



Oct 14: Urban Heat Islands (UHI)

Foci of the Day

- Causes and consequences of UHI effects
- Major methods for quantifying UHI
- Strategies to reduce UHI effects

Reading: What Are Heat Islands? (<https://www.epa.gov/heatislands/what-are-heat-islands>)

Reference: Oke, T.R. (1973). City size and the urban heat island. *Atmospheric Environment*, 7(8), 769–779.



Urban Heat Islands (UHI)

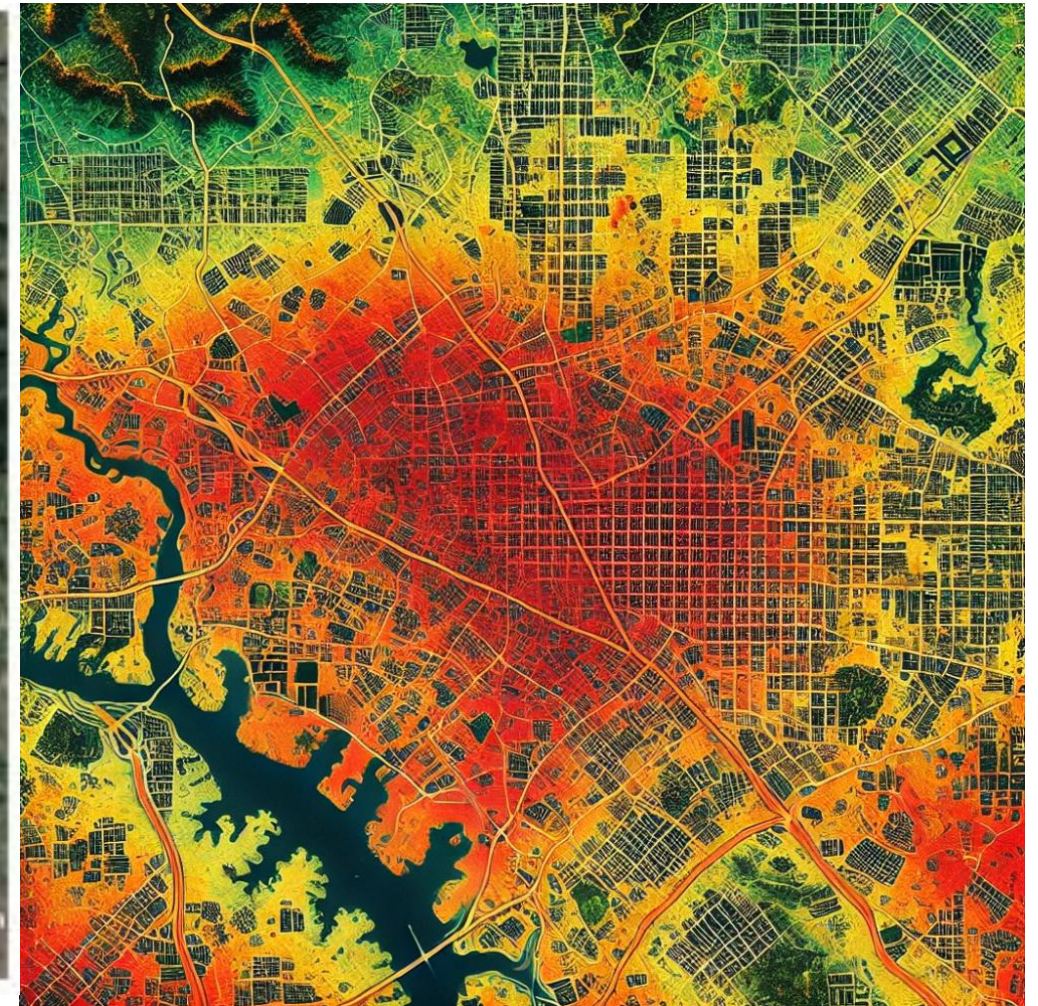
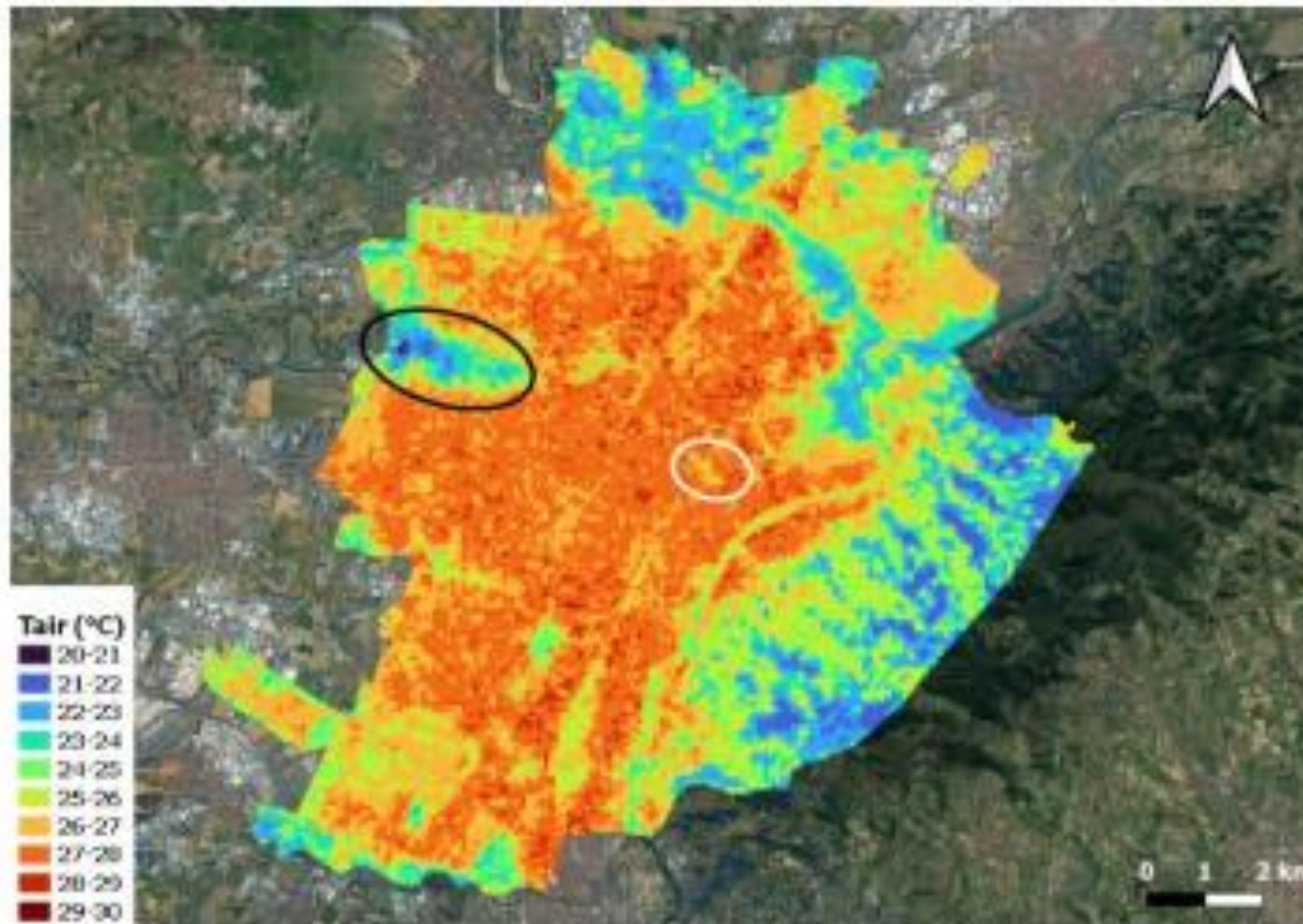
- The UHI effect is defined as a difference in temperature between the built environment and the natural (surrounding) environment.
- The UHI intensity can be measured by one of two closely coupled temperatures: (a) the **urban skin temperature** (pavements and buildings) or (b) the meteorological UHI (**air temperature**)



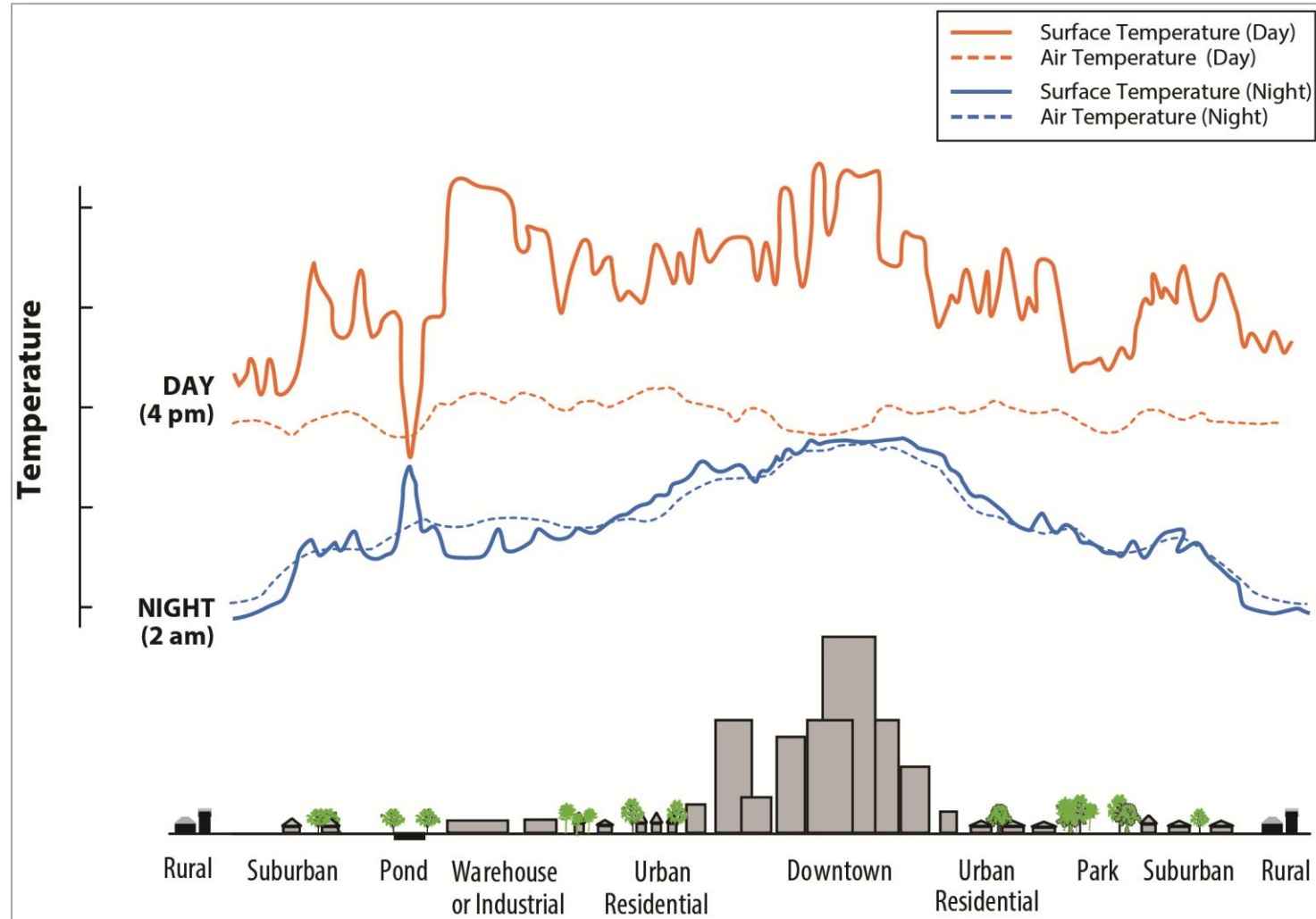
Urban Heat Islands (UHI)

Air temperature prediction in Turin for 7/10/2022

A GIS-generated heat map showing temperature variations across an urban area



Surface temperatures vary more than atmospheric air temperatures during the day, but they are generally similar at night. The dips and spikes in surface temperatures over the pond area show how water maintains a nearly constant temperature day and night because it does not absorb the sun's energy the same way as buildings and paved surfaces. Parks, open land, and bodies of water can create cooler areas within a city. Temperatures are typically lower at suburban-rural borders than in downtown areas.





Mileage stones

Howard, Luke (1833). *The Climate of London.* Harvey and Darton, London.

- First to systematically document how temperatures in London were higher than in surrounding rural areas.
- Concept of “urban climate” -- first quantitative evidence of URI.

AVERAGE MONTHLY MEAN TEMPERATURES, FROM 1817 TO 1823.

The Results obtained from a twenty years' series of these were made the basis, in the early part of this article, of a comparison between the London and country temperatures, which was illustrated by a set of Curves. It is proper that I should exhibit a continuation of these to the extent at which it can at present be done satisfactorily; which, for reasons already given, is only to the year 1823 inclusive. The following are the Averages in question.

	Month	In the Country	In London	Difference
1	Jan.	36.39	39.10	2.71
2	Feb.	38.38	41.31	2.93
3	Mar.	42.39	44.81	2.42
4	April	47.42	49.94	2.52
5	May	53.77	56.16	2.39
6	June	59.97	62.13	2.16
7	July	62.45	63.95	1.50
8	Aug.	62.21	64.07	1.86
9	Sept.	57.35	59.77	2.42
10	Oct.	49.01	52.04	3.03
11	Nov.	44.55	47.46	2.91
12	Dec.	37.22	40.61	3.39
	Mean	49.26	51.78	2.52

Mileage stones

Oke, T.R. (1973). City size and the urban heat island. *Atmospheric Environment*, 7(8), 769–779.

- Relationship between city size and UHI intensity in Canada, North America and Europe

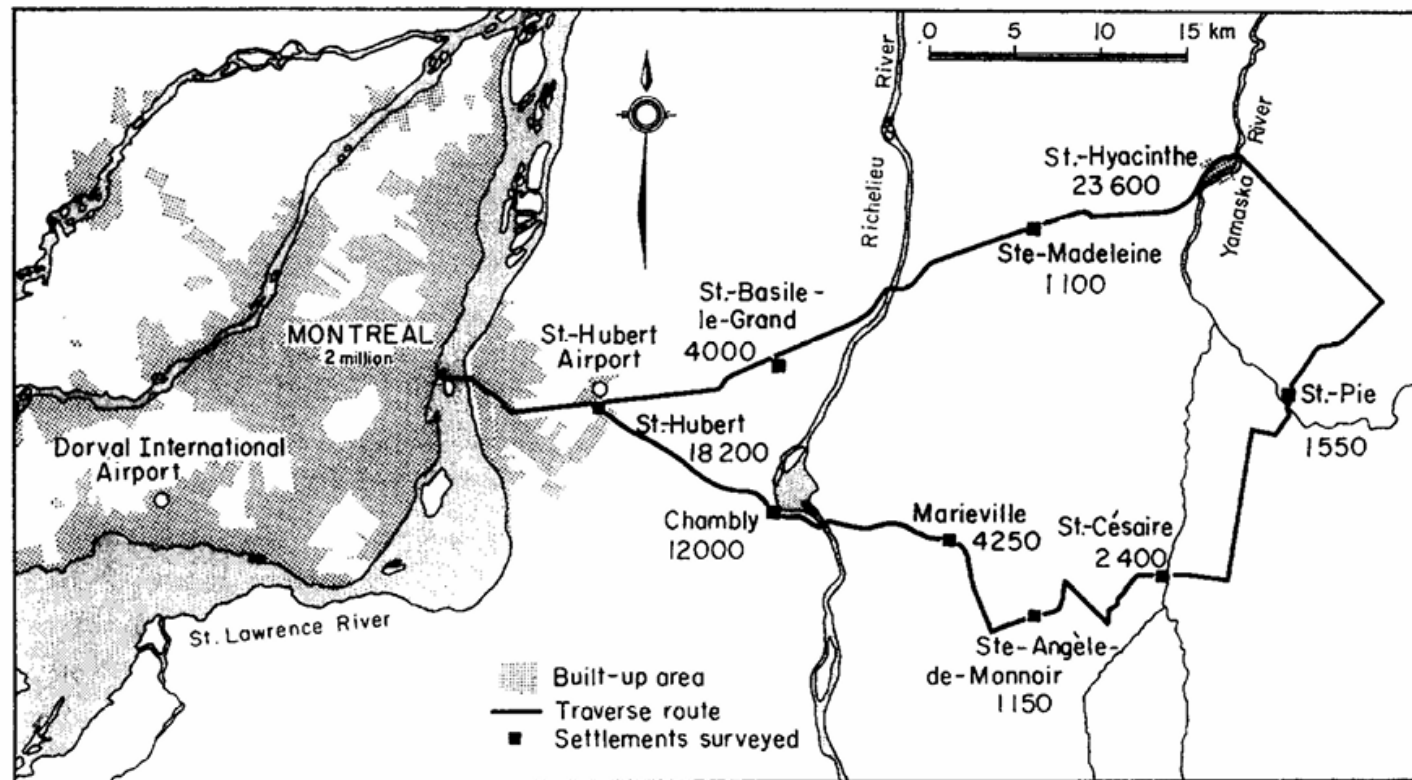


FIG. 1. Traverse route in the St. Lawrence Lowland, Quebec.

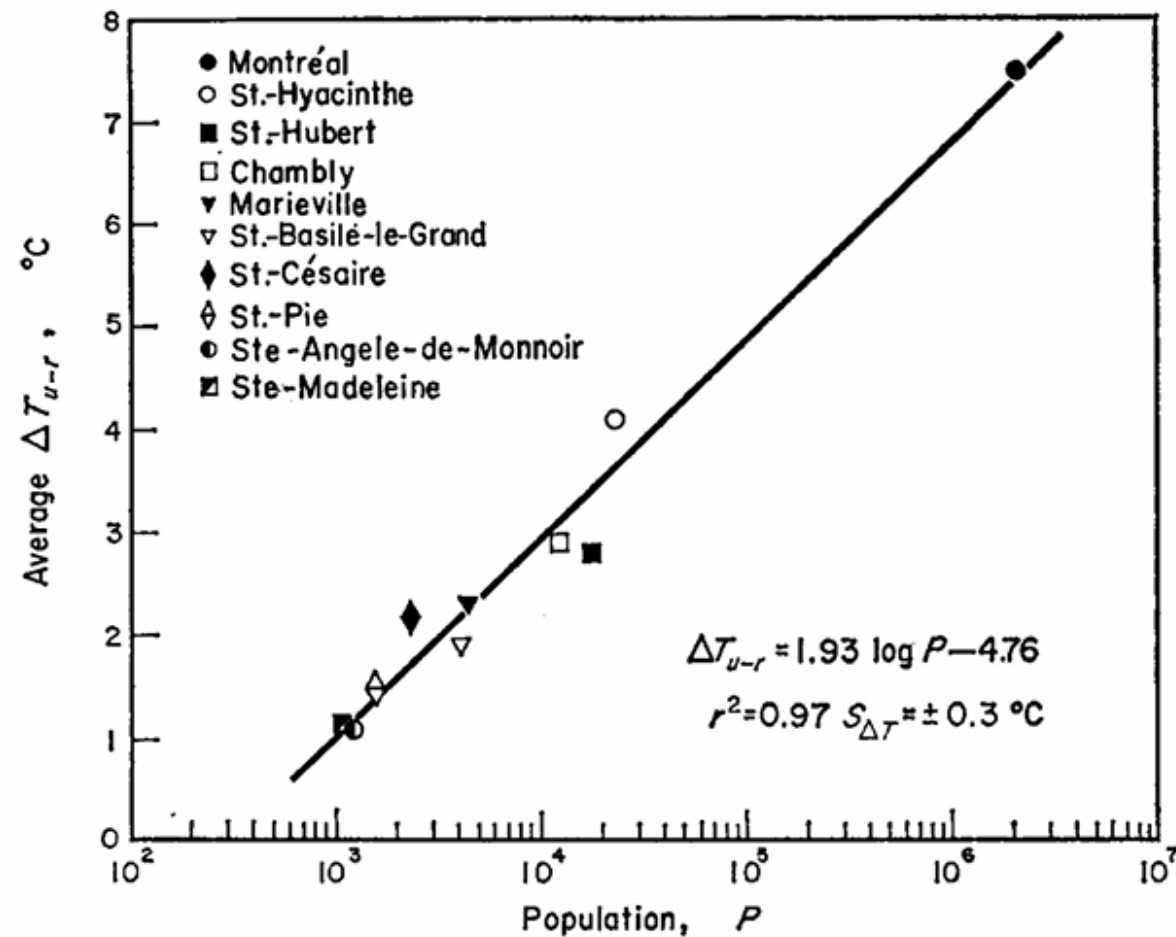


FIG. 2. Relation between the average survey ΔT_{u-r} , and city size (as given by P), for 10 settlements on the St. Lawrence Lowland. (Average windspeed 2.3 m s^{-1} and clear skies.)

Oke, T.R. (1973). City size and the urban heat island. *Atmospheric Environment*, 7(8), 769–779.

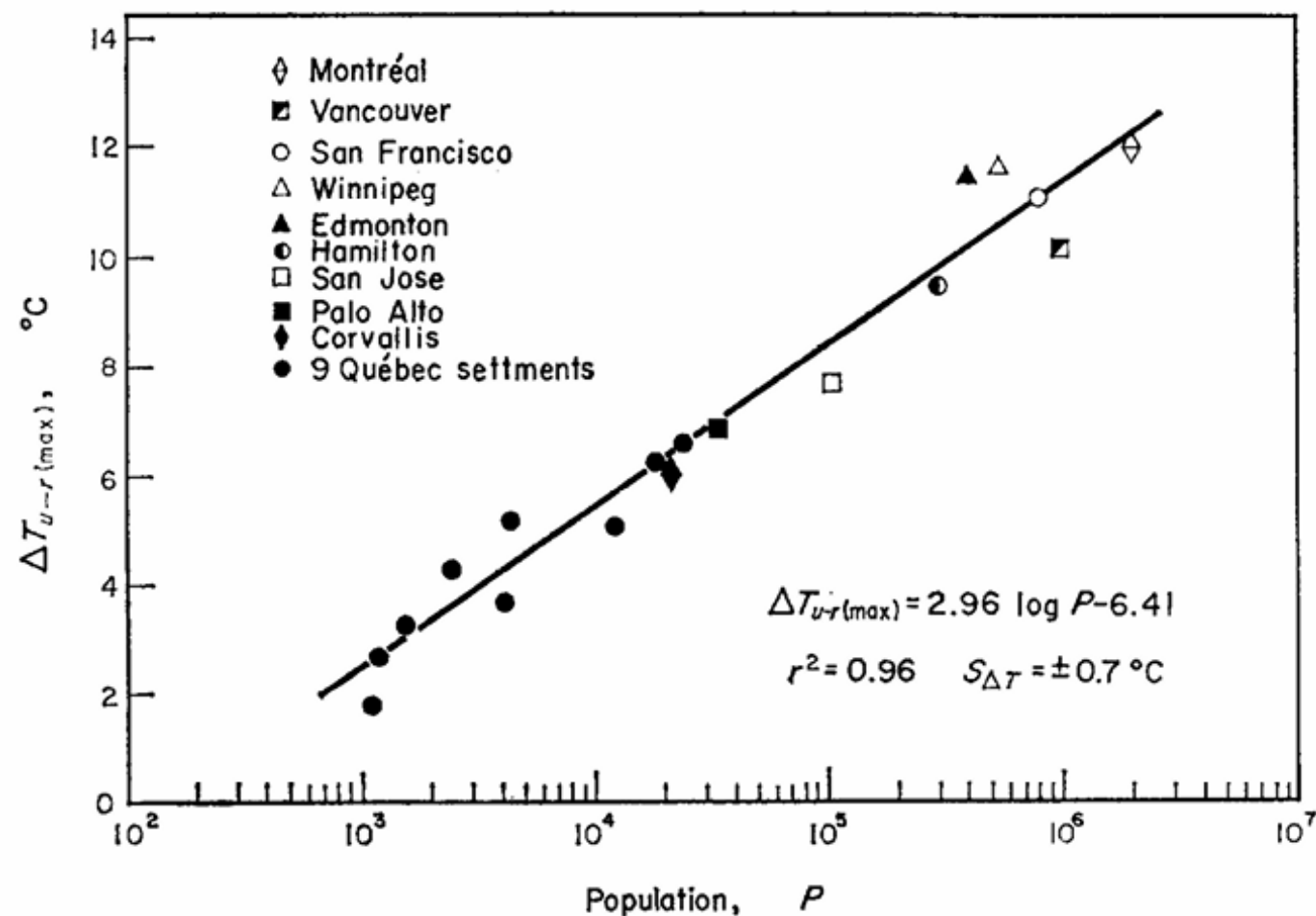


FIG. 4. Relation between $\Delta T_{u-r(max)}$ and $\log P$ for North American settlements (Source: TABLES 1 and 2).

Oke, T.R. (1973). City size and the urban heat island. *Atmospheric Environment*, 7(8), 769–779.

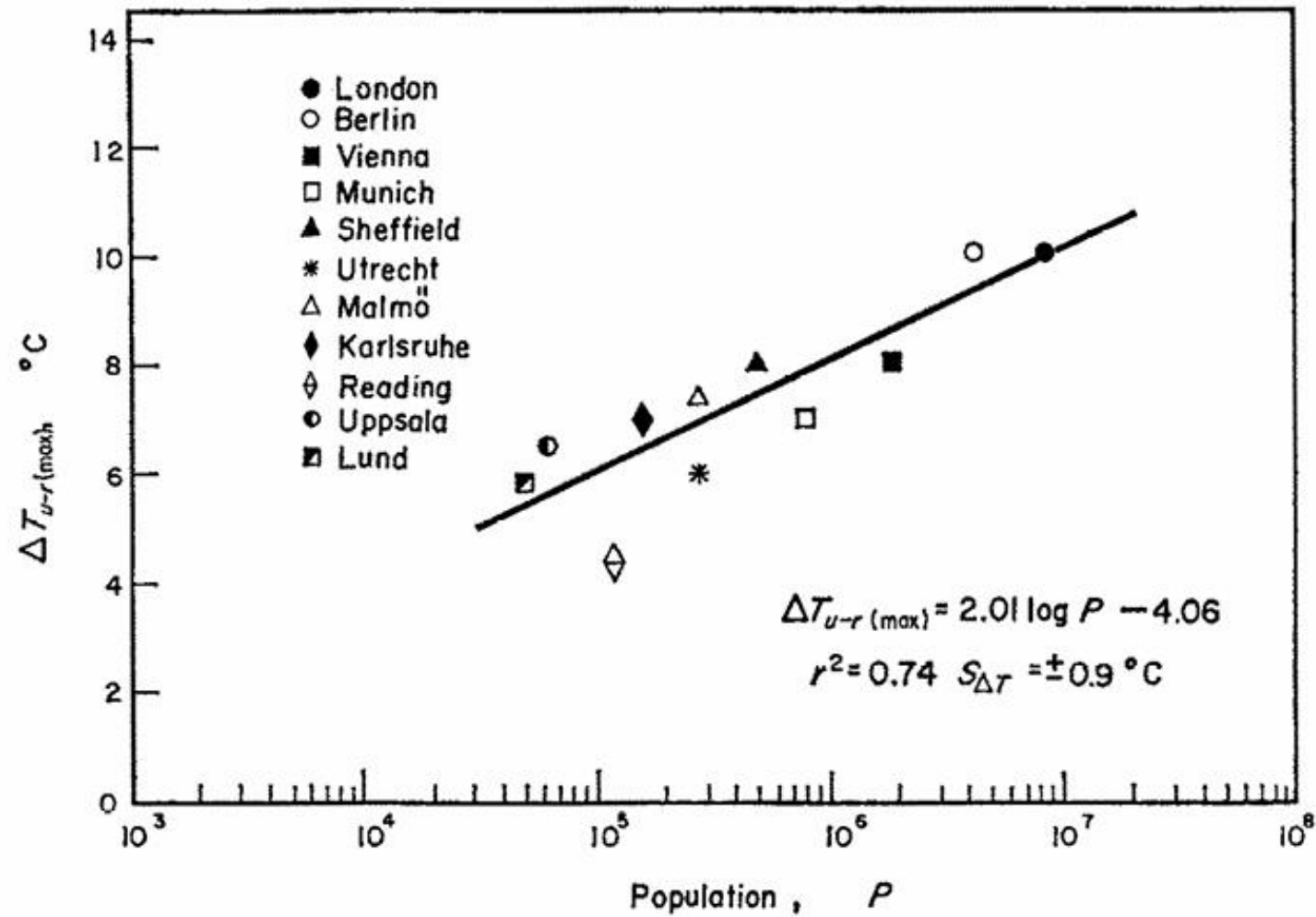


FIG. 5. Relation between $\Delta T_{u-r(max)}$ and $\log P$ for European settlements (Source: TABLE 2).

Oke, T.R. (1973). City size and the urban heat island. *Atmospheric Environment*, 7(8), 769–779.

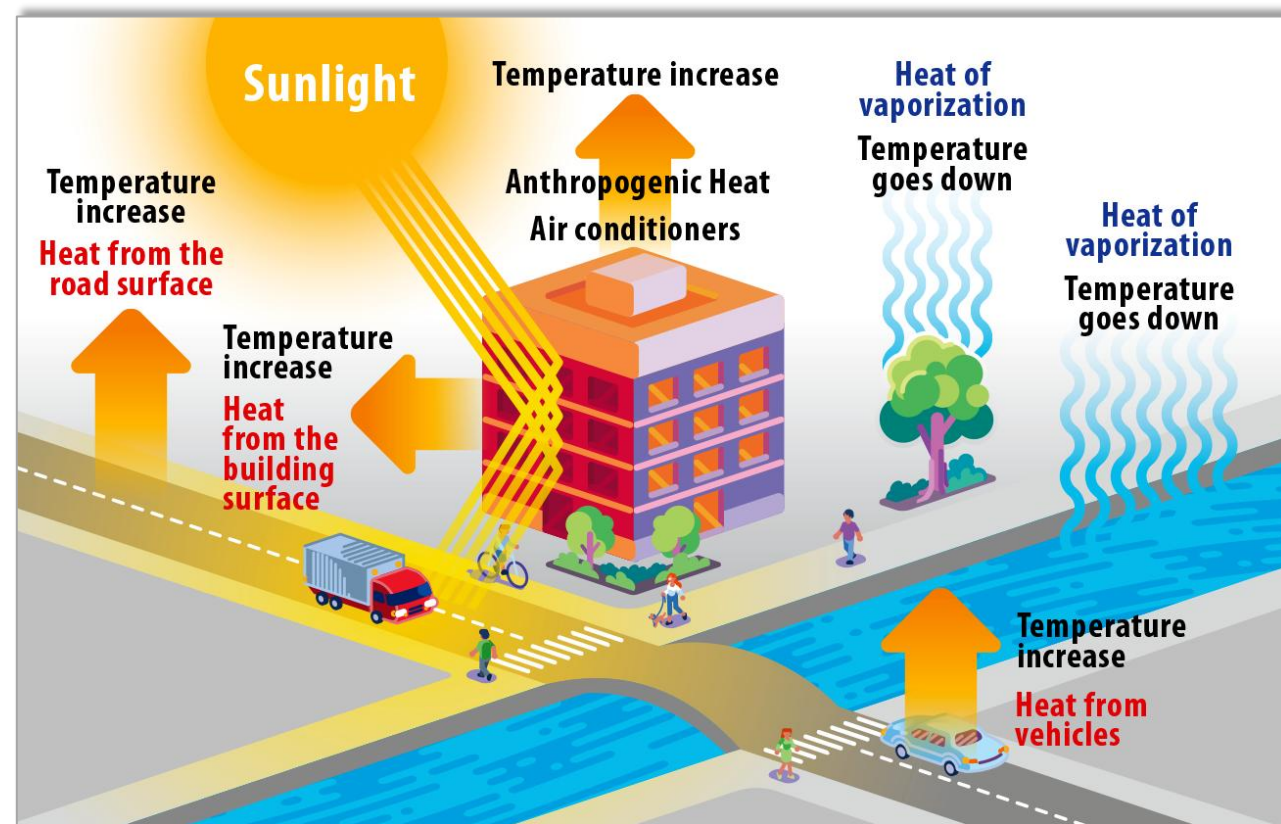


Causes of Heat Islands

(<https://www.epa.gov/heatislands/what-are-heat-islands>)

- 1) Reduced Natural Landscapes in Urban Areas.
- 2) Urban Material Properties.
- 3) Urban Geometry.
- 4) Heat Generated from Human Activities.
- 5) Weather and Geography.

Factors Contributing to UHI Effect



<https://www.pavetechinc.com/uhi-mitigation/>

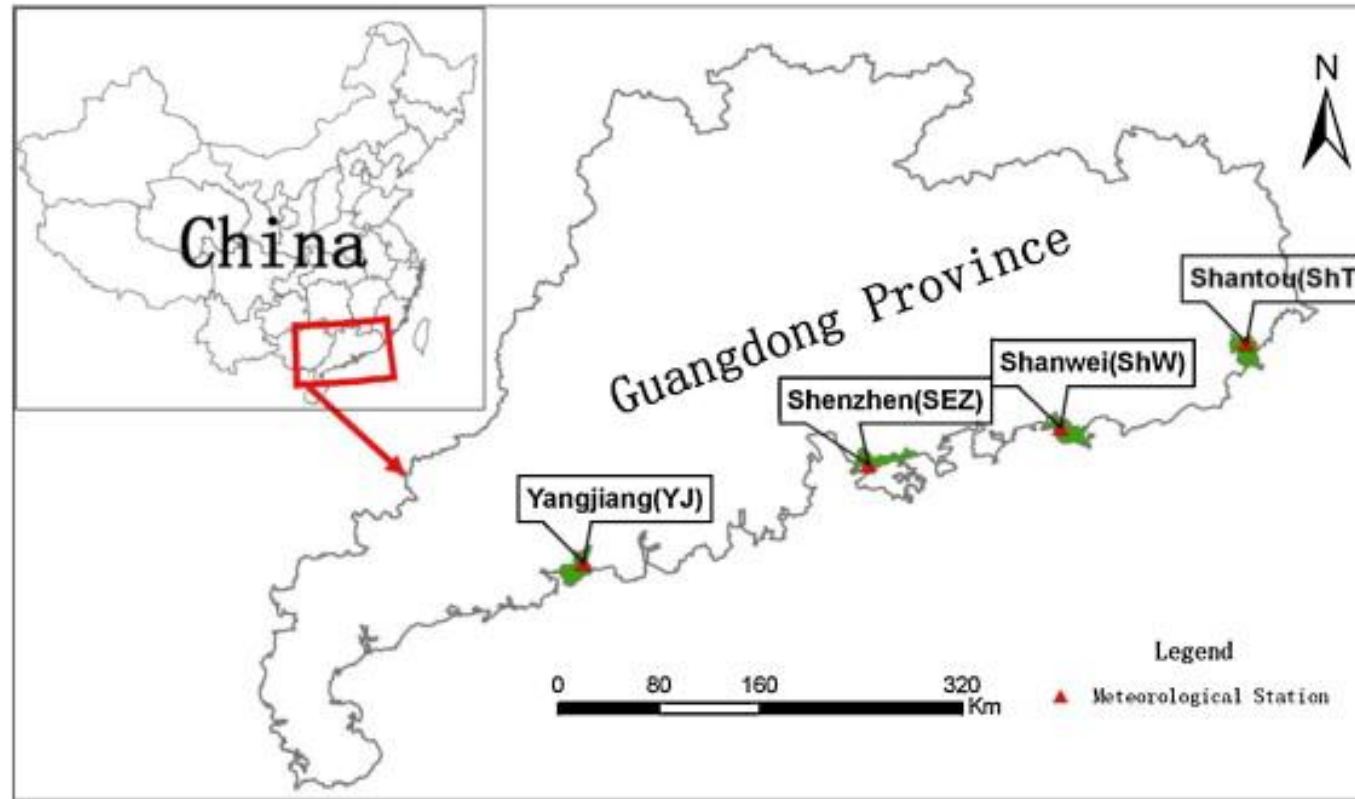


How is UHI quantified?

- 1) Long-term climate (weather) stations
- 2) Remote sensing of land surface temperature (LST)
- 3) Modeling



Tian, L., Chen, J., & Yu, S. (2013). How has Shenzhen been heated up during the rapid urban build-up process?. *Landscape and Urban Planning*, 115, 18-29.



Spatial locations of the four urban climatic stations used in this study in the southeast coast of PR China. The land cover was from urban fringe to a residential landscape setting in or near business areas. Shenzhen is a new city built from a small town in 1980.



12/1979

Write a description for your map.

Legend

- Hong Kong Disneyland
- Shenzhen

Google Earth

Image NASA
Image U.S. Geological Survey



10 km



12/1990

Write a description for your map.

Legend

-  Hong Kong Disneyland
-  Shenzhen

Google Earth

Image NASA
Image U.S. Geological Survey

Chek Lap Kok

Hong Kong Disneyland

Hong Kong 香港

TSEUNG KWAN O 將軍澳

10 km









Global warming (temperature increase) vs urbanization induced UHI.

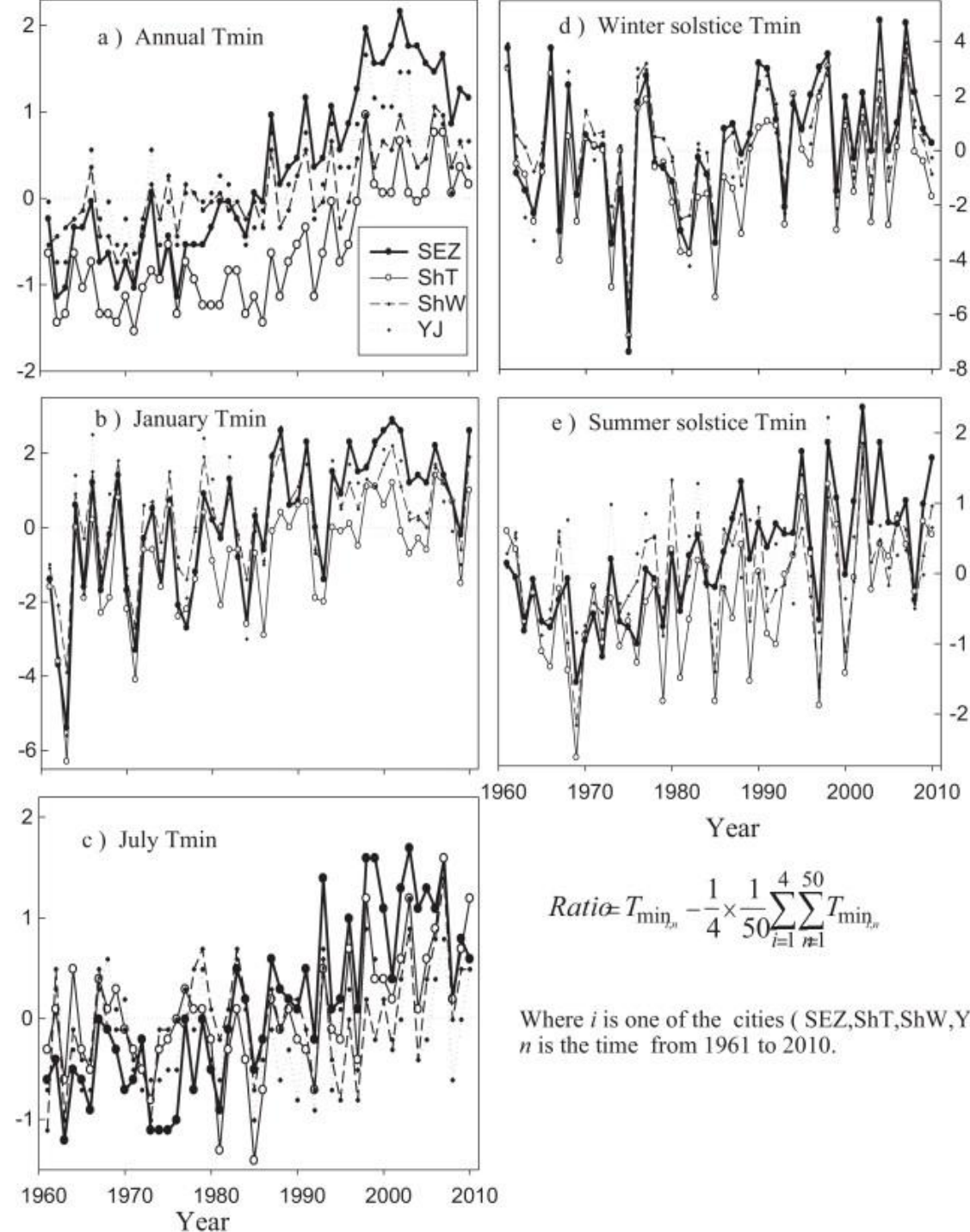
Warming trends (i.e., temperature increases) were found in all four study cities, likely due to warming trends in the region and globe

Table 2. Statistics of the absolute temperatures of four study cities before and after the SEZ was built in the mid-1980s.

		SEZ		ShT		ShW		YJ					
		1961– 1985	1986– 2010	1961– 1985	1986– 2010	1961– 1985	1986– 2010	1961– 1985	1986– 2010	1961– 1985	1986– 2010	1961– 1985	1986– 2010
T_{ann} (°C)	Mean	22.06	23.18	1.12	21.2	22.19	0.99	22.06	22.55	0.49	22.19	22.79	0.60
	Max	26.45	26.92	0.47	24.84	25.96	1.12	25.58	26.10	0.52	26.14	26.50	0.36
	Min	18.92	20.56	1.64	18.36	19.28	0.92	19.23	19.82	0.59	19.26	20.07	0.81
T_{jan} (°C)	Mean	14.04	15.69	1.65	130	14.51	1.51	14.26	15.24	0.98	14.42	15.44	1.02
	Max	19.36	19.92	0.56	17.26	18.69	1.43	18.53	19.52	0.99	19.30	19.75	0.45
	Min	10.46	12.79	2.33	9.87	11.38	1.51	11.14	12.24	1.10	10.94	12.40	1.46
T_{jul} (°C)	Mean	28.26	28.99	0.73	28.18	28.79	0.61	28.10	28.36	0.26	28.10	28.27	0.17
	Max	32.08	32.34	0.26	31.56	32.33	0.77	30.86	31.12	0.26	31.51	31.55	0.04
	Min	25.20	26.44	1.24	25.48	26.02	0.54	25.58	25.80	0.22	25.47	25.70	0.23
T_w (°C)	Mean	15.43	16.98	1.55	14.67	15.83	1.16	15.88	16.53	0.65	15.75	16.69	0.94
	Max	20.85	21.43	0.58	19.13	20.15	1.02	20.35	21.04	0.69	20.91	21.37	0.46
	Min	11.74	13.88	2.14	11.22	12.40	1.18	12.42	13.32	0.90	11.98	13.22	1.24
T_s (°C)	Mean	27.82	28.41	0.59	27.08	27.73	0.65	27.42	27.69	0.27	27.66	28.07	0.41
	Max	31.36	31.45	0.09	30.09	30.88	0.79	29.98	30.13	0.15	30.75	30.97	0.22
	Min	24.91	26.15	1.24	24.62	25.35	0.73	25.11	25.47	0.36	25.26	25.73	0.47



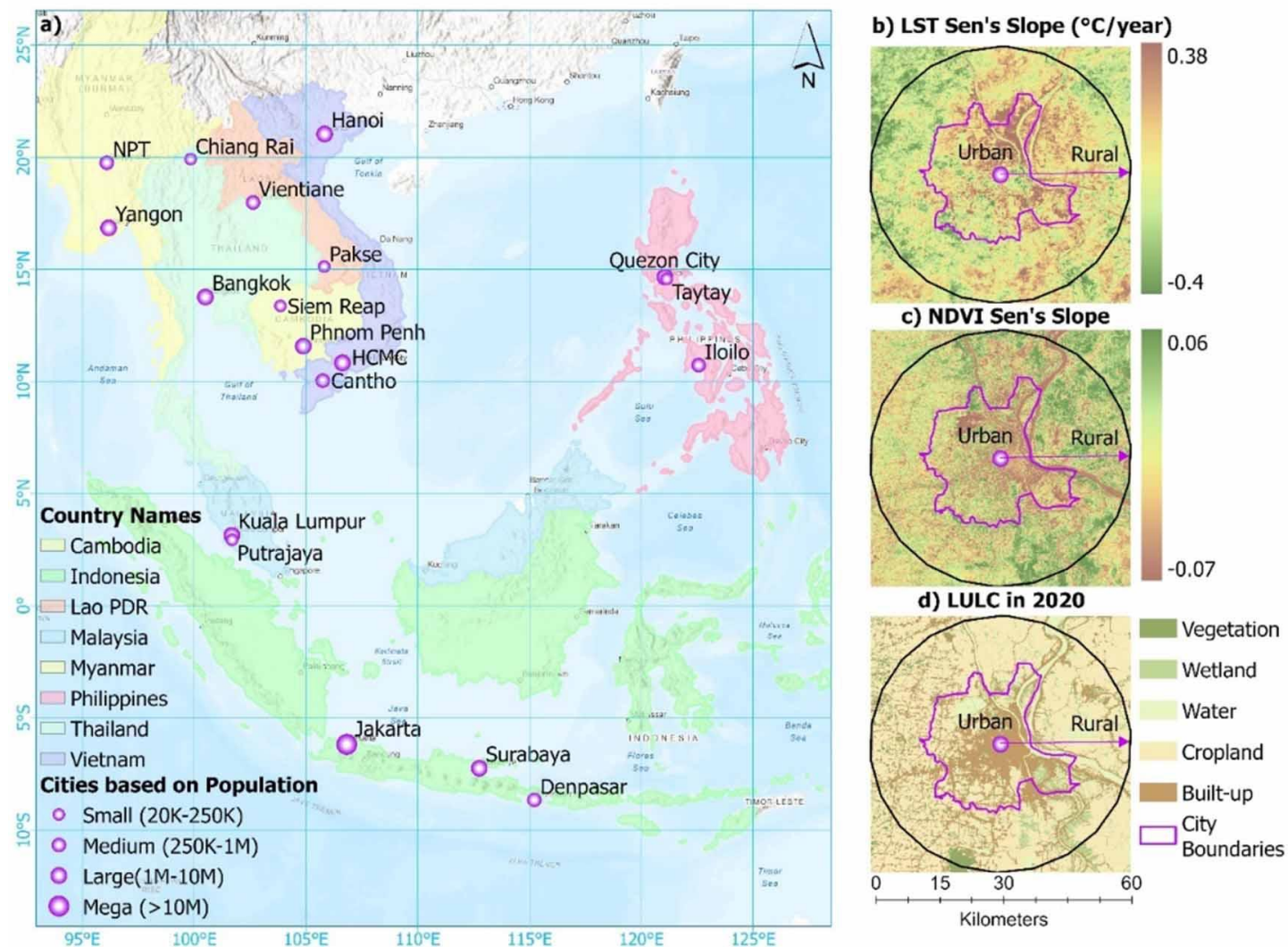
- Changes in the absolute and relative temperatures of four urban areas from 1960 to 2010. The $T_{\min}$ values of the year, January, July, and around summer/winter solstices (i.e., two weeks) were calculated based on the daily measurements.
- $T_{\min}$ appeared to be the most sensitive variable quantifying the magnitude and direction of UHI in all four cities





Zhu, Y., Myint, S. W., Chen, J., Fan, P., Seto, K. C., Jain, A., ... & Wang, J. (2025). Thermal changes along the urban-rural continuums in Southeast Asia. *Environmental Research Letters*, 20(5), 054051.

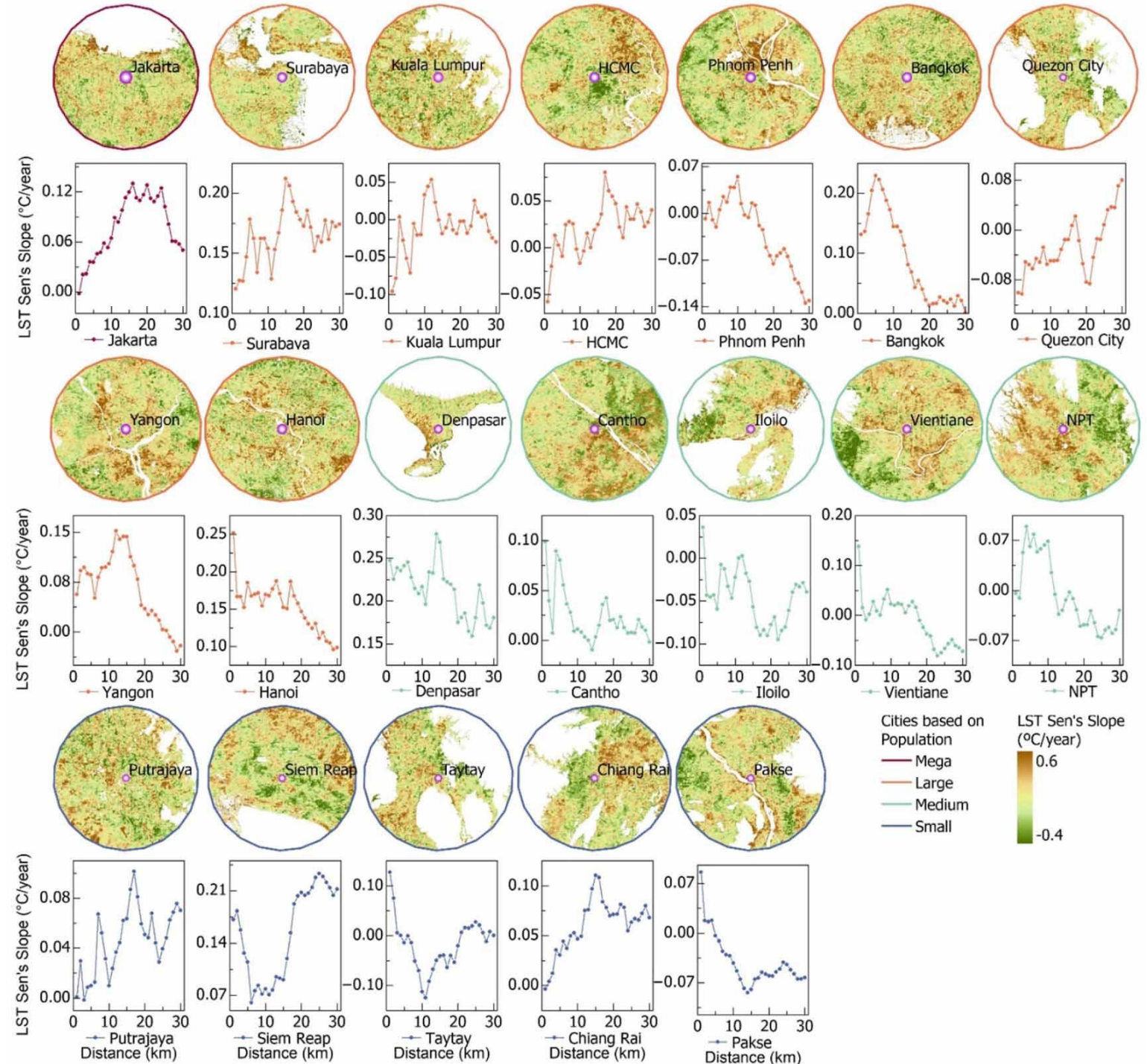
- This study examines LST, LCLU, and NDVI changes across 19 SEA cities of varying urbanization levels from 2000 to 2022 using Landsat images.
- LST change rates differ by urbanization levels, with built-up lands driving urban warming.
- Larger cities exhibited more intense and widespread LST increases extending into rural areas.
- The megacities experienced significant LST growth within 5 km of city centers despite limited built-up expansion.





We used the Mann–Kendall trend analysis to calculate Sen's slope for each pixel, capturing the change rate in LST between 2000 and 2022.

The spatial patterns of LST Sen's slope and their disparities from urban to rural areas by their mean values of each ring buffer for each 1 km ring buffer within a 30 km radius.





Schlünzen, K. H., Grimmond, S., & Baklanov, A. (2023). Guidance on measuring, modelling and monitoring the canopy layer urban heat island (CL-UHI).

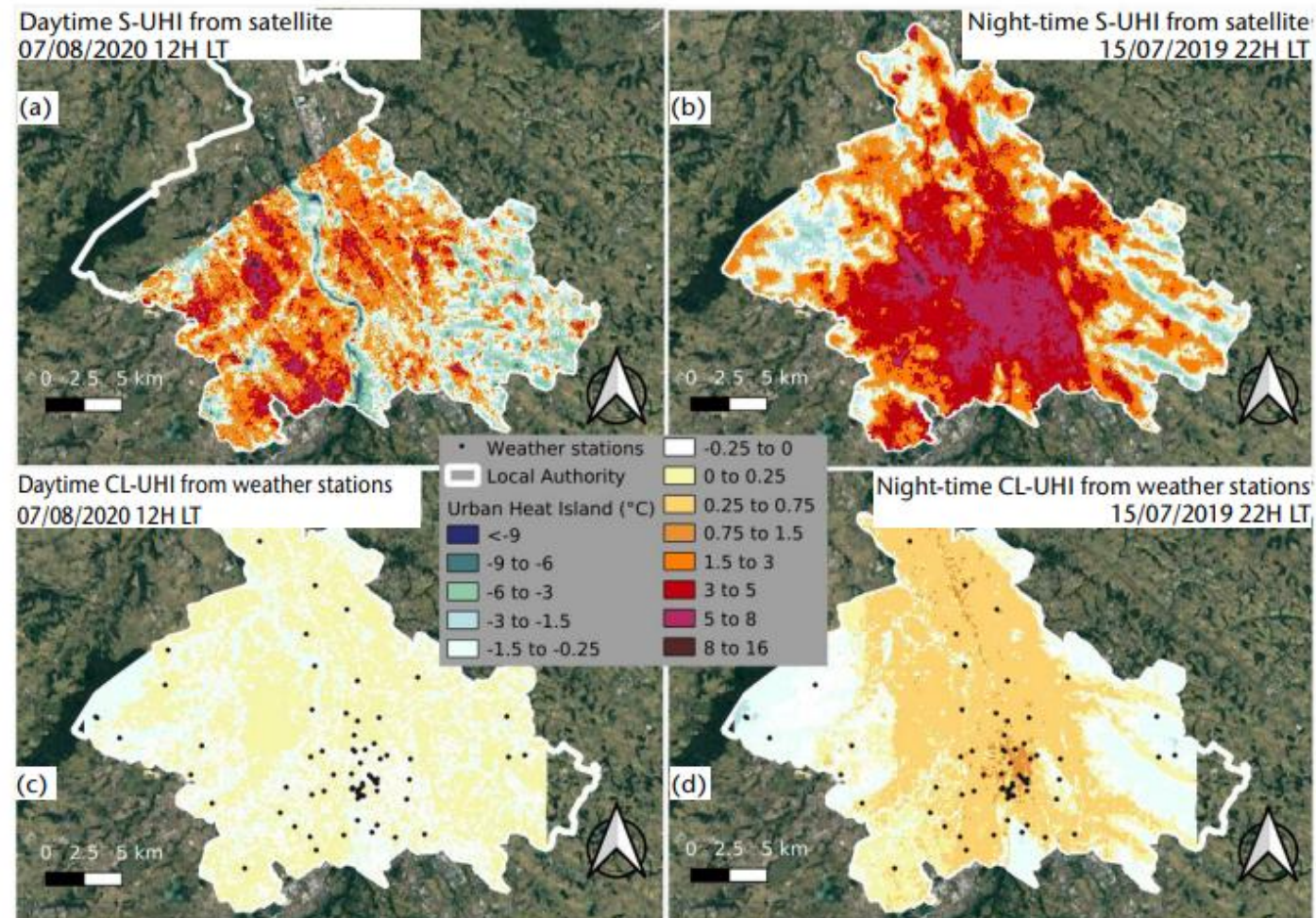


Figure A3.1. Toulouse, France (a, b) S-UHI (ECOSTRESS satellite, 70 m resolution) and (c, d) CL-UHI spatially interpolated network (dots) to 250 m using additional information on urban fraction and altitude (Touati et al., 2020). (a, c) 12:00 local time, 7 August 2020, (b, d) 22:00 local time 15 July 2019.



Heat Island Impacts

(<https://www.epa.gov/heatislands/what-are-heat-islands>)

- 1) Increased Energy Consumption.
- 2) Elevated Emissions of Air Pollutants and Greenhouse Gases.
- 3) Compromised Human Health and Comfort.
- 4) Impaired Water Quality.

https://www.youtube.com/watch?v=Y-bVwPRy_no&t=20s



Heat Island Reduction Solutions

(<https://www.epa.gov/heatislands/what-are-heat-islands>)



Increase Trees and Vegetation

Learn simple and effective ways plants can cool the environment.

Find Trees and Vegetation Solutions



Create Green Roofs

Explore green roofs as a proven method to reduce heat islands and achieve cost-effective benefits.

Explore Green Roof Solutions



Install Cool Roofs

Find what cool roofs are, how they work to reduce heat islands, and other benefits.

Learn About Cool Roofs



Heat Island Reduction Solutions

(<https://www.epa.gov/heatislands/what-are-heat-islands>)



Use Cool Pavement

Learn how cities are using cool pavements and emerging technologies as heat island reduction measures.

**Access Cool Pavement
Information**



Adapt to Heat

Find ways communities can effectively plan and adapt to heat.

Assess Ways to Adapt to Heat



Follow Smart Growth Principles

Learn the principles to make communities more attractive, livable, and economically vibrant.

**Apply Smart Growth
Principles**

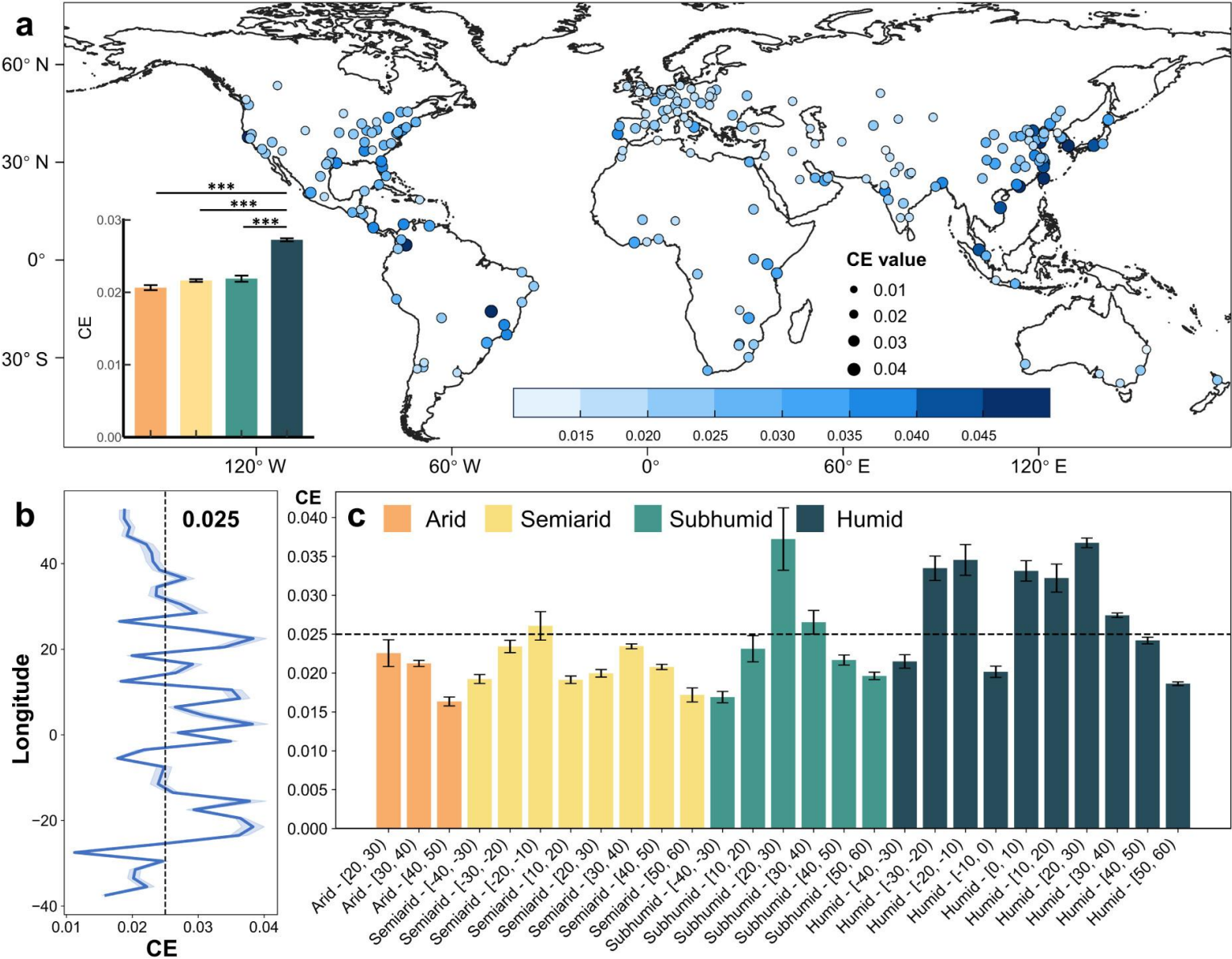


Yu, Z., Li, S., Yang, W., Chen, J., Rahman, M. A., Wang, C., ... & Zhou, W. (2025). Enhancing Climate-Driven Urban Tree Cooling with Targeted Nonclimatic Interventions. *Environmental Science & Technology*, 59(18), 9082-9092.

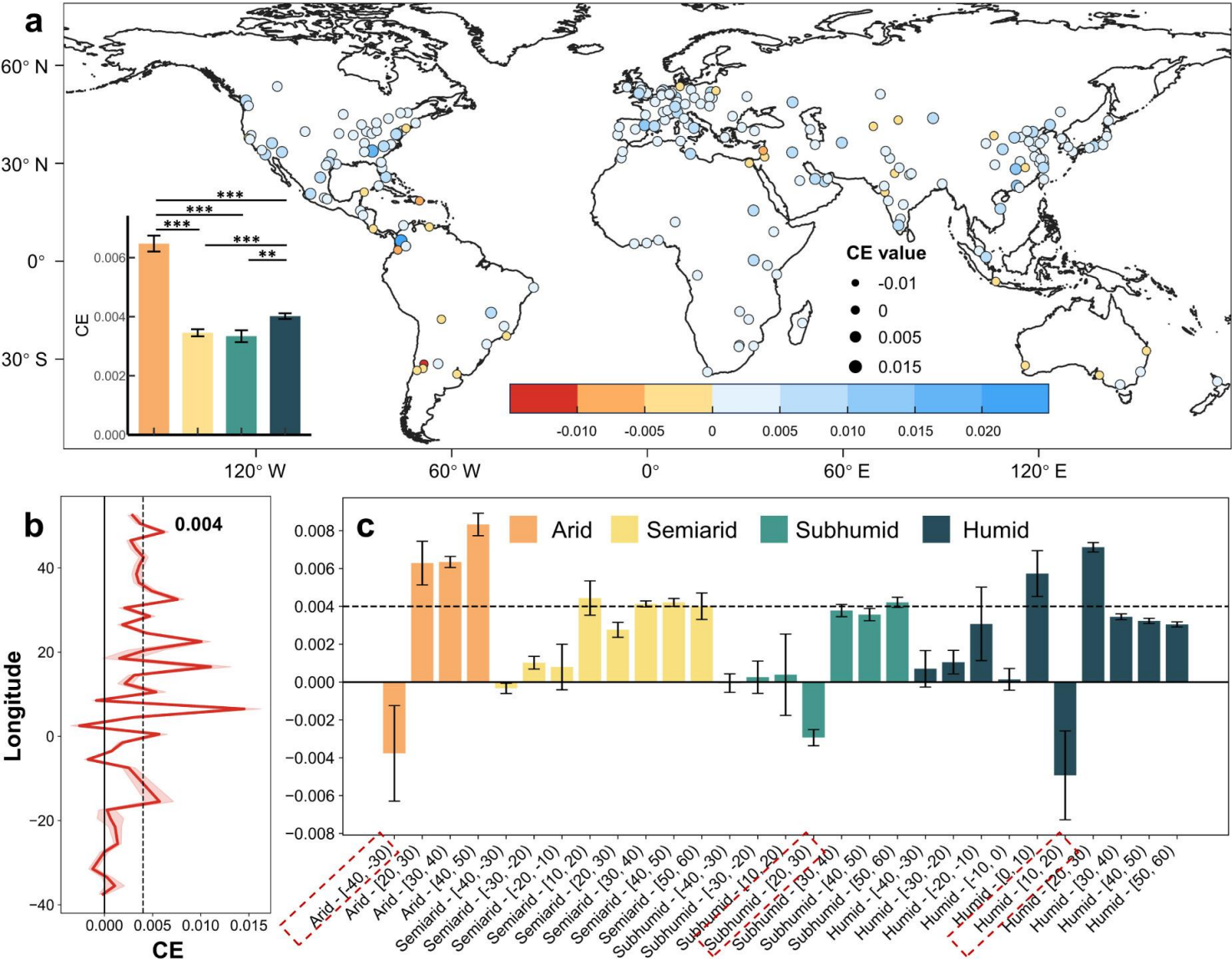
- We quantify the diel CE of 229 cities across four climatic zones and employ a machine-learning model to assess the influence of variables on CE.
- We found that for every 10% increase in tree cover, surface temperatures are reduced by 0.25 °C during the day and 0.04 °C at night.
- Trees in humid regions exhibit the highest daytime CE, while those in arid zones demonstrate the greatest cooling effect at night.



Global patterns of daytime cooling efficiency (CE) of urban trees



Global patterns of nighttime cooling efficiency (CE) of urban trees





Take-home-messages

Five major causes of UHI

- 1) Reduced natural landscapes in urban areas.
- 2) Urban material properties.
- 3) Urban geometry.
- 4) Heat generated from human activities.
- 5) Weather and geography.

Three major approaches to quantify UHI

- 1) Long-term climate (weather) stations.
- 2) Remote sensing of land surface temperature.
- 3) Modeling.

Four major consequences

- 1) Increased energy consumption.
- 2) Elevated emissions of air pollutants and GHG.
- 3) Compromised human health and comfort.
- 4) Impaired water quality.

Six strategies to reduce UHI effects

- 1) Increase Trees and Vegetation
- 2) Create Green Roofs
- 3) Install Cool Roofs
- 4) Use Cool Pavement
- 5) Adapt to Heat
- 6) Follow Smart Growth Principles

Use less energy

i.e., similar to carbon footprint!



Next Lecture: Phenological Changes and Climate (Prof. G. Henebry)