Using ECOSTRESS to explore diurnal evolution of city-scale tree temperature

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Why do we need to study urban tree temperature?

Urban settings:

- **enhanced** longwave and/or shortwave radiation (Oke 1989,Chow 2012,Wang 2014)
- **limited** water availability and **poor** soil conditions (Bassuk 1988,Nowak 2004)

⇒ **negatively** impacts tree's functionality

Tree canopy temperature, as a resultant of **surface energy balance** between leaves and ambient environment

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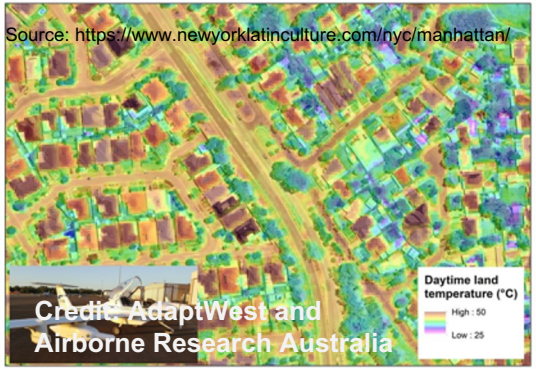
Micro-climate influences of trees and their **health** conditions

Knowledge gaps



The picture was taken on February 9 2017 at the peak of a three-day **40°C** heatwave.

- Local-scale studies of tree temperature (Meier et al 2012, Leuzinger et al 2010)
- **Diurnal** evolutions of tree temperature in **urban areas** largely unstudied
- It is unclear how other **environmental factors** influence on tree temperature at city-wide scale

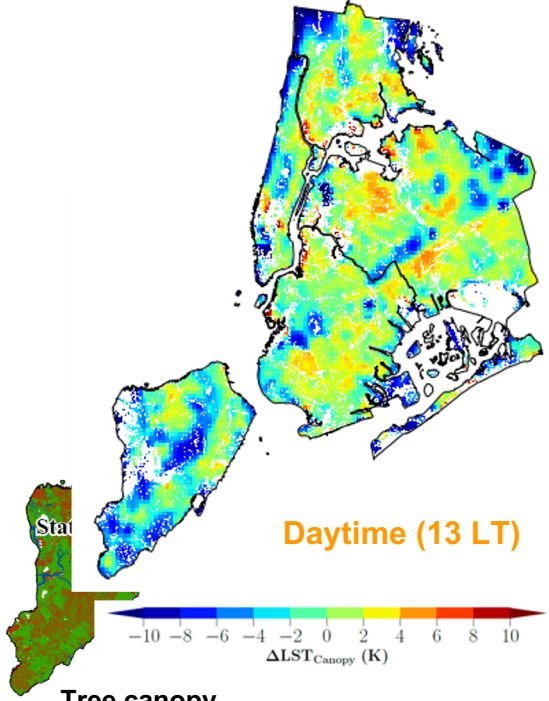
Research questions

1. How does **city-wide** tree canopy temperature vary **diurnally**?

2. What **environmental factors** and to what extent contribute to its spatiotemporal variation?

Study area and methodology

- 12 clear-sky **ECOSTRESS** imaginary:
  - Time: June-October (2018 - 2020) (chosen representative for each time of the day)
  - Spatial resolution: ~70 m



- Downscaled urban element LST approach:

$$\varepsilon_{(i,j)} LST^4_{(i,j)} = \sum_{k=1}^{8} \varepsilon_{k(i,j)} * f_{k(i,j)} * LST^4_{k(i,j)} + r_{(i,j)} \quad (1)$$

where ε_k is the emissivity of the urban element k; f_k is the areal fraction of the urban element k in a given pixel; LST_k is the LST of corresponding urban element k in a given pixel; and r is the residuals.

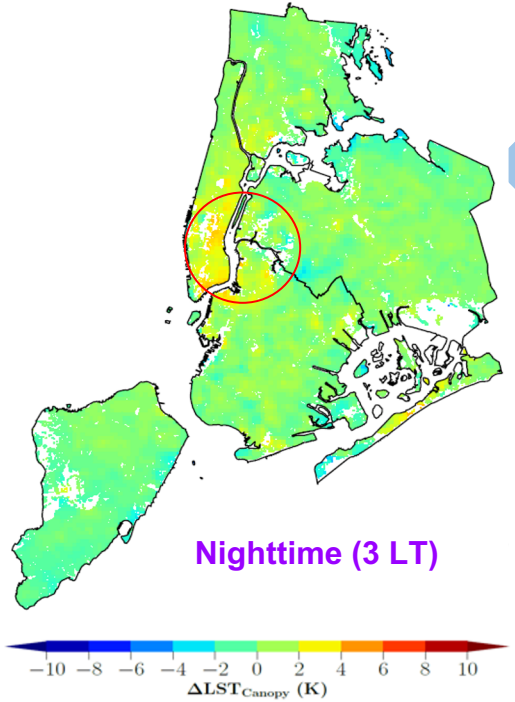
Tree canopy
Grass
Water
Bare soil
Building/roof
Road
Railway
Other impervious

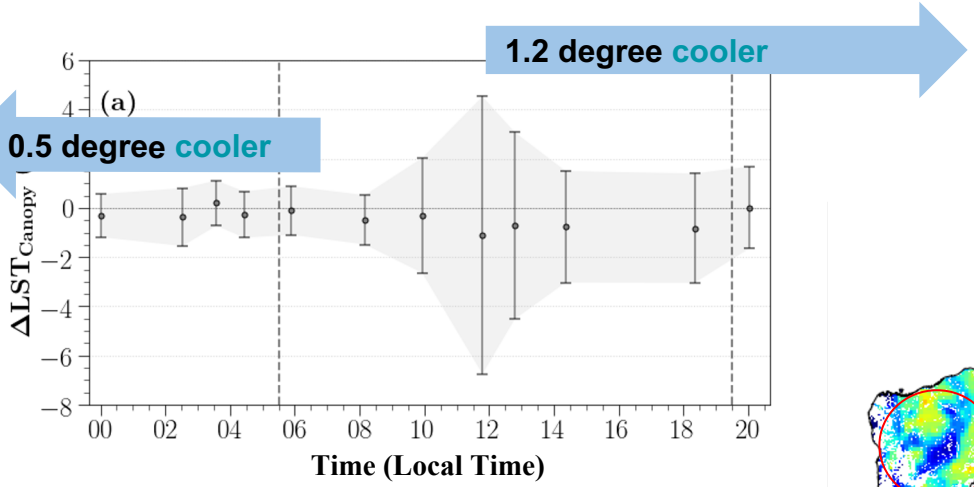
- **GAMs** (Generalized additive models): statistically investigated joint influences of environmental factors (greenspaces, bluespaces, and building height) on tree temperature

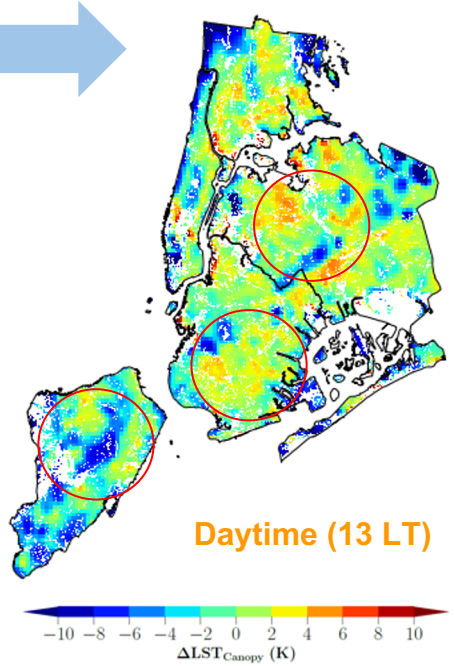
Diurnal evolution of canopy temperature

Spatial Anomaly of Tree Canopy Temperature

$$\Delta LST_{Canopy}(i,j) = \overbrace{LST_{Canopy}(i,j)}^{\text{Tree LST}} - \overbrace{\overline{LST_{ECOSTRESS}}}^{\text{Domain mean}}$$

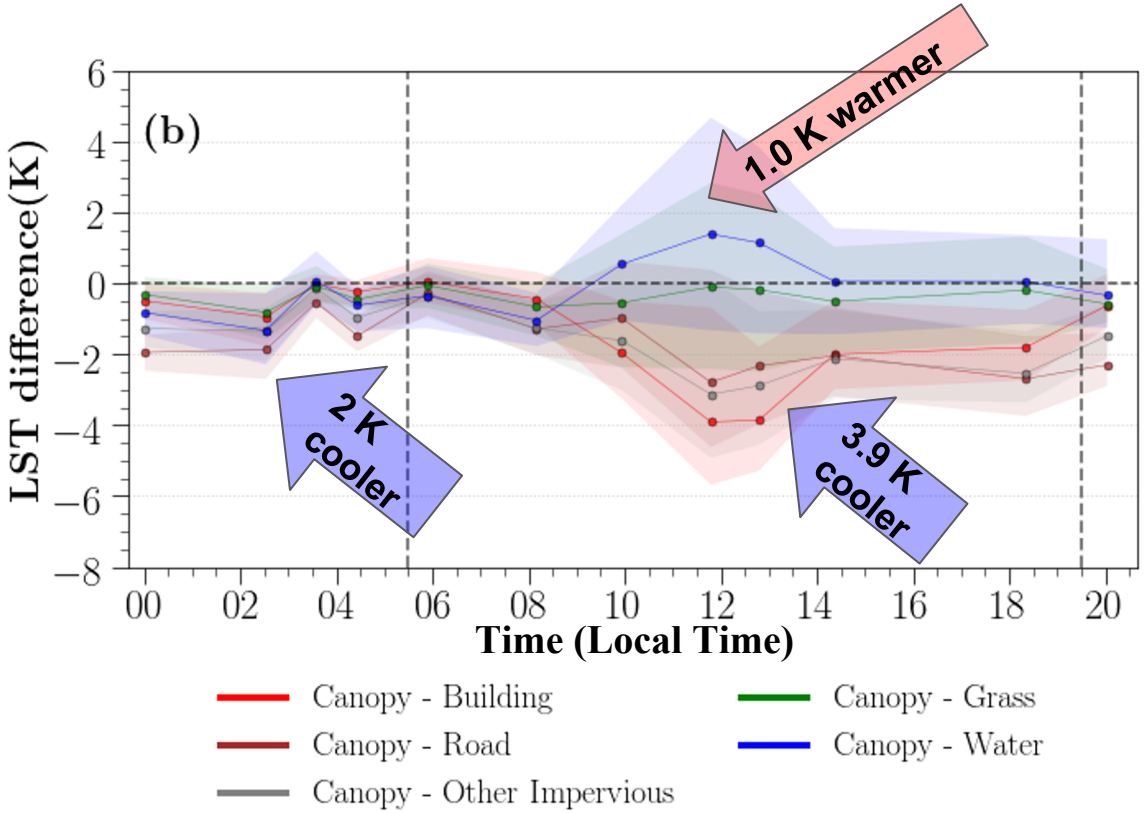




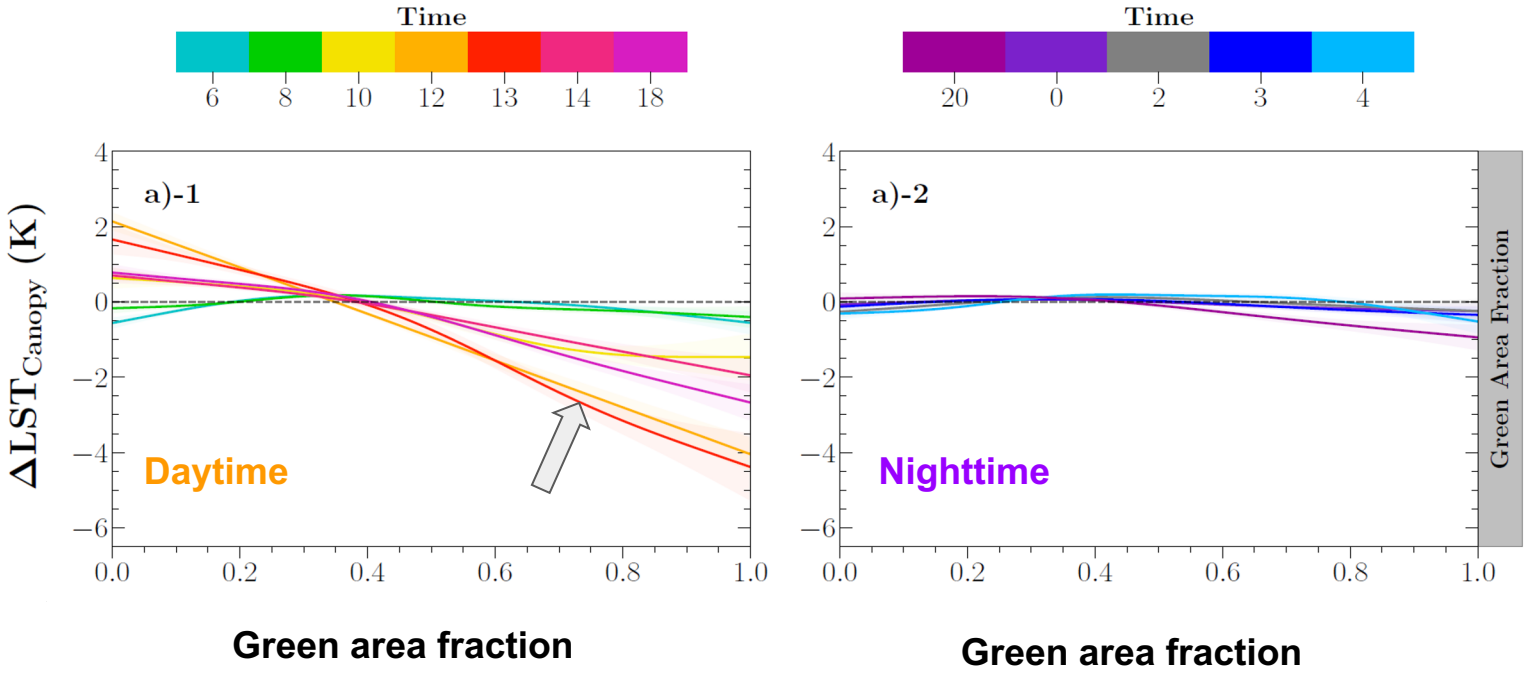


Tree temperature compared to other urban element temperatures

- Trees are consistently **cooler** than ambient urban elements
- The **human-made** surfaces (building, road and other impervious areas) has the **largest contrast** to trees
- Daytime contrast is higher than nighttime

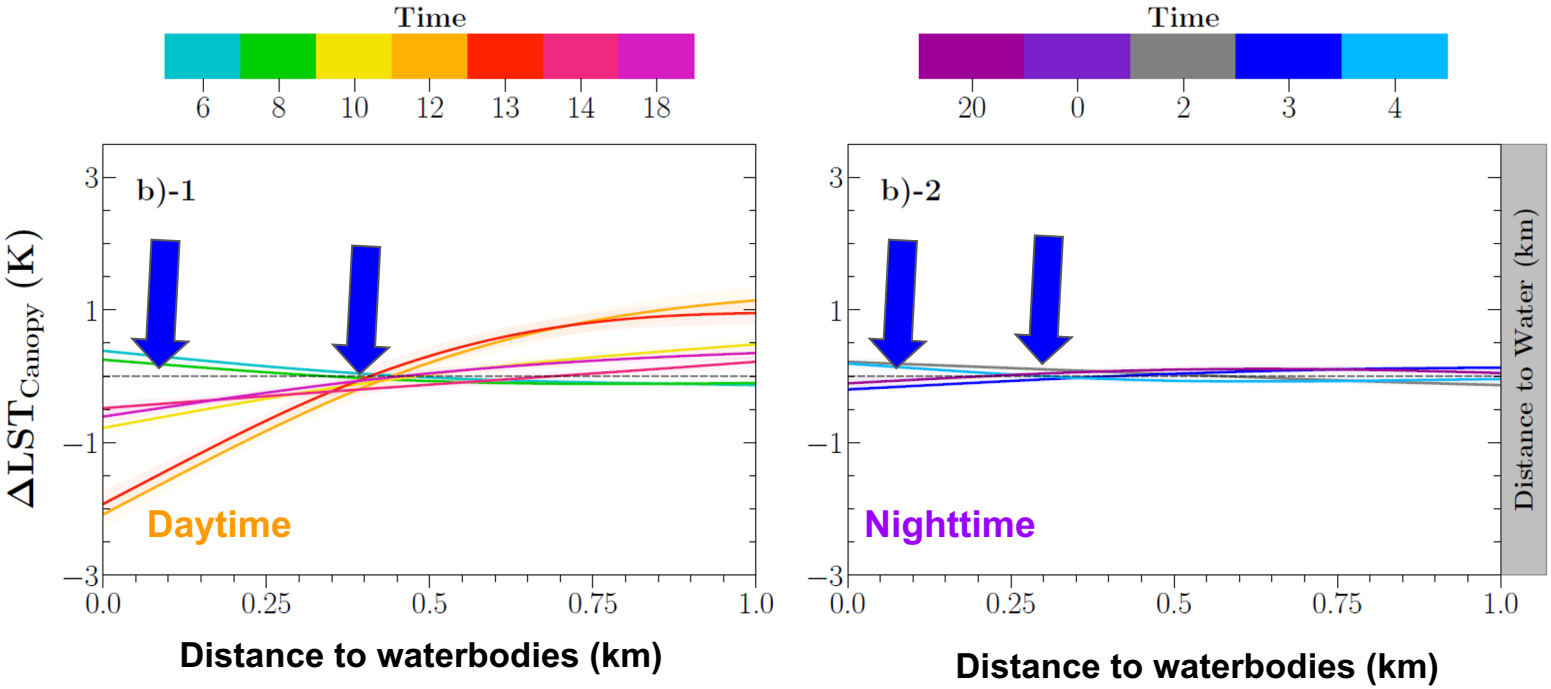


Influences of greenspace coverage (green area fraction)



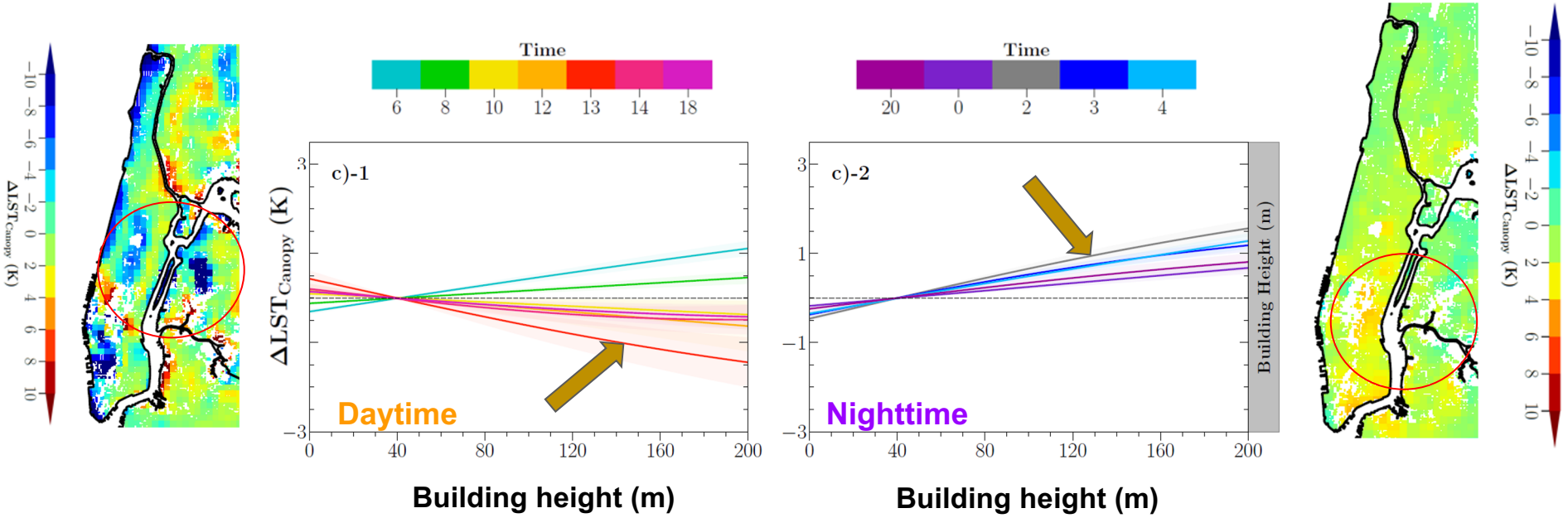
- **Greater** greenspaces, **cooler** tree temperatures
- **Hotter** environment ⇒ **stronger** cooling effect

Influences of bluespaces (distance to water bodies)



- **Linear** daytime cooling extends up to about 0.5 km from the shore diurnally
- **Weak linear** early morning and nocturnal warming signals

Influences of morphology (building height)



- Extensive **daytime cooling** caused by shadows from tall buildings
- Persistent **nighttime warming** due to small sky view factor within deep street canyons

Take home messages

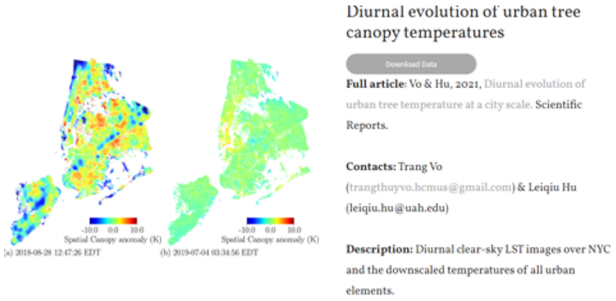
1. Daytime spatial variation of tree temperature is **5 times greater** than nocturnal variation.
2. **Greenspace** and **Bluespaces** contribute to daytime cooling effects

   Building height contributes to daytime cooling and nighttime warming effects

1. Identifications of hot and cold spots of tree temperature across cities ⇒ appropriate strategic care

Hu's Urban Remote Sensing Lab:

https://huleiqiu.wordpress.com/data-2/



T. T. Vo and L. Hu, “Diurnal evolution of urban tree temperature at a city scale,” Sci. Rep., vol. 11, no. 1, p. 10491, Dec. 2021

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