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Land and Infrastructure  
Engineering

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# MTD: a new powerful method to select urban-rural pairs for Urban Heat Island quantification applied to Turin, Italy

Francesca Bassani, PhD candidate<sup>1</sup>

V. Garbero, D. Poggi, L. Ridolfi, J. von Hardenberg, M. Milelli

<sup>1</sup> *Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Turin, Italy*






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# The Urban Heat Island (UHI) effect

## Causes

- thermal properties → urbanized areas ≠ natural lands
- anthropogenic heat emissions → vehicles, air conditioning, industries...   
- geometric effects: buildings
  - blocking of wind → inhibits cooling by convection
  - multiple surfaces for the reflection and absorption of sunlight (limited thermal dispersion)



The **city** *traps heat* during the day and *releases* it at night  
 ⇒ *warmer* temperatures than its rural surroundings

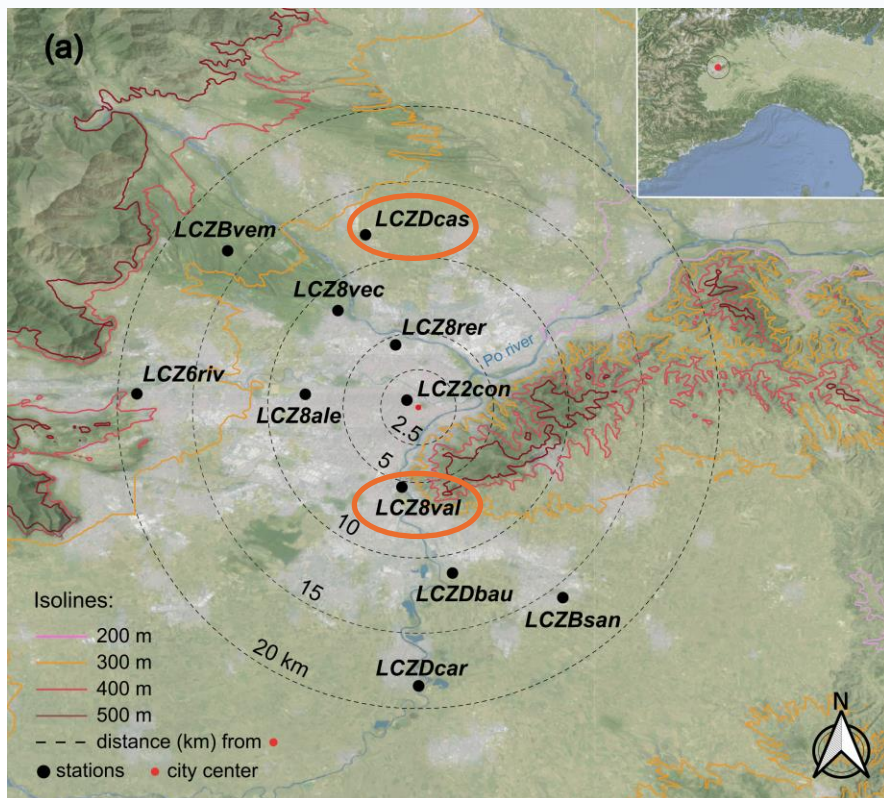
$$UHI = T_{\text{urban}} - T_{\text{rural}}$$



**Crucial task:** selecting proper urban-rural pairs



# The case of Turin



- 11 weather stations on a complex morphology
- The Local Climate Zones (LCZ) do not always classify them correctly:





	reality	LCZ type*	classification
<b>LCZ8val</b>		8. Large low-rise 	<i>wrong</i>
<b>LCZDcas</b>		D. Low plants 	<i>too local</i>

Figure from Bassani, F., Garbero, V., Poggi, D., Ridolfi, L., von Hardenberg, J., & Milelli, M. (2022). An innovative approach to select urban-rural sites for Urban Heat Island analysis: the case of Turin (Italy). *Urban Climate*, 42, 101099.

\*From Stewart, I.D., Oke, T.R. (2012). Local climate zones for urban temperature studies. *Bull. Am. Meteorol. Soc.* 93, 1879–1900.



# The MTD method

## (Mean Temperature Difference)

### Step 1: the metric

- No *preliminary* classification of sites

- For each station **S**:  $MTD_{i,M}^S = T_{i,M}^S - \overline{T_{i,M}^S} - \left\langle T_{i,M}^S - \overline{T_{i,M}^S} \right\rangle$

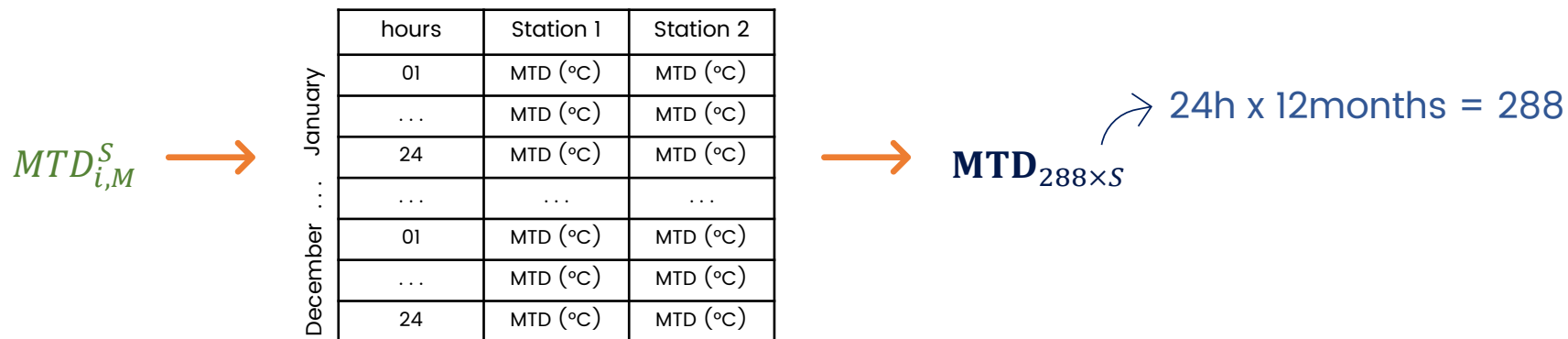
$T_{i,M}^S$  : monthly-averaged hourly temperature  
( $i=1,\dots,24$  hours,  $M=1,\dots,12$  months)

$\overline{\cdot}$  : temporal average over all times

$\langle \cdot \rangle$  : spatial mean among all  $N_S$  stations

⇒ Detects common *thermal behaviors* in a group of heterogeneous stations

### Step 2: application of PCA

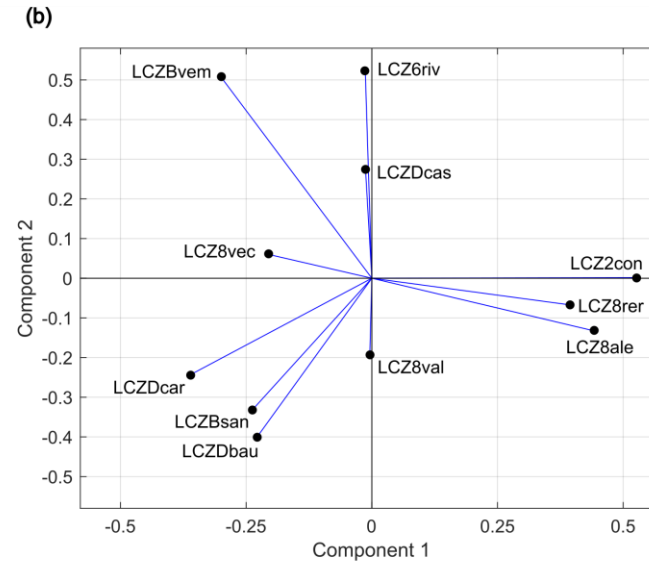
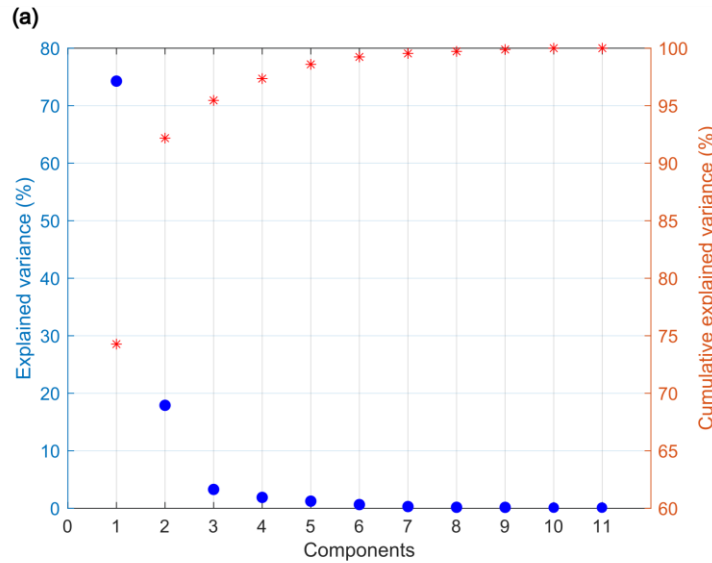


- Clustering of the thermal patterns (from step 1) into distinct groups, basing on the largest variance



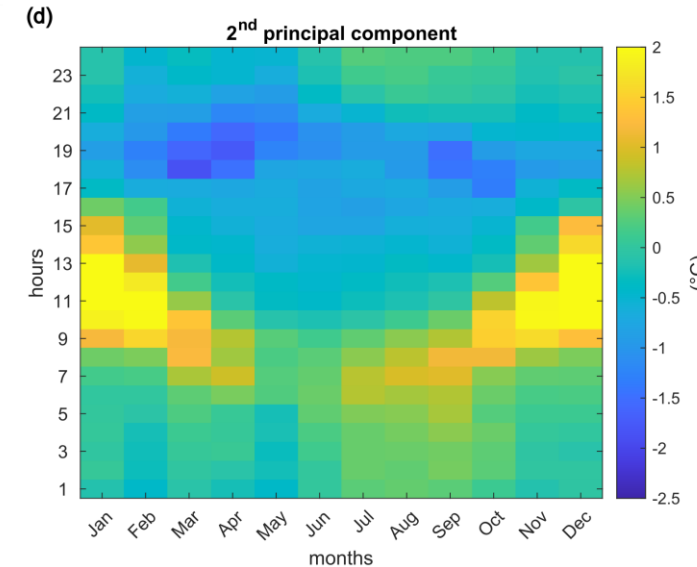
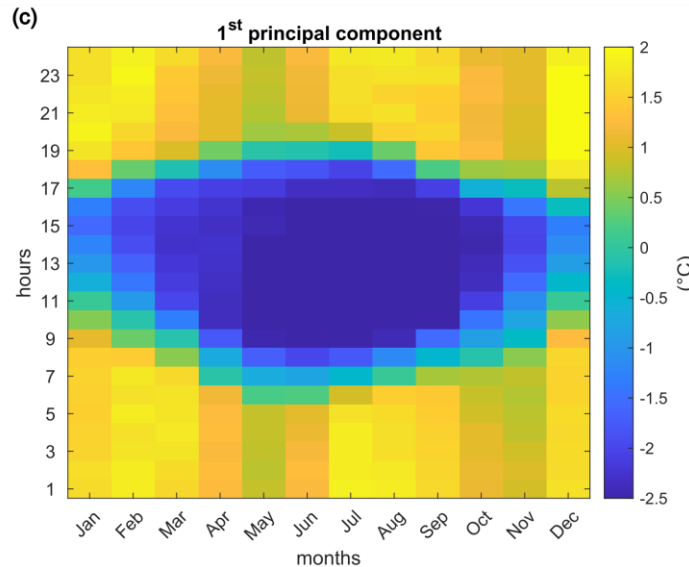
# Results: classification of stations

% variance of each component:  
1st  $\approx$  74%



P.C. 1: clustering into 3 groups  
1. Comp.1 > 0  
2. Comp.1  $\approx$  0  
3. Comp.1 < 0

urban thermal pattern (Comp.1 > 0)

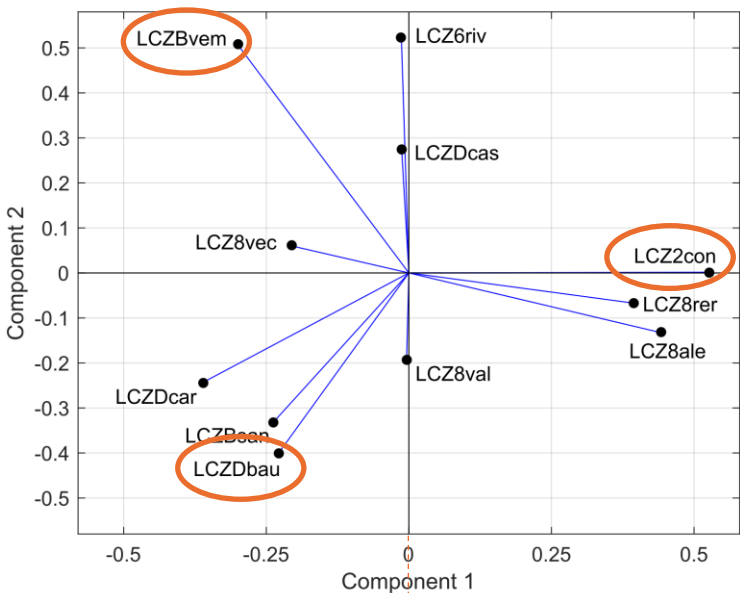


other geographical features (e.g., North-South)

Figure from Bassani, F., et al. (2022). *Urban Climate*, 42, 101099.



# Results: UHI over Turin

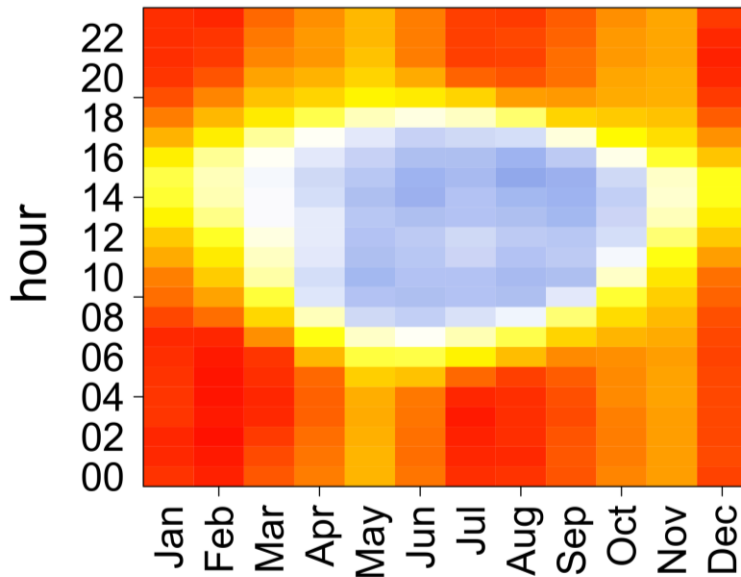


rural stations      urban stations



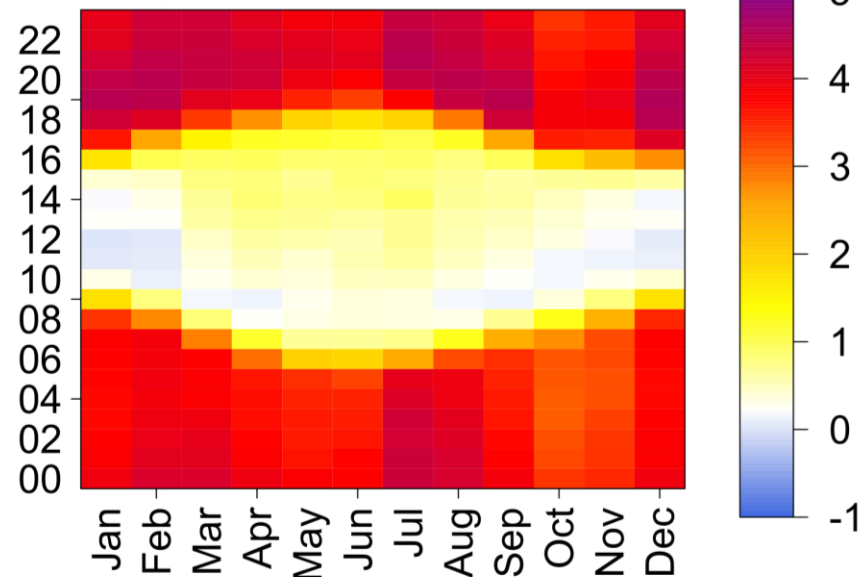
⇒ choice of 1 urban and 2 rural stations

LCZ2con - LCZDbau

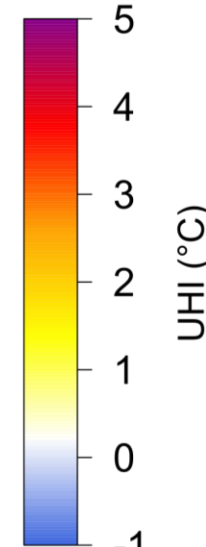


month

LCZ2con - LCZBvem



month



- Mean annual UHI over 14 years of data availability
- Slight Urban Cool Island (UHI < 0 at daytime) for LCZDbau
- Nocturnal UHI ≈ 3°C (LCZDbau) and ≈ 4°C (LCZBvem)





# Conclusions

## MTD features

- Objective classification of stations
  - No preliminary assumptions needed
    - Works very well for complex territories

## Turin UHI

- Stations: 3 urban, 5 rural (3 hybrid → not proper for UHI)
  - UHI city-South  $\approx 3^{\circ}\text{C}$ 
    - UHI city-North  $\approx 4^{\circ}\text{C}$

**Thank you!**

francesca.bassani@polito.it

