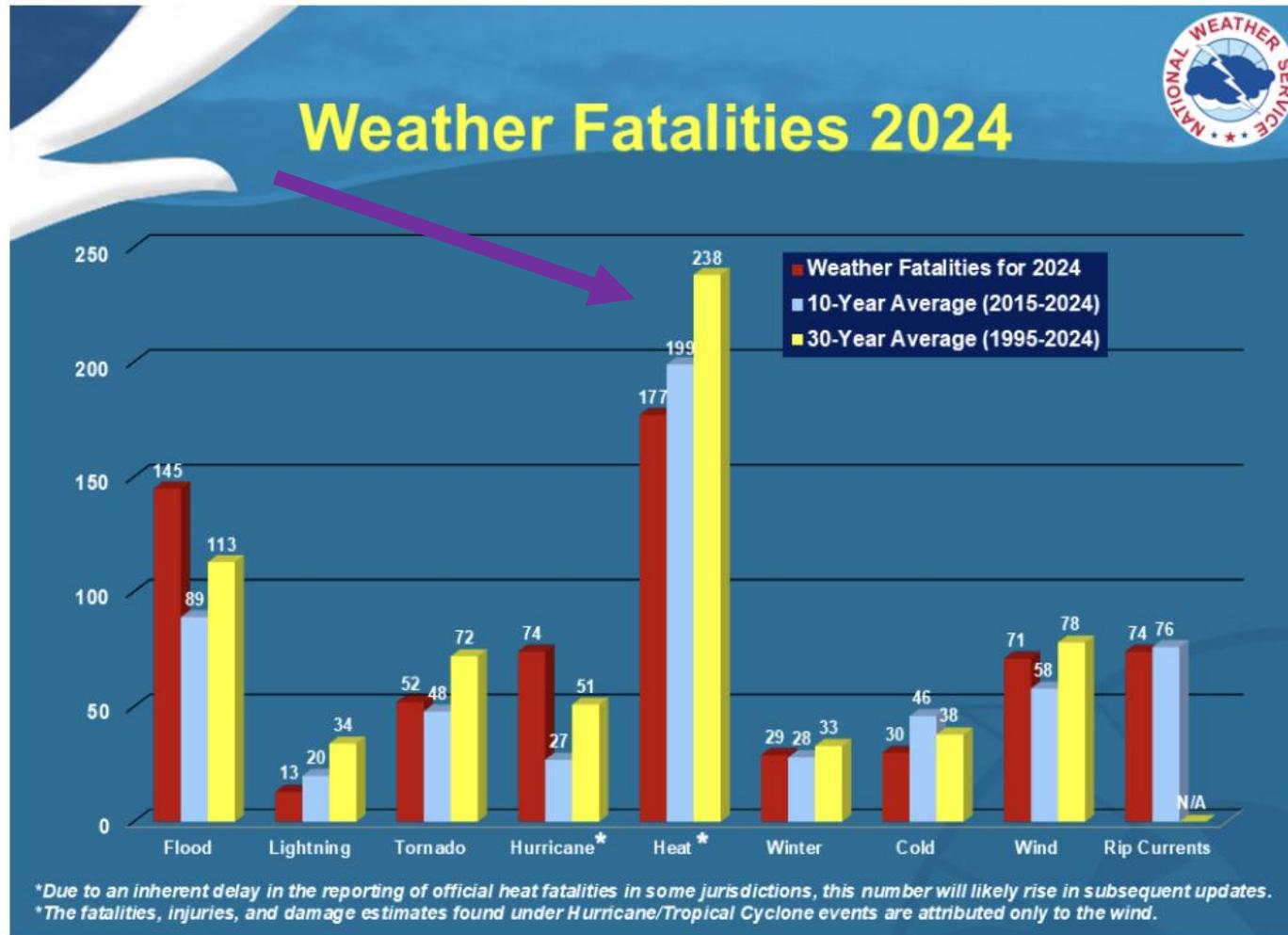
1. Review of vegetation and urban heat
2. New Haven, CT Case Study
3. Hand off to Baltimore Green Space for Baltimore Bike-based work

Heat kills more than any other weather-related fatality – for 30 years



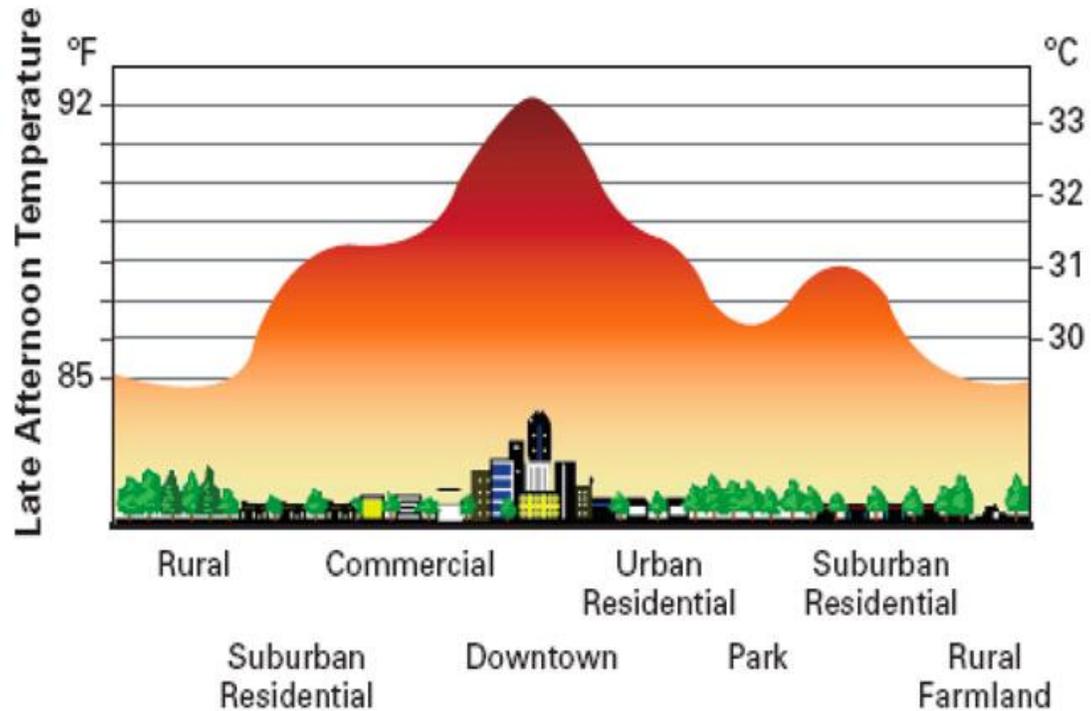
<https://www.weather.gov/hazstat/>

Heat kills more than any other weather-related fatality – for 30 years



<https://www.weather.gov/hazstat/>

Urban Heat Island Basics



Cities are hotter than rural counterparts

Morbidity, mortality, and plant stress

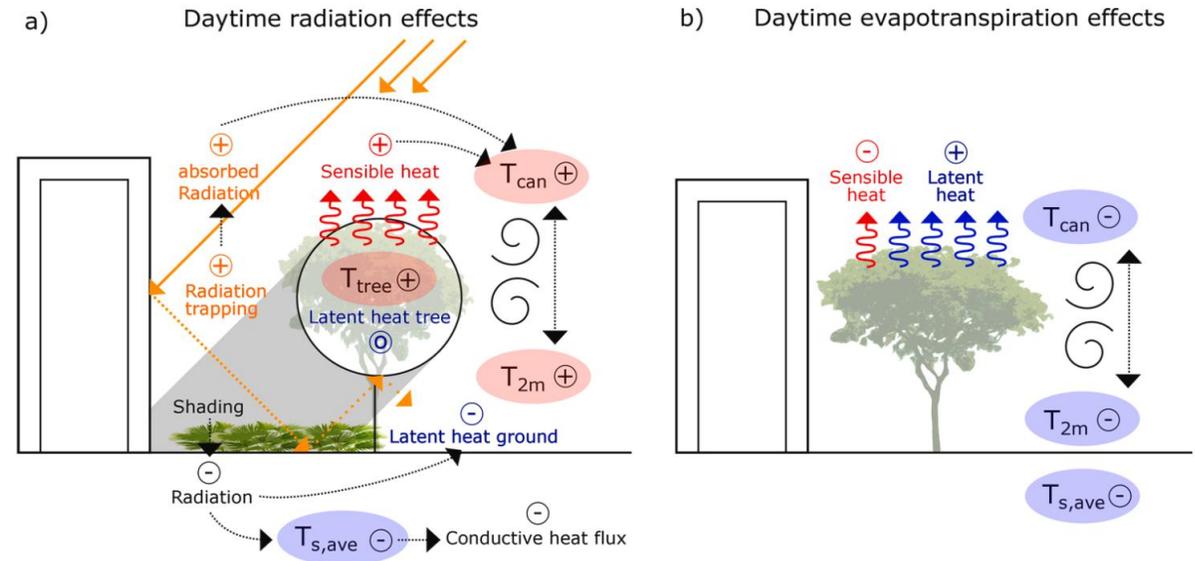
Trees reduce temperatures

Trees and Urban Heat: 3 mechanisms

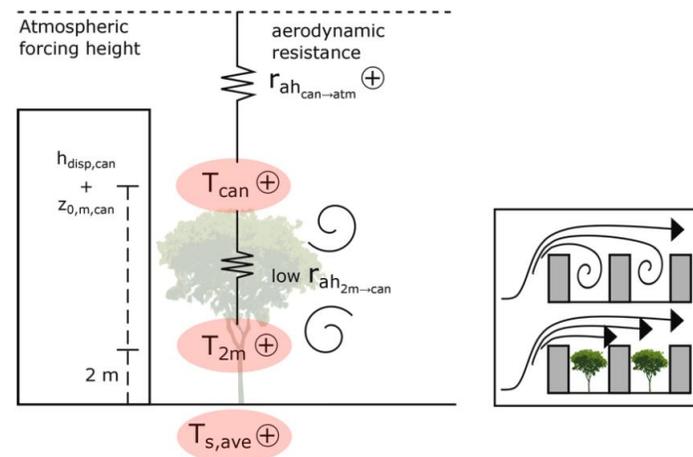
a) Shade

b) Evapotranspiration

c) Roughness / aerodynamics



c) Daytime aerodynamic roughness effects



Meili, N., Manoli, G., Burlando, P., Carmeliet, J., Chow, W. T. L., Coutts, A. M., Roth, M., Velasco, E., Vivoni, E. R., & Fatichi, S. (2021). Tree effects on urban microclimate: Diurnal, seasonal, and climatic temperature differences explained by separating radiation, evapotranspiration, and roughness effects. *Urban Forestry and Urban Greening*, 58, 126970. <https://doi.org/10.1016/j.ufug.2020.126970>

International Society of Arboriculture (ISA)

RESEARCH

RESEARCH > RESEARCH RESOURCES > LITERATURE REVIEW SERIES

The International Society of Arboriculture Science and Research Committee has commissioned a series of comprehensive literature reviews focused key areas of concern in the fields of arboriculture and urban forestry.

Each topic features an Arborist News technology transfer article, an Arboriculture & Urban Forestry review paper, annotated list of citations, and a whitepaper from an associated research summit. Key research findings and trends are highlighted throughout the publications, as well as research gaps and priorities for future research.

SEARCHABLE DATABASE

Urban Forest Sustainability

- [Urban Forests and Sustainability International Symposium \(Shenyang, China, May 29-June 4, 2016\)](#)

Pruning

- [Arborist News Technology Transfer Article](#)
- [Arboriculture & Urban Forestry Article](#)
- [Reference List](#)
- [Researcher Summit White Paper](#)

Trees and Risk

- [Arborist News Technology Transfer Article](#)
- [Reference List](#)
- [Researcher Summit White Paper](#)

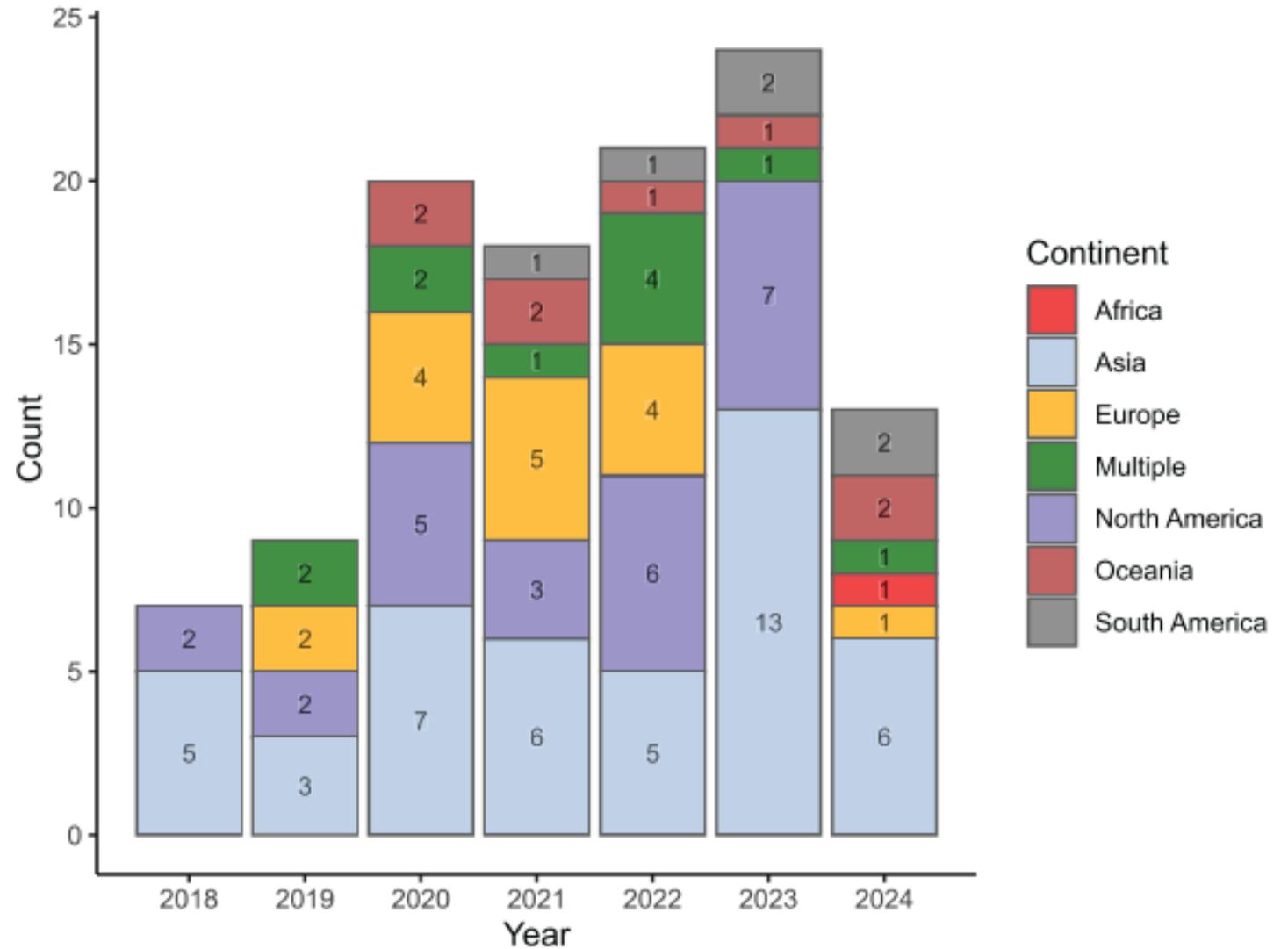
Root Growth and Development

- [Arborist News Technology Transfer Article](#)
- Arboriculture & Urban Forestry [Article 1](#) [Article 2](#)
- [Reference List](#)
- [Researcher Summit White Paper](#)

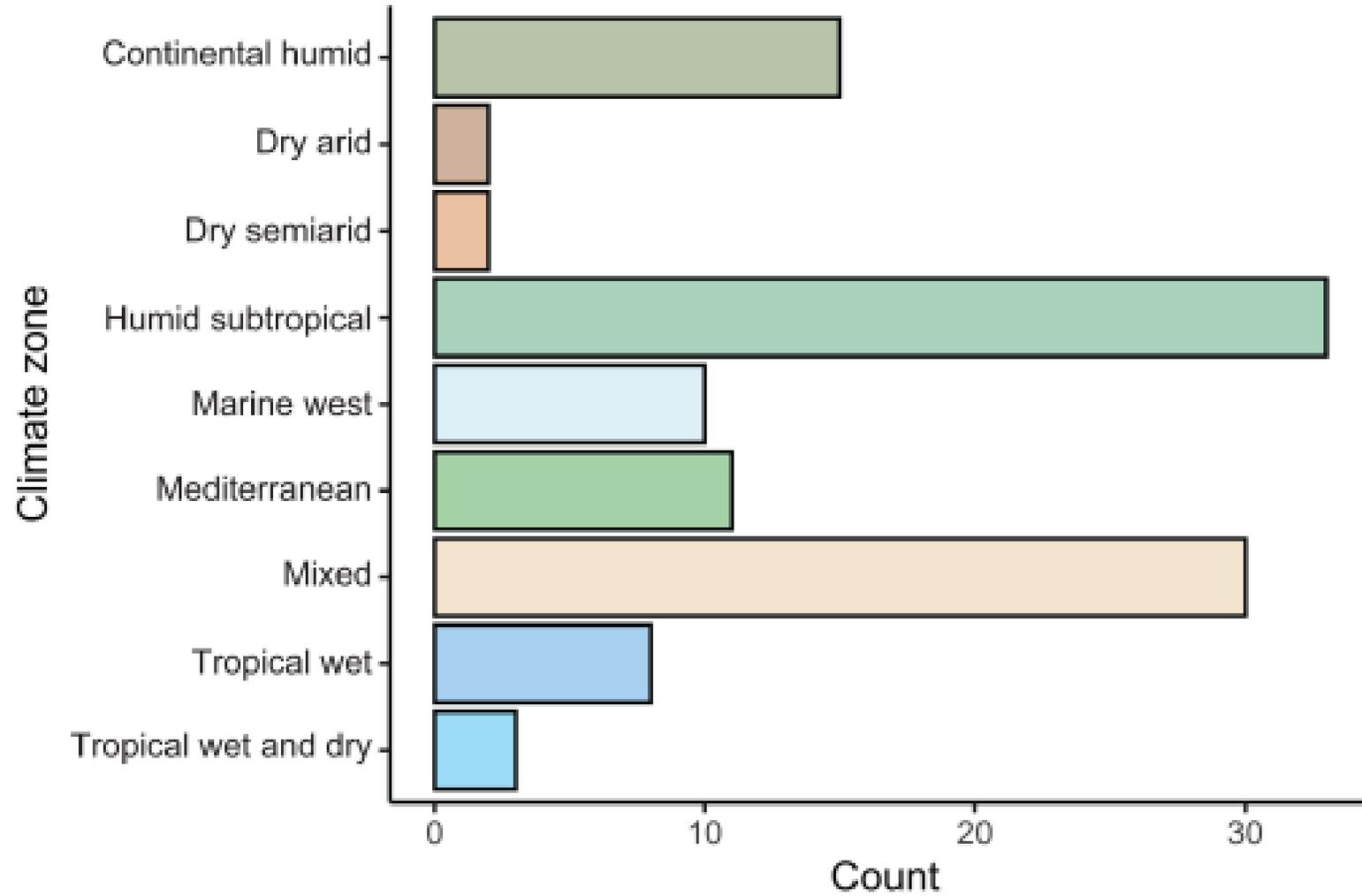
<https://www.isa-arbor.com/Research/Literature-Review-Series>

Where

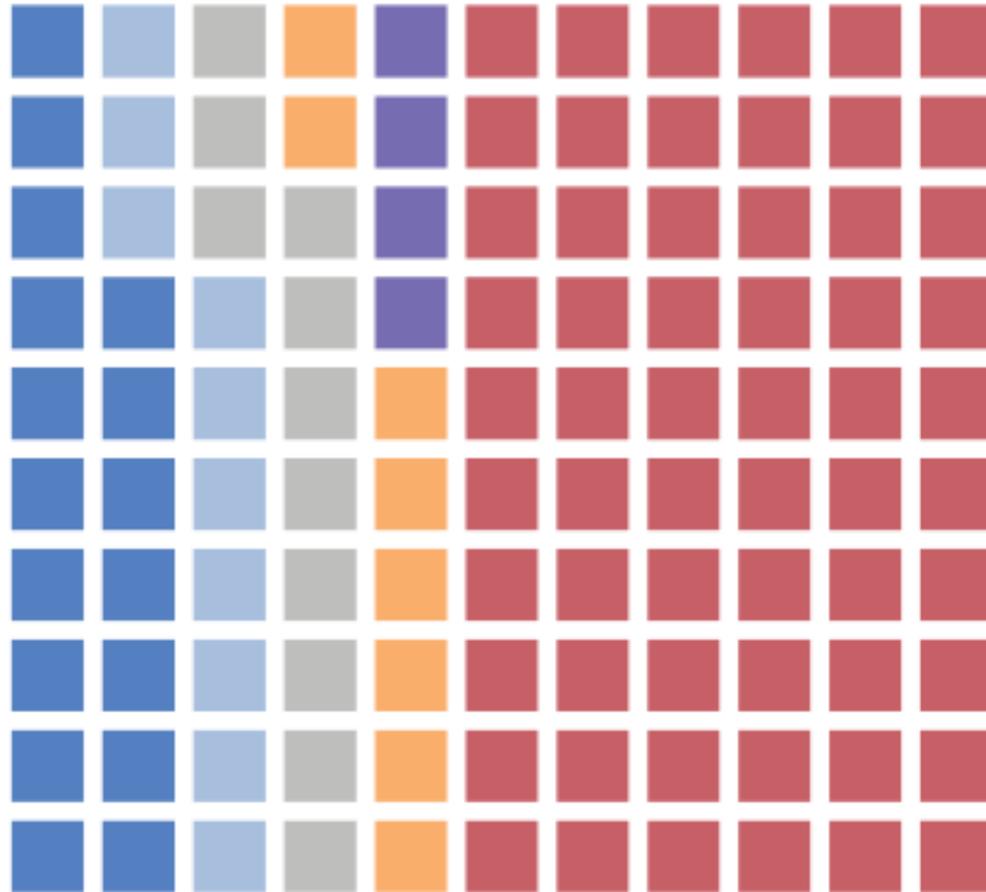
Publication title	Count
<i>Urban Forestry & Urban Greening</i>	15
<i>Sustainable Cities and Society</i>	10
<i>Forests</i>	7
<i>Landscape and Urban Planning</i>	7
<i>Science of the Total Environment</i>	7
<i>Building and Environment</i>	5
<i>Urban Climate</i>	5
<i>Atmosphere</i>	4
<i>International Journal of Applied Earth Observation and Geoinformation</i>	4
<i>Agricultural and Forest Meteorology</i>	3
<i>Environmental Research Letters</i>	3
<i>Remote Sensing</i>	3
<i>Scientific Reports</i>	3
<i>Sustainability (Switzerland)</i>	3
<i>Ecological Indicators</i>	2
<i>ISPRS Journal of Photogrammetry and Remote Sensing</i>	2
<i>Remote Sensing of Environment</i>	2



Where (2)



What



ET or LE: evapotranspiration or laten heat flux

HTC: human thermal comfort

LST: land surface temperature

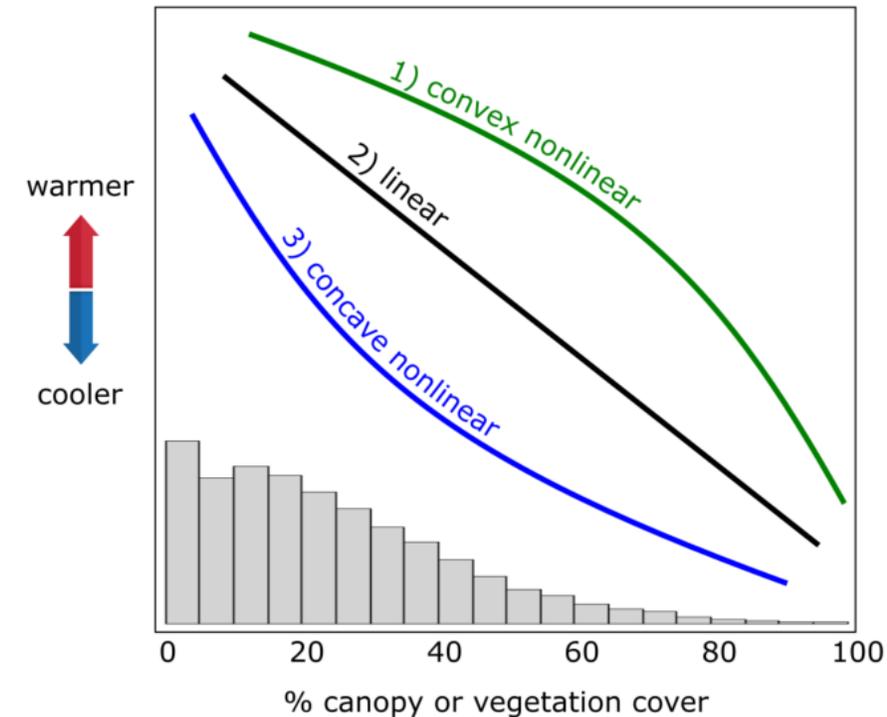


Synthesis

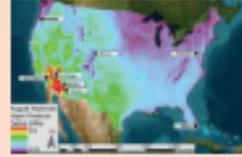
Individual tree-scale	
Consensus results Greater water availability increases air cooling	 Denser, broader crowns increase cooling
Key drivers of cooling: <ul style="list-style-type: none">• High leaf area index• Soil moisture availability• Short/wide crowns shade best but tall trees cool most overall	
Knowledge gaps: <ul style="list-style-type: none">• How much water is used to increase transpirational cooling• Species choice: native vs introduced; survival under future climate scenarios• What species shut down under heatwave conditions	

Synthesis

Individual tree-scale	Large patch & cityscape-scale
<p>Consensus results</p> <p>Greater water availability increases air cooling</p>  <p>Denser, broader crowns increase cooling</p>	<p>Consensus results</p> <p>Canopy area is more important than canopy configuration</p>  <p>Canopy has a convex relationship with air temperature</p>
<p>Key drivers of cooling:</p> <ul style="list-style-type: none"> • High leaf area index • Soil moisture availability • Short/wide crowns shade best but tall trees cool most overall 	<p>Key drivers of cooling:</p> <ul style="list-style-type: none"> • Citywide tree canopy amounts • Large tree patches cool more than small • Multiple layers of vegetation (e.g., tree over grass) enhances air cooling
<p>Knowledge gaps:</p> <ul style="list-style-type: none"> • How much water is used to increase transpirational cooling • Species choice: native vs introduced; survival under future climate scenarios • What species shut down under heatwave conditions 	<p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Cooling thresholds: how many trees does it take to cool? • How to direct cooling to hotter and more underserved neighborhoods • Do trees cool more or less in impervious dominated zones



Synthesis

Individual tree-scale	Large patch & cityscape-scale	Regional-scale
<p>Consensus results</p> <p>Greater water availability increases air cooling</p>  <p>Denser, broader crowns increase cooling</p>	<p>Consensus results</p> <p>Canopy area is more important than canopy configuration</p>  <p>Canopy has a convex relationship with air temperature</p>	<p>Consensus results</p> <p>Trees have stronger cooling magnitudes in hot, dry climates</p>  <p>Trees offer more cooling than grass alone</p>
<p>Key drivers of cooling:</p> <ul style="list-style-type: none"> • High leaf area index • Soil moisture availability • Short/wide crowns shade best but tall trees cool most overall 	<p>Key drivers of cooling:</p> <ul style="list-style-type: none"> • Citywide tree canopy amounts • Large tree patches cool more than small • Multiple layers of vegetation (e.g., tree over grass) enhances air cooling 	<p>Key drivers of cooling:</p> <ul style="list-style-type: none"> • Climate (background temperature and humidity) moderate tree cooling efficiency • Maritime effects in coastal cities overall dampen tree cooling efficiency
<p>Knowledge gaps:</p> <ul style="list-style-type: none"> • How much water is used to increase transpirational cooling • Species choice: native vs introduced; survival under future climate scenarios • What species shut down under heatwave conditions 	<p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Cooling thresholds: how many trees does it take to cool? • How to direct cooling to hotter and more underserved neighborhoods • Do trees cool more or less in impervious dominated zones 	<p>Knowledge gaps:</p> <ul style="list-style-type: none"> • Lack of consistent data for land cover and tree demography (tree species, function type, and sizes) • Converting multi-city or global findings to local planting plans

The paper

Alonzo, M., Ibsen, P. C., & Locke, D. H. (2025). Urban Trees and Cooling: A Review of the Recent Literature (2018 to 2024). *Arboriculture & Urban Forestry*, jauf.2025.023. <https://doi.org/10.48044/jauf.2025.023>

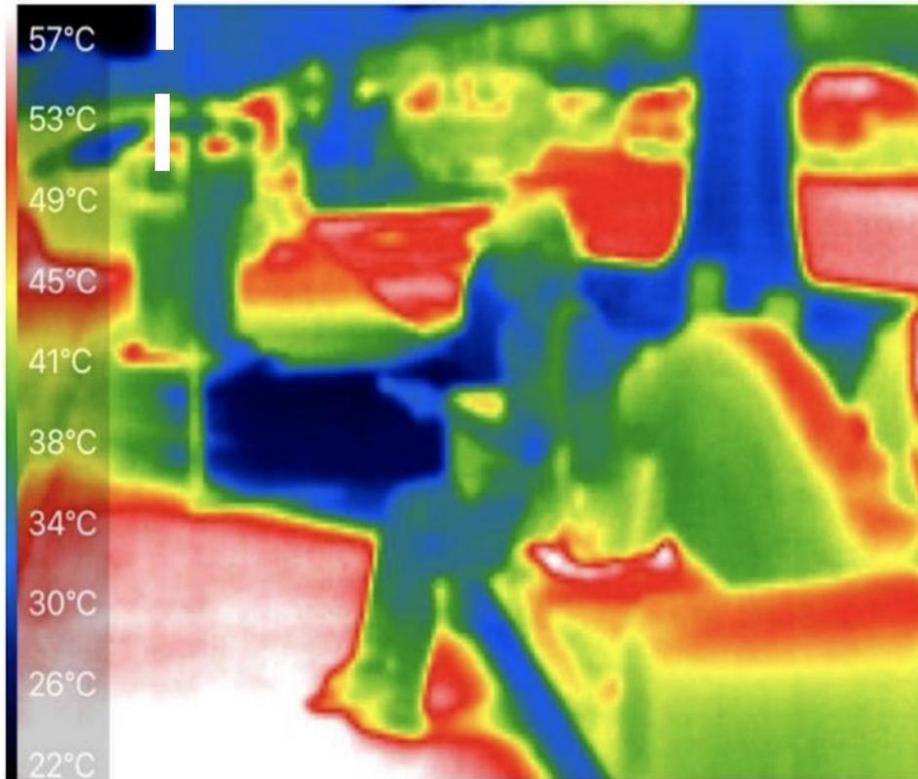
Alonzo, M., & Ibsen, P. C. (2025). Urban Trees and Cooling. *Arborist News, October*.



AMERICAN UNIVERSITY
WASHINGTON, DC



The human context



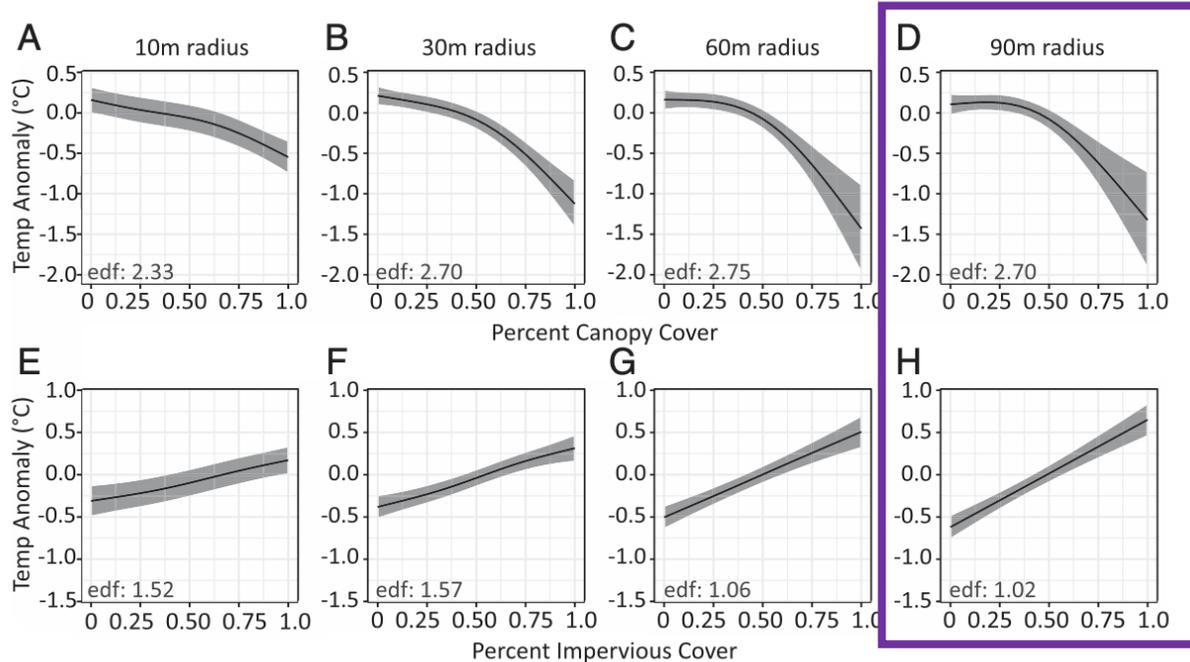
Credit: UCLA Environmental Science Practicum 2016-2017

“Improving Microclimates in Los Angeles’ Heat-Vulnerable Communities”

Advisor: Dr. Aradhna Tripathi

Team Members: Nathan Fan, Stacey Li, Ingrid Maradiga, Apsara Perera, Jonathan Tedjakusnadiand, Jiahui Wang

Prior work



Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences*, 116(15), 7575–7580. <https://doi.org/10.1073/pnas.1817561116>

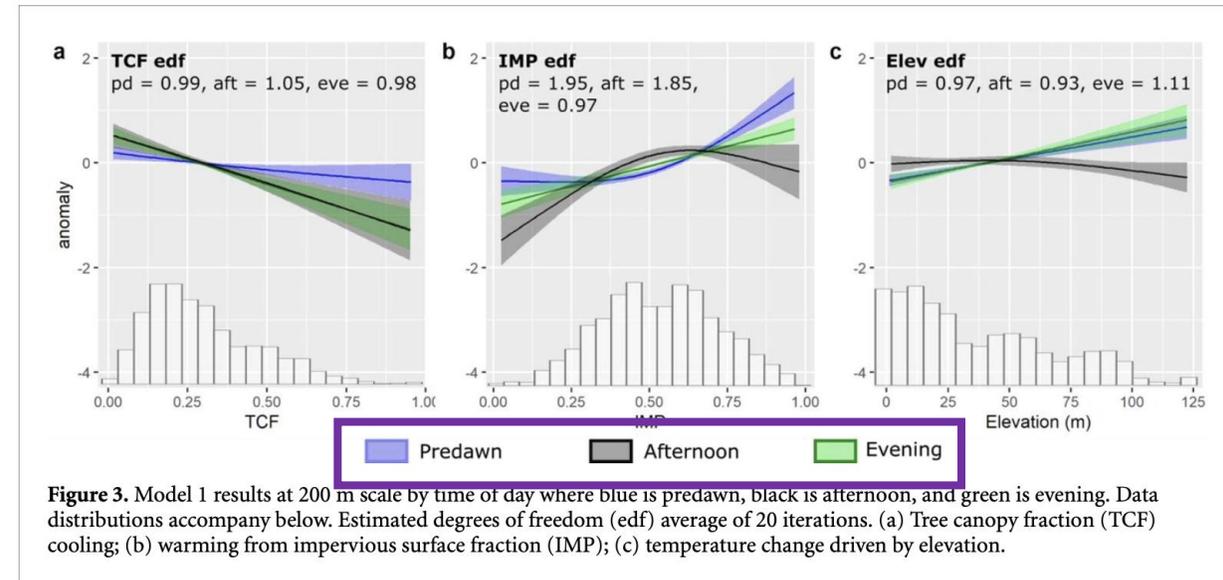
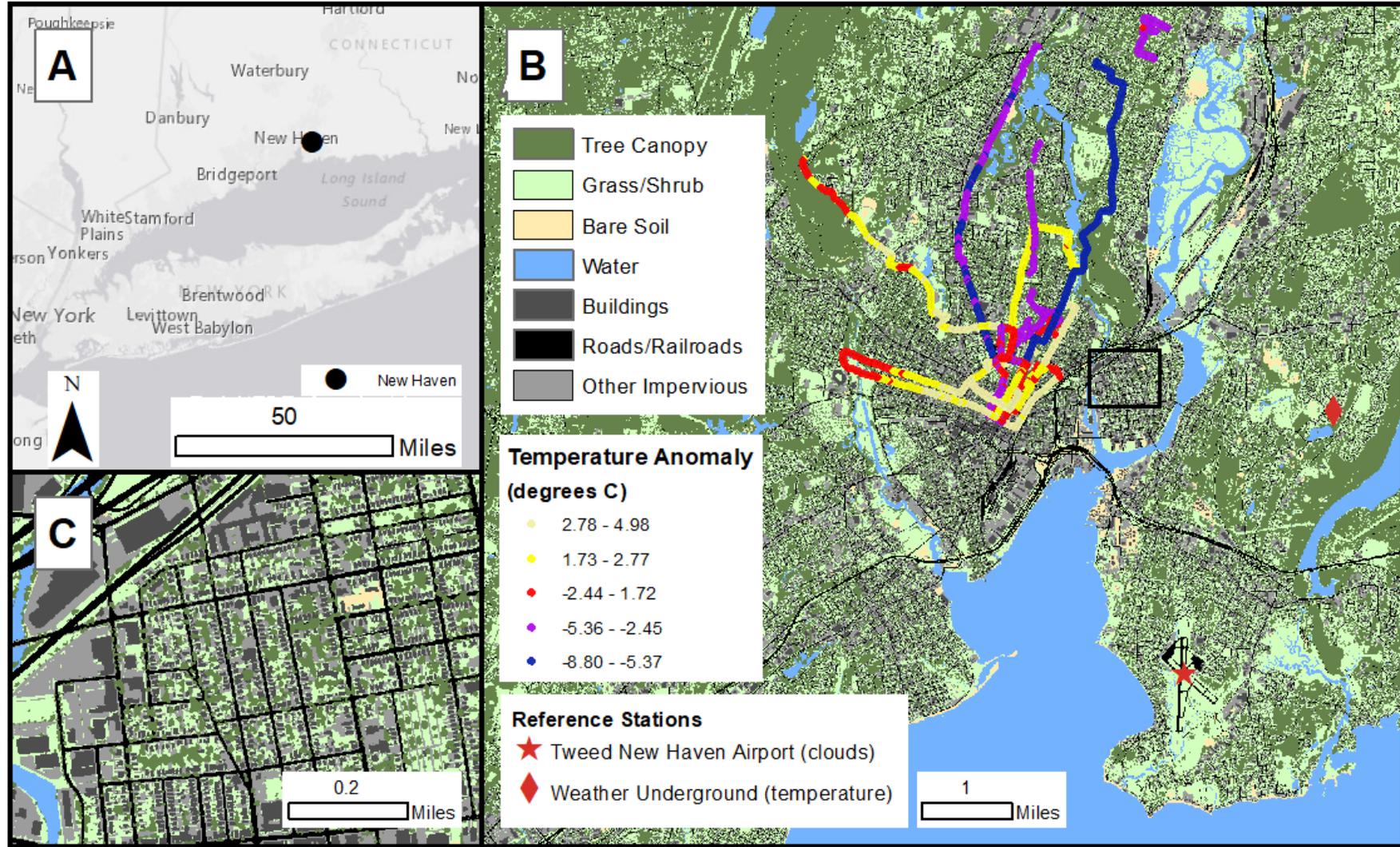


Figure 3. Model 1 results at 200 m scale by time of day where blue is predawn, black is afternoon, and green is evening. Data distributions accompany below. Estimated degrees of freedom (edf) average of 20 iterations. (a) Tree canopy fraction (TCF) cooling; (b) warming from impervious surface fraction (IMP); (c) temperature change driven by elevation.

Alonzo, M., Baker, M. E., Gao, Y., & Shandas, V. (2021). Spatial configuration and time of day impact the magnitude of urban tree canopy cooling. *Environmental Research Letters*, 16(8), 84028. <https://doi.org/10.1088/1748-9326/ac12f2>

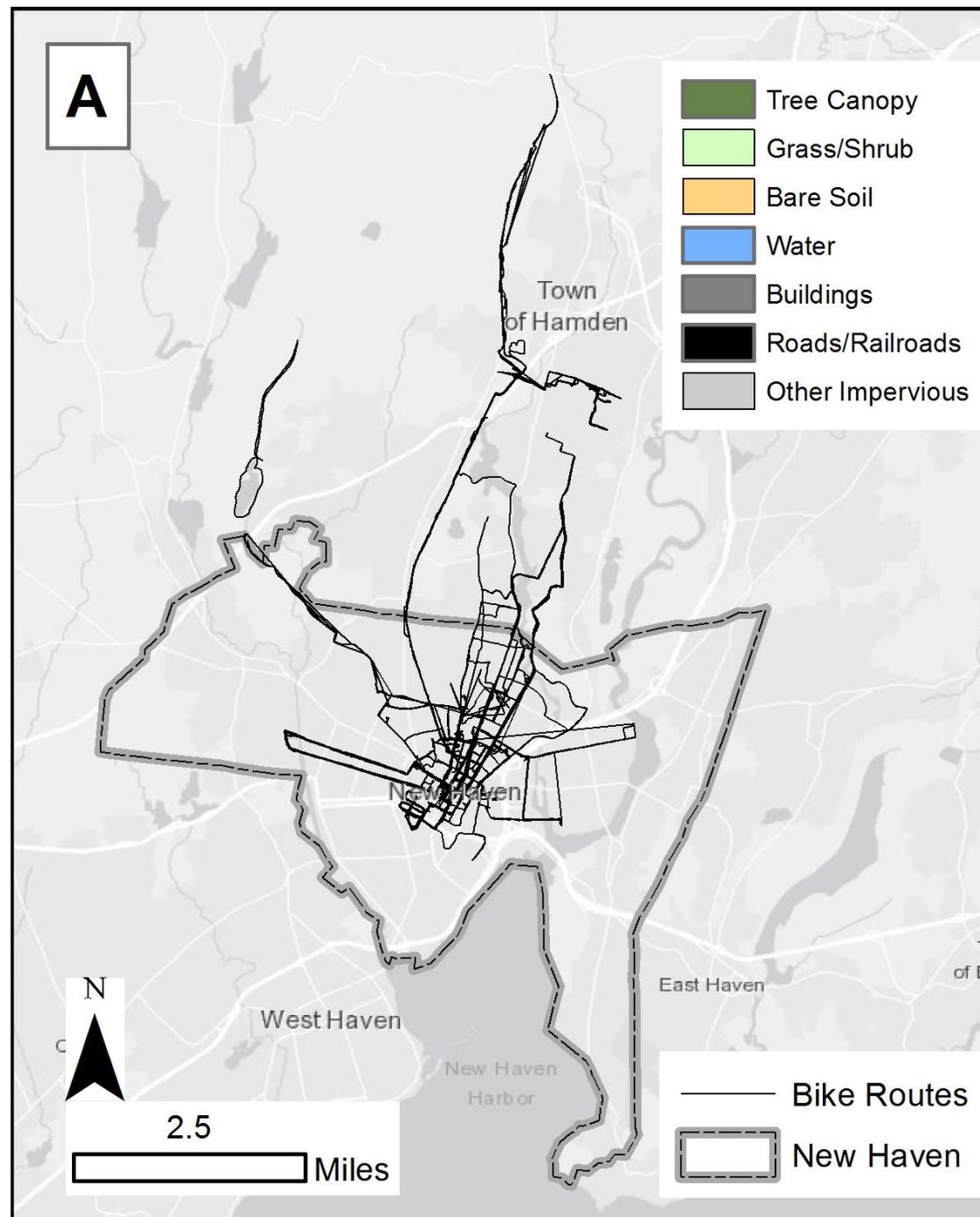
Study Area:

- New Haven, CT
- June 15 – September 15
- 2019, 2020, 2021
- 156 total rides
 - Duration Range 1 – 86 mins
 - Mean duration = 32 mins
 - Median duration = 32 mins
 - IQR: 19.11 mins
- 201,879 observations



Study Area:

- New Haven, CT
- June 15 – September 15
- 2019, 2020, 2021
- 156 total rides
 - Duration Range 1 – 86 mins
 - Mean duration = 32 mins
 - Median duration = 32 mins
 - IQR: 19.11 mins
- 201,879 observations



How does the relationship between air temperature and land cover change within a day?

...when controlling for clouds, elevation, wind speed and direction..

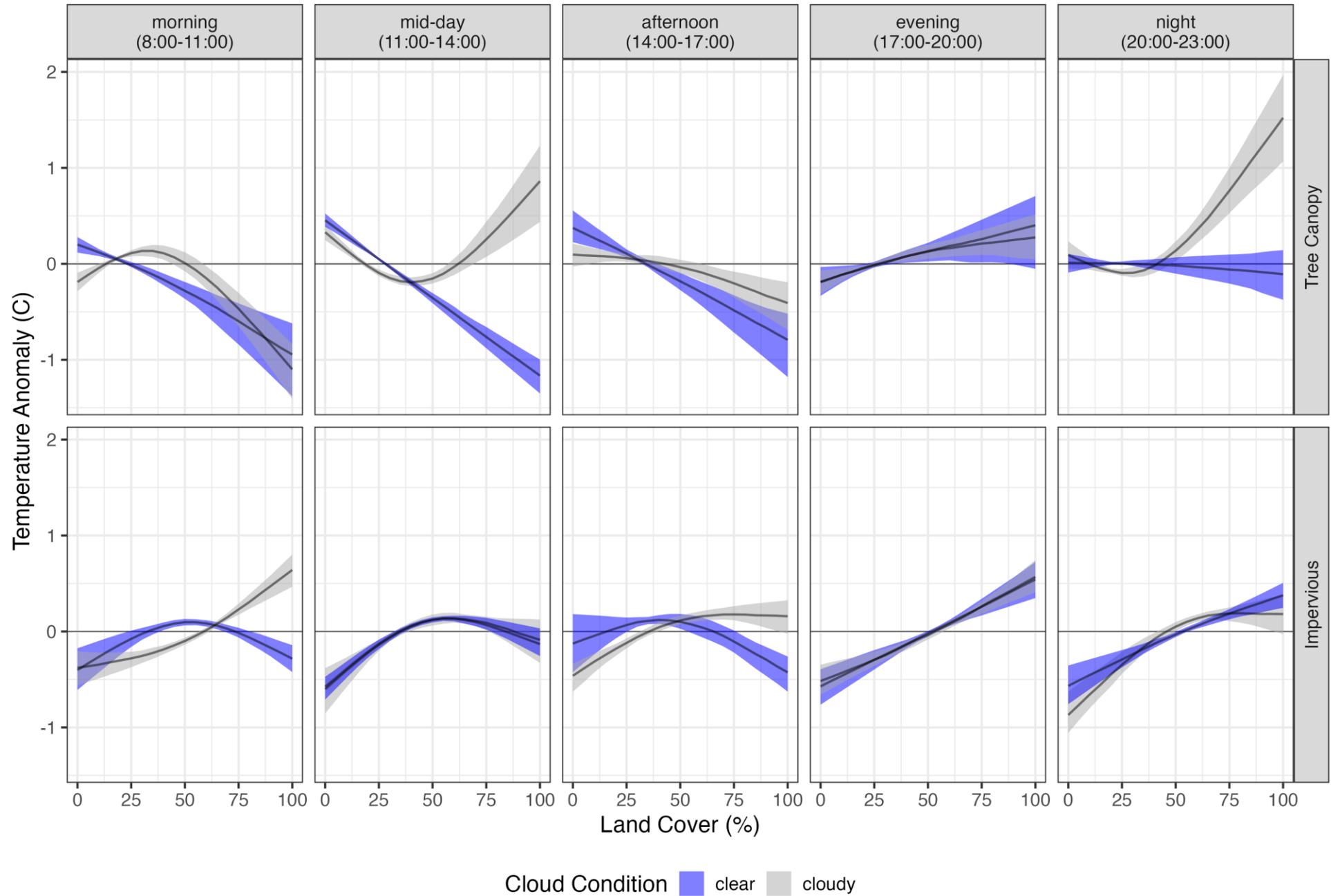
temperatureAnomaly =
clouds +
s(treeCanopyCover, by = clouds) +
s(imperviousSurface, by = clouds) +
s(elevation) +
s(windSpeed, by = windDirection) +
s(lon, lat) +
ride

1. Time of day (5)
 - Morning (2% 500x)
 - Mid-day
 - Afternoon
 - Evening
 - Night
2. Each buffer distance (4x)
 - 10m
 - 30m
 - 60m
 - **90m**
3. = 10,000 model fits

Results

Predicted temperature anomaly:

90 meter buffer



Paper

Locke, D. H., Baker, M., Alonzo, M., Yang, Y., Ziter, C. D., Murphy-Dunning, C., & O'Neil-Dunne, J. P. M. (2024). Variation in the relationship between urban tree canopy and air temperature reduction under a range of daily weather conditions. *Heliyon*, 10(3), e25041. <https://doi.org/10.1016/j.heliyon.2024.e25041> [LINK]

Data/code

<https://doi.org/10.2737/RDS-2024-0012>

Press

<https://www.fs.usda.gov/research/nrs/projects/urban-trees-and-air-temp>



Yale SCHOOL OF THE ENVIRONMENT
Hixon Center for Urban Sustainability



What's next?

More bikes!

- Baltimore
 - Baltimore Green Space
 - Johns Hopkins University
 - Bike Party?



Trees are Cool!

Dexter H. Locke

Chesapeake Bay Program, Forestry Working Group

March 4, 2026

USDA Forest Service, Northern Research Station, Baltimore Field Station

dexter.locke@usda.gov

<http://dexterlocke.com/>



Questions? Thank you!

Dexter H. Locke

Chesapeake Bay Program, Forestry Working Group

March 4, 2026

USDA Forest Service, Northern Research Station, Baltimore Field Station

dexter.locke@usda.gov

<http://dexterlocke.com/>