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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[1]
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

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

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

# The case of Turin

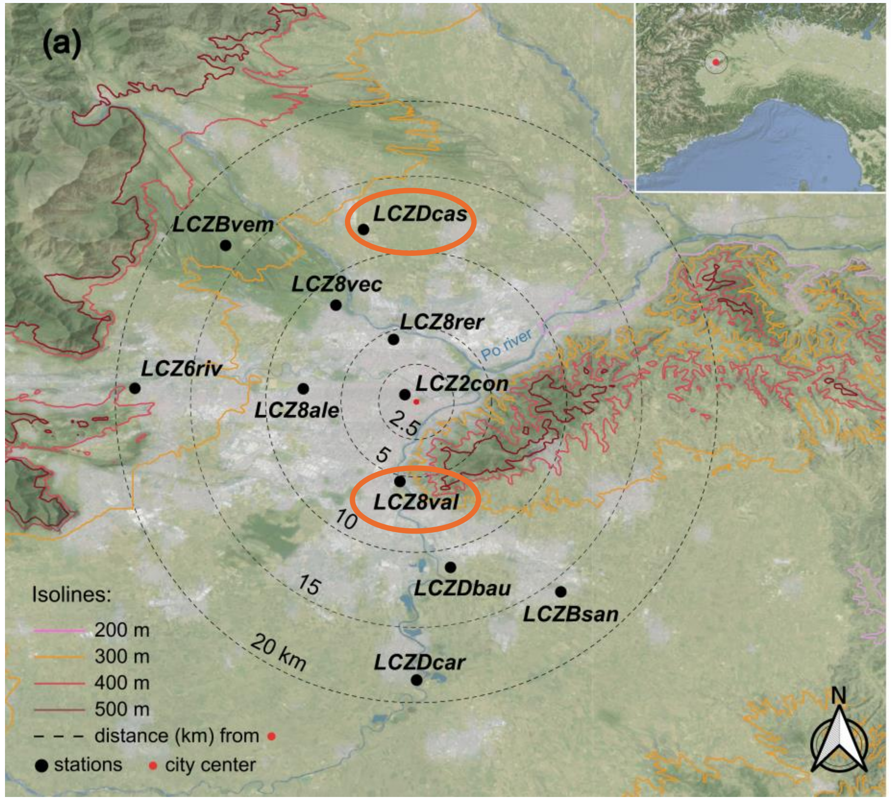


Figure from Bassani, F., Garbero, V., Poggi, D., Ridolfi, L., von Hardenberg, J., & Milelli, M. (2022). An innovative approach to select urban-rural sites for Urban Heat Island analysis: the case of Turin (Italy). *Urban Climate*, 42, 101099.

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

| | reality | LCZ type* | classification |
|---|---|---|---|
| **LCZ8val** |  |   | *wrong* |
| **LCZDcas** |   |   | *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

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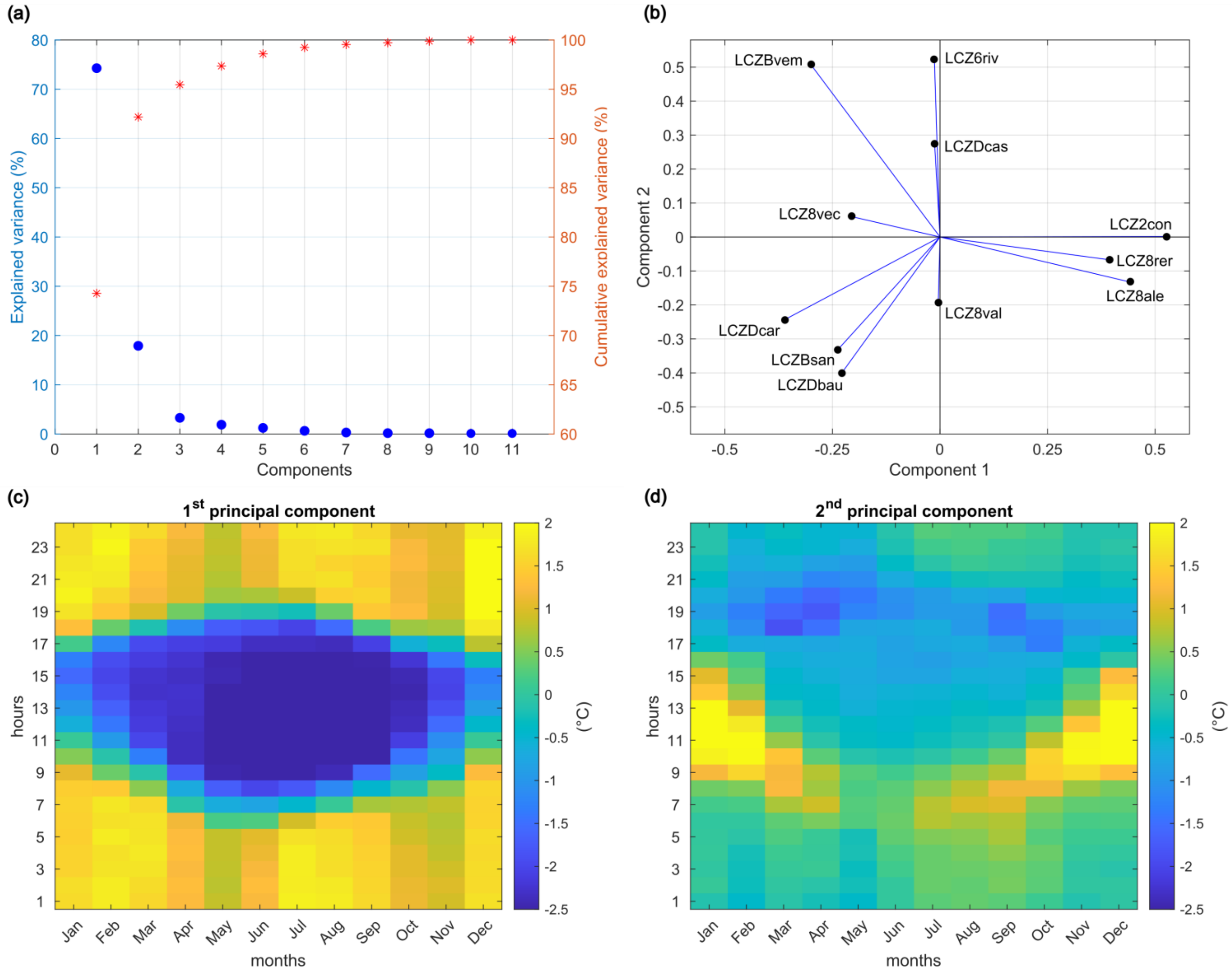
% variance of each component: 1st ≈ 74%

urban thermal pattern (Comp.1>0)




P.C. 1: clustering into 3 groups

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

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

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

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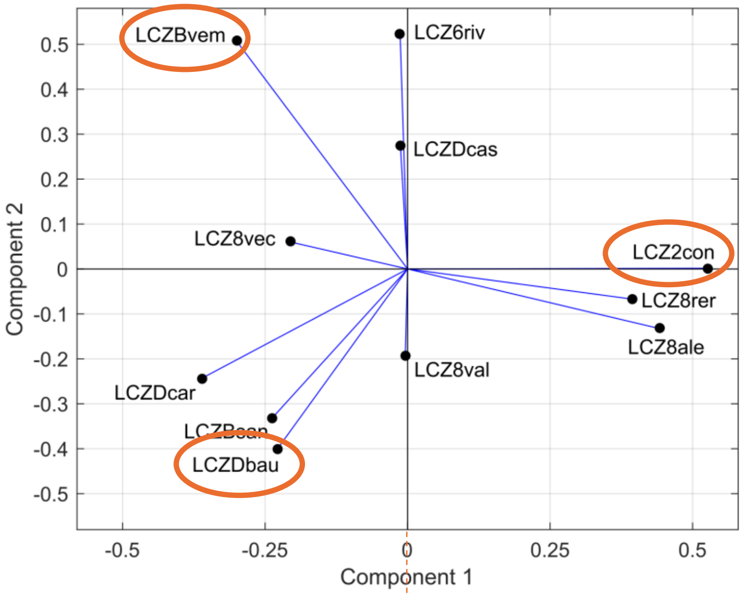
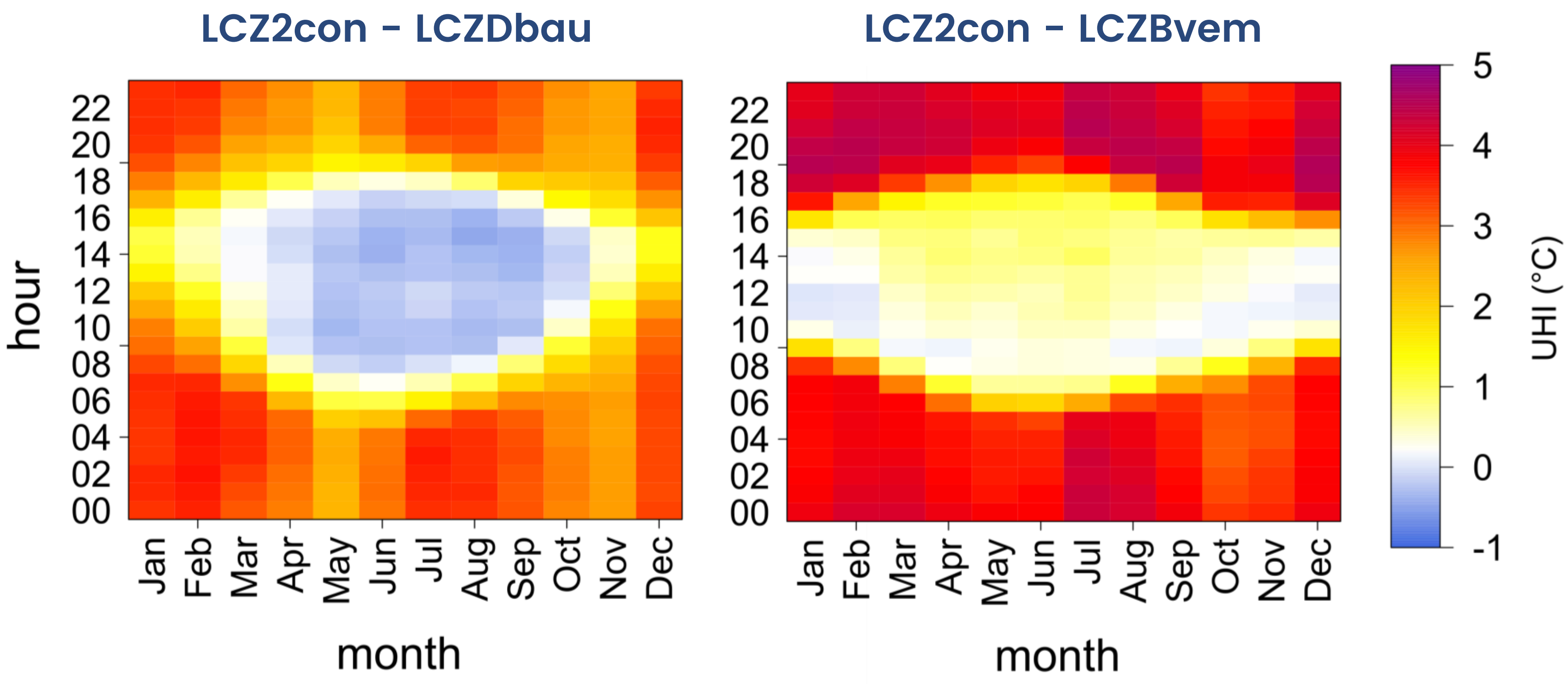
# Results: UHI over Turin




*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!

francesca.bassani@polito.it