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

Original

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**Politecnico
di Torino**

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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 candidate¹

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

¹ *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

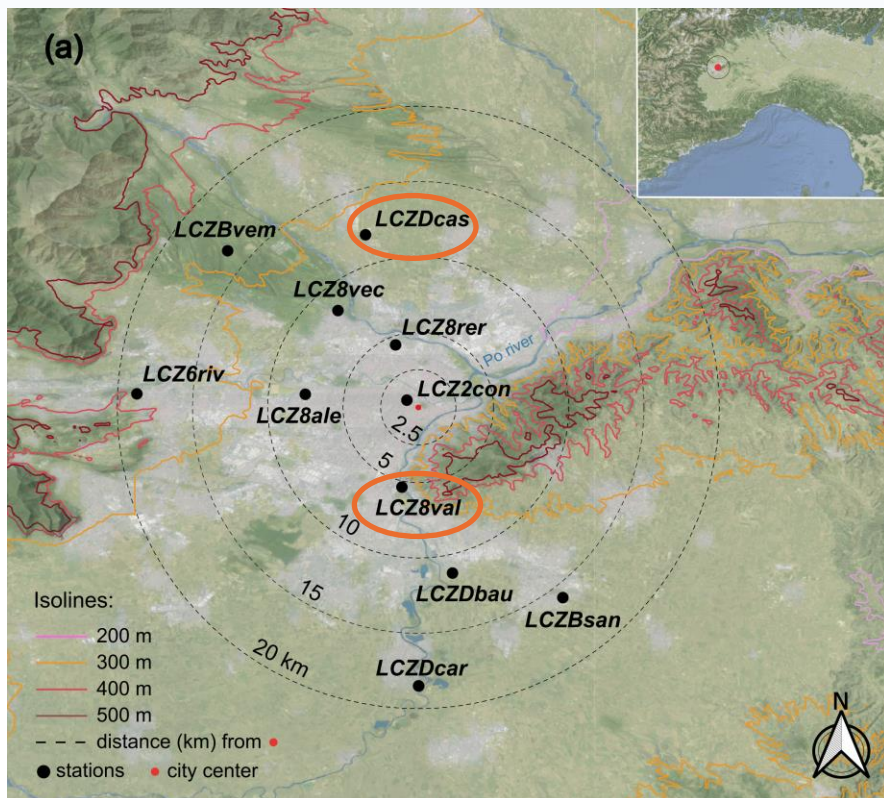
$$UHI = T_{\text{urban}} - T_{\text{rural}}$$



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
LCZ8val		8. Large low-rise 	<i>wrong</i>
LCZDcas		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**: $MTD_{i,M}^S = T_{i,M}^S - \overline{T_{i,M}^S} - \left\langle T_{i,M}^S - \overline{T_{i,M}^S} \right\rangle$

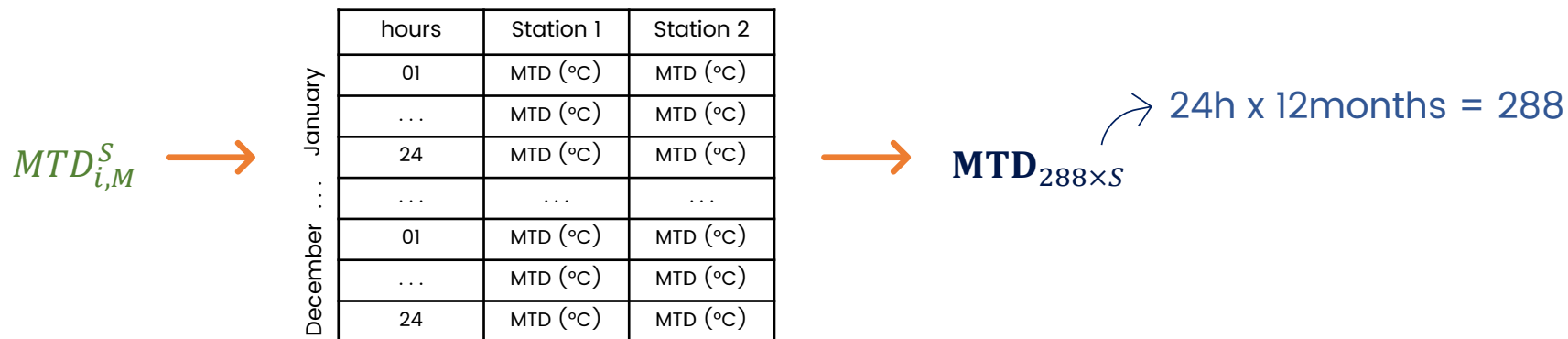
$T_{i,M}^S$: monthly-averaged hourly temperature
($i=1,\dots,24$ hours, $M=1,\dots,12$ months)

$\overline{\cdot}$: 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

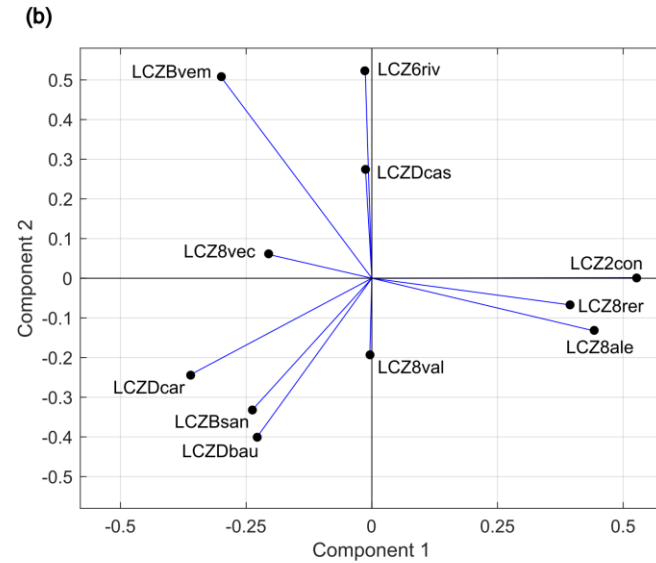
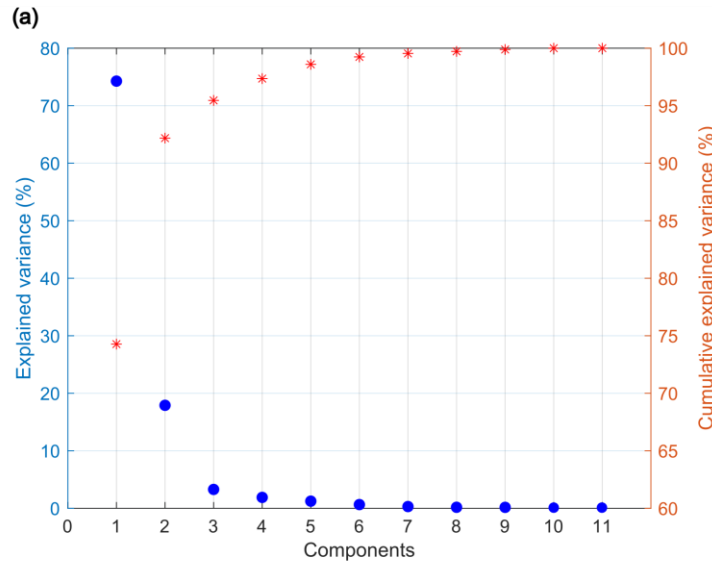


- Clustering of the thermal patterns (from step 1) into distinct groups, basing on the largest variance



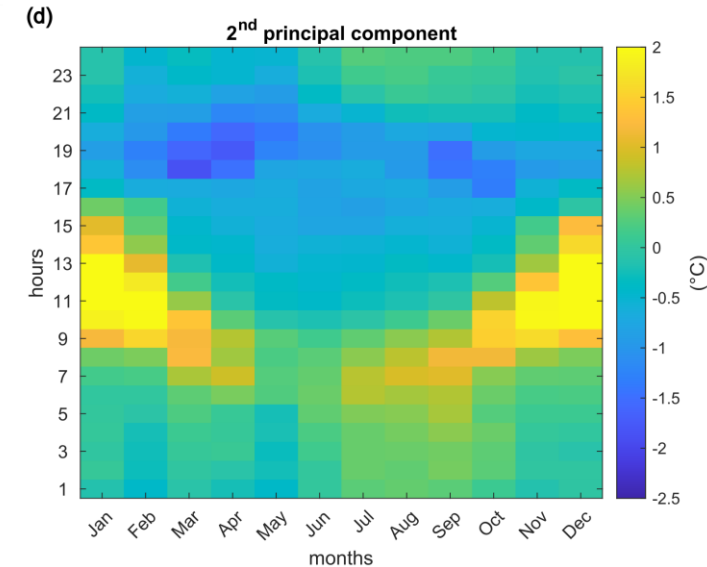
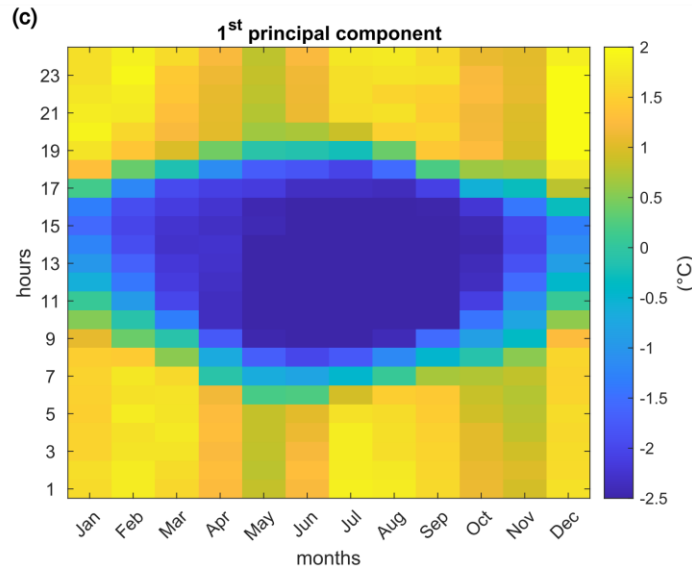
Results: classification of stations

% 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)

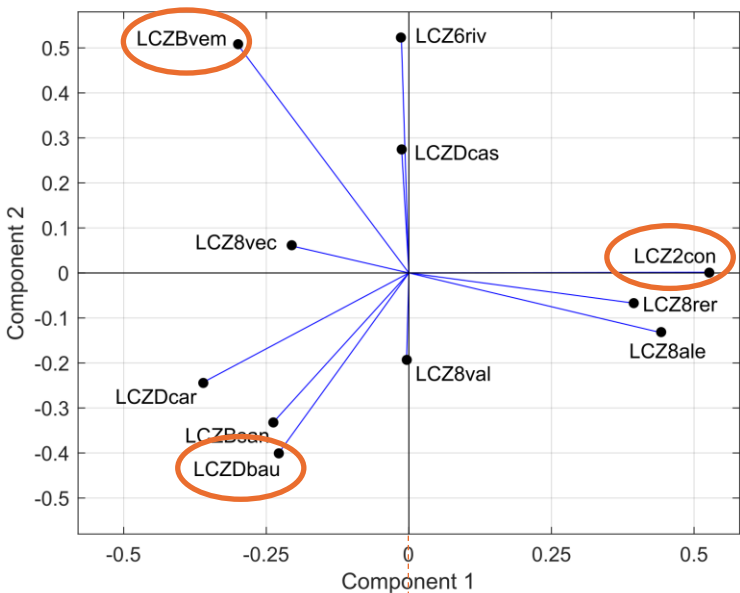


other geographical features (e.g., North-South)

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



Results: UHI over Turin

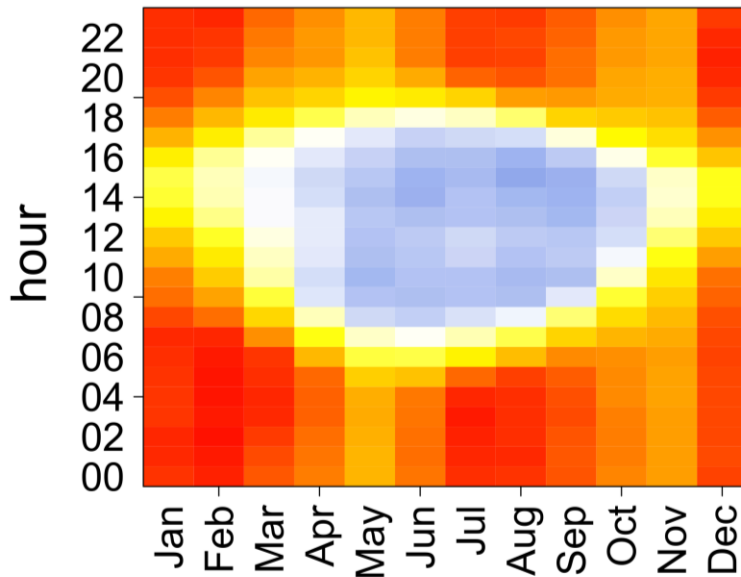


rural stations urban stations



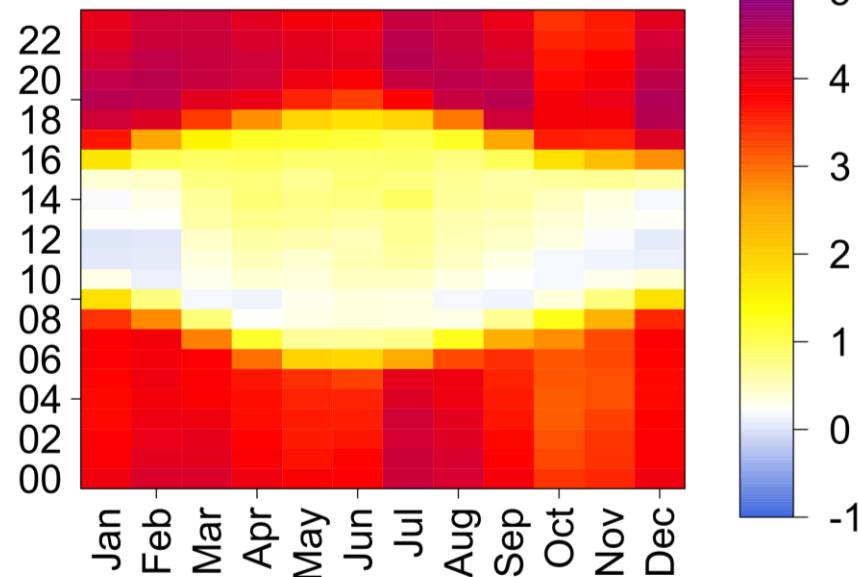
⇒ choice of 1 urban and 2 rural stations

LCZ2con - LCZDbau

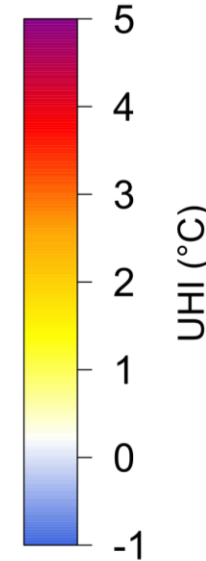


month

LCZ2con - LCZBvem



month



- Mean annual UHI over 14 years of data availability
- Slight Urban Cool Island (UHI < 0 at daytime) for LCZDbau
- Nocturnal UHI $\approx 3^{\circ}\text{C}$ (LCZDbau) and $\approx 4^{\circ}\text{C}$ (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

