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Modeling the role of urban green spaces in cooling urban environments: the case of the Villa Ada Park, Rome

Daiane de Vargas Brondani[1], Tony Christian Landi[2], Oxana Drofa[2], Vito Imbrenda[3], Alessandra Gaeta[4], Rosa Coluzzi[3], Daniela Cava[1], Umberto Giostra[5], Stefano Decesari[2], Luca Mortarini[6]

[1]CNR-ISAC, Lecce, Italy, [2]CNR-ISAC, Bologna, Italy, [3]CNR-IMAA, Tito Scalo, Italy, [4]ISPRA-Rome, Italy, [5]University of Urbino, Urbino, Italy, [6]University of Milan, Milan, Italy

INTRODUCTION & AIM

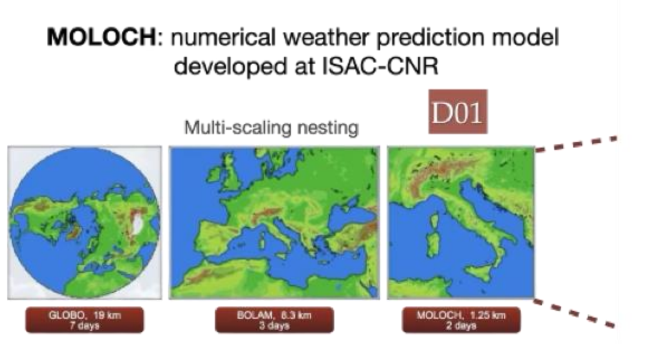
Green parks help mitigate urban heat through evapotranspiration and shading, yet their cooling effect is often assessed using static satellite imagery taken at a single time of day. In this study, **we used the PALM model to explore how spatial heterogeneity in the urban environment influences park cooling intensity (PCI) over time**. Focusing on Villa Ada in Rome, we applied a **buffer ring** and **sector-based approach** to examine **surface temperature** and **wind speed** across two anomalous autumns heatwave. Preliminary results show that surface temperature patterns follow variations in built-up density, and wind speed decreases in areas with greater surface roughness from urban structures. Large Eddy Simulation (LES) modeling reveals the spatial and temporal variability of park cooling beyond what static imagery can show.

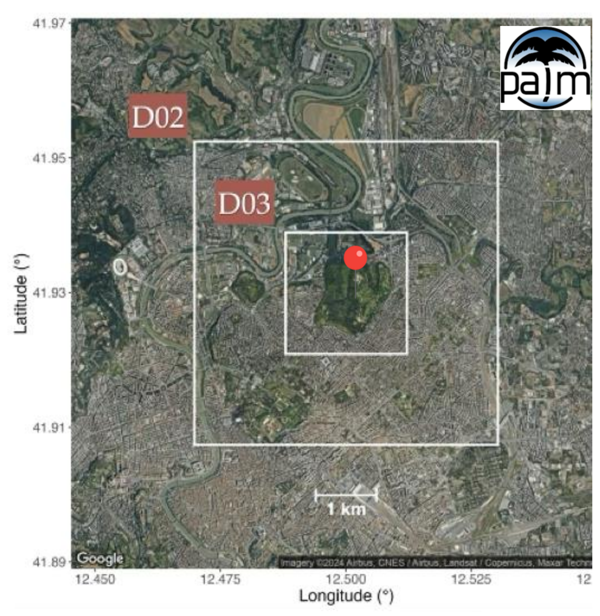
METHOD

Site: Villa Ada is an urban park in Rome covering approximately 160 ha, characterized by mid-rise surroundings and largely unmanaged vegetation.

Heatwave identification, simulated days and model setup: October 08–09 2023 was classified as a heatwave using the CTX90pct index. Data from Ciampino weather station (72-year record) confirmed this anomaly.

Simulation initialized at **03:00 UTC** on 08 October 2023

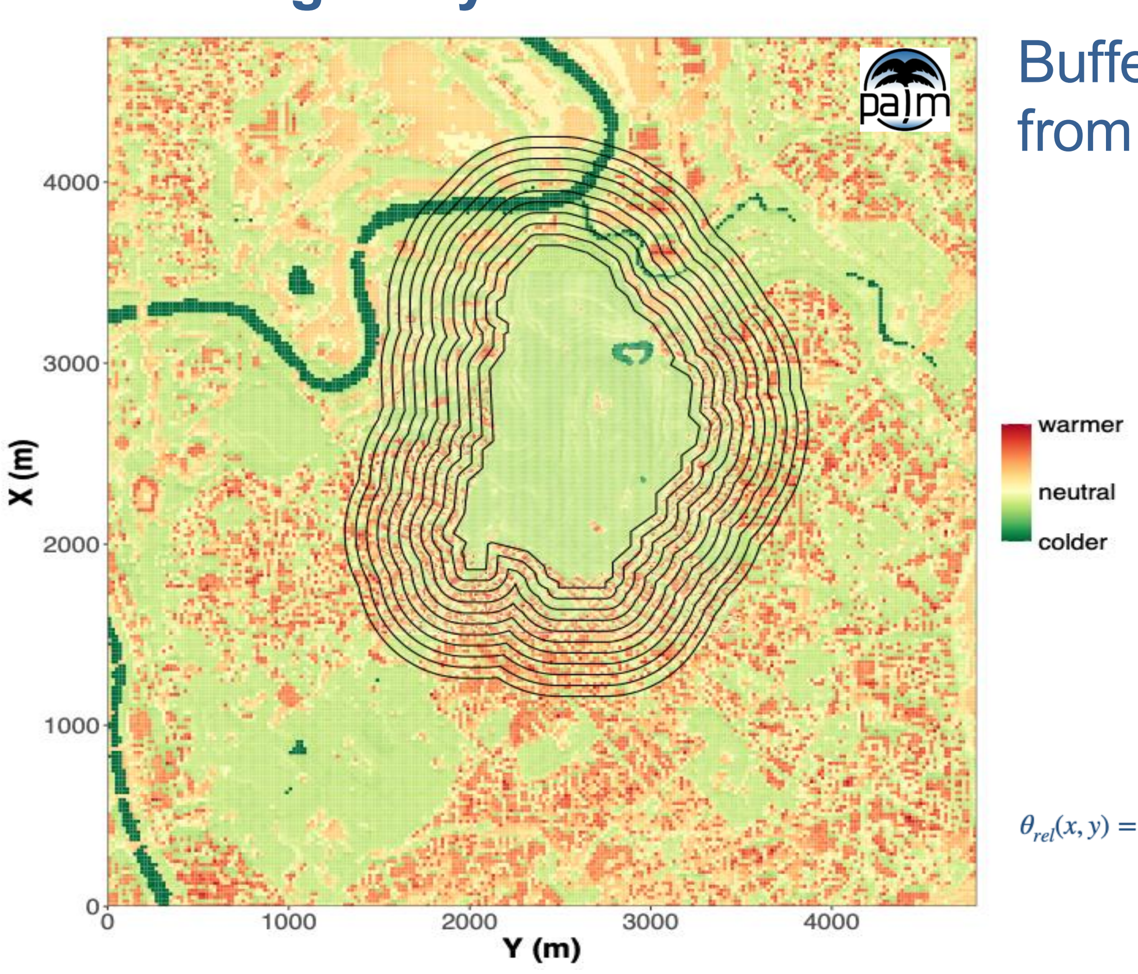




Domain	Dimensions (km)	Grid Spacing (m)	Grid Points (x × y × z)
D02	4.8 × 4.8 × 2.88	20	240 × 240 × 144
D03	2.0 × 2.0 × 2.0	10	200 × 200 × 200

Three greenery scenarios were simulated: (1) a baseline with the current park vegetation; (2) a short grass scenario, where the park was entirely replaced by short grass; and (3) a dense trees scenario, where the park was replaced by trees with the maximum leaf area density observed in the baseline.

Buffer ring analysis:



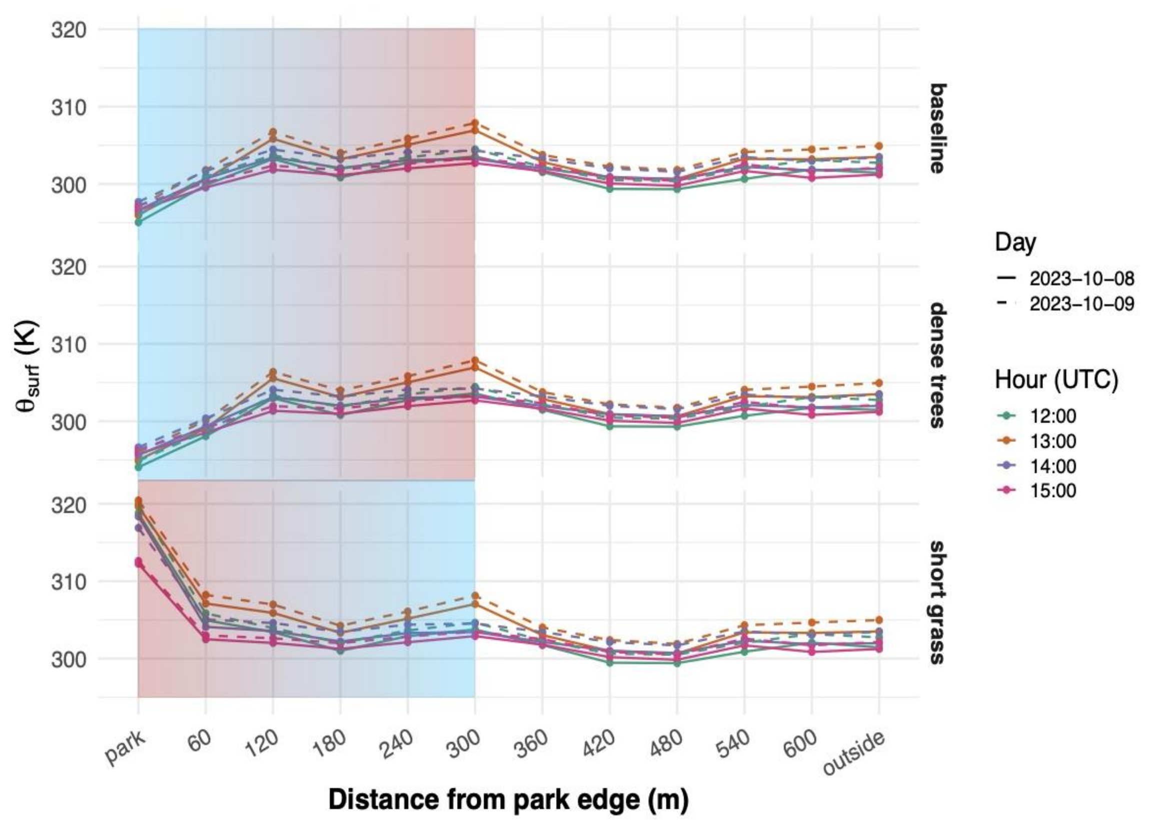
Buffer rings every 60 m from the park edge to 600 m

The $(\theta_{rel})(x, y)$ is calculated for each grid cell at 10 m and 20 m resolution, by subtracting the park median temperature from the local surface temperature.

$$\theta_{rel}(x,y) = \theta_{surf}(x,y) - \tilde{\theta}_{park} \begin{cases} > 0 & \text{: warmer than the park} \\ = 0 & \text{: same as park (neutral)} \\ < 0 & \text{: cooler than the park} \end{cases}$$

RESULTS & DISCUSSION

Park Cooling Intensity and Wind Speed Across Buffers



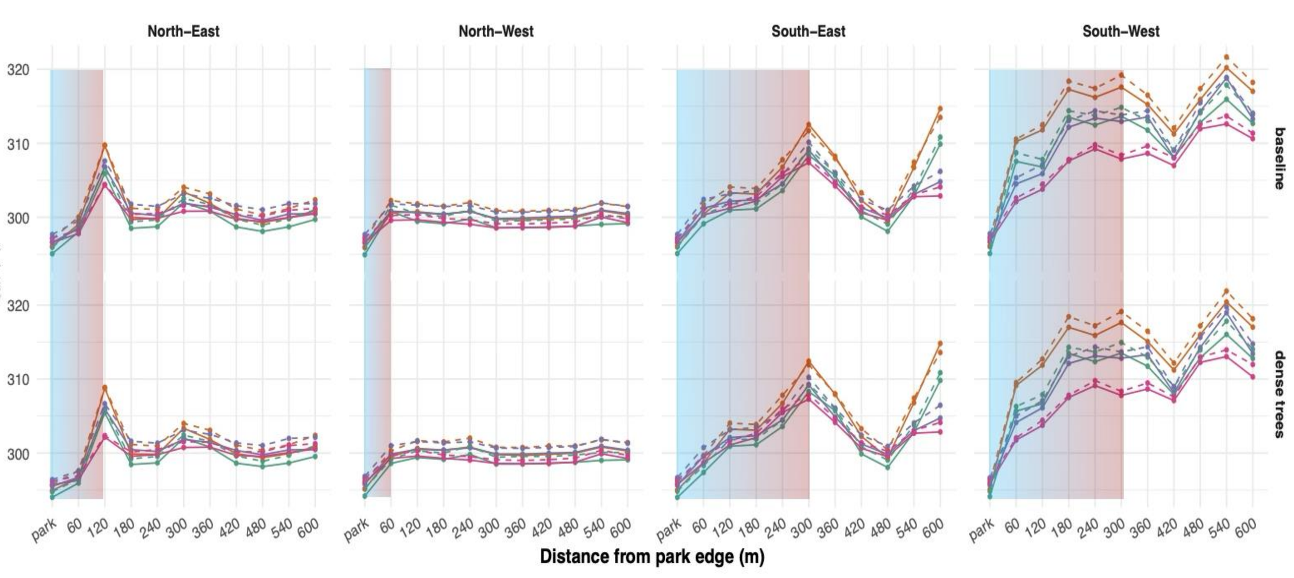
◆ **Surface temperature** (θ_{surf}) **increases with distance from the park**, especially in the baseline and dense tree scenarios.

◆ Cooling exceeds **10 K** in built-up areas (~300 m) by early afternoon, highlighting the role of vegetation in regulating temperature through shading and evapotranspiration.

Park Cooling Intensity and Wind Speed by sector around the Villa Ada Park

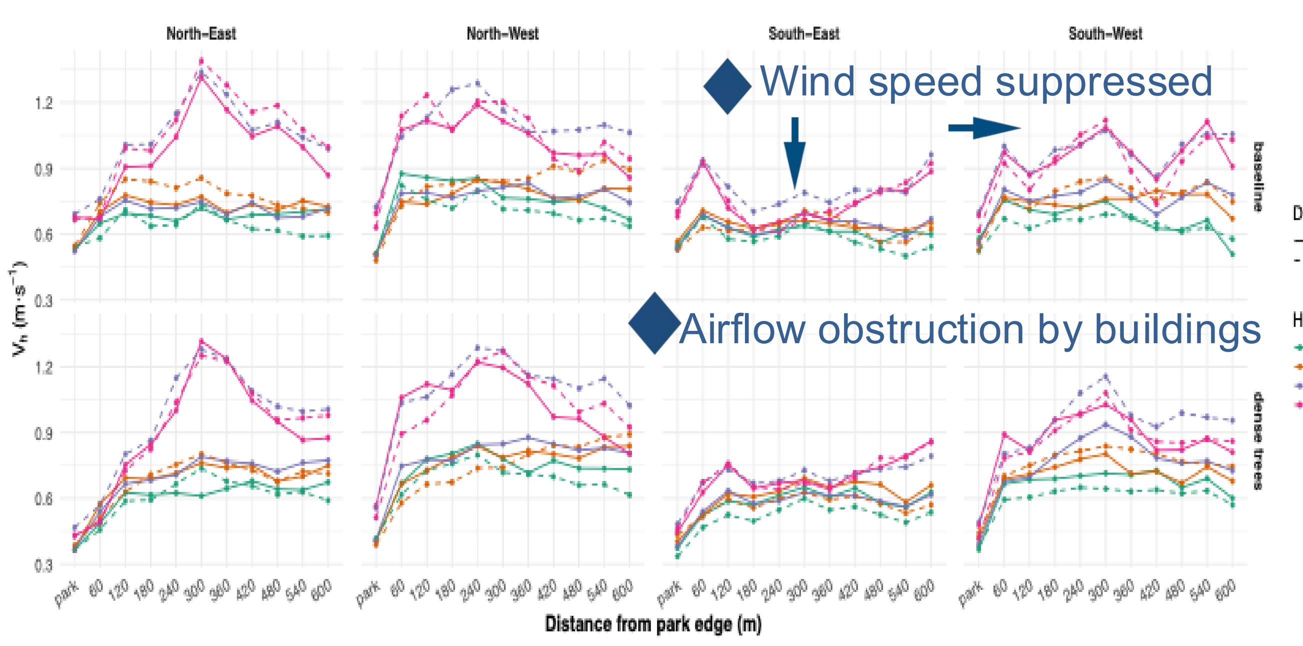
◆ **PCI >15 K** at 300 m in denser built-up sectors

◆ This effect is most pronounced in the **South-West** sector, around **13:00 UTC**



◆ **Wind speed (V_h) remains weak throughout the days**

V_h stays mostly below **1.5 m/s**, indicating **stagnant airflow ar conditions** during the heatwave.



CONCLUSION

While satellite-based studies often report moderate cooling effects (typically ≤ 6 K), limited by the time of image acquisition, our high-resolution simulation reveals that cooling intensity can reach up to 15 K in densely built-up sectors, depending on the time of day.

REFERENCES

Zhao, C., Wu, J., Liu, Y., Wang, J., & Xu, J. (2023). How to quantify the cooling effect of urban parks? Linking maximum and accumulation perspectives. *Building and Environment*, 244, 110714. https://doi.org/10.1016/j.buildenv.2023.110714

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