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

Politecnico di Torino
Department of Environment, Land and Infrastructure Engineering

EGU General Assembly 2022

Arpa Piemonte Agenzia Regionale per la Protezione Ambientale

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

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EGU General Assembly
Session CL3.2.1 – 25 May 2022

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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

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

Crucial task: selecting proper urban-rural pairs

The case of Turin

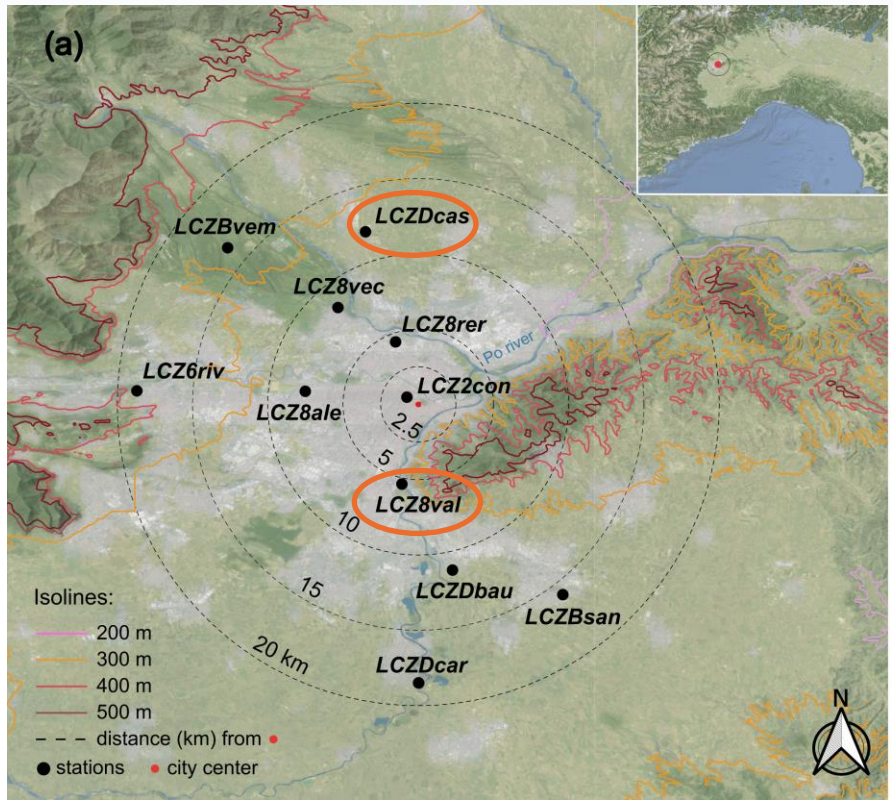


Figure from Bassani, F., Garbero, V., Poggi, D., Ridolfi, L., von Hardenberg, J., & Milelli, M. (2022). An innovative approach to select urban-rural sites for Urban Heat Island analysis: the case of Turin (Italy). *Urban Climate*, 42, 101099.

- 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 	*wrong*
LCZDcas		D. Low plants 	*too local*

*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,..,24 hours, M=1,..,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

$MTD_{i,M}^{S}$ →

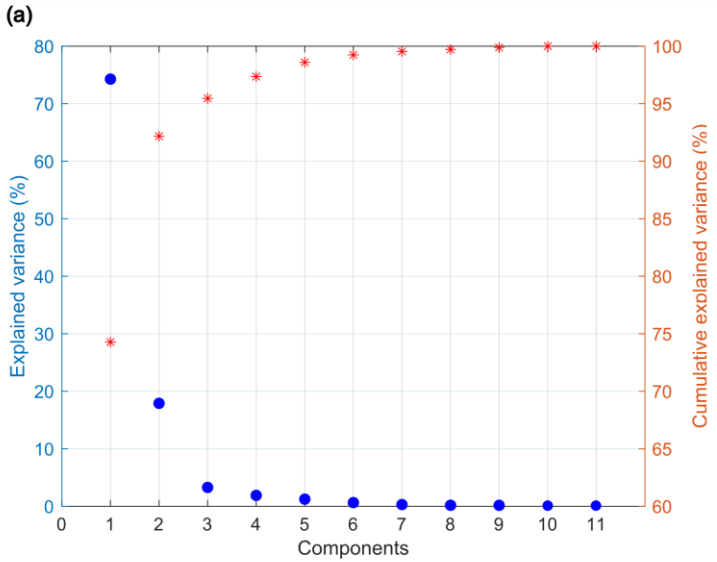
	hours	Station 1	Station 2
January	01	MTD (°C)	MTD (°C)
	...	MTD (°C)	MTD (°C)
	24	MTD (°C)	MTD (°C)
...	...	...	...
December	01	MTD (°C)	MTD (°C)
	...	MTD (°C)	MTD (°C)
	24	MTD (°C)	MTD (°C)

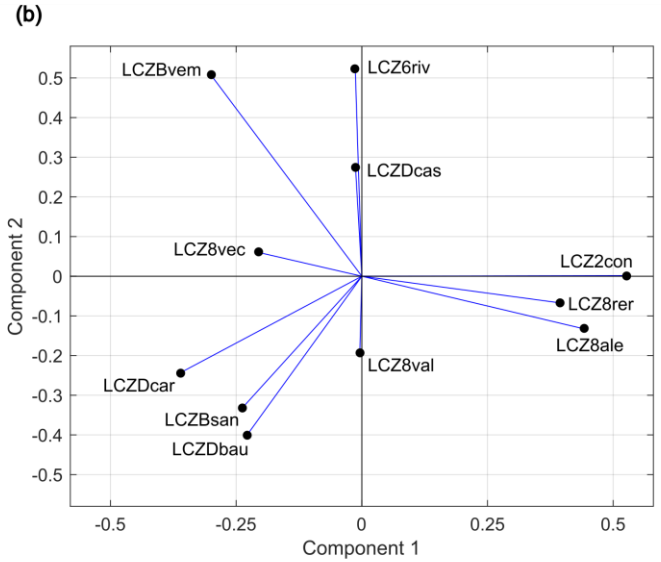
→ $\mathbf{MTD}_{288\times S}$ (24h x 12months = 288)

- 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 ≈ 74%

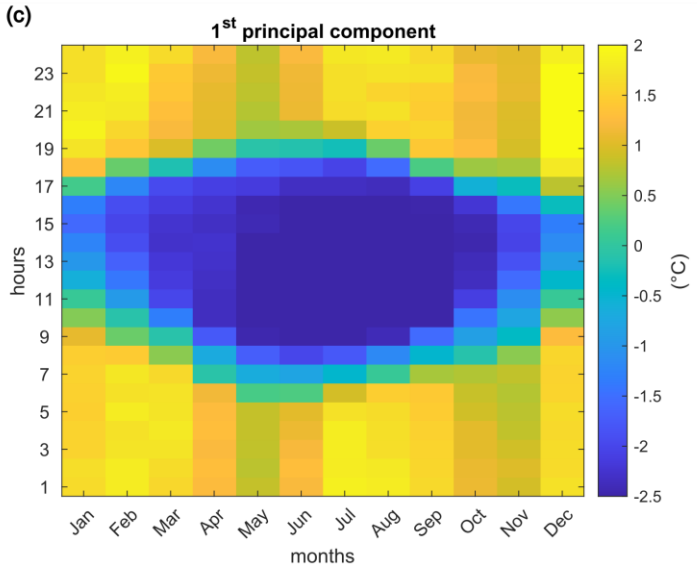


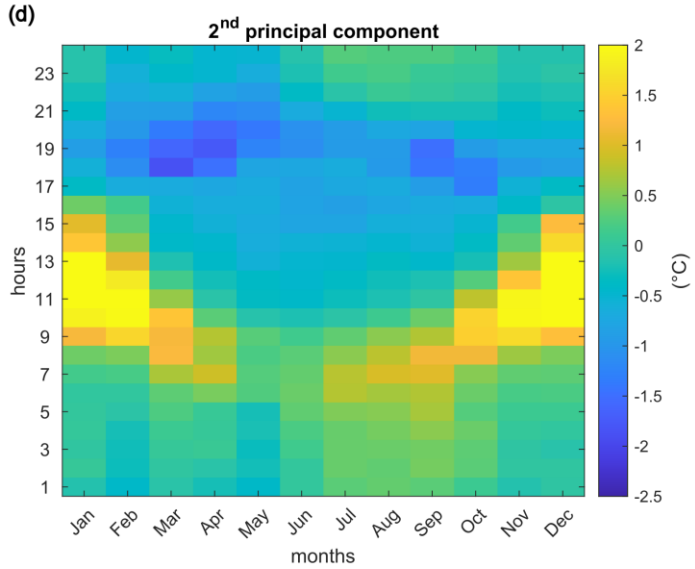


P.C. 1: clustering into 3 groups

1. Comp.1 >0
2. Comp.1 ≈ 0
3. Comp.1 <0

urban thermal pattern (Comp.1>0)

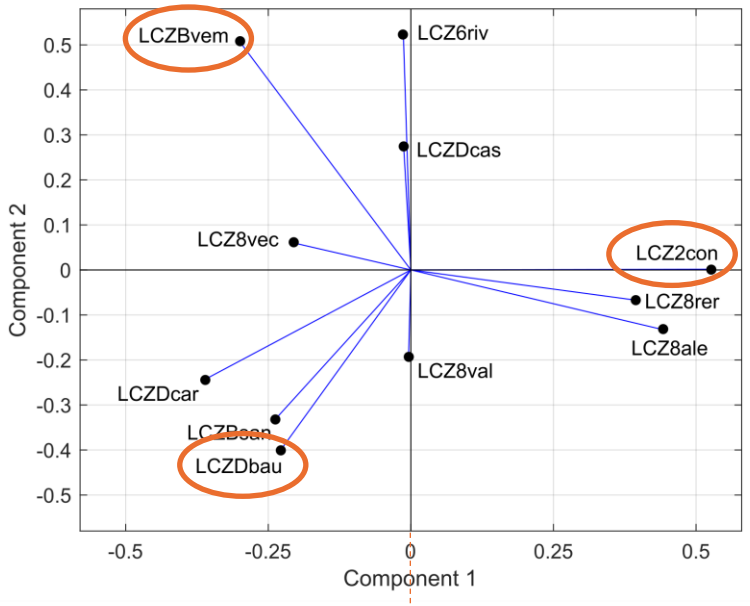




other geographical features (e.g., North-South)

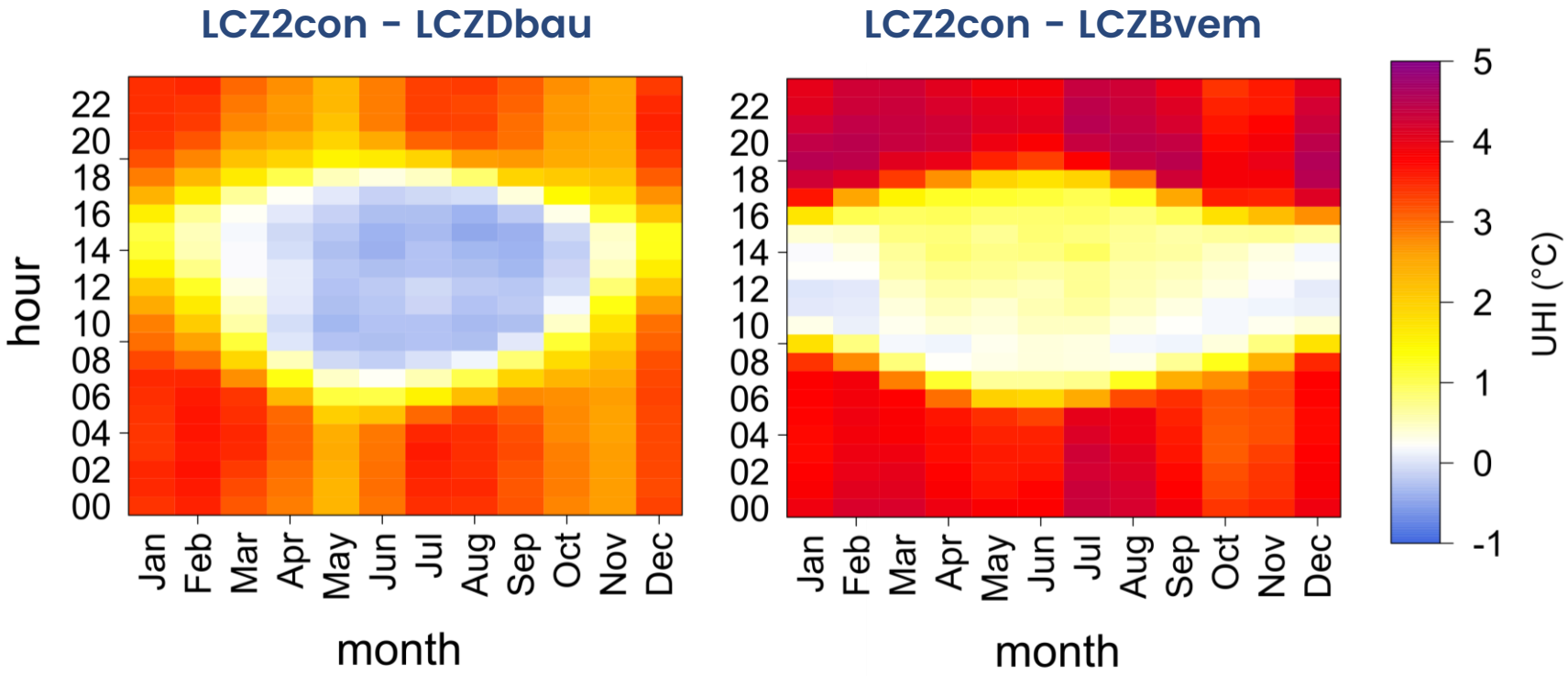
Figure from Bassani, F., et al. (2022). *Urban Climate*, 42, 101099.

Results: UHI over Turin



rural stations ⟷ *urban* stations

⇒ choice of 1 urban and 2 rural stations



- 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)

Figure from Milelli, M., Bassani, F., Garbero, V., Poggi, D., von Hardenberg, J., & Ridolfi, L. (2022). Under review in *Urban Climate*.

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 ≈ 3°C
    - UHI city-North ≈ 4°C

Thank you!

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