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POTENTIAL OF ECOSTRESS DATA TO IMPROVE UHI MODELING DURING WARM SEASON

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28 Aug - 1 Sept 2023



Context

Several techniques for assessing the UHI



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Several techniques for assessing the UHI



Objectives

- Studying correlation between land surface temperature (LST) data obtained from the ECOSTRESS thermal radiometer and air temperatures.
- Analyzing the variability of LST and air temperatures in relation to urban morphology and land use through Wudapt local climate zone (LCZ) classification.
- Mapping the spatial distribution of temperatures and analyzing the UHI effect on the city of a medium size city (Metz, France).

Study area

The Metz metropolitan area is a European medium sized city with a semi-oceanic temperate climate.

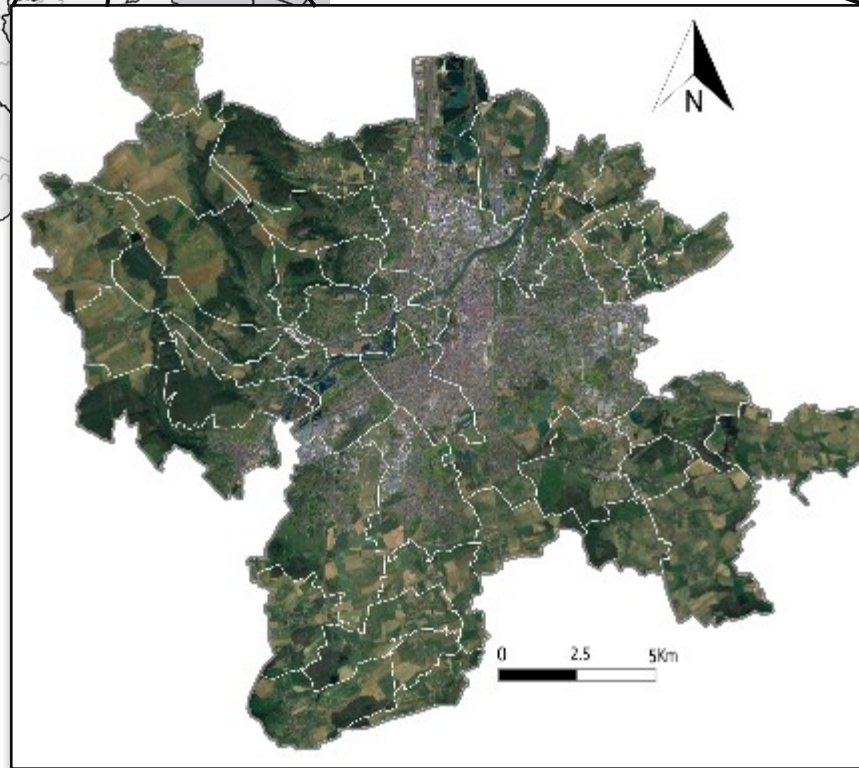
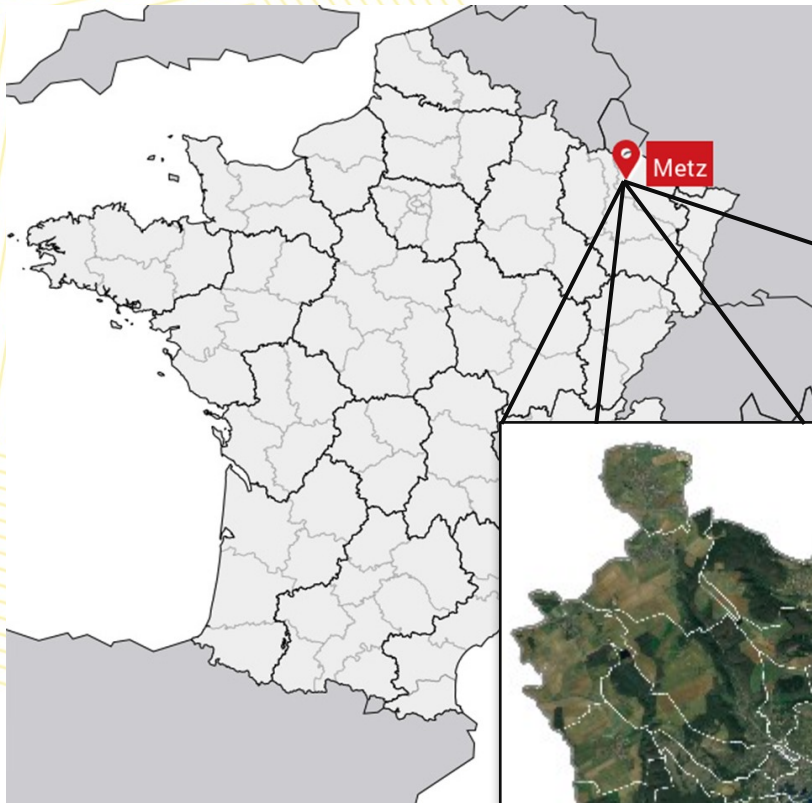
Downtown: narrow streets with close buildings.

Surface: 306 km²

<P_{year}>: 850mm

Inhabitants: 225 000

<T_{year}>: 10.6°C



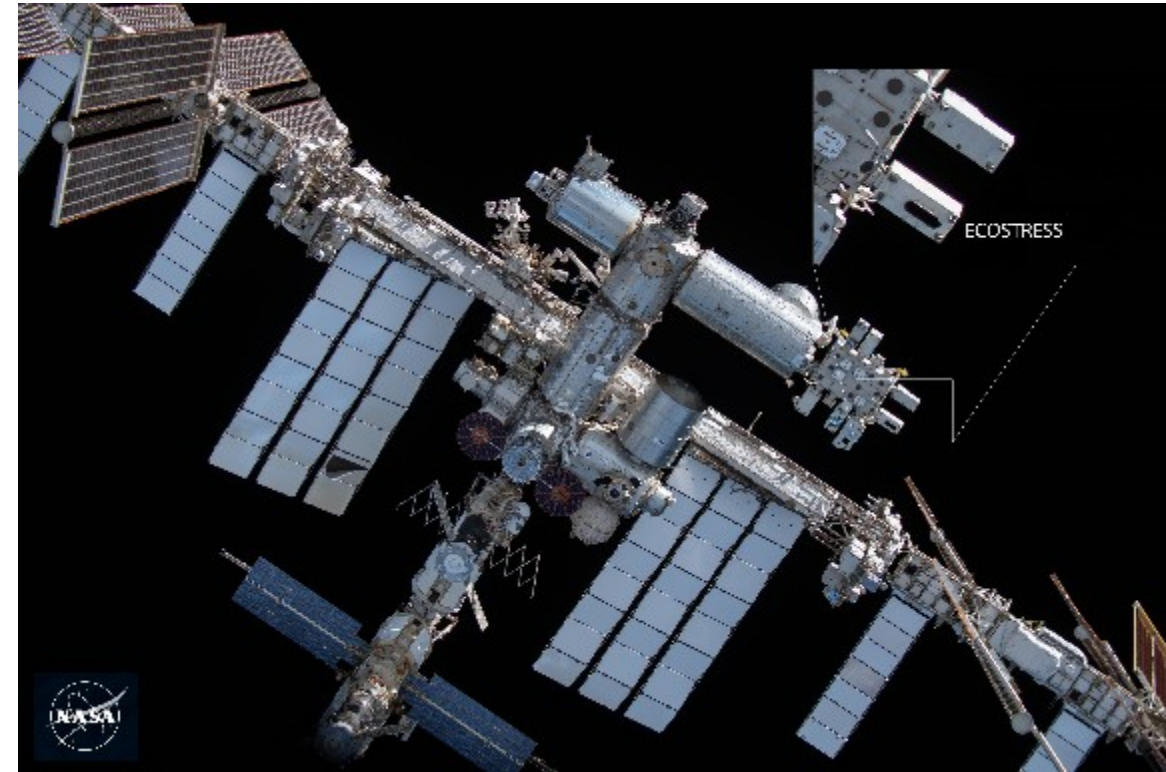
Satellite data

ECOSTRESS Radiometer

Orbit: ISS orbit (53.6 °S to 53.6 °N) / pass

Operational since July 2018.

Sensor Characteristics: 5 spectral bands
in the 8 - 12.1 μm range

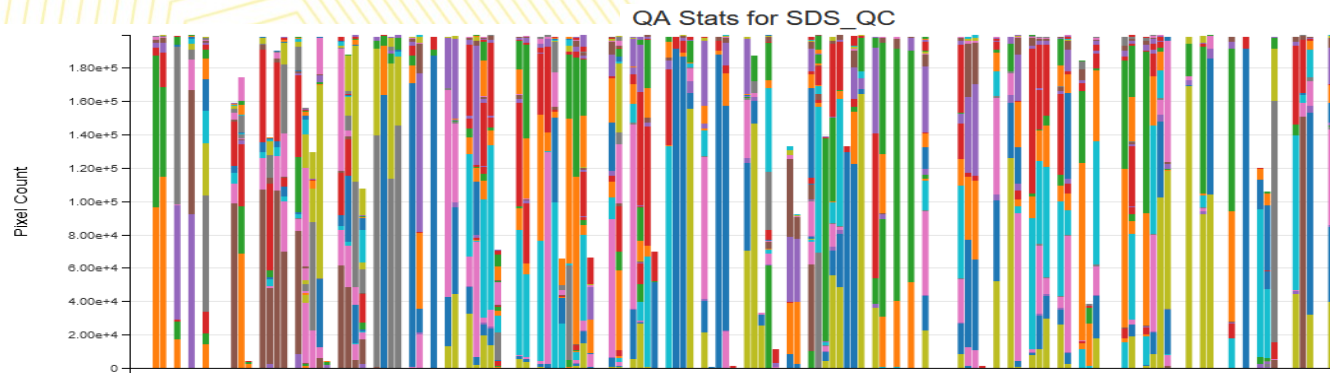


Thermal Image Characteristics LST2:

- Imagery aggregated from the native spatial resolution (70m x 38m) to pixels of $\sim 70\text{m} \times 70\text{m}$
- Accuracy : 0.15 K, Uncertainty : 0.5 K (@300K)

Satellite data

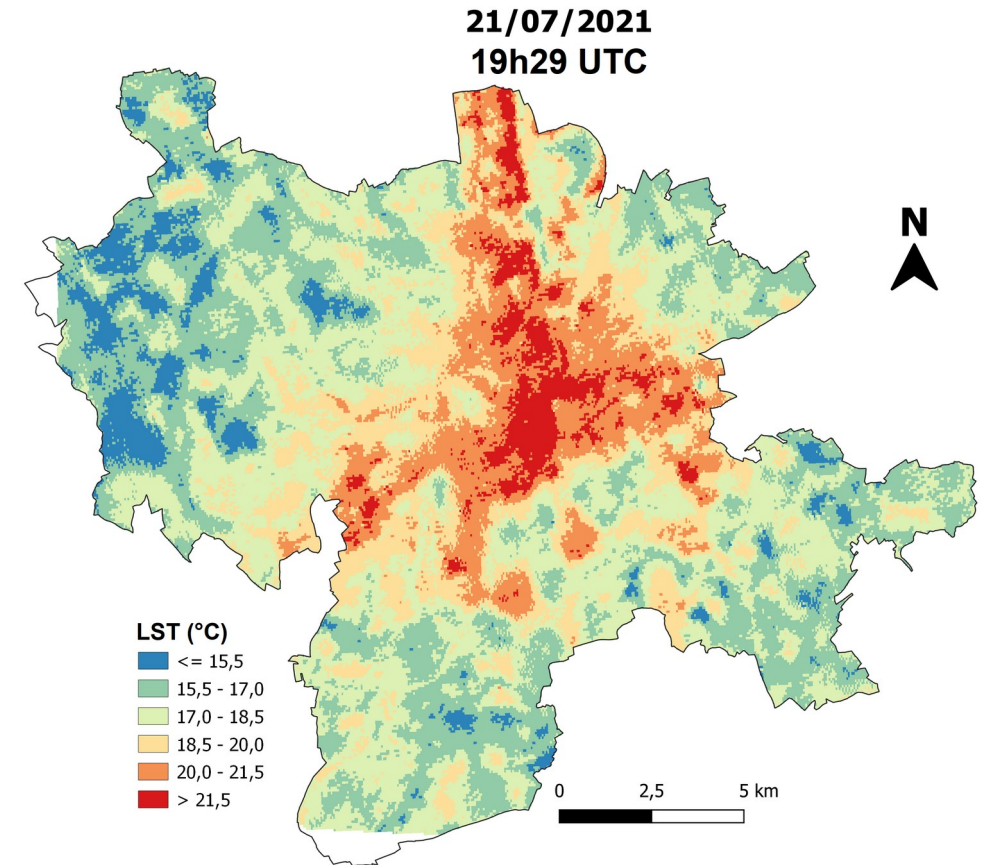
The ECOSTRESS images (scenes)



Out of 622 scenes from May to September (2019 to 2021), **47 were selected**

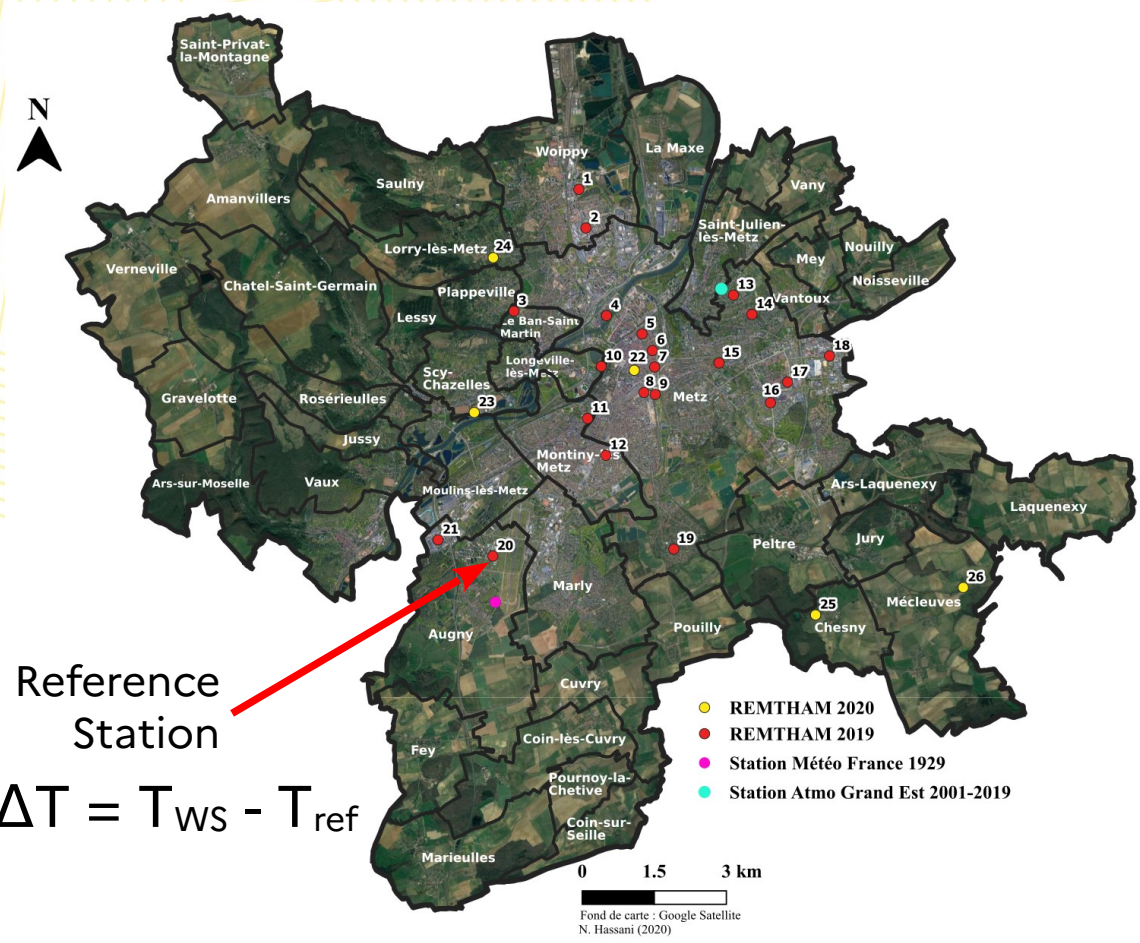
Selection of images based on accuracy and uncertainty criteria

Quality Value: 35520	Iterations: Fast
Count: 39,860 (20.1%)	Atmospheric Opacity: 0.1 - 0.2 (Nominal value)
Date: 07-21-2021	MMD: 0.03 - 0.1 (Mostly soils, mixed pixel)
Mandatory QA flags: Pixel produced, best quality	Emissivity accuracy: >0.02 (Poor performance)
Data quality flag: Good quality L1B data	LST accuracy: 1 - 1.5 K (Good performance)
Cloud/Ocean Flag: Not set. Please check ECOSTRESS GEO and CLOUD products for this information.	



Air temperature at ground level

23 measurement points between 2019 and 27 since 2020



HOBO MX2301A thermal probe



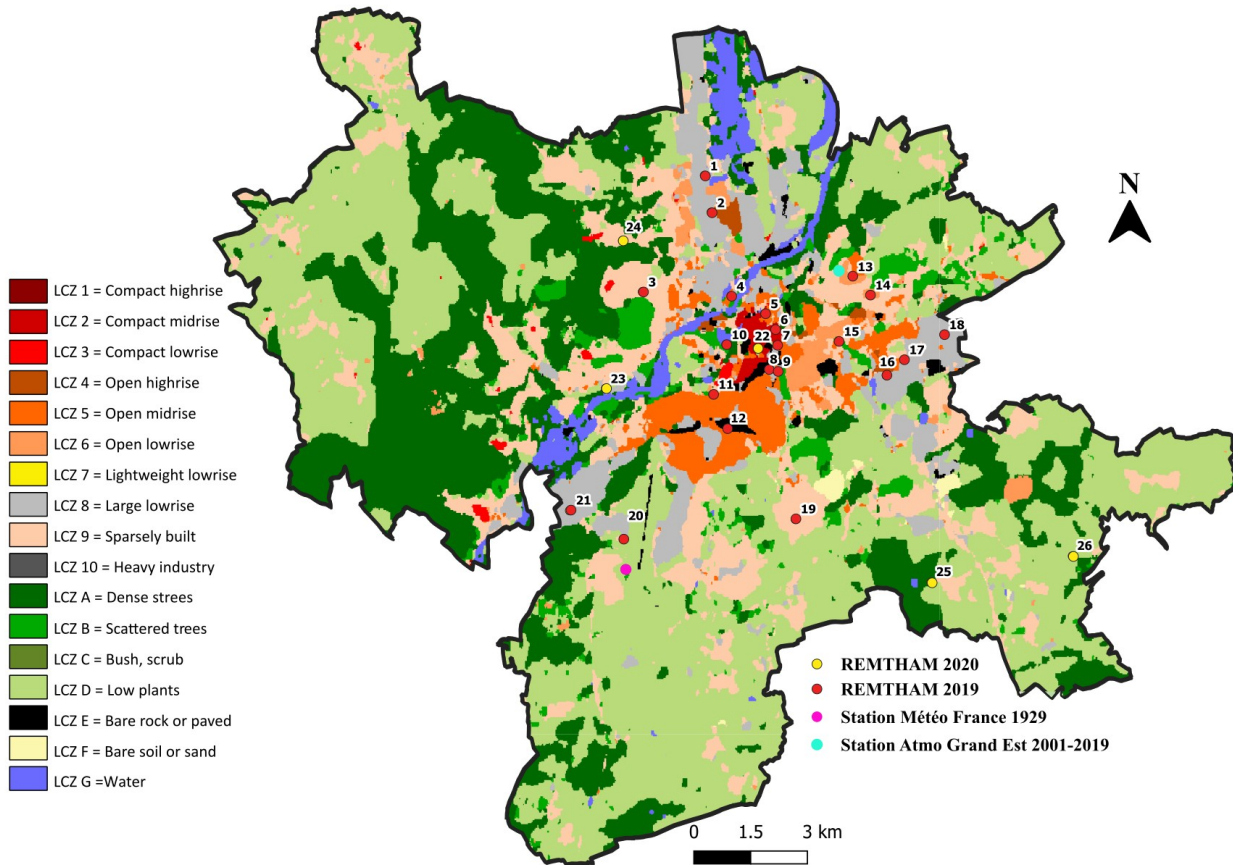
Davis Vantage Pro 2+ weather station

A network of 21 weather stations since 2019. 5 additional stations in 2020.



Method

LCZ map of Metz metropolitan area

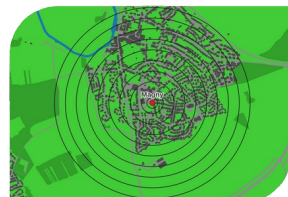
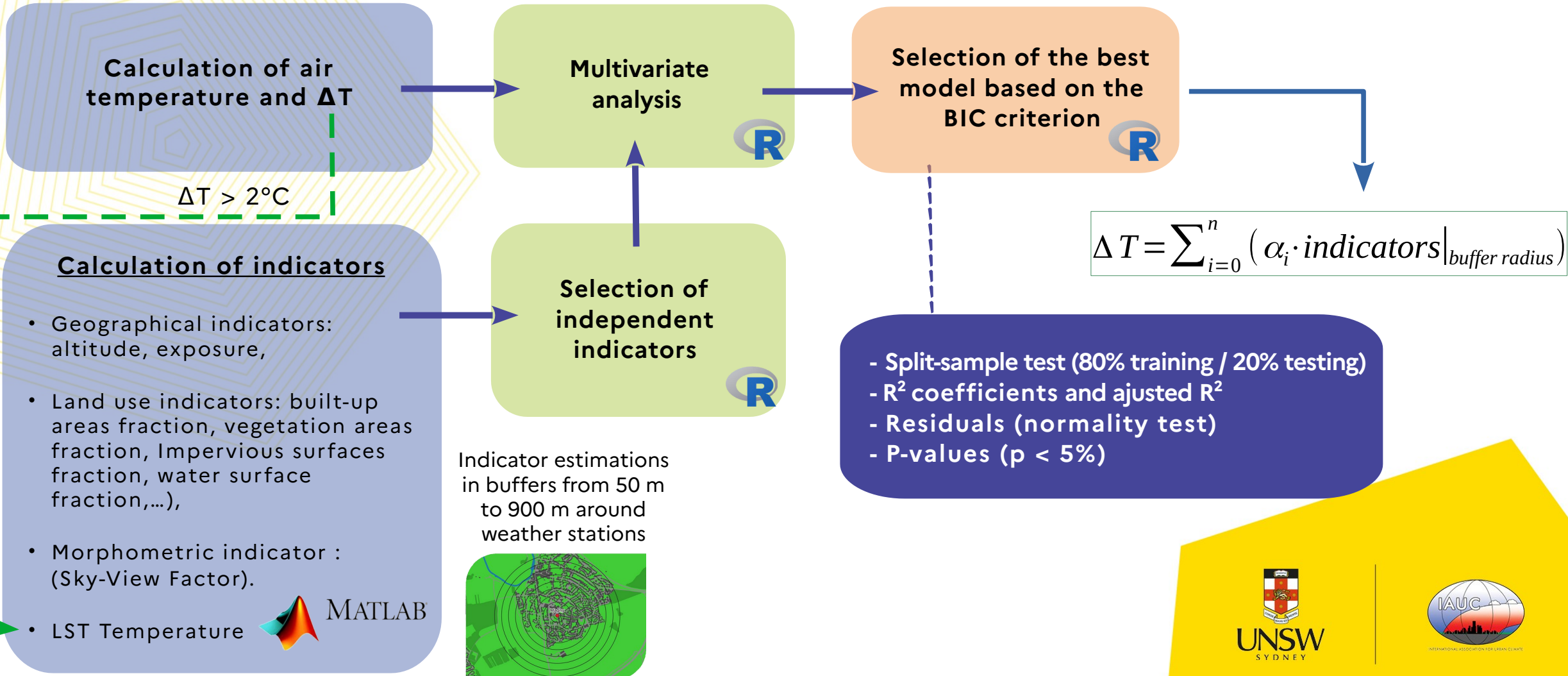


17 WS inside the 47 scenes

Nom station	N° station	Classe
Place Janne d'Arc	6	LCZ 2
Place au Lièvre	7	LCZ 3
Le-Ban-Saint-Martin	3	LCZ 6
Haut de Vallieres	13	LCZ 6
Lorry-lès-Metz	24	LCZ 6
ZAC de Sébastopol	17	LCZ 8
ZAC d'Actipole	18	LCZ 8
Jardin de la Cheneau	15	LCZ B
Les Arènes	9	LCZ B
Météo-France		LCZ D
Base-vie	20	LCZ D
Mécleuves	26	LCZ D
Plan d'eau	10	LCZ G
Scy-Chazelles	23a	LCZ G

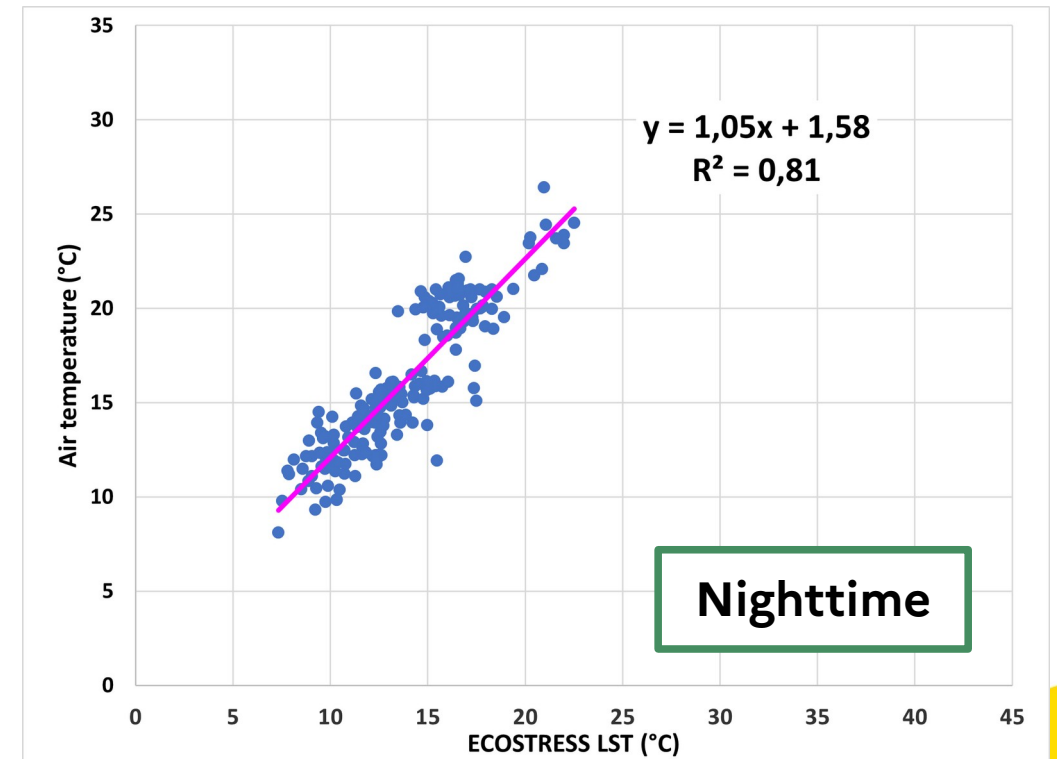
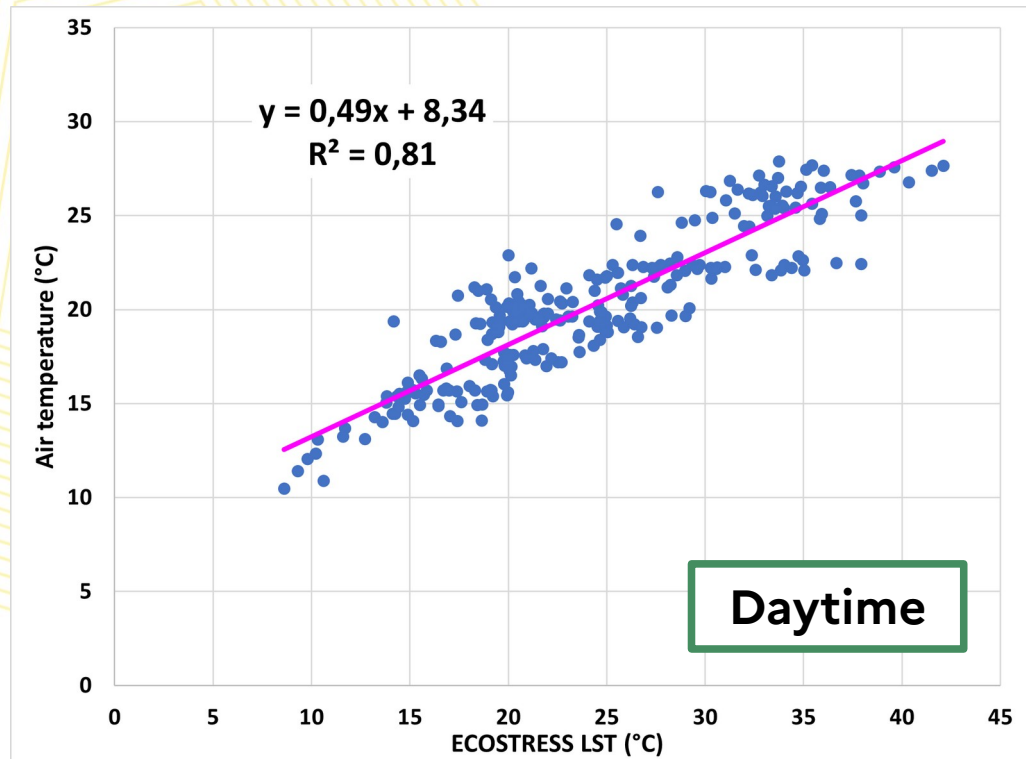
Method

Modeling



Results

ECOSTRESS LST vs Air temperatures

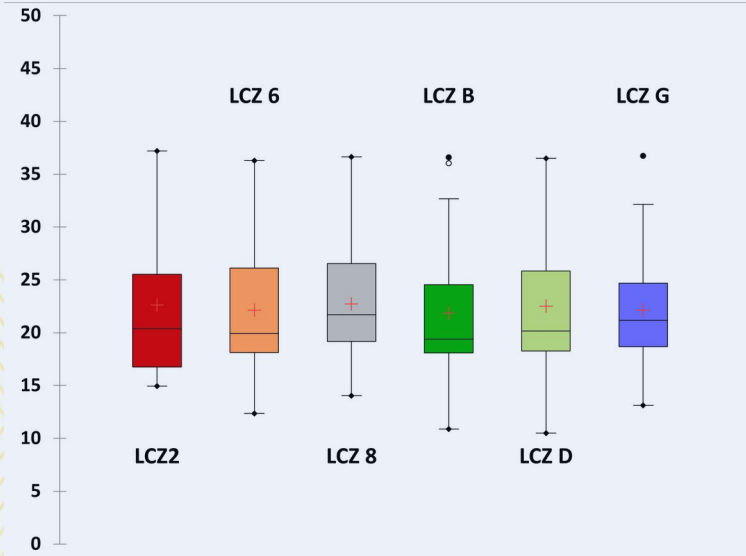


- Good linear relation between surface and air temperatures
- Identical dispersion during the day and at night
- At night, surface and air temperatures are well correlated

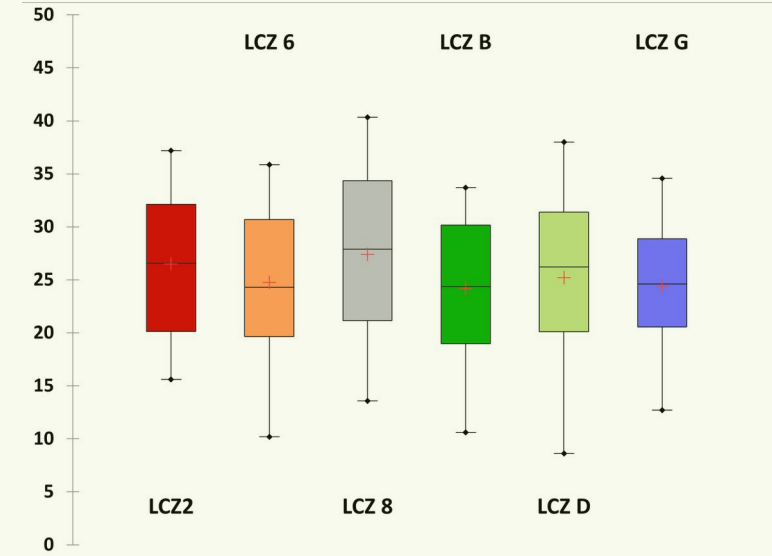
Results

LCZ Variabilities

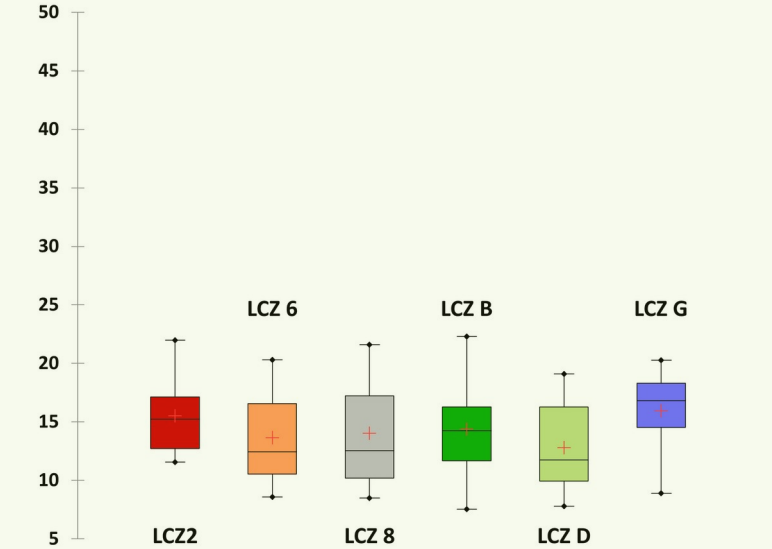
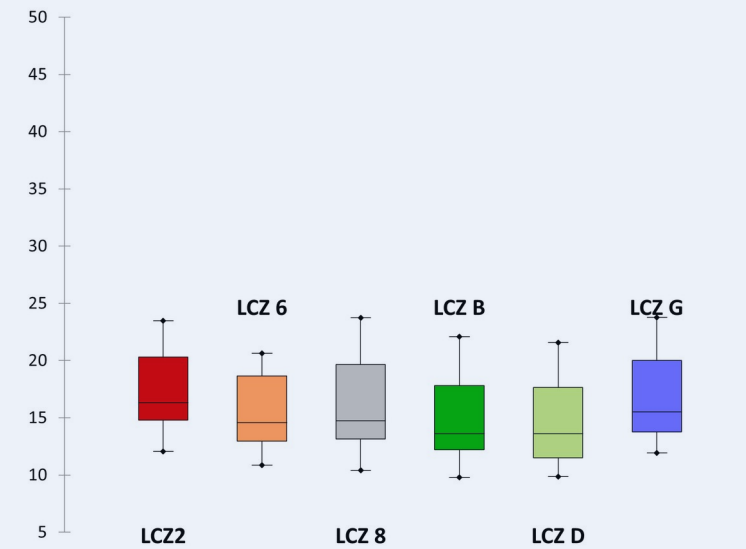
Daytime



LST temperatures

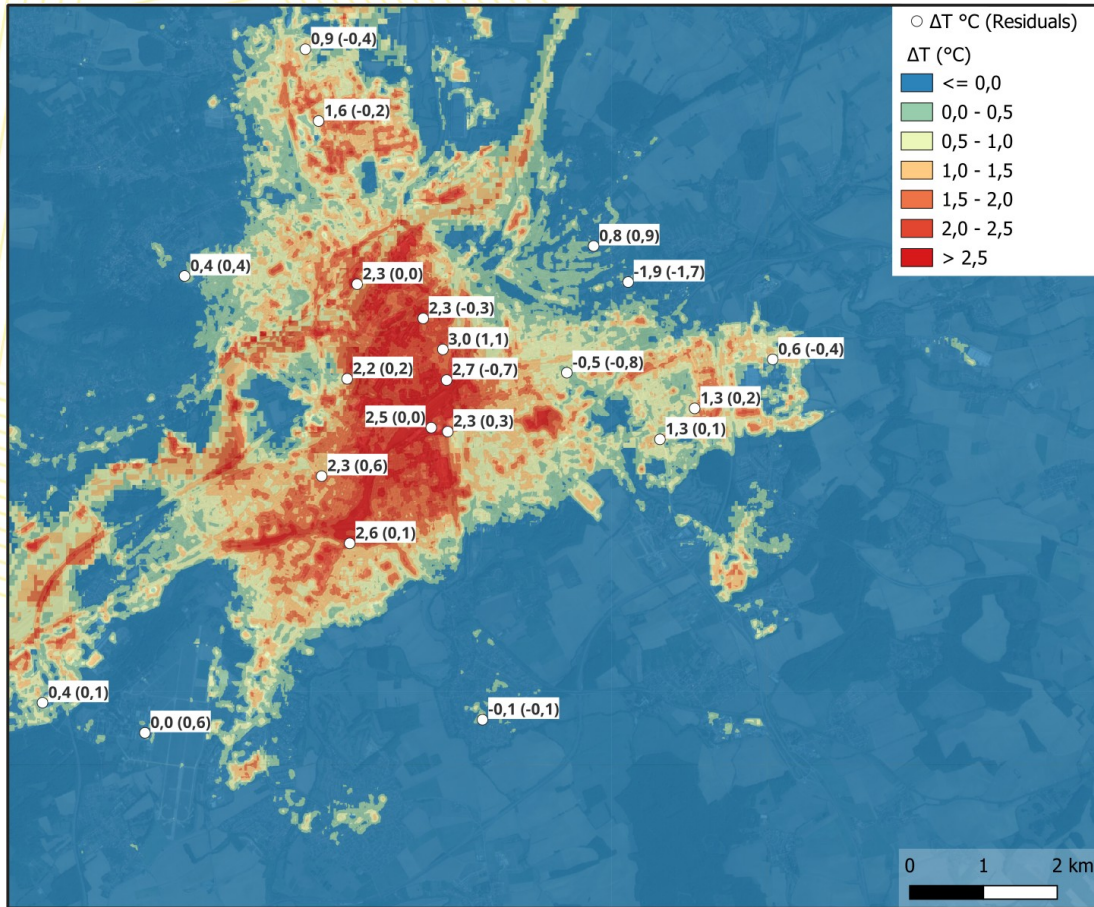


Nighttime



Results

July 10th 2019 at 01h16 UTC



UHII = 3.0°C

$$\Delta T = -4.89 + 3.51 \cdot 10^{-1} \cdot Ind_1 + 5.86 \cdot 10^{-5} \cdot Ind_2 + 5.95 \cdot 10^{-3} \cdot Ind_3$$

$R^2 = 0.78$; $R^2_{adj} = 0.74$; $RMSE = 0.59^\circ\text{C}$

Indicators

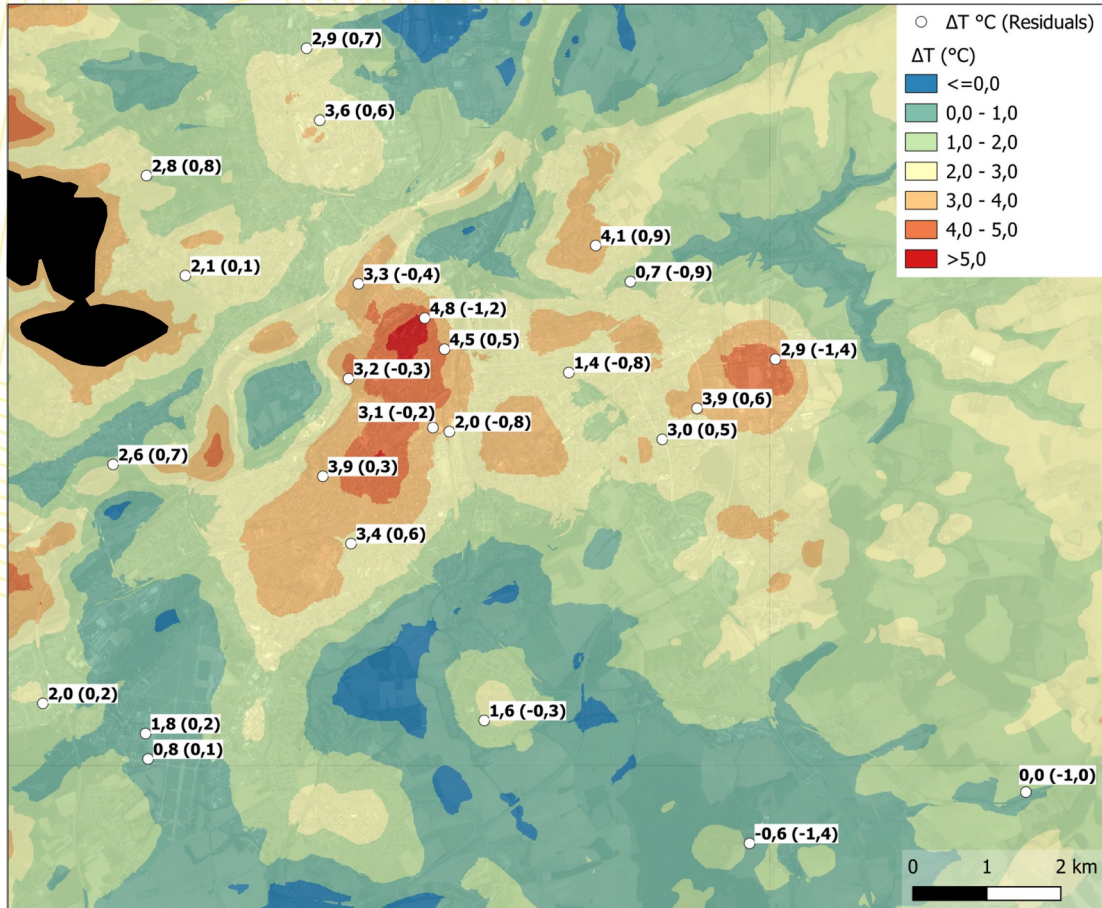
- Ind_1 : LST
- Ind_2 : Built-up areas @R = 900m
- Ind_3 : Impervious surfaces @R = 50m

Linear regression

Maximum over-estimated value	0.90 °C
Maximum under-estimated value	- 1.90 °C
Number of residuals $\geq \pm 1^\circ\text{C}$	3
Number of residuals $\geq \pm 0.5^\circ\text{C}$	7

Results

September 12th 2020 at 2h50 UTC



UHII = 4.8°C

$$\Delta T = -6.11 + 1.93 \cdot 10^{-4} \cdot Ind_1 + 7.74 \cdot 10^{-4} \cdot Ind_2 + 3.23 \cdot 10^{-2} \cdot Ind_3$$

$R^2 = 0.70$; $R^2_{adj} = 0.66$; $RMSE = 0.72^\circ C$

Indicators

- Ind_1 : Built-up areas @R = 700m
- Ind_2 : Water surfaces @R = 300m
- Ind_3 : Altitude

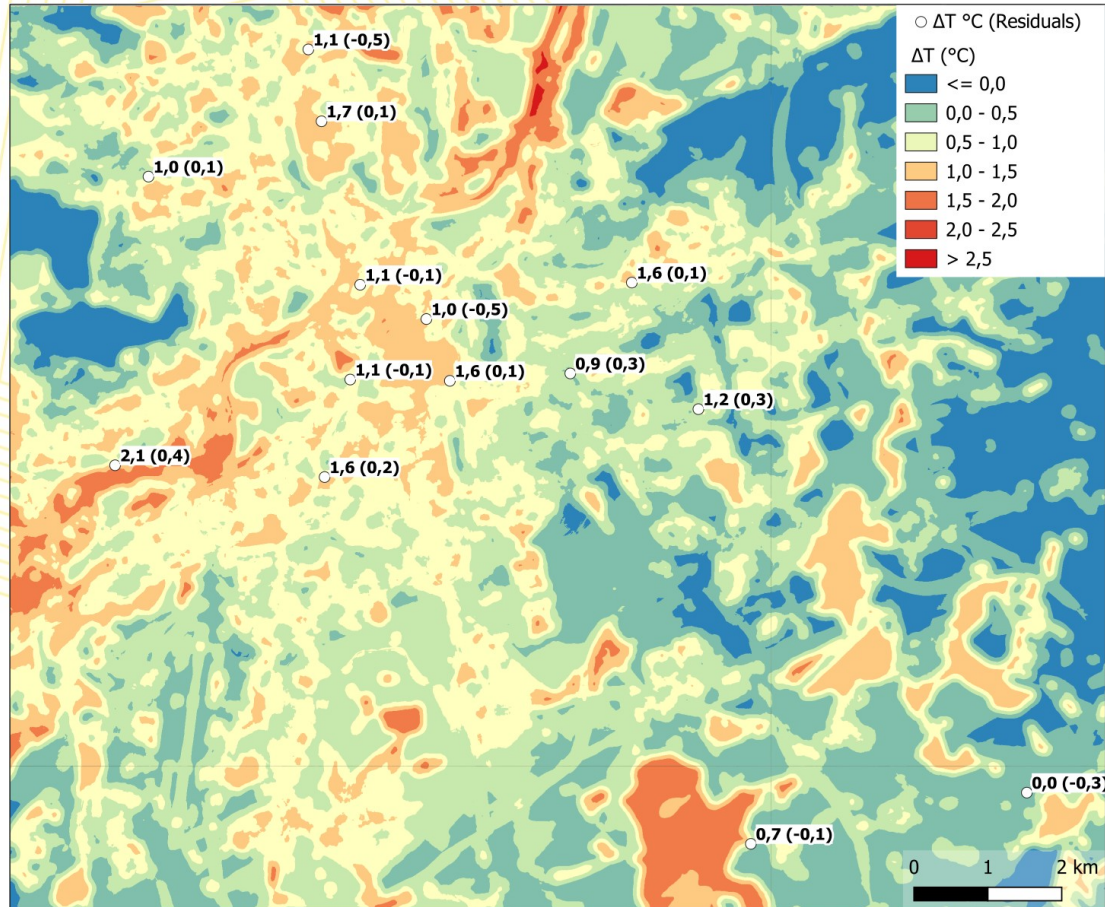
Linear regression

Maximum over-estimated value	0.9 °C
Maximum under-estimated value	- 1.4 °C
Number of residuals ≥ ±1°C	3
Number of residuals ≥ ±0.5°C	14



Results

May 30th 2021 at 16h18 UTC



$$\Delta T = 4.53 - 1.18 \cdot 10^{-2} \cdot Ind_1 - 6.02 \cdot 10^{-5} \cdot Ind_2 - 1.37 \cdot 10^{-3} \cdot Ind_3$$

$R^2 = 0.69$; $R^2_{adj} = 0.60$; $RMSE = 0.27^\circ\text{C}$

Indicators

- Ind_1 : Altitude
- Ind_2 : Impervious surfaces @R = 500m
- Ind_3 : Low vegetation surfaces @R = 100m

Linear regression

Maximum over-estimated value	-0.54 °C
Maximum under-estimated value	0.10 °C
Number of residuals $\geq \pm 1^\circ\text{C}$	0
Number of residuals $\geq \pm 0.5^\circ\text{C}$	1

Highlights

- ECOSTRESS data can be used to spatially predict UHI ($R^2 = 0,78$; $R^2_{aj} = 0,74$, $RMSE = 0,59$).
- The models elaborated could also estimate the impact of a vegetative cover.
- The ECOSTRESS LST data show variability within the LCZ during both daytime and nighttime. Some indicators were not relevant (exposure, SVF)
- The ECOSTRESS radiometer sheds new light on the diurnal and nocturnal thermal cycle at a metropolitan scale.

Limits & Prospects

- The limited number of weather stations makes it difficult to accurately interpolate the UHI intensity over the entire urban area.
- Not all LCZ are investigated
- So, more WS need be installed
- And complementary data (ASTER, mobile measurements) could be mobilized to complete and refine the results.
- Investigating during heatwaves could comfort the results.



Thank you for your attention

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