EUMETrain Event Week on Heatwaves & Droughts

Urban Heat Islands

Panagiotis Sismanidis

In collaboration with:

Bechtel B., Keramitsoglou I., Krelaus L., Apfel J., and Demuzere M.

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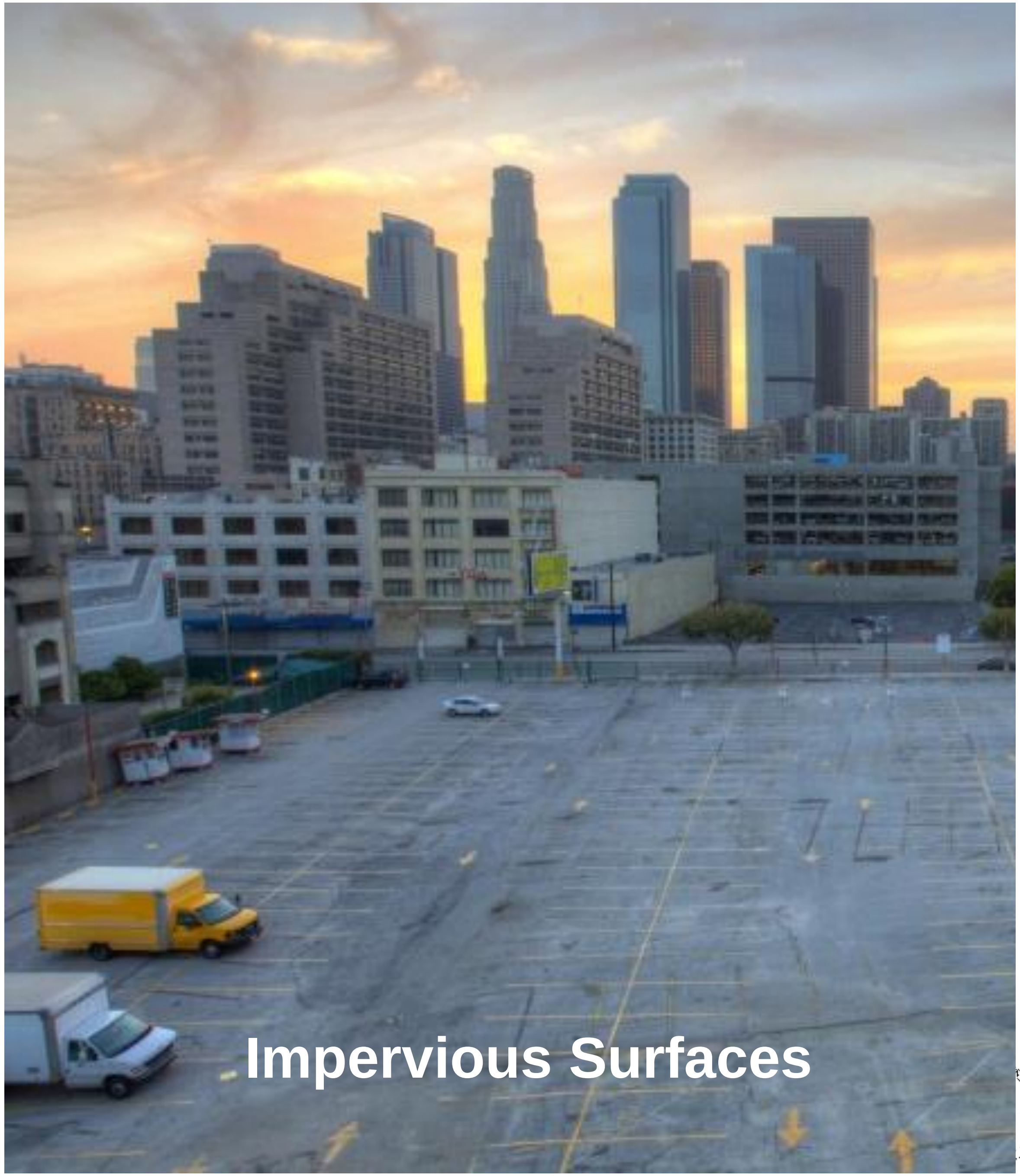
Contents

- Drivers and Different Types of Urban Heat Islands.
- Caveats in using remotely-sensed LST to study SUHIs.
- Local Climate Zones.

Higher **Thermal Conductivity**

Higher **Heat Capacity**

Lower Overall **Albedo**



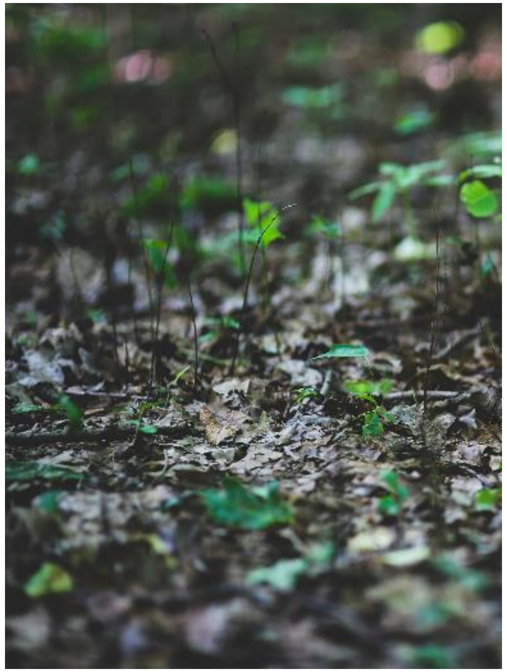
Man-made Surface and Atmospheric Modification

Decrease in **evapotranspiration**

Reduction in **turbulent heat transport** due to the geometry of the street canyons

Increased **anthropogenic heat emissions**

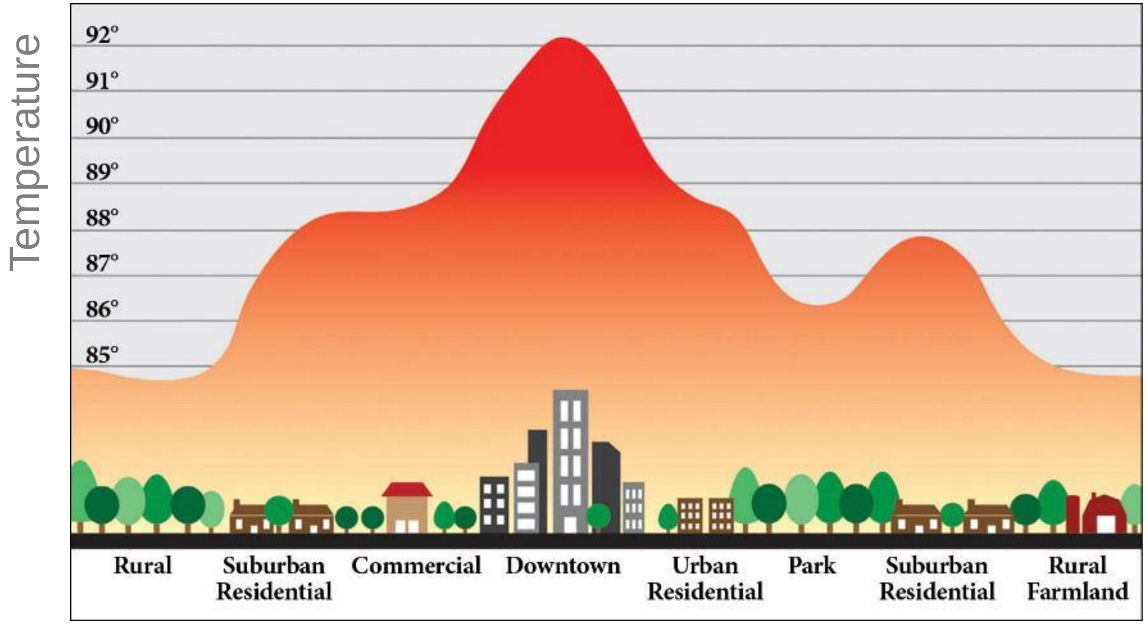
Air **pollution**




Urban Climate

Cities are **warmer** than their surrounding non-urbanized areas.

This is known as the **Urban Heat Island** effect.



Negative effects:

1. Degrade the **environment**
2. Impact the **human health**
3. Impact the **thermal comfort**
4. Increase the **energy demand**
5. Intensify and prolong **heatwaves**

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slido

If you work on UHI impacts, what is your focus area?

ⓘ Start presenting to display the poll results on this slide.

Urban Heat Islands Types

4 Different Types

Section	UHI type	Scale	Processes	Models	Direct measurement	Remote sensing
7.2	**Surface heat island** (UHI_{Surf})	Micro	Surface EB	Surface EB and equilibrium surface temperature	Temperature sensors attached to surface	Satellite/ aircraft sensors
7.3	**Canopy layer heat island** (UHI_{UCL})	Local	Surface EB and EB of UCL air volume	Canopy and RSL scheme incl. interactions with subsurface and overlying BL	Temperature sensors at fixed points, arrays and mobile in UCL and rural SL	Mini-sodar[(1)], mini-lidar
7.4	**Boundary layer heat island** (UHI_{UBL})	Local and meso	EB at top of RSL and BL EB	BL scheme incl. interaction with RSL/surface and free atmosphere	Temperature sensors mounted on aircraft, balloons and tall towers	Sodar, lidar, RASS profiler
7.5	**Subsurface heat island** (UHI_{Sub})	Local	Subsurface Energy Balance (EB)	Heat (water) diffusion in solid	Temperature sensors within substrate	-

[(1)] Sodar does not measure *T*, but can sense temperature structure.

Oke et al. 2017

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Surface Temperature

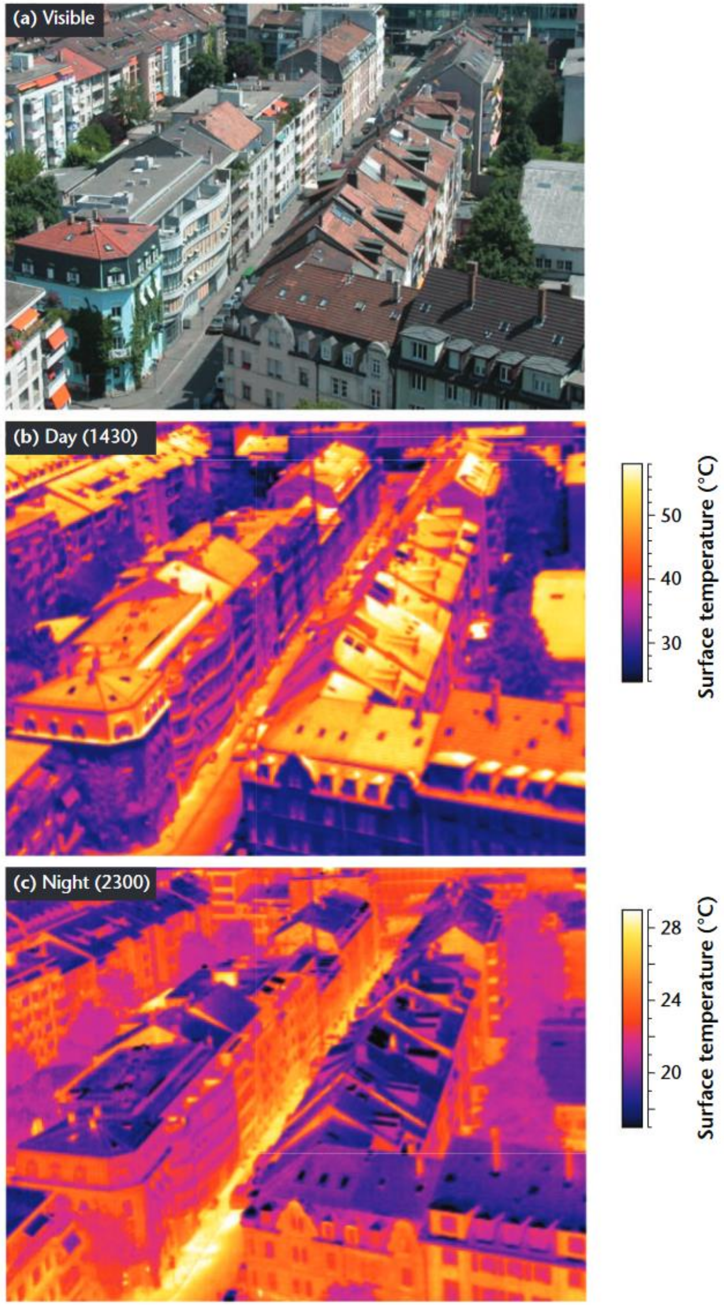
It is central to the **surface energy balance**

It modulates the **air temperature** of the lowest layers of the urban atmosphere

It affects the **energy exchanges** that impact the human thermal comfort

Enables the study of **surface UHIs** (SUHIs)

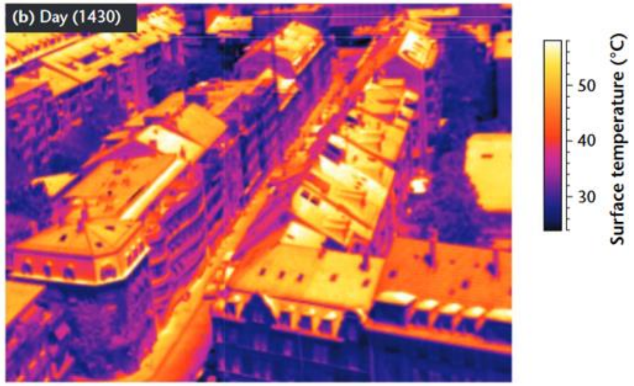
The only practical way is measuring the surface-emitted **thermal infrared radiation** from space

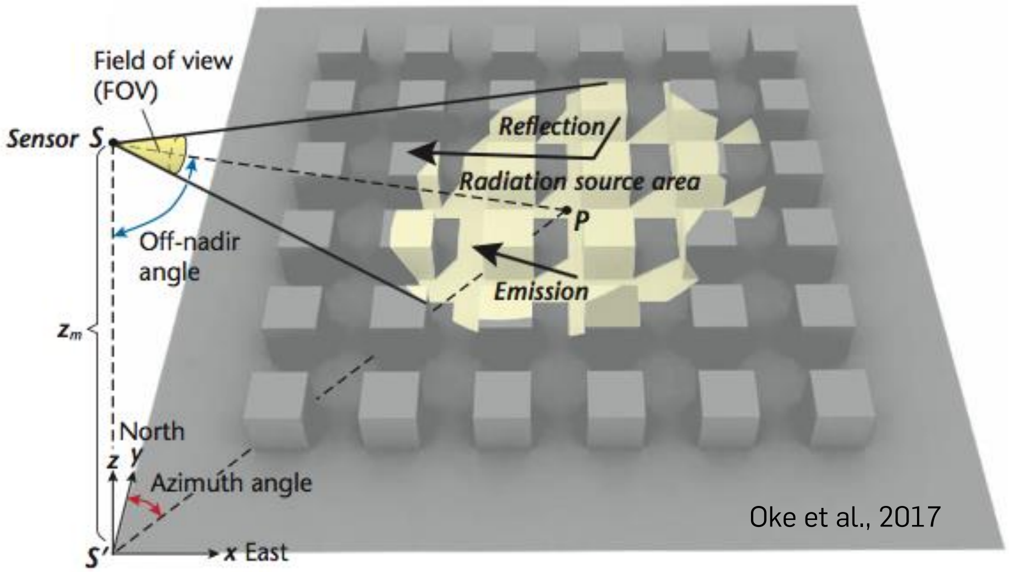


Oke et al. 2017

Biased to Flat Roofs

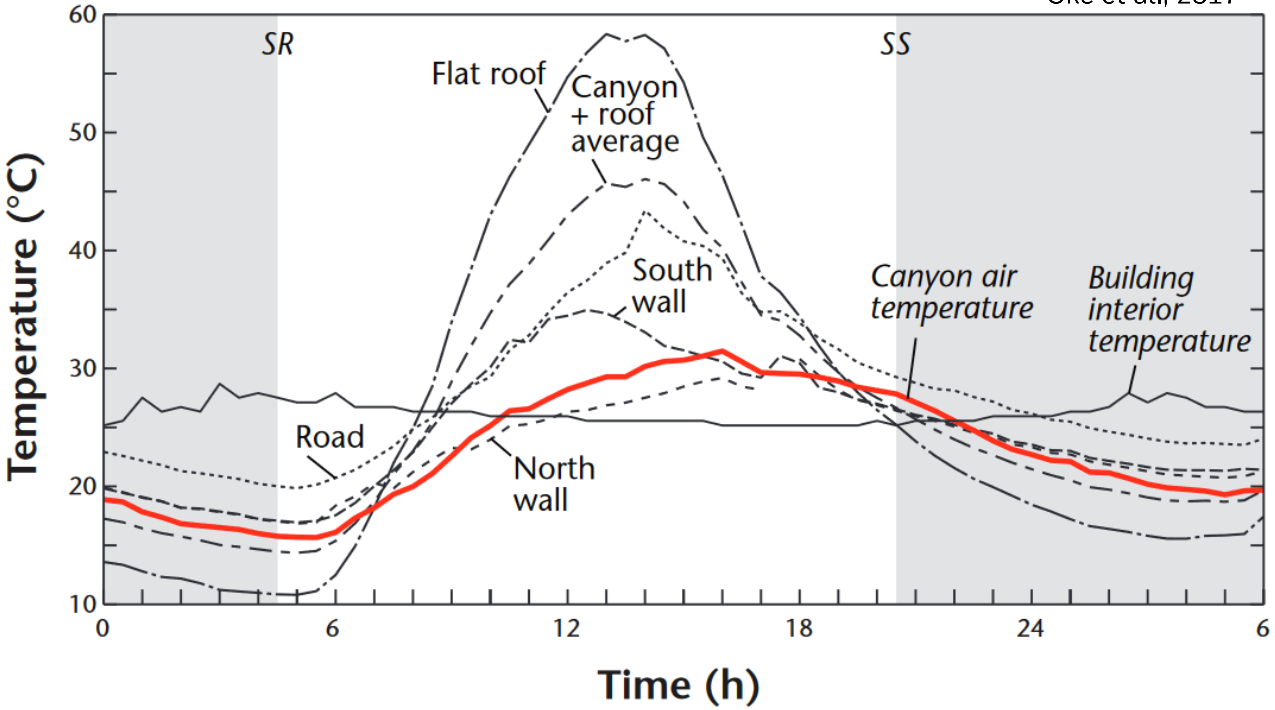
Satellites sense the TIR radiation from an **overhead perspective.**



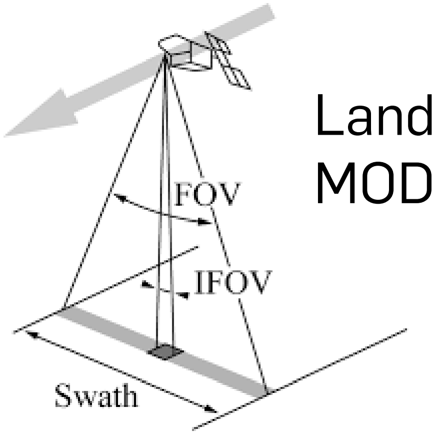


Oke et al., 2017

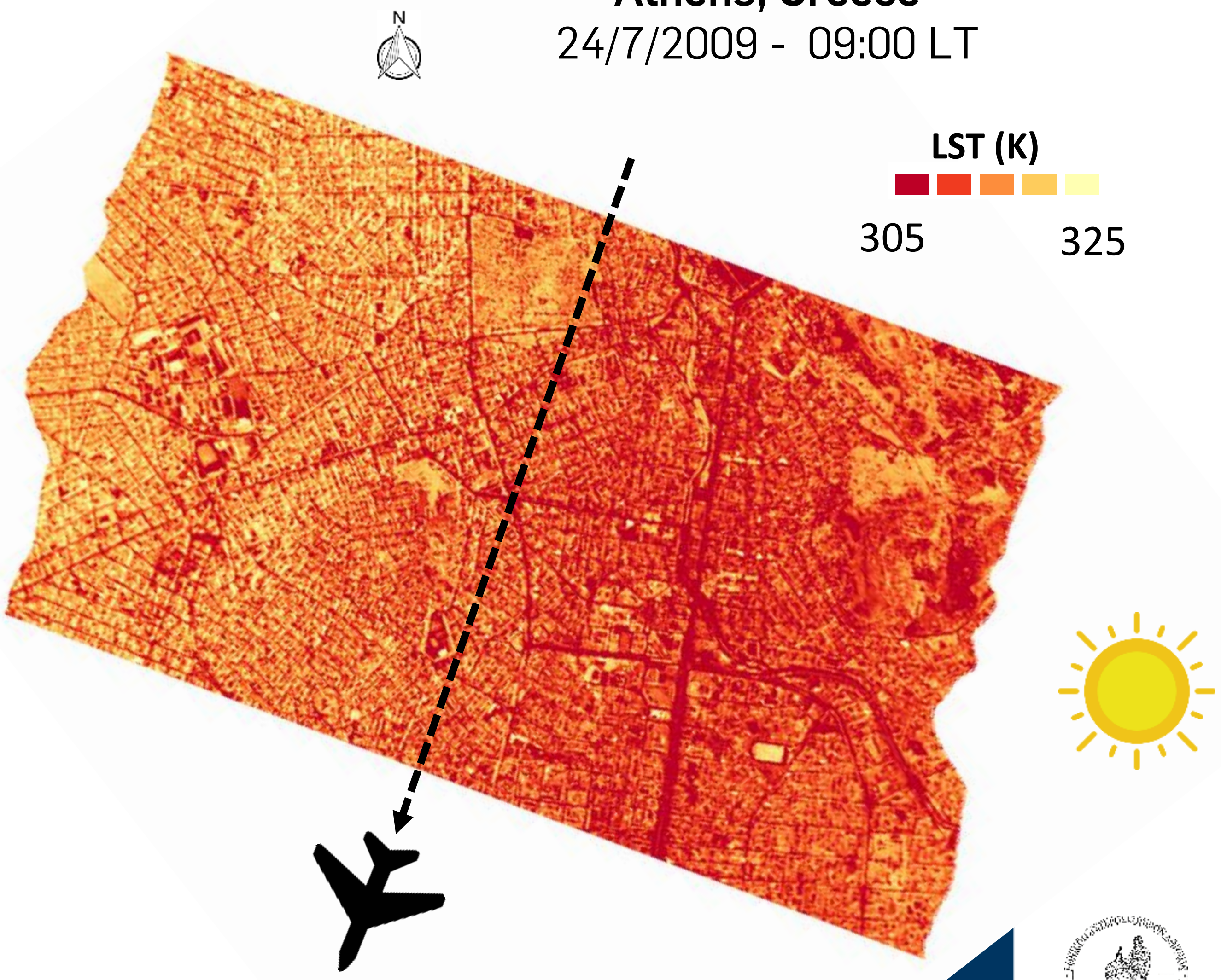
Oke et al., 2017



LST Anisotropy

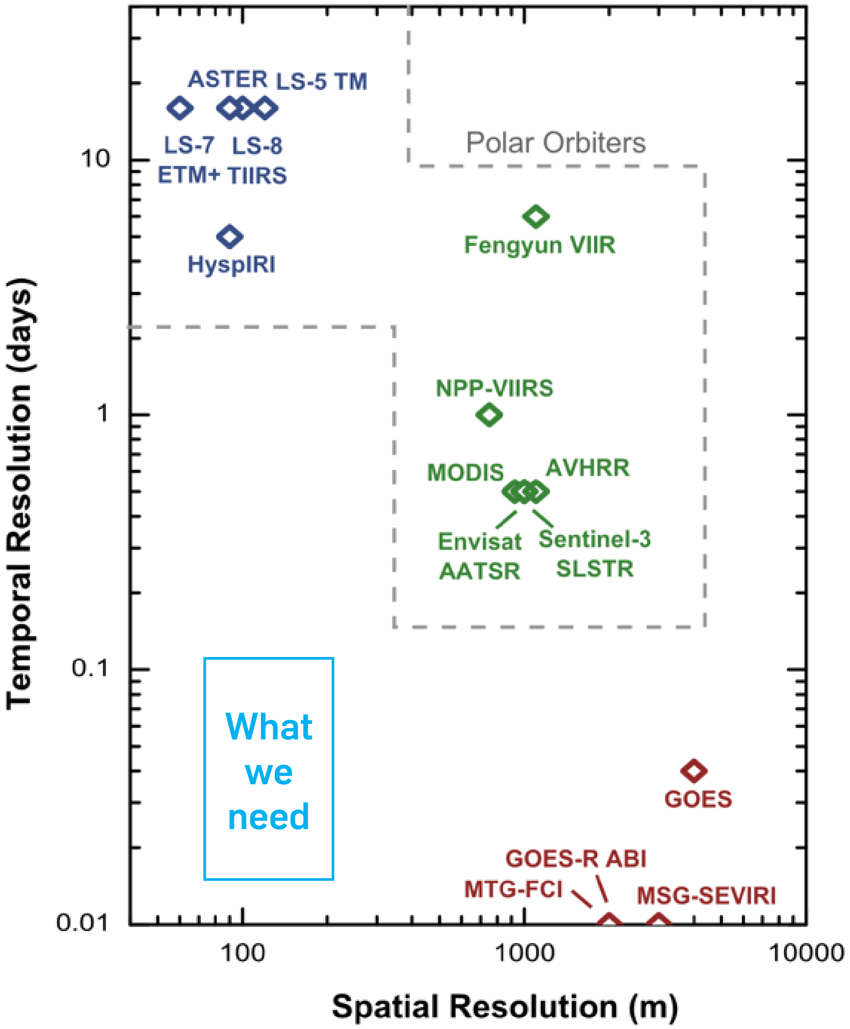


Landsat 8 : **–7.5◦** to **+7.5◦**
MODIS : **– 55◦** to **+55◦**



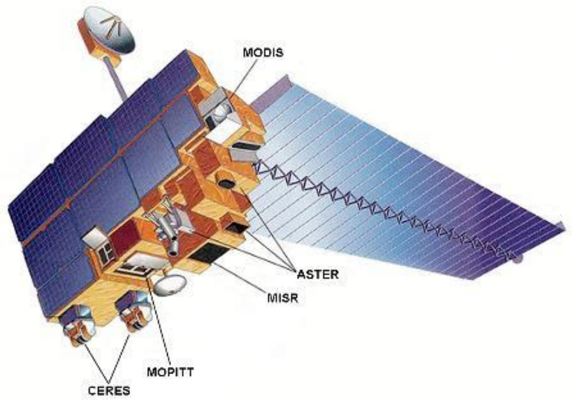
Source: NOA/IAASARS & ESA

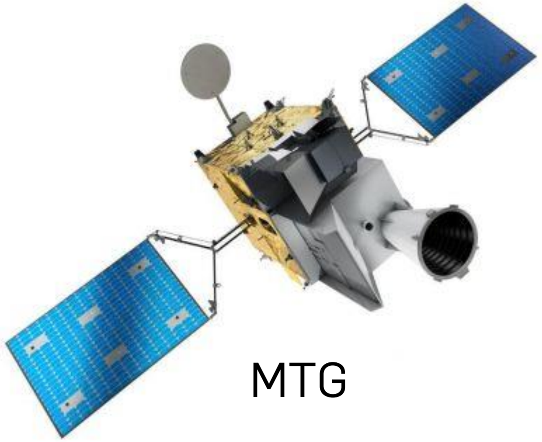
Satellite Instruments



Landsat 8

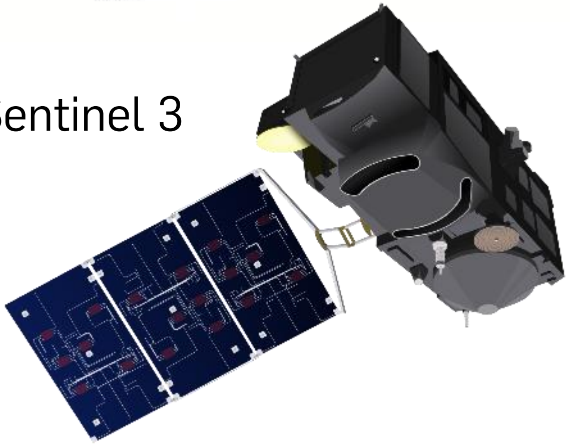
Terra MODIS





MTG

Sentinel 3



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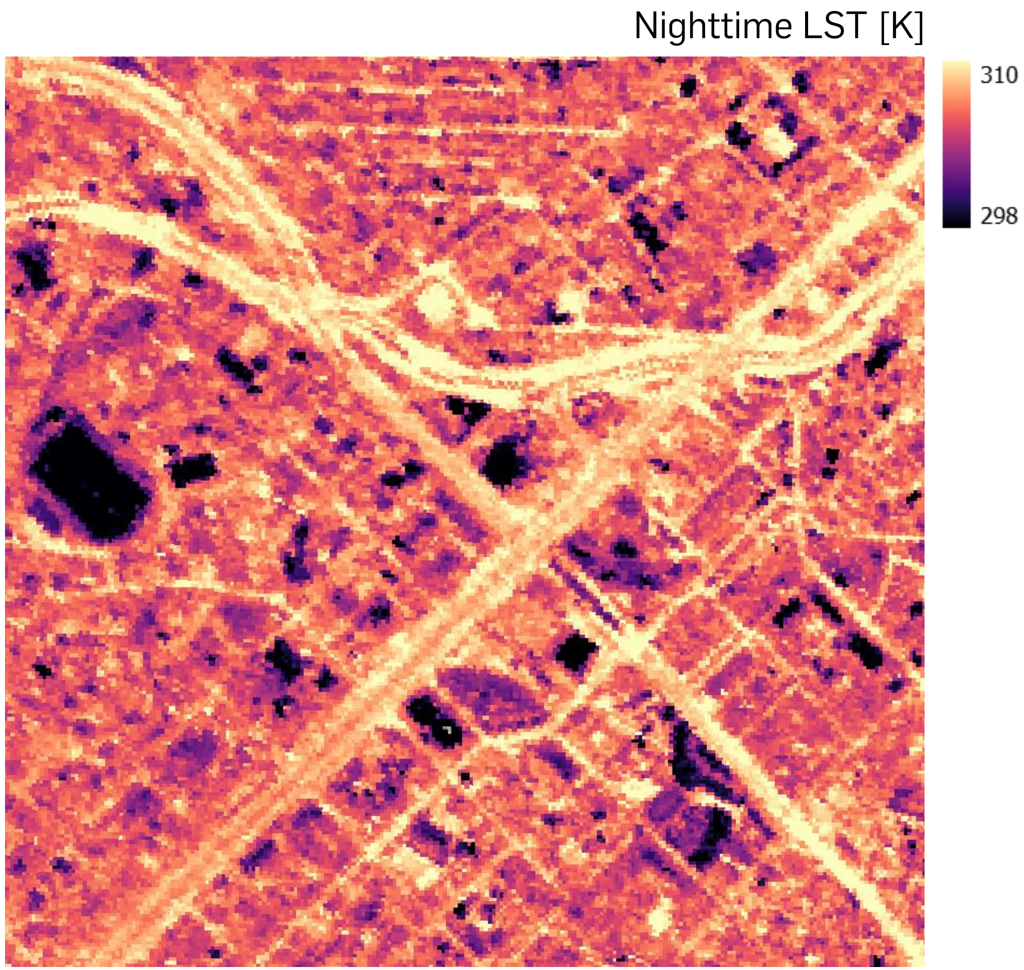
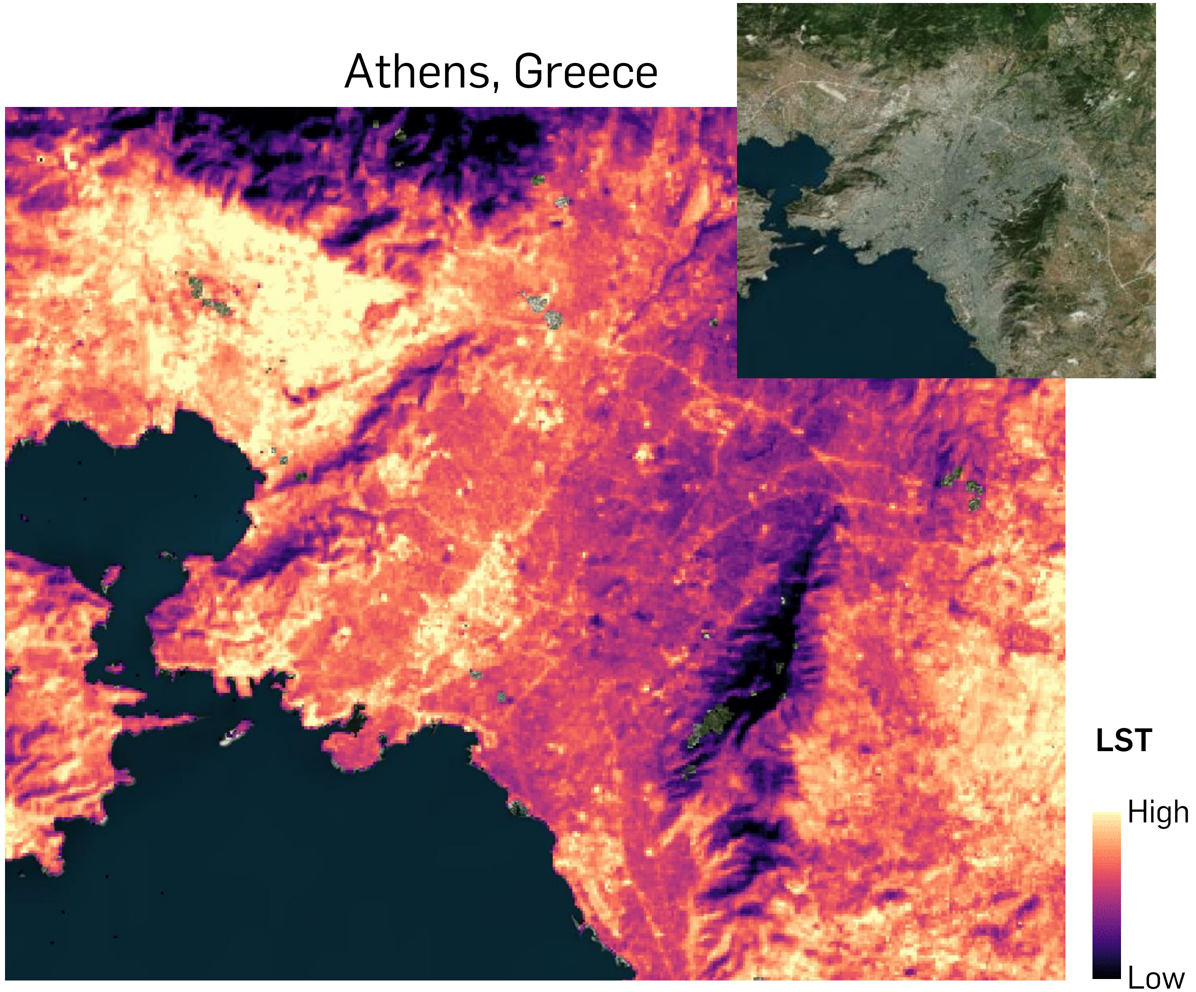
Resolve Building Blocks

Athens, Greece



Source: IAASARS, ESA

Main [Problematic] Assumptions



- High LST ⇒ High Air Temperature
- LST and Air Temperature patterns coincide

In most cases these assumptions are **<u>not</u>** valid!

Negative Critique

remote sensing

MDPI

Article

Regarding Some Pitfalls in Urban Heat Island Studies Using Remote Sensing Technology

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2021

Abstract: This paper attempts to illustrate the complexity of thermal infrared (TIR) data analysis for

(using the term "surface urban heat island") could be observed, the literature is full of incorrect conclusions and results using erroneous terminology. This seems to be the result of the ease of such

drawing conclusions for urban planning authorities. It seems that the UHI is easy to measure, easy to explain, easy to find, and easy to illustrate—simply take a TIR-image. Due to this apparent simplicity, many authors seem to jump into UHI studies without fully understanding the nature of the phenomenon as far as time and spatial scales, physical processes, and the numerous methodological pitfalls inherent to UHI studies are concerned. This paper attempts to point out some of the

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LST vs. Near-surface Air Temperature

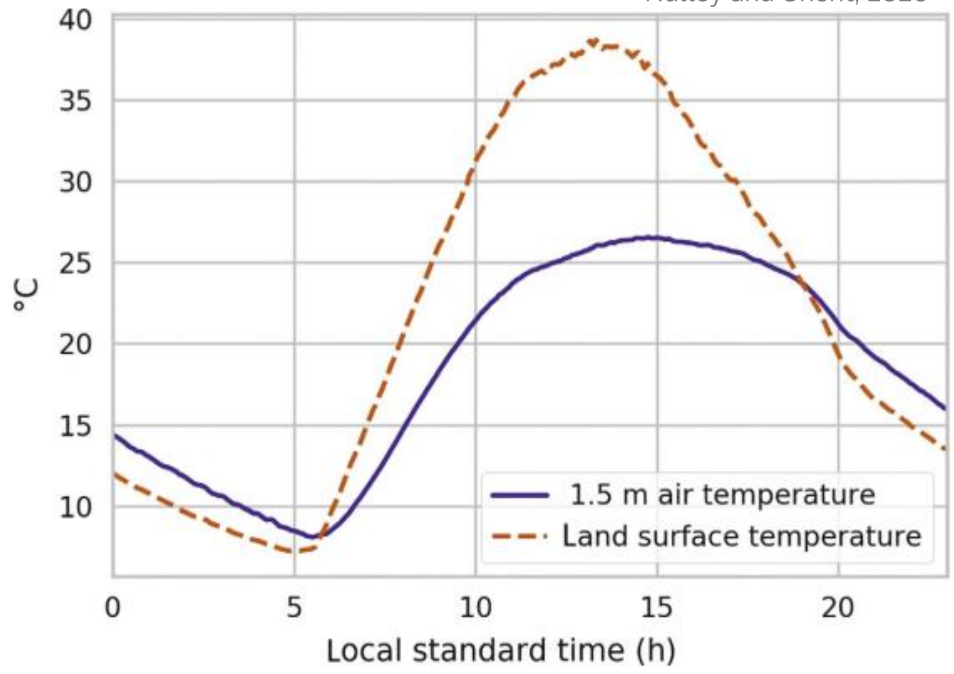
- LST is the temperature you would feel if you placed your hand on the surface.

- LST is not a direct surrogate of Tair, but is directly related and can exhibit strong spatiotemporal correlation.

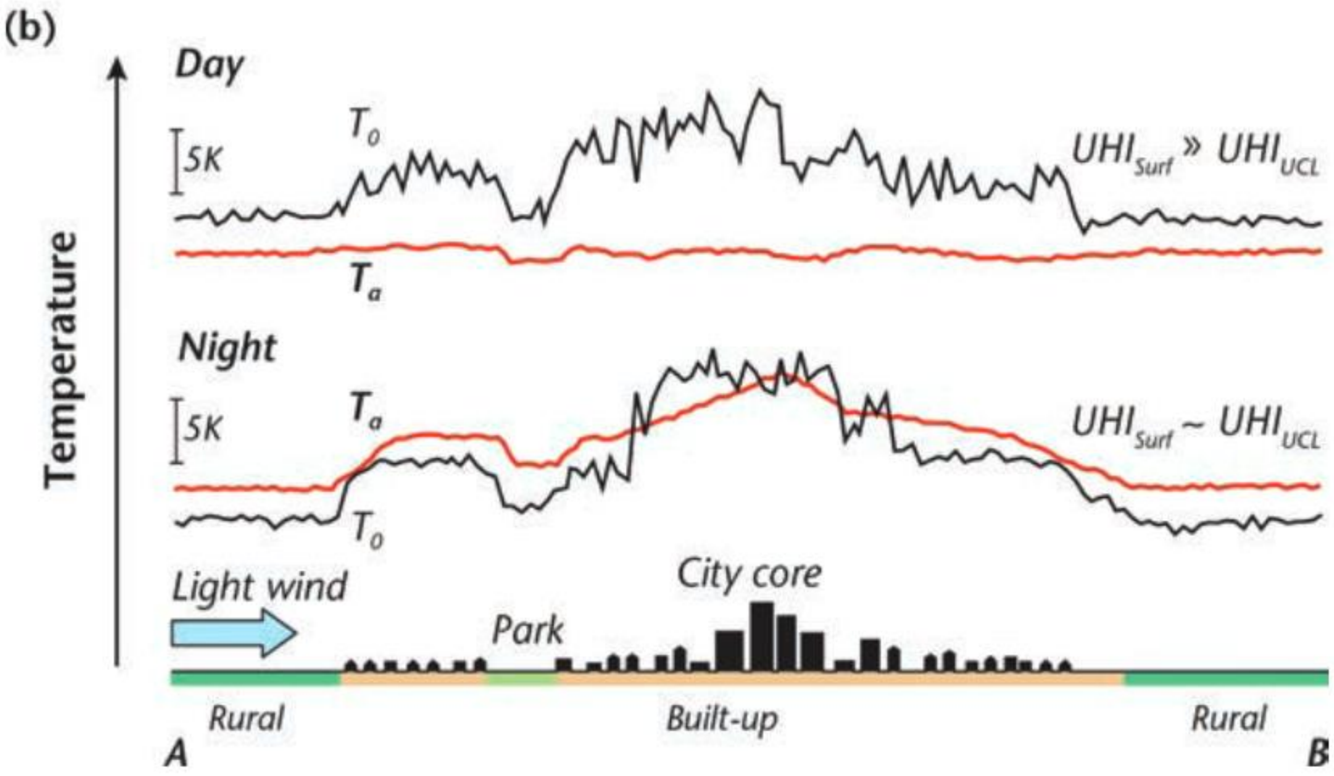
- LST is much warmer than Tair during the day and more like Tair at night.

- Daytime LST is more spatially variable than daytime Tair.

Hulley and Ghent, 2019



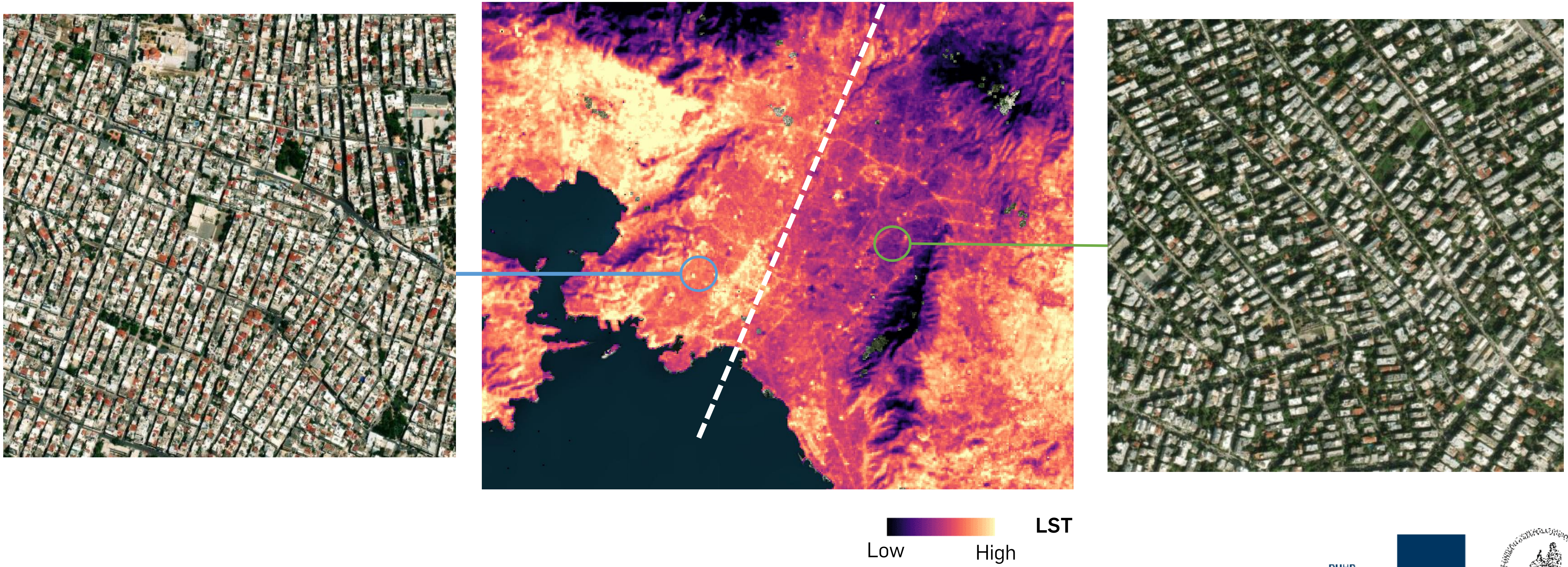
Surface vs. Canopy-layer UHI



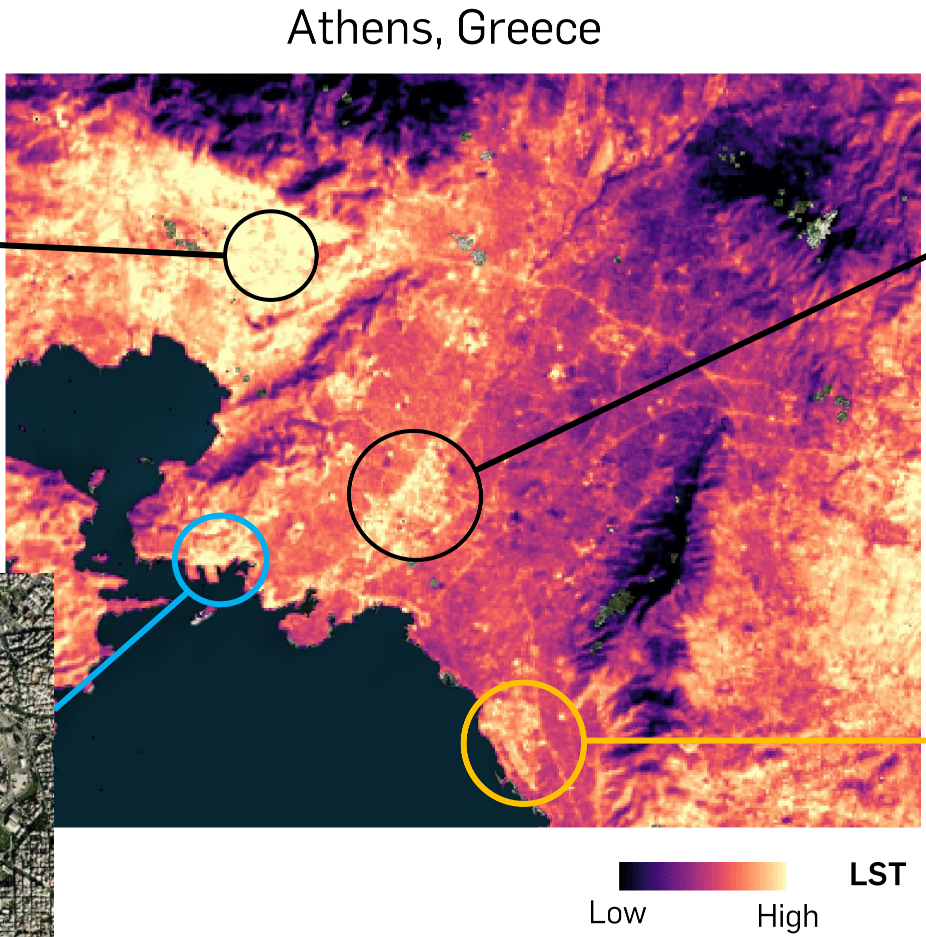
Source: Oke et al., 2017

Why you may make these assumptions

Athens, Greece

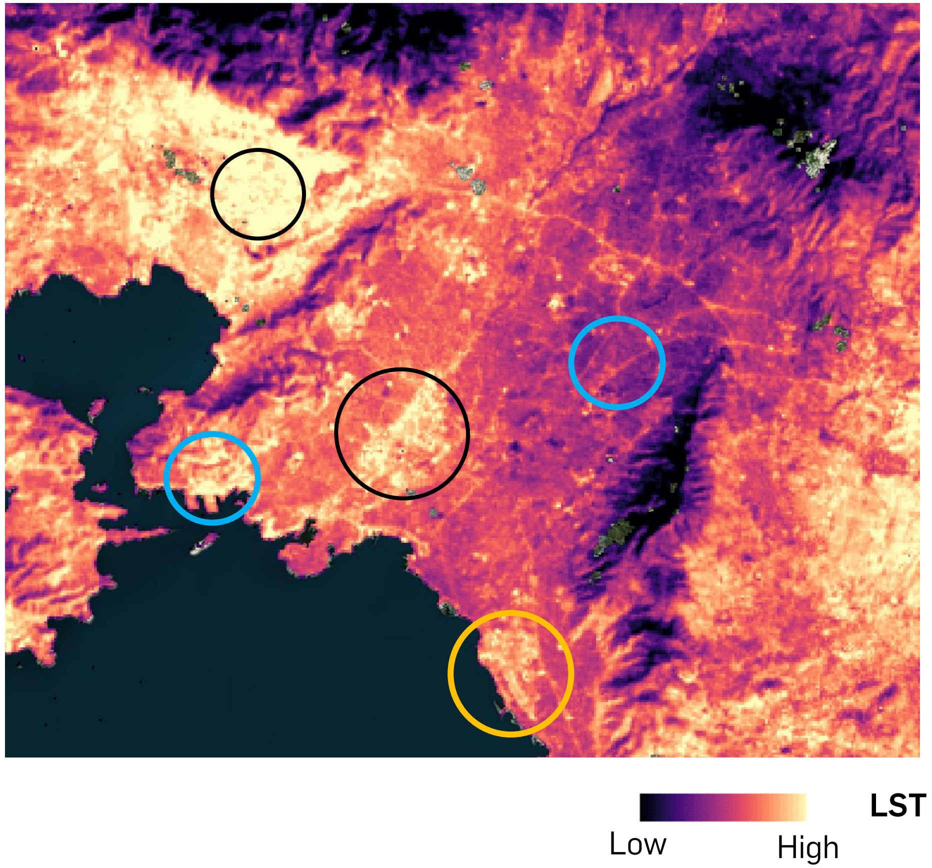


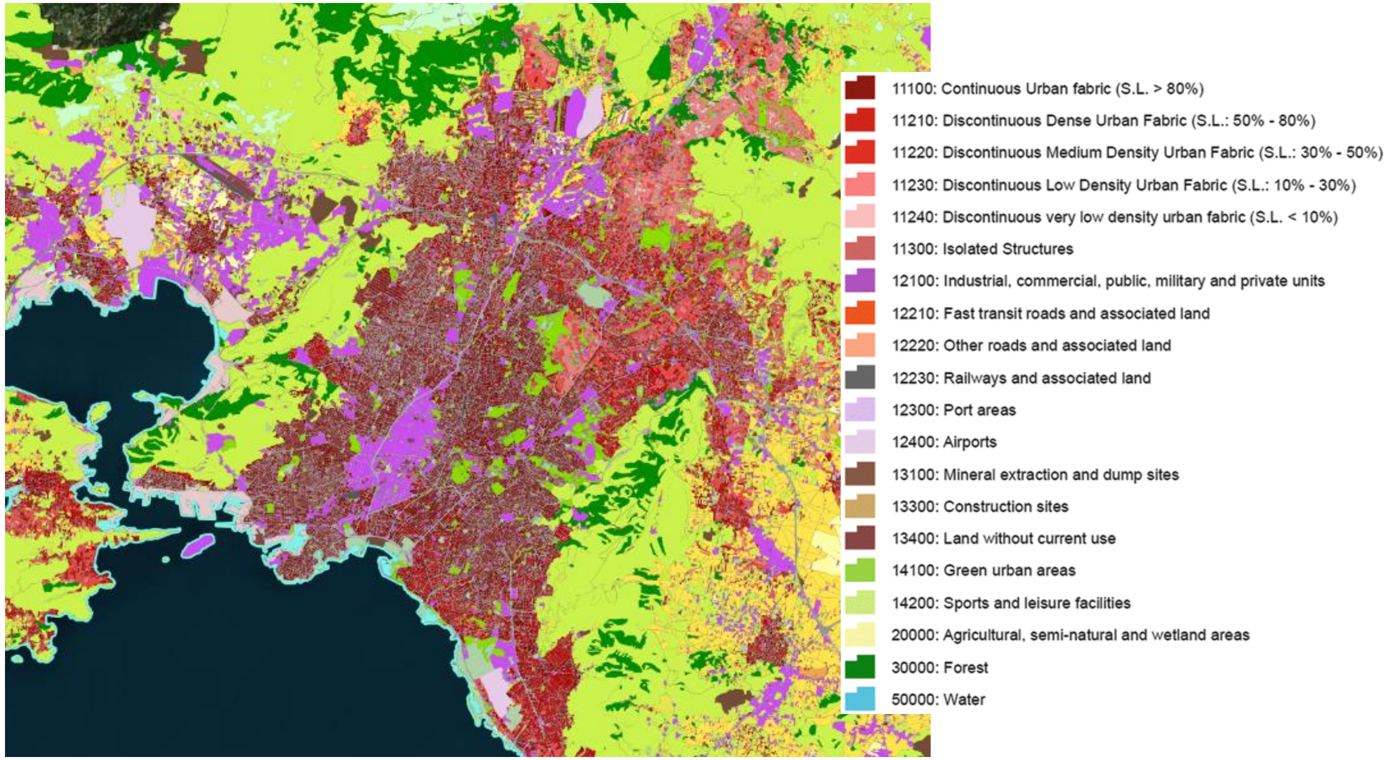
Why you may make these assumptions



Daytime LST Land Cover

Athens, Greece





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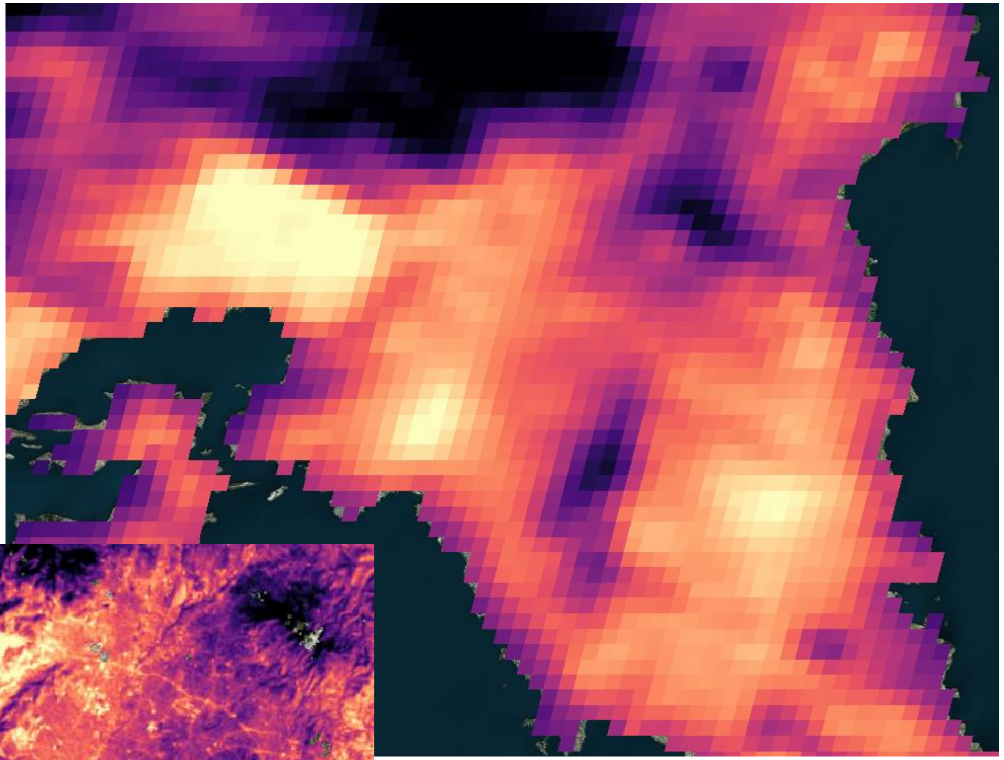
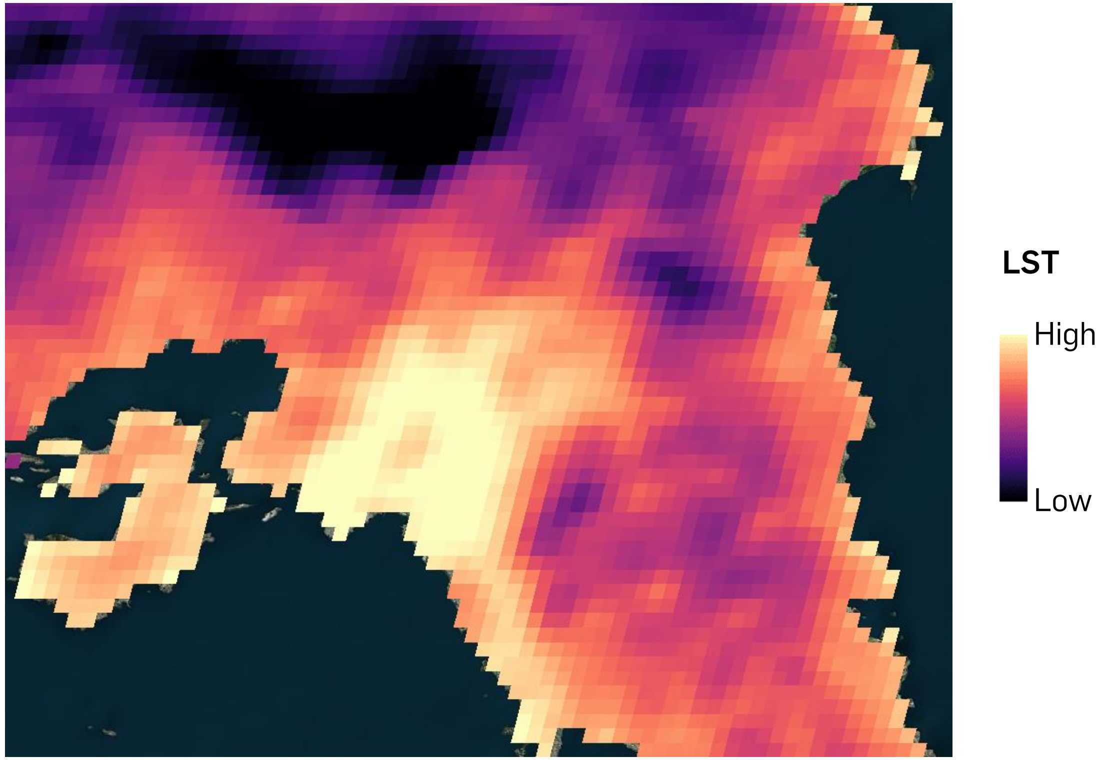
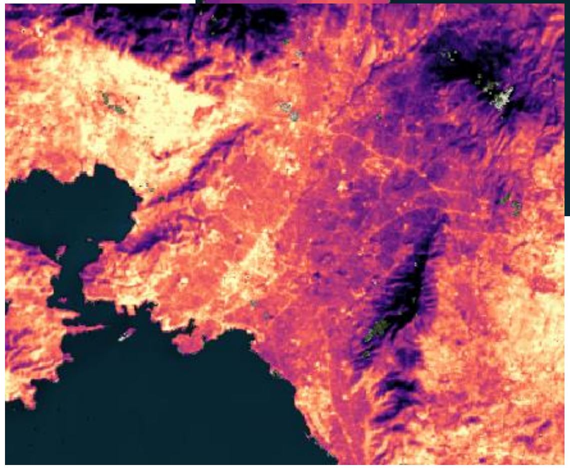
Daytime vs. Nighttime LST

Daytime (10:30 LT)



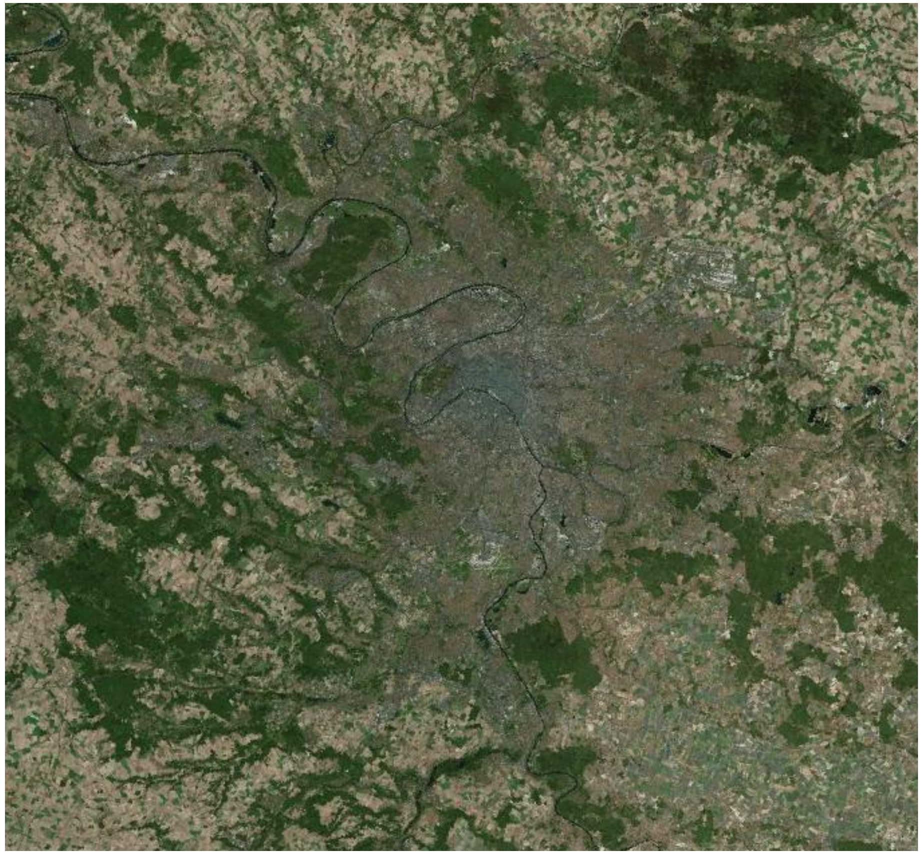
Nighttime (22:30 LT)

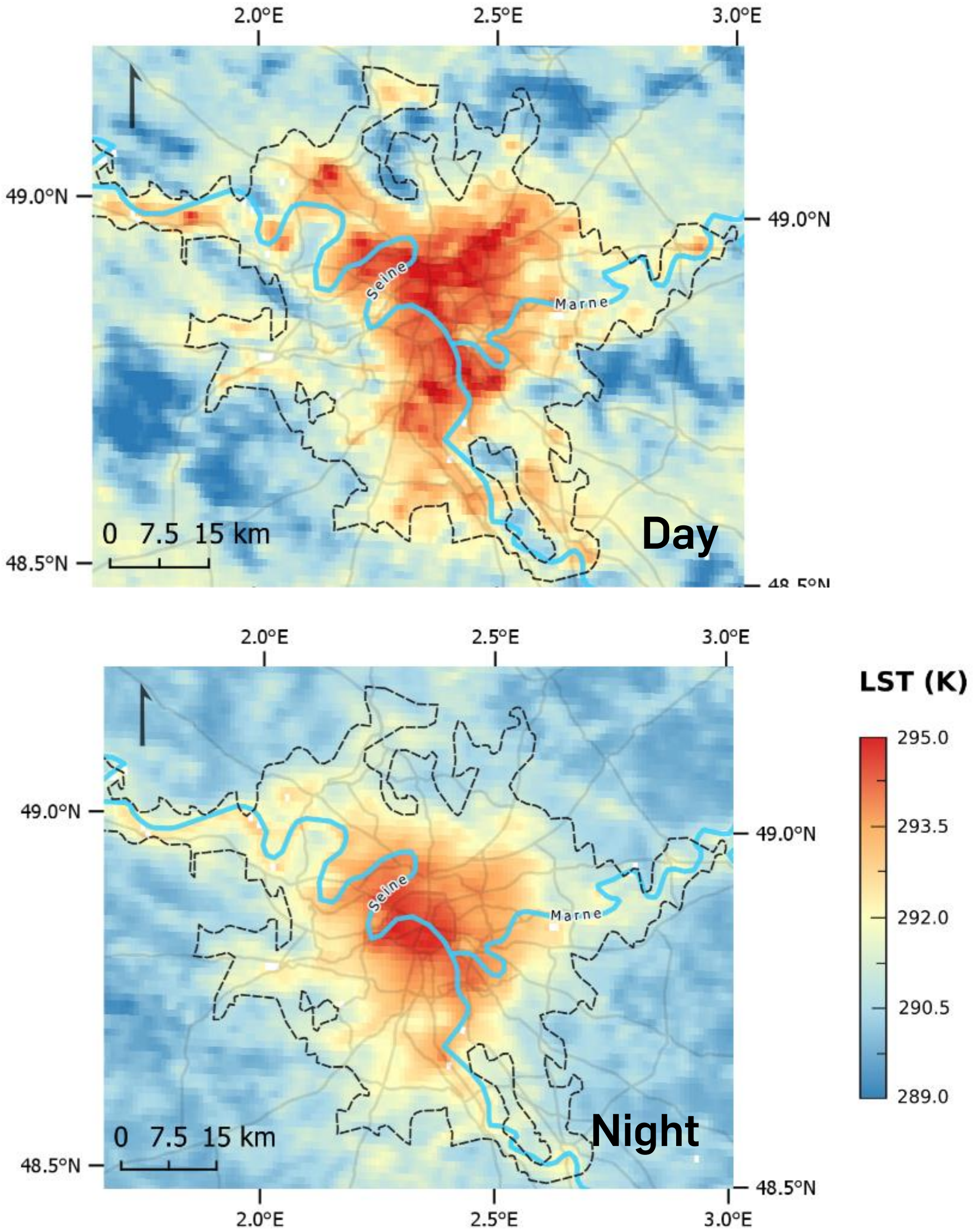




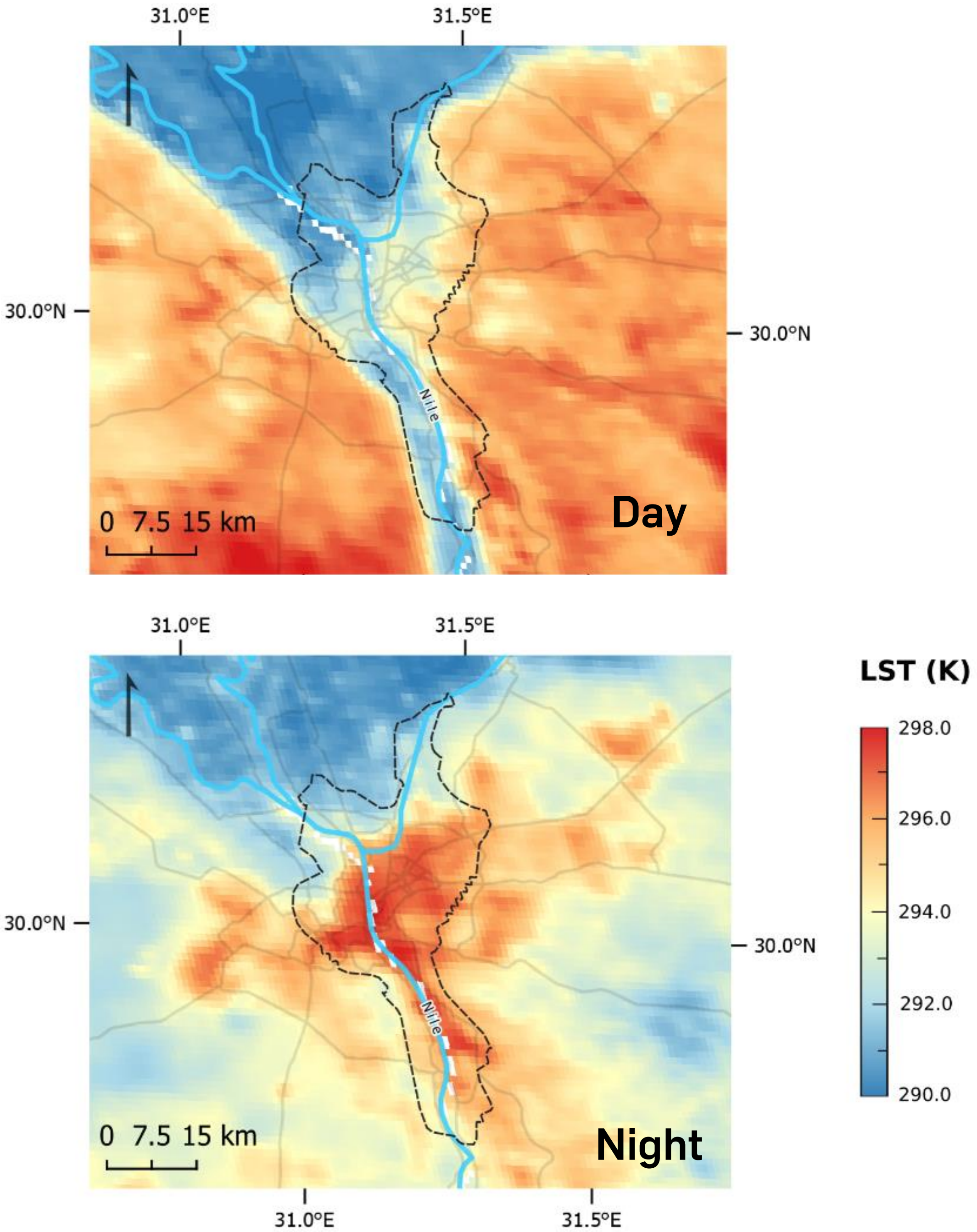
Athens, Greece

Paris, France



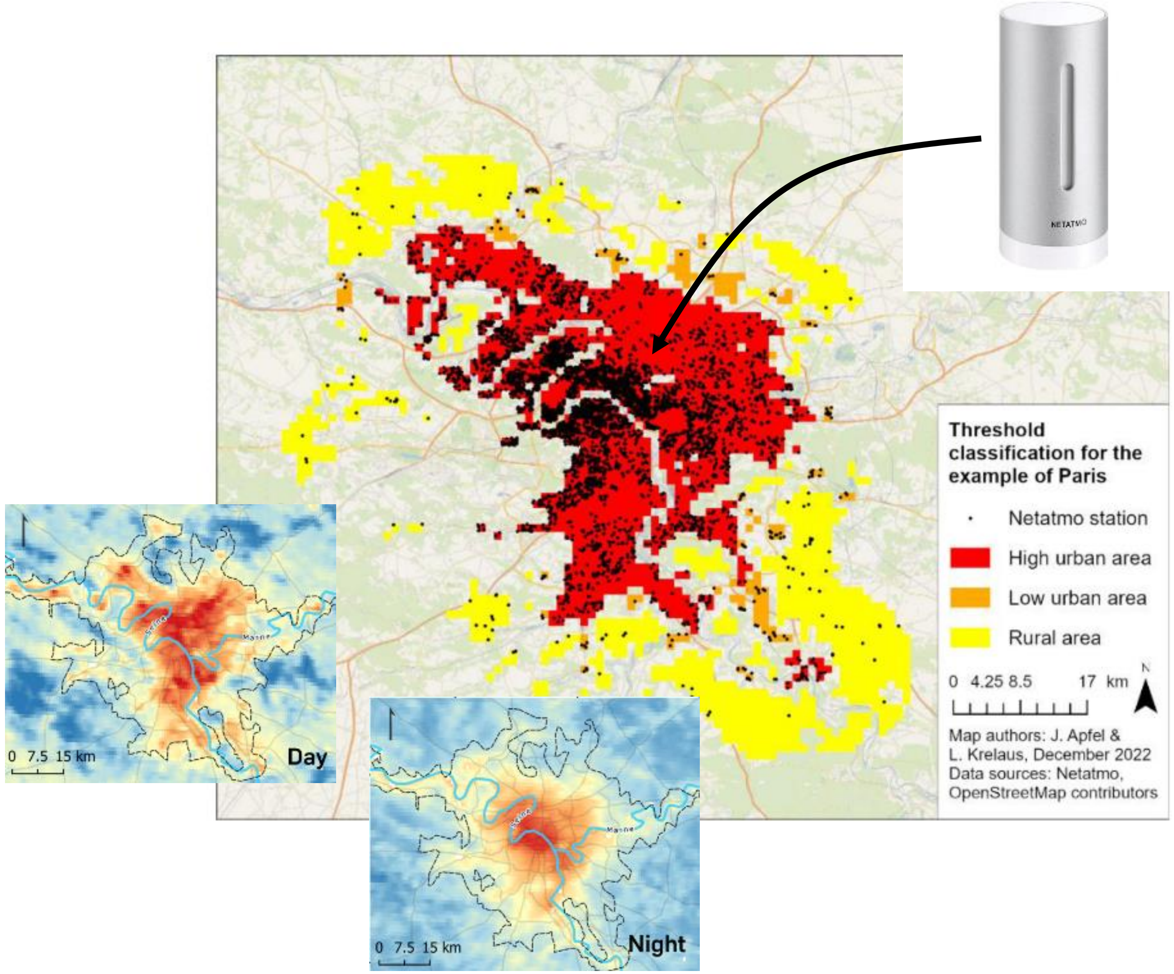


Cairo, Egypt



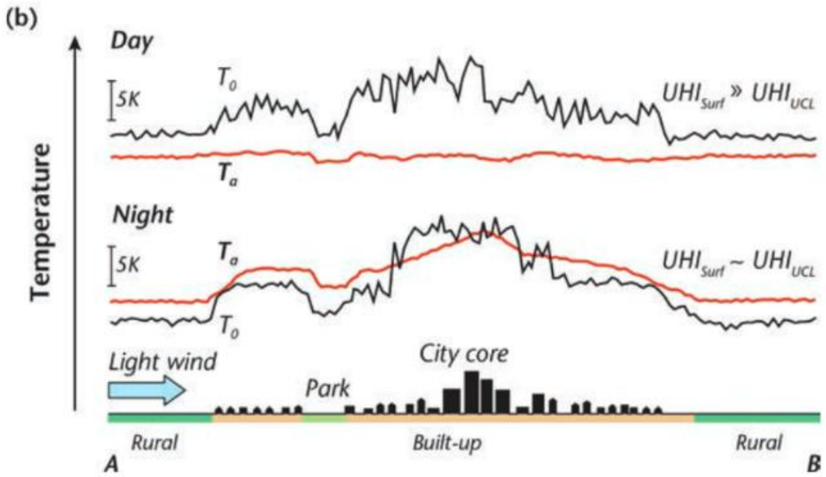
Data: LST_cci Terra MODIS

SUHII vs. CUHII



$$SUHII = LST_U - LST_R$$

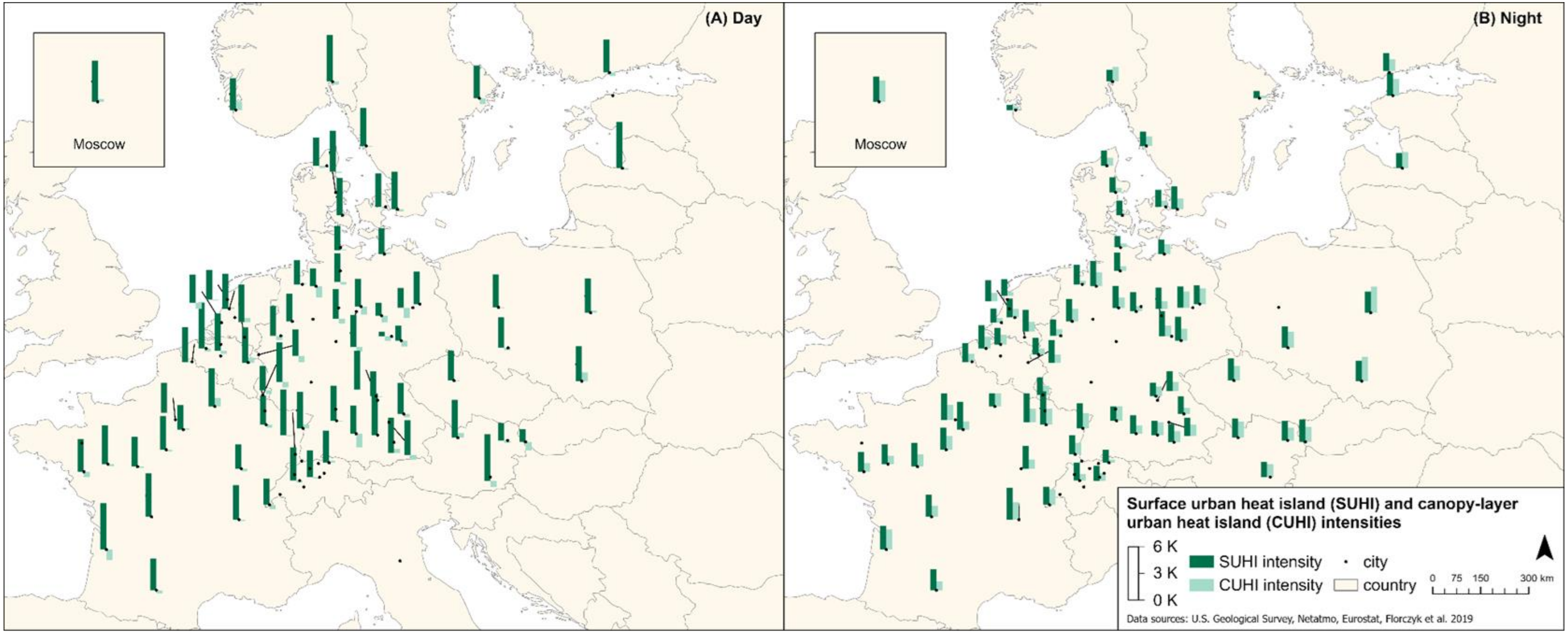
$$CUHI = AT_U - AT_R$$



Summertime 2019, 2020, and 2021

Source: Apfel and Krelaus, 2022

SUHII vs. CUHII



Source: Apfel and Krelaus, 2022

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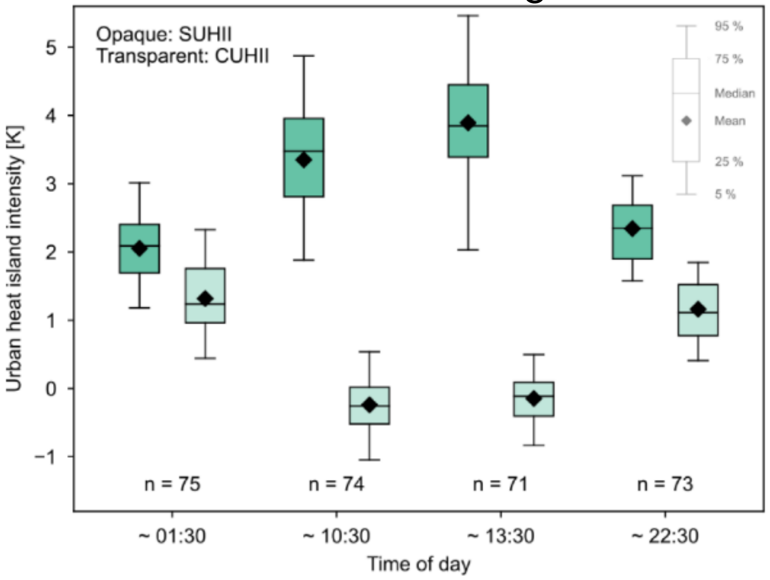
SUHII vs. CUHII

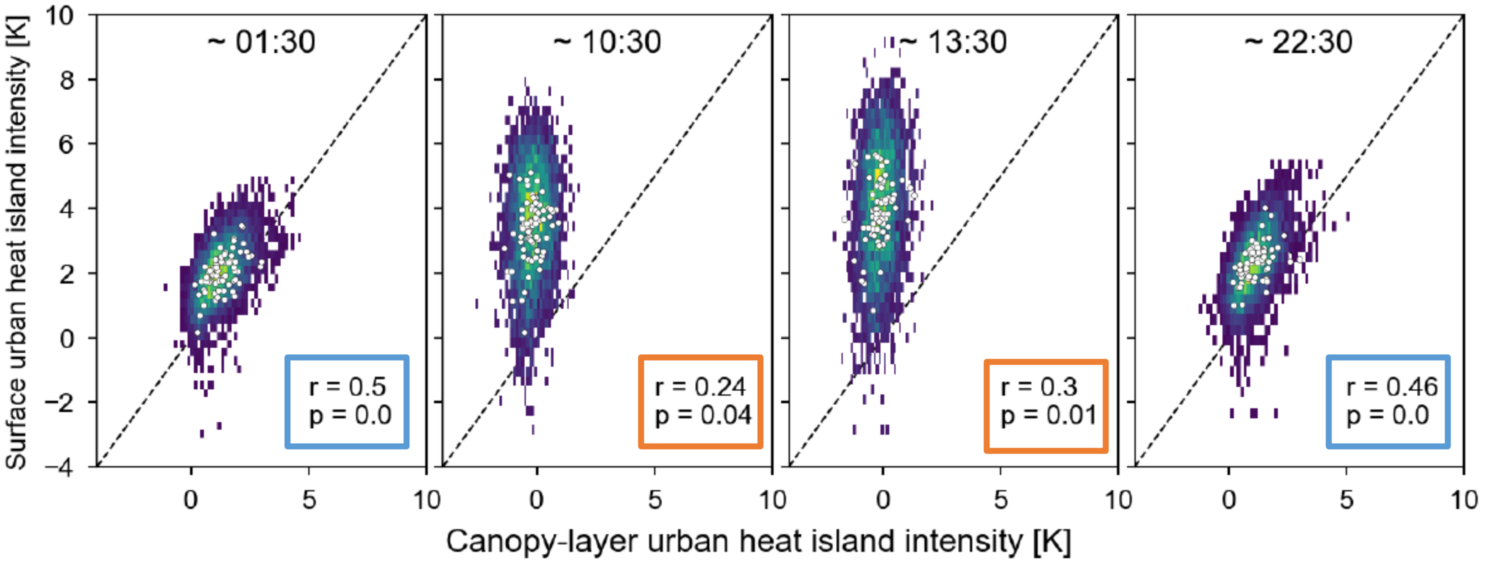
Difference in Magnitude



SUHII minus CUHII

+0.7 K +3.6 K +4.0 K +1.2 K

Agreement between the daily SUHII and CUHII



Source: Apfel and Krelaus, 2022

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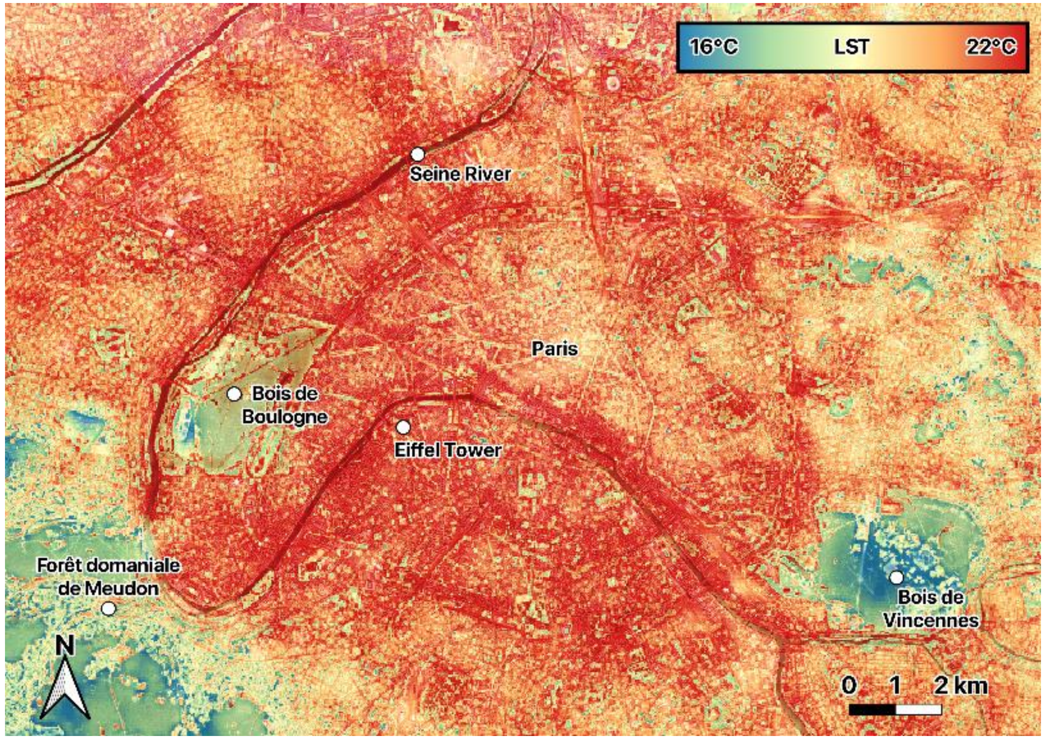
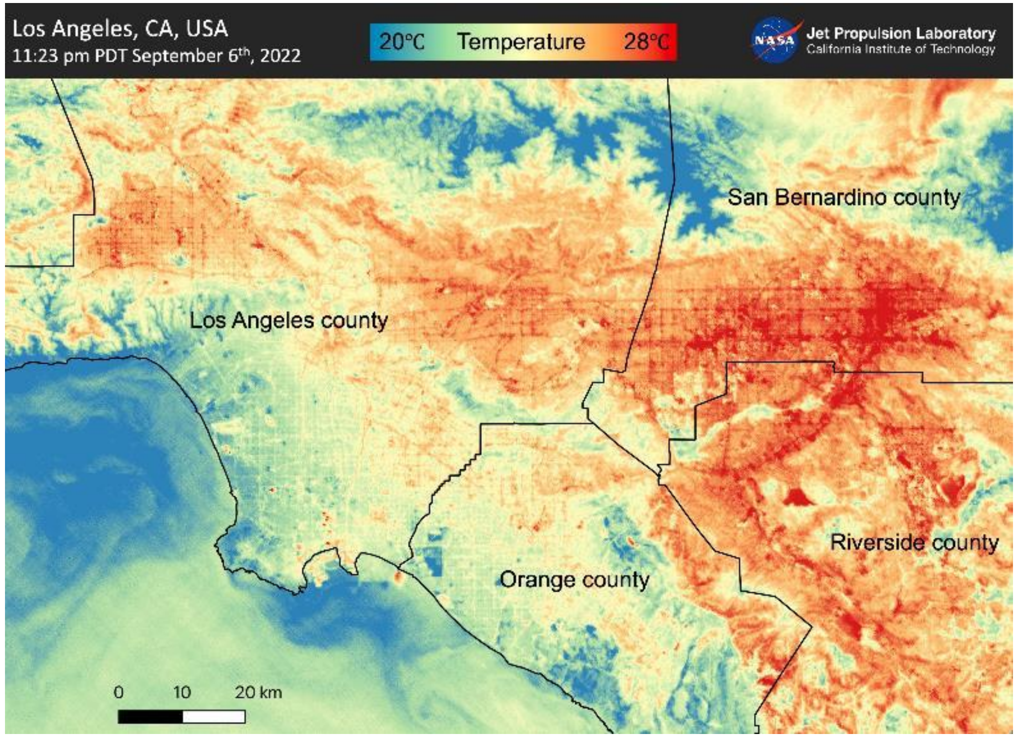
ECOSTRESS

ECOSTRESS is the only **high-resolution** TIR instrument that can provide nighttime data.

Paris, France on July 15th, 2022, 11:21 pm



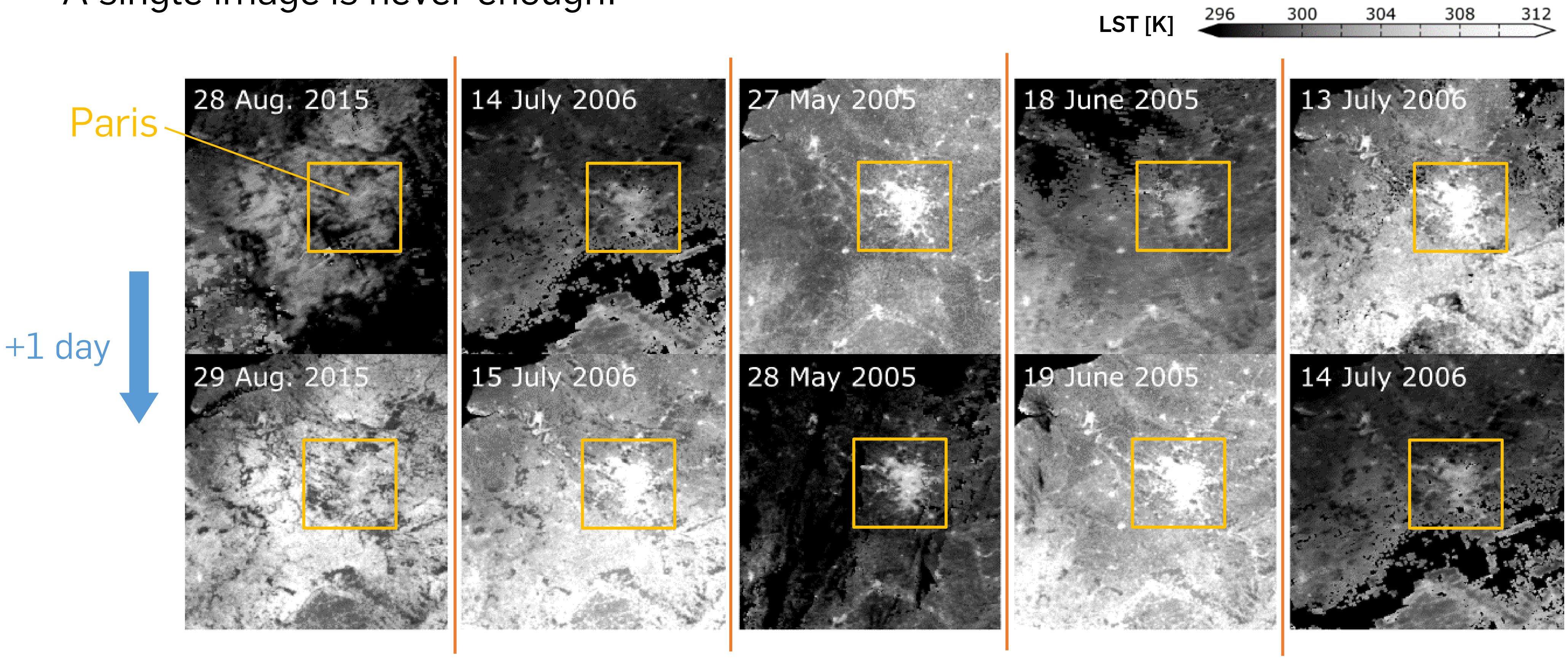
Paris, France experienced record-breaking temperatures in July 2022.



A 10-day long heatwave persisted from the end of August to September 9th with temperatures reaching well over 40 degrees Celsius in some regions

High Spatiotemporal Variability

A single image is never enough!



Aqua MODIS, **Daytime** Data

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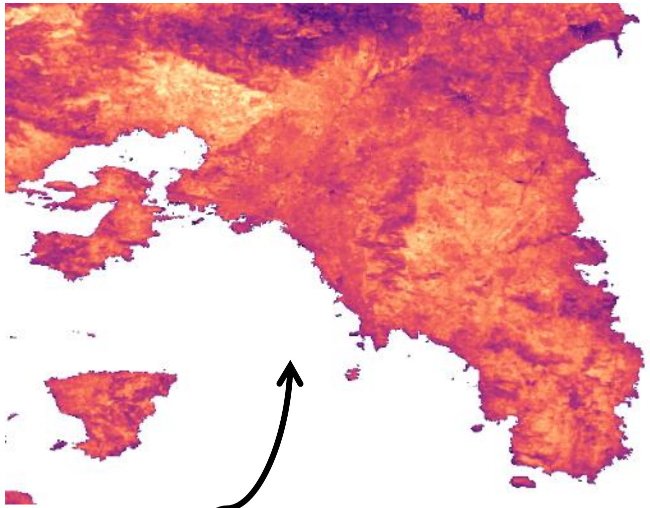
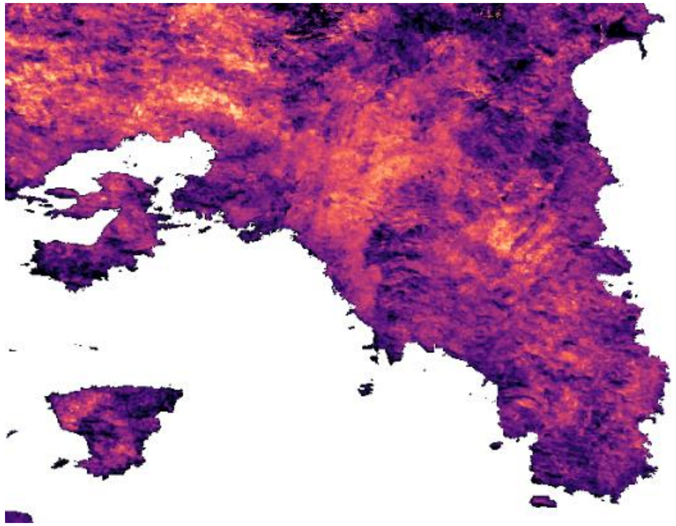
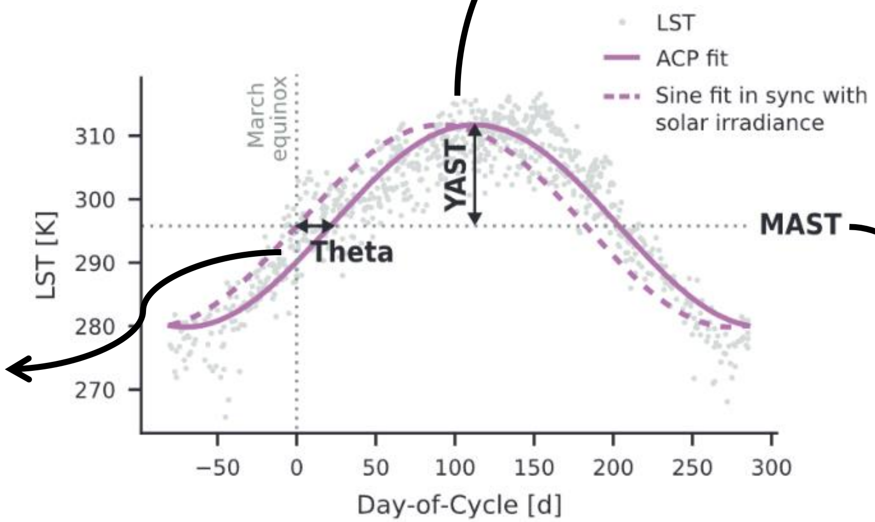
Annual Cycle Parameters (ACP)

LST Annual Amplitude [K]

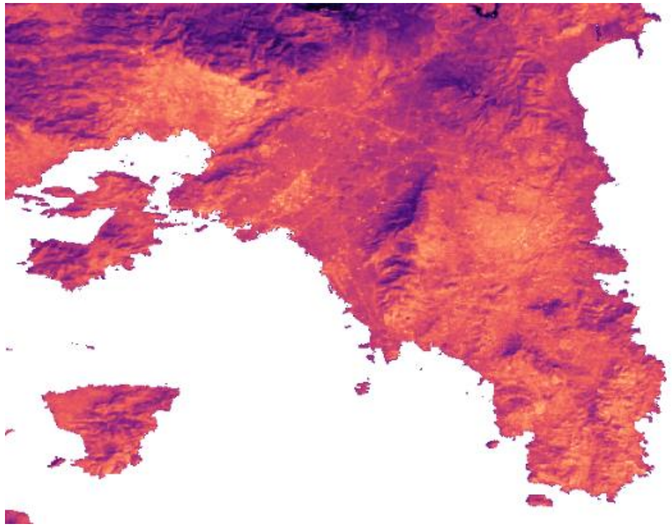


LST peak time lag [days]

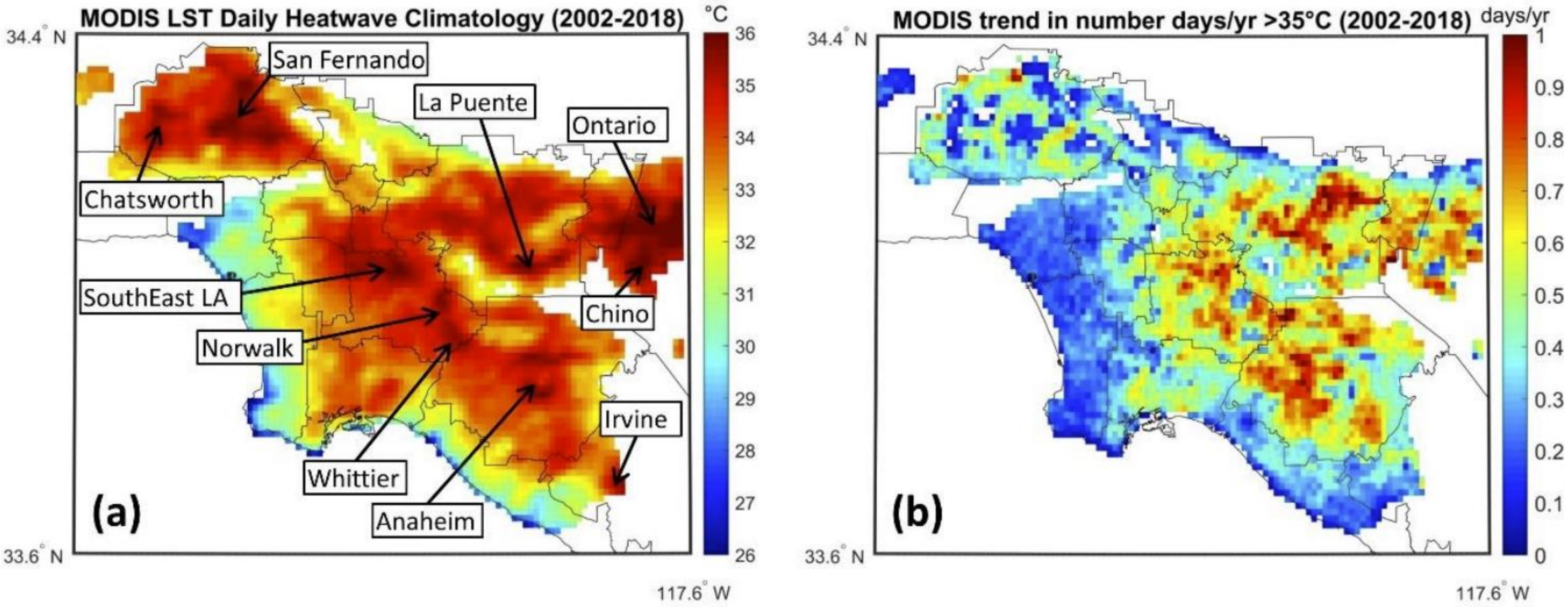




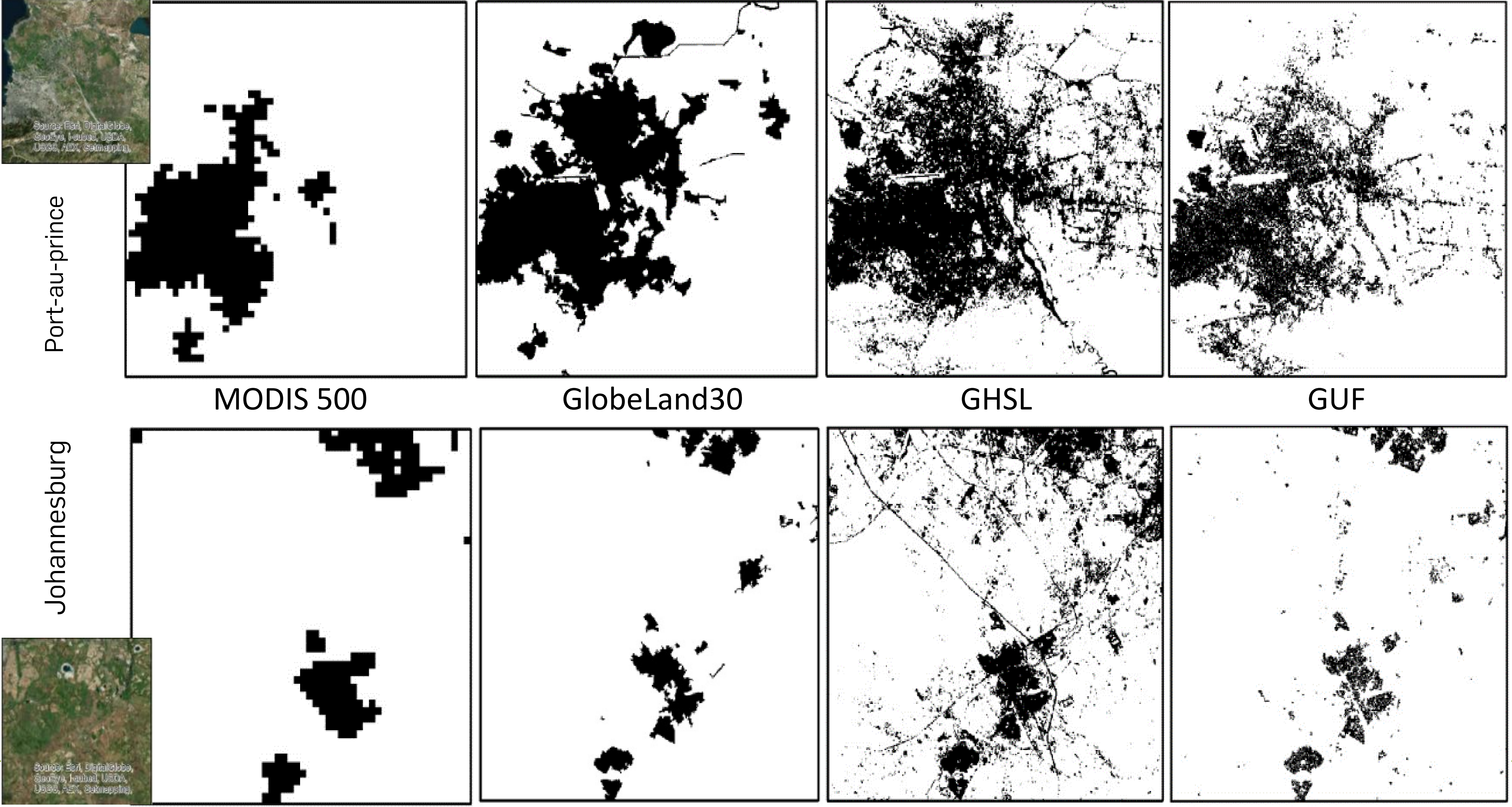
Mean Annual LST [K]



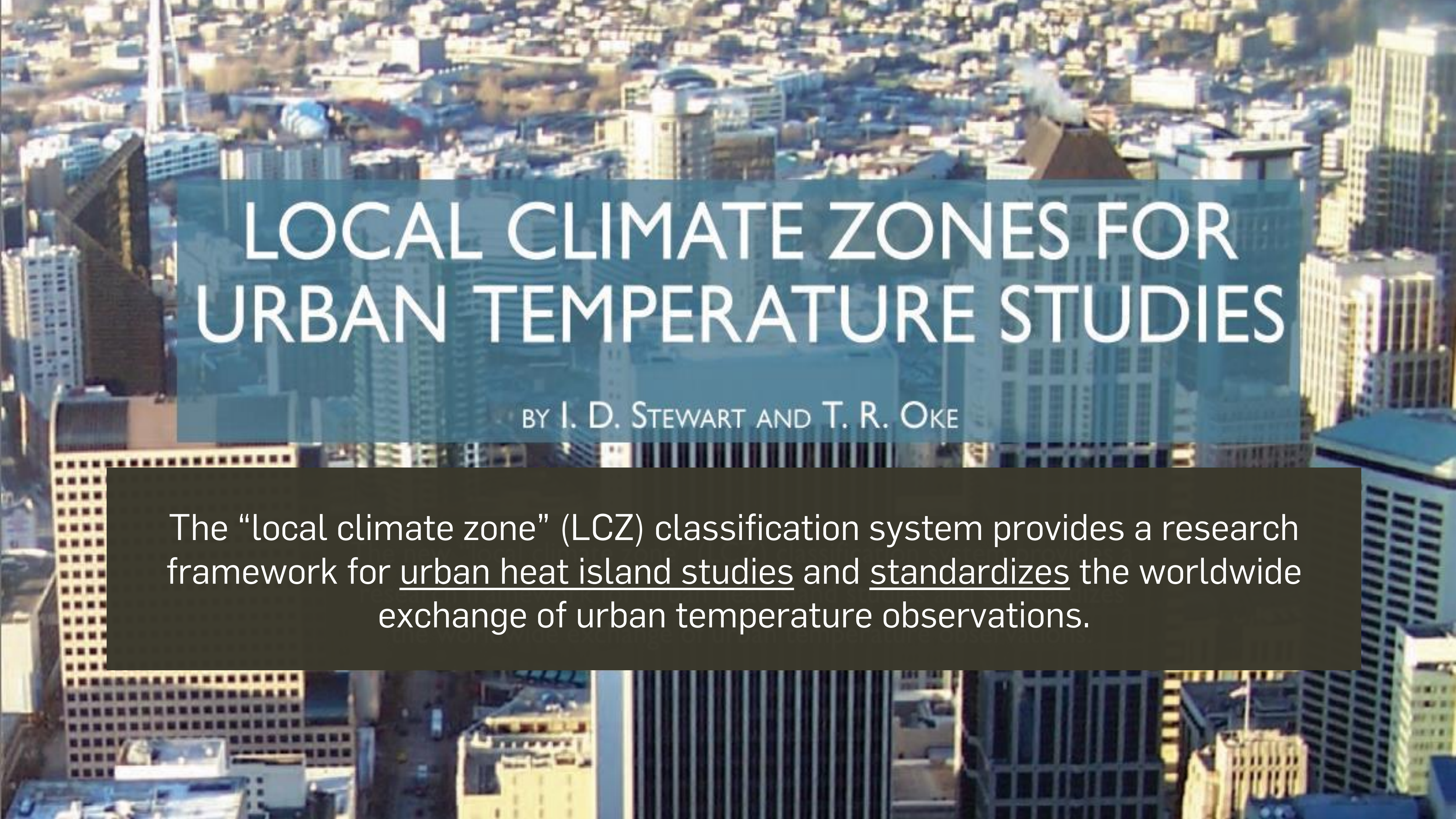
LST Heatwave Climatology and Trends



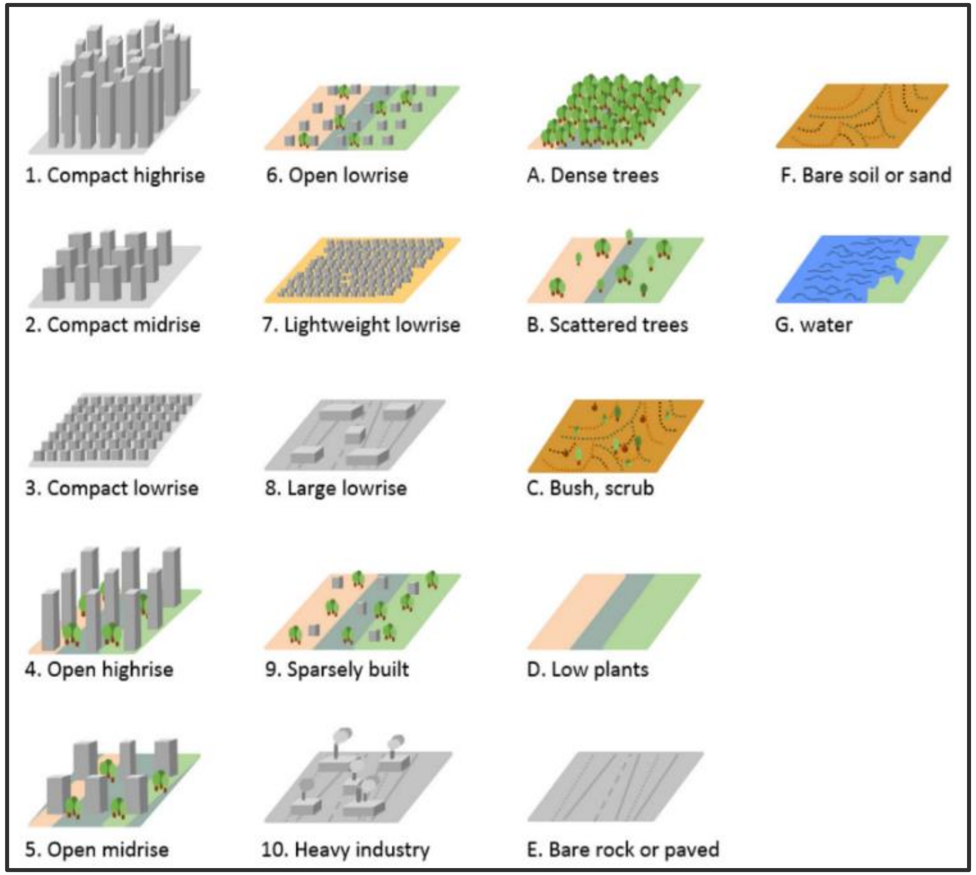
Source: Hulley et al., 2019

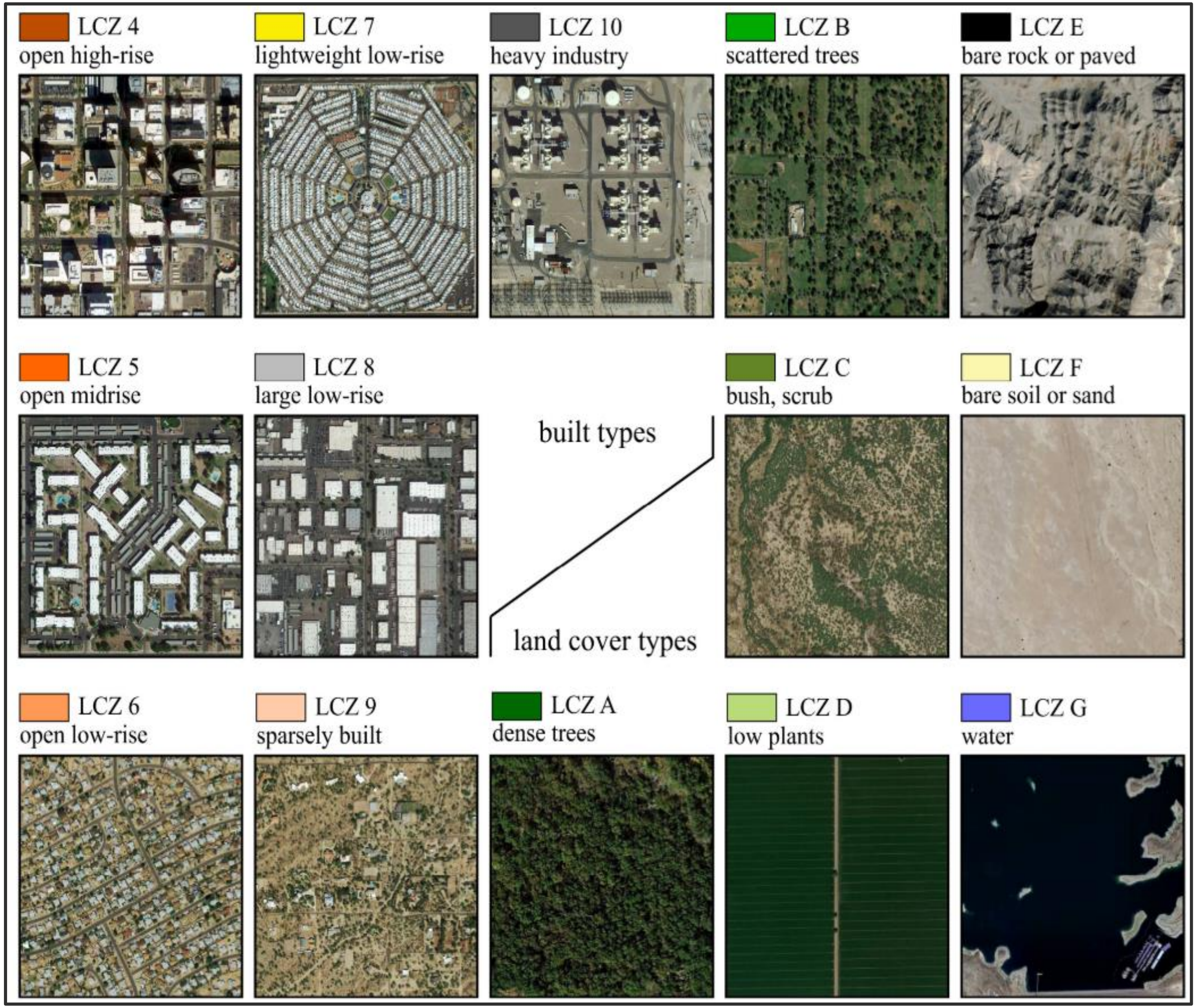


Esch et al. (2017)



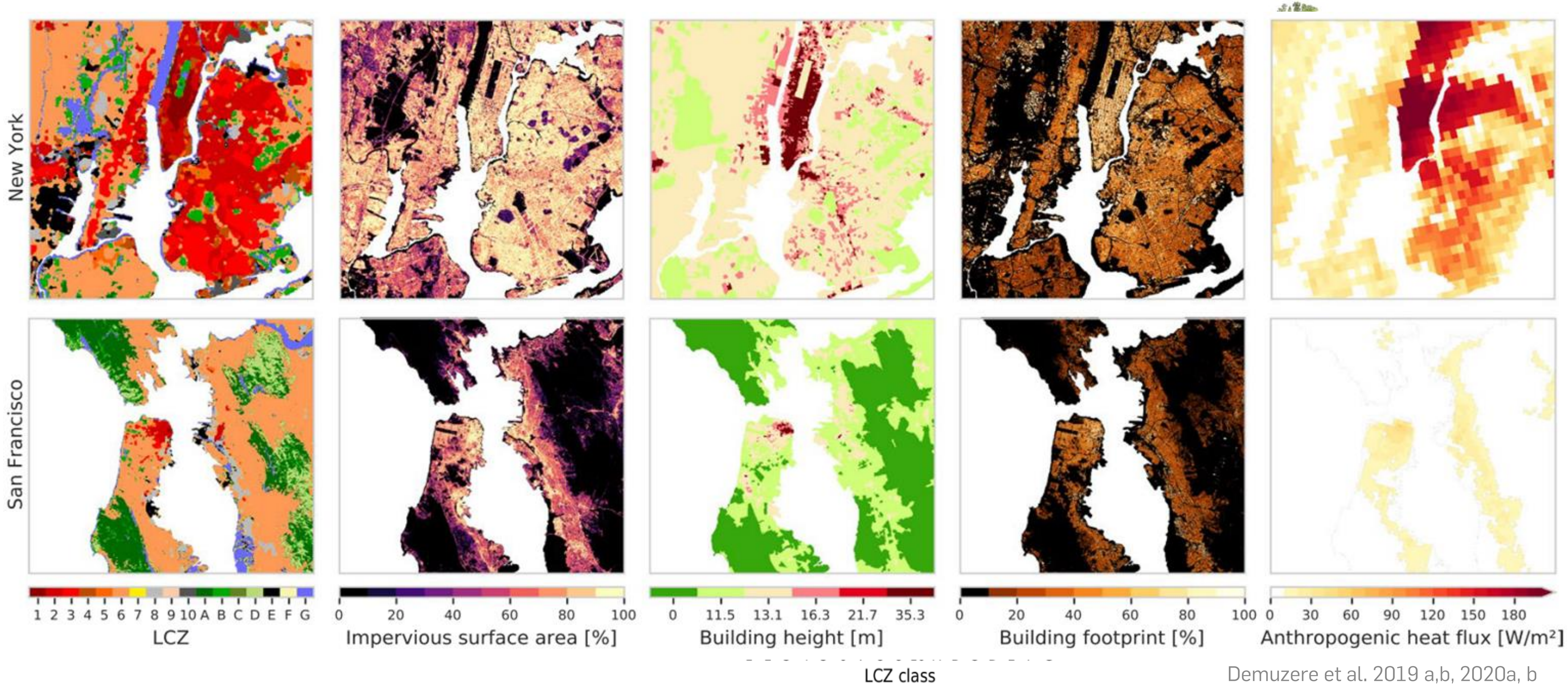
The "local climate zone" (LCZ) classification system provides a research framework for urban heat island studies and standardizes the worldwide exchange of urban temperature observations.





The “local climate zone” (LCZ) classification system provides a research framework for urban heat island studies and **standardizes** the worldwide exchange of urban temperature observations.

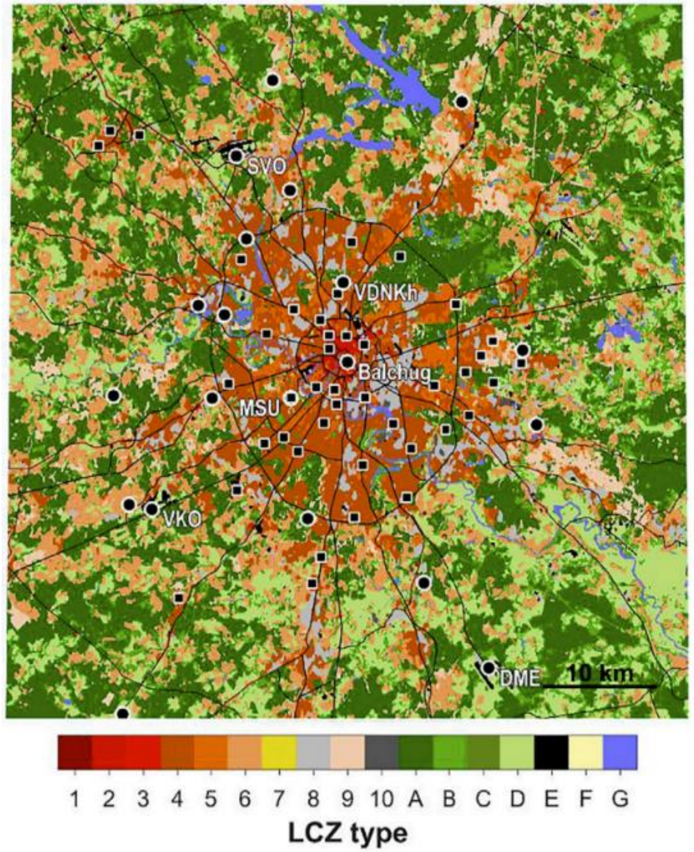
Mapping the Local Climate Zones at 100 m



Demuzere et al. 2019 a,b, 2020a, b

Why to use them?

Moscow, Russia



Source: Varentsov et al. 2021

Assign a LCZ label to an image pixel or a weather station and quantify the excess urban heat:

Instead of: $\Delta T = T_{\text{urban}} - T_{\text{rural}}$

Prefer this: $\Delta T = T_{\text{LCZ 2}} - T_{\text{LCZ D}}$

$\Delta T = T_{\text{LCZ 2}} - T_{\text{LCZ 6}}$

- More informative
- More consistent

Hamburg, DE

Athens, GR

$\text{Rural}_{\text{Ham}} \neq \text{Rural}_{\text{Ath}}$

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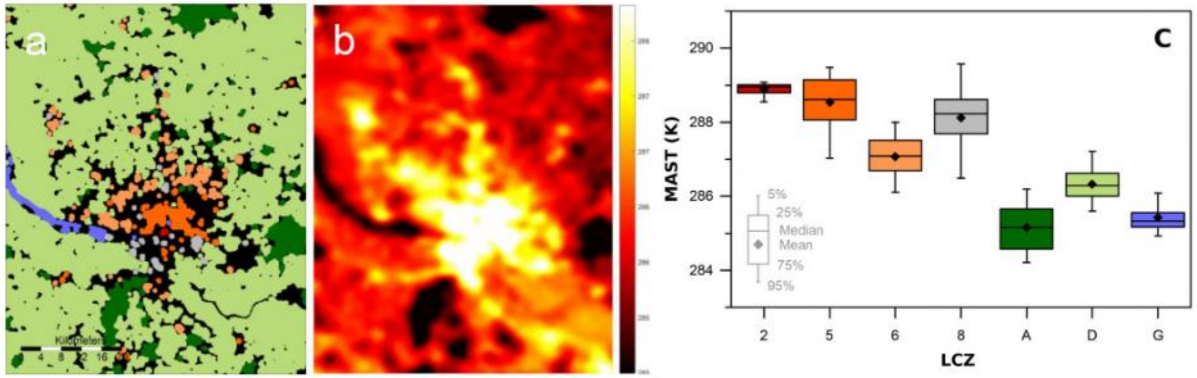
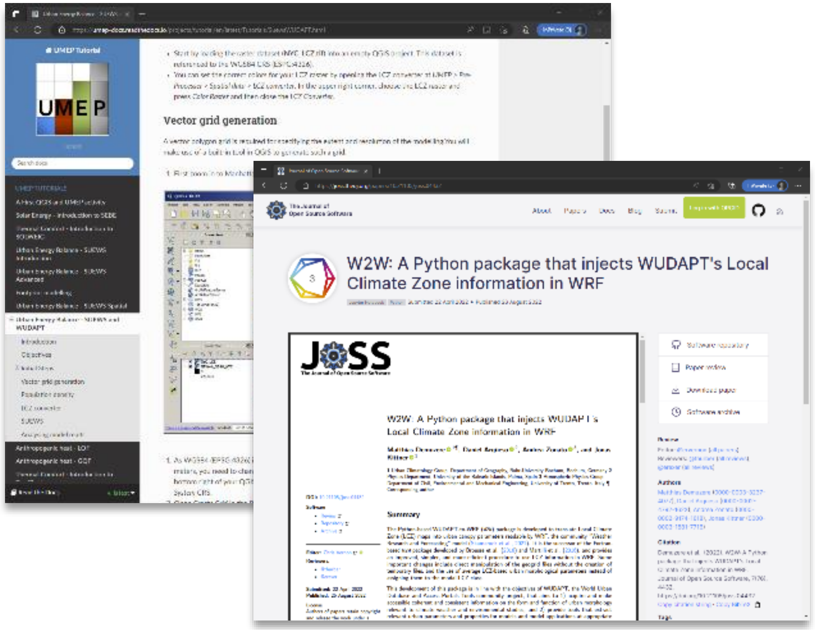
Usage Examples

To calculate **zonal statistics**



Bechtel et al. 2019

Derive **urban canopy parameterizations** (UCP) that capture aspects of morphology, material properties, etc. to inform urban climate and weather forecast models.



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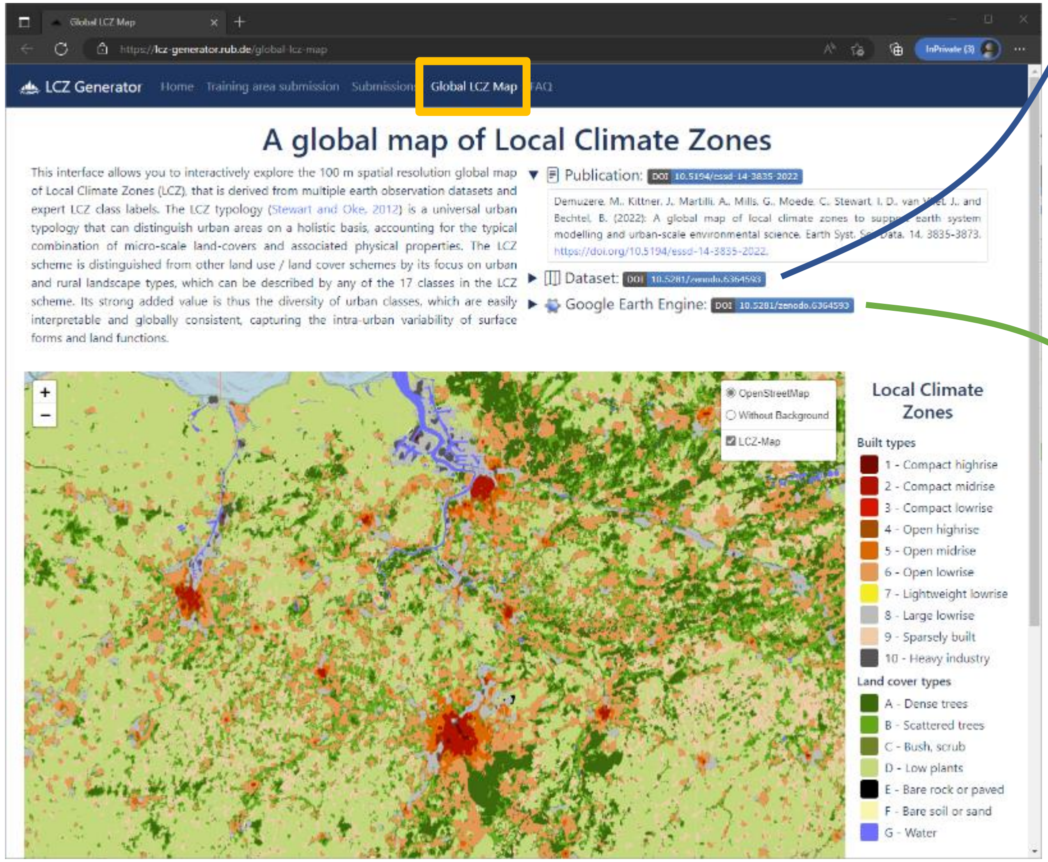
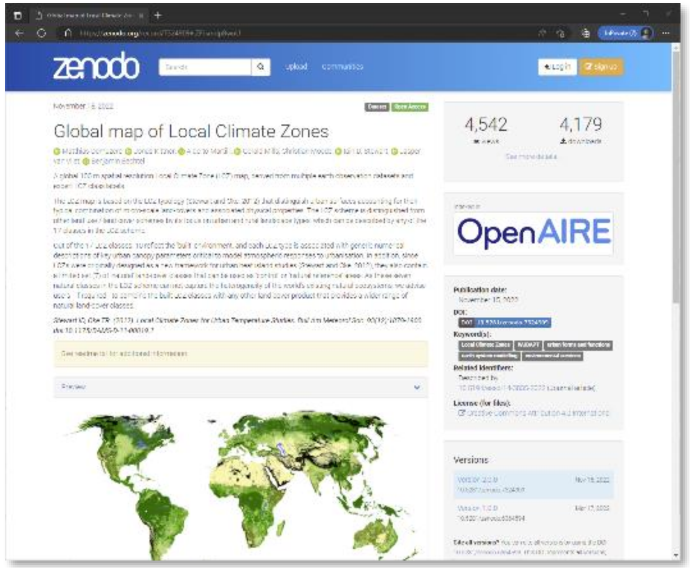
LCZ Global Map

https://**lcz-generator**.rub.de/



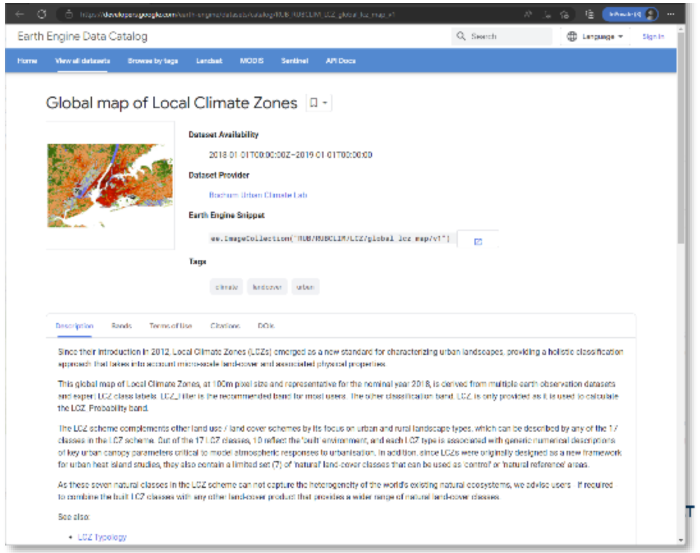
Spatial Coverage: **Global** | Spatial resolution: **100 m**

https://doi.org/10.5281/zenodo.7324909



GeoTIFF

`ee.ImageCollection("RUB/RUBCLIM/LCZ/global_lcz_map/v1")`

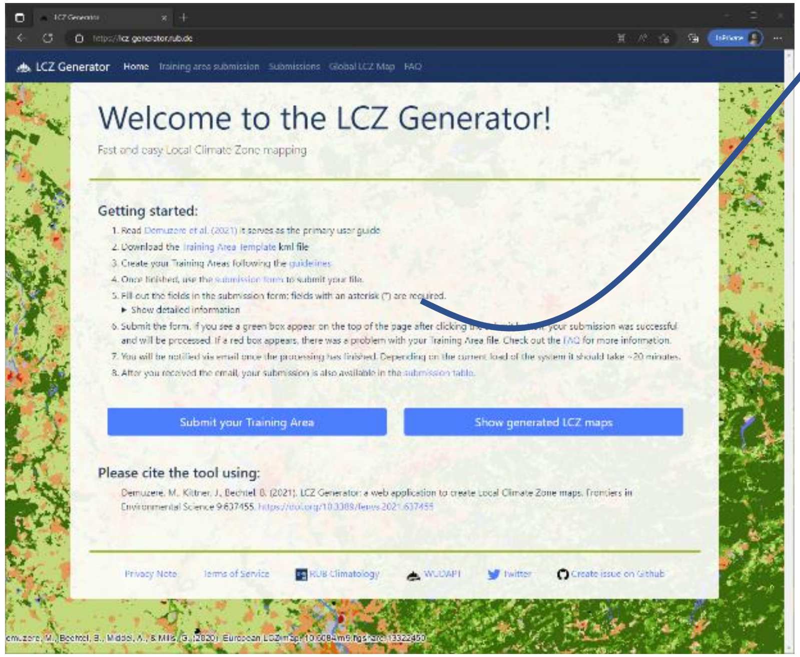


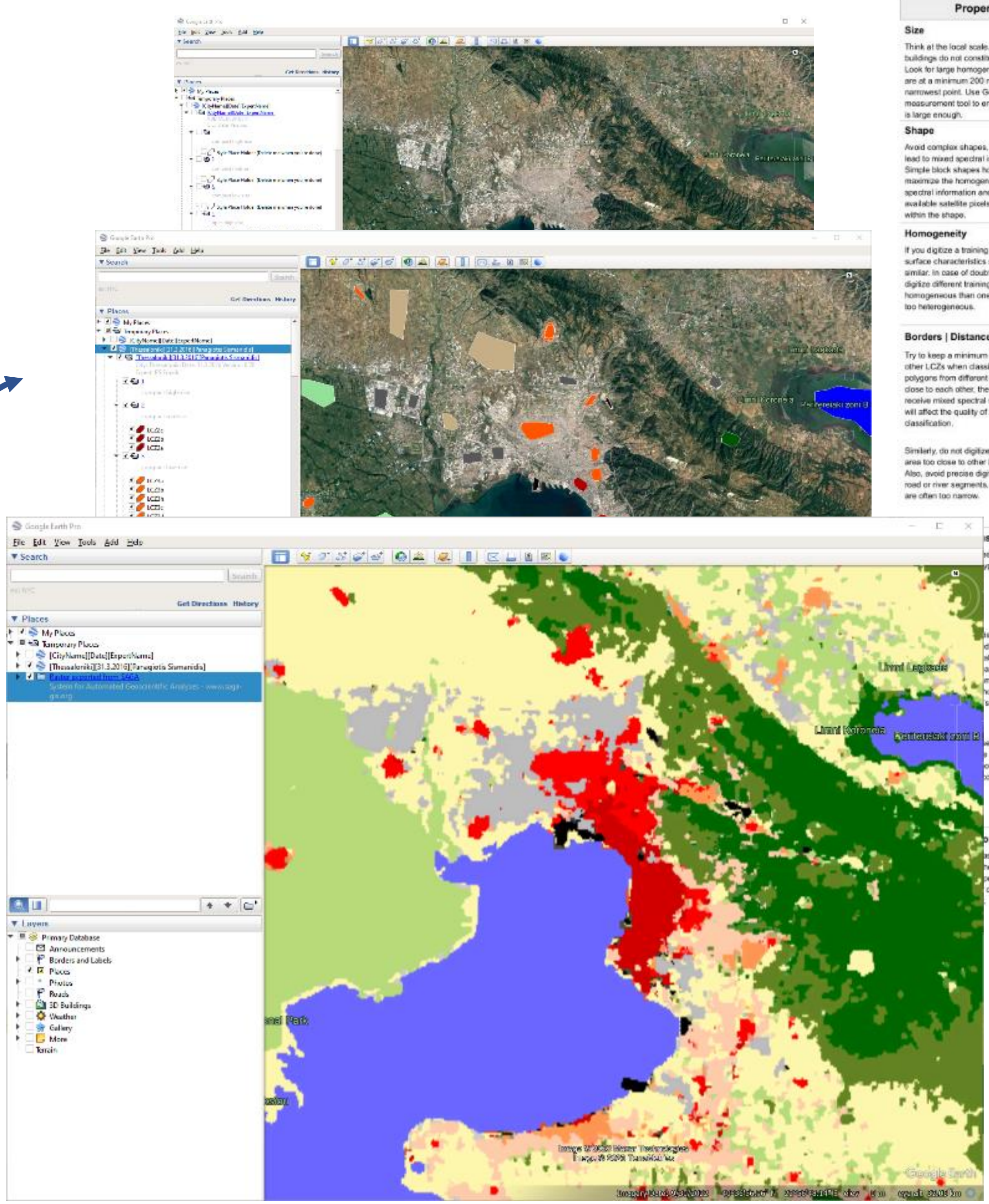
Google Earth Engine

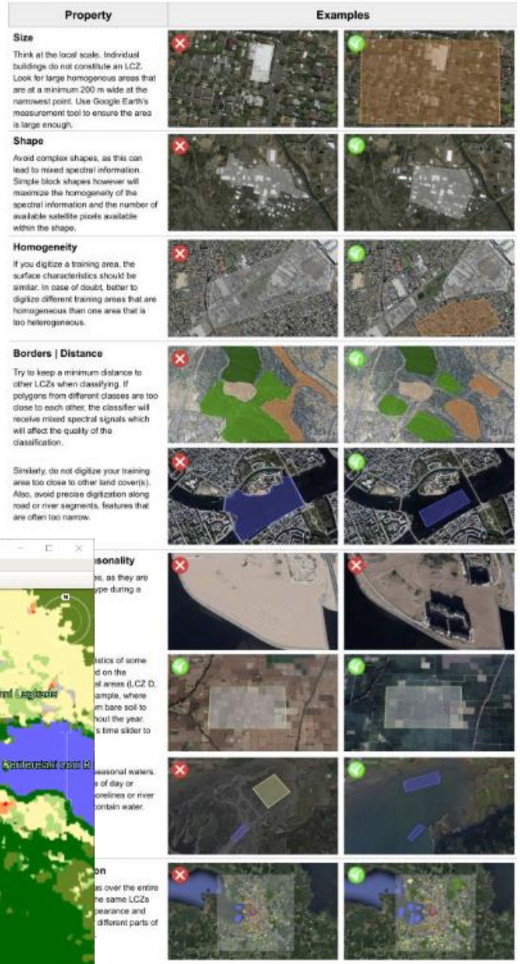
RUB

LCZ Generator

https://**lcz-generator**.rub.de/







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Take Home Messages

- Use **nighttime LST** to study the urban thermal environment.
- Use LST **time series**; a single image is never enough.
- Use the **LCZ** to characterize the urban environment and analyze the LST data.

Thank you!

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