

Evaluating the Influence of Large-Scale Cool Pavement Implementation on Air Temperature in Phoenix, Arizona: Correcting Daytime Bias with Aspirated Air Temperature Sensors

Sina Sedaghat^{a,c}, Eli P. Martin^{b,c}, David J. Sailor^{b,c}

^a Design School, Arizona State University, Tempe, AZ, USA

^b School of Geographical Science and Urban Planning, Arizona State University, Tempe, AZ, USA

^c Urban Climate Research Center, Arizona State University, Tempe, AZ, USA

Abstract

Pavements contribute to the urban heat island (UHI) because their low surface reflectance increases solar heat absorption. Reflective “cool” pavements are a mitigation strategy that can reduce surface absorption, but prior evidence is largely based on numerical modeling and laboratory studies, and field results have been limited and sometimes inconsistent. This study evaluates the air-temperature impacts of large-scale cool pavement implementation in Phoenix, Arizona, using a long-duration field monitoring campaign designed to address key methodological limitations. Initial results using unaspirated sensors showed apparent daytime warming over cool pavements, caused by reflected shortwave radiation affecting the sensor enclosure. We therefore built and deployed aspirated air temperature sensors to reduce radiative and ventilation biases common in non-aspirated measurements, especially during daytime conditions. Air temperature responses to cool pavement were quantified using real-time, side-by-side comparisons between treated and reference locations across the monitoring period, and difference-in-differences (DD) to quantify changes before and after cool pavement installation. The results show that sensor aspiration substantially reduces apparent daytime warming artifacts and provides more reliable estimates of cool pavement effects on near-surface air temperature. Overall, these findings provide robust field evidence for cool pavements as an urban heat mitigation strategy and highlight the importance of aspirated sensing and rigorous quasi-experimental analysis in real-world deployments.

Problem statement and research question

Although cool pavements are widely proposed as an urban heat mitigation strategy, their effect on near-surface air temperature remains uncertain because conventional non-aspirated sensors can be biased by reflected shortwave radiation. This makes it difficult to distinguish true cooling effects from measurement artifacts in real-world field studies.

The question is: How does large-scale cool pavement installation affect 3 m air temperature in Phoenix, and to what extent do aspirated sensors improve the accuracy of detecting true cooling effects by reducing reflected-radiation bias?

Study Site & Methods

- **Study Site:** Desert Ridge Marketplace parking lot, northeast Phoenix, AZ (33.677°N, 111.972°W). **Climate:** BWh hot desert.
- In late summer 2023, a cool seal coat (initial solar reflectance = 0.28) was applied to 5,853 m². Surrounding pavement received a dark seal coat (reflectance = 0.04). The cool test area measured approximately 100 m × 48 m, and the dark control area approximately 100 m × 78 m.
- **Monitoring setup:** Four unaspirated sensors (DN, DS, CN, CS) measured air temperature at 3 m height on light poles.
- Two aspirated sensors with double-walled, fan-aspirated radiation shields were deployed from June 25 to July 15, 2025.
- **Analysis:** Air-temperature impacts were evaluated using (1) **real-time (RT)** side-by-side comparisons and (2) **difference-in-differences (DD)** analysis to quantify changes before and after cool pavement installation.

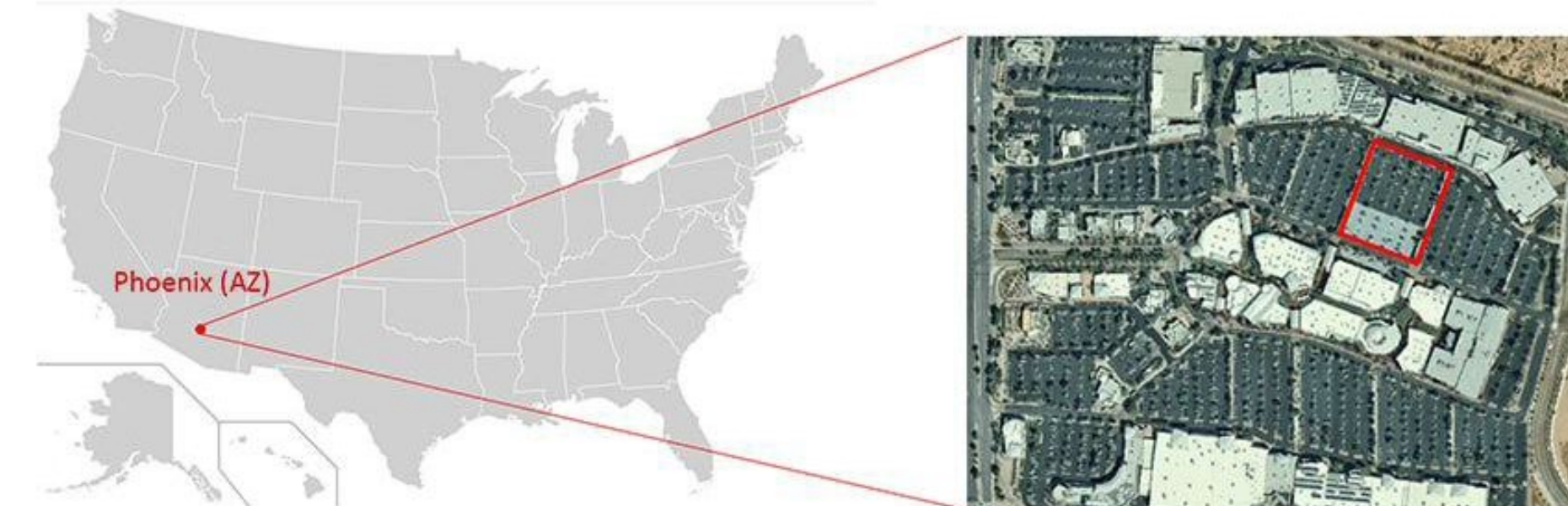
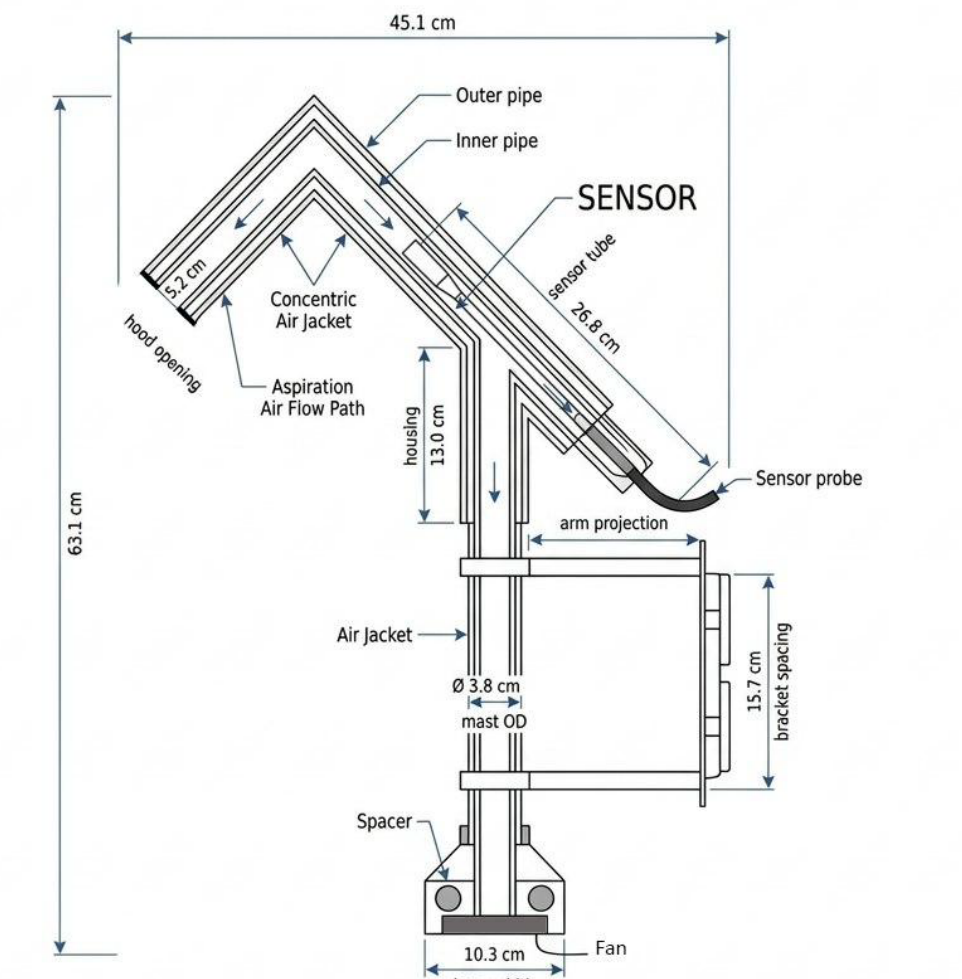


Fig. 1: Study site and sensor layout at Desert Ridge Marketplace, Phoenix, AZ.



Notes	Dimension	Value
1. Dimensions were derived from the uploaded hand-drawn sketch.	Overall height	43.1 cm
2. Conversion used: 1 grid square = 1/2 in = 1.27 cm actual size.	Overall width	45.1 cm
3. Values are nominal and inferred from the scanned sketch.	Sensor type	24.8 cm
4. Recommended tolerance for fabrication from this drawing: ±0.8 cm.	Housing height	13.0 cm
	Arm projection	11.8 cm
	Bracket spacing	15.7 cm
	Mast OD	3.8 cm
	Base width	16.3 cm
	Hood opening	5.2 cm



Fig. 2: left: Aspirated sensor assembly (double-walled configuration); right: the picture of installed aspirated and non aspirated sensors at 3m height

Results: Unaspirated Sensors (3 m)

Stationary sensors on light poles collected year-long T_{air} data above cool and dark pavements. Real-time comparison revealed both cooling periods and counterintuitive apparent warming.

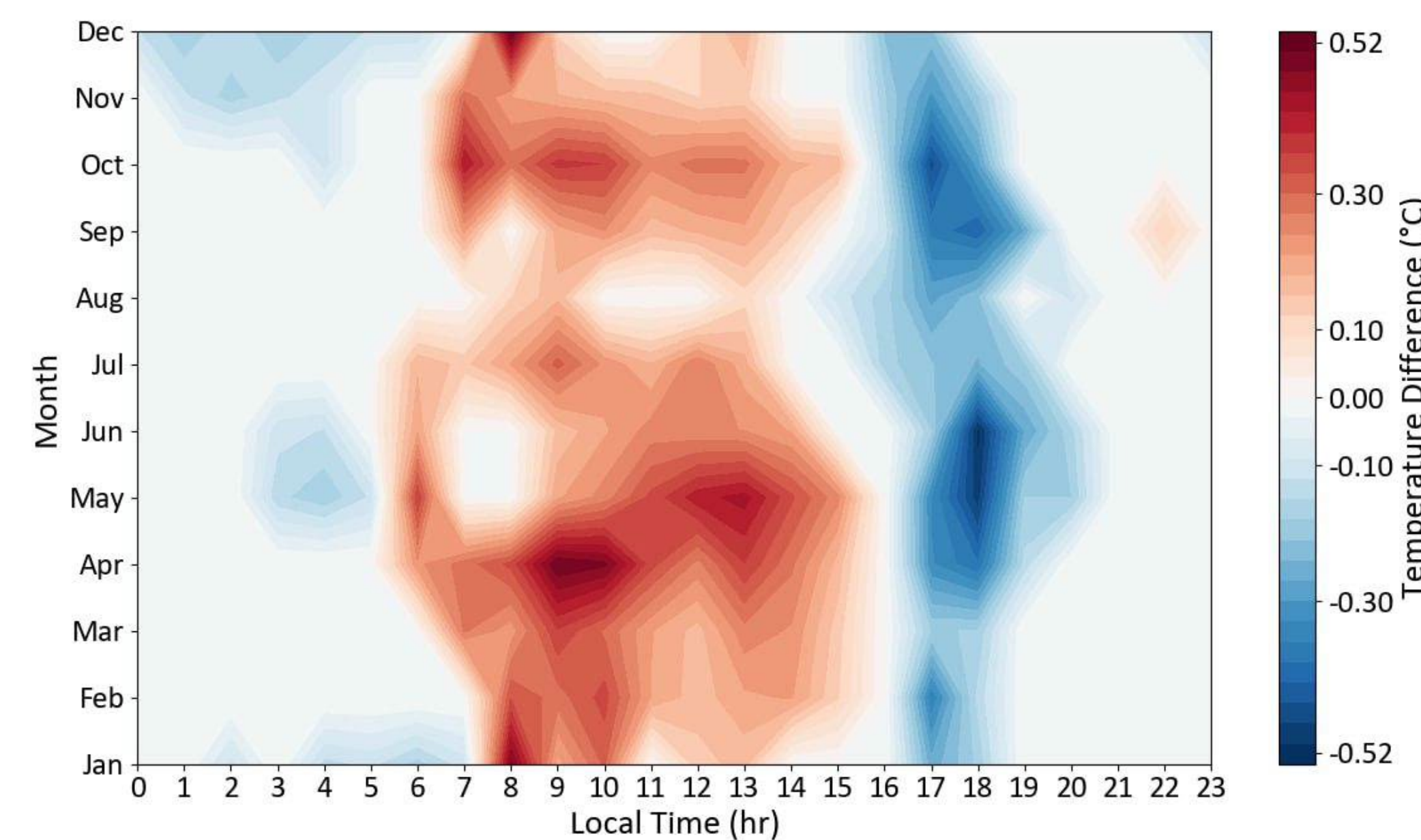


Fig. 3: Real-time hourly T_{air} difference (cool – dark) at 3 m across one year.

Key findings from unaspirated sensors:

- Greatest cooling: 5:00–7:00 PM (max ~0.52 °C)
- Slight cooling: 2:00–5:00 AM (reduced stored heat)
- Counterintuitive warming during morning (9–11 AM) and afternoon (12–2 PM), up to ~0.47 °C, especially during March–May and October–November
- Warming attributed to reflected shortwave radiation biasing sensor enclosures above the more reflective cool surface

Difference-in-Differences Analysis

The DD approach compares T_{air} differences before and after installation, excluding confounding variables.

- Cooling in late afternoon, evening, and midnight hours
- Maximum T_{air} drop: 0.58 °C at 6:00 PM
- Greatest overnight decrease: 0.38 °C before 6:00 AM
- Apparent warming persists during most daylight hours

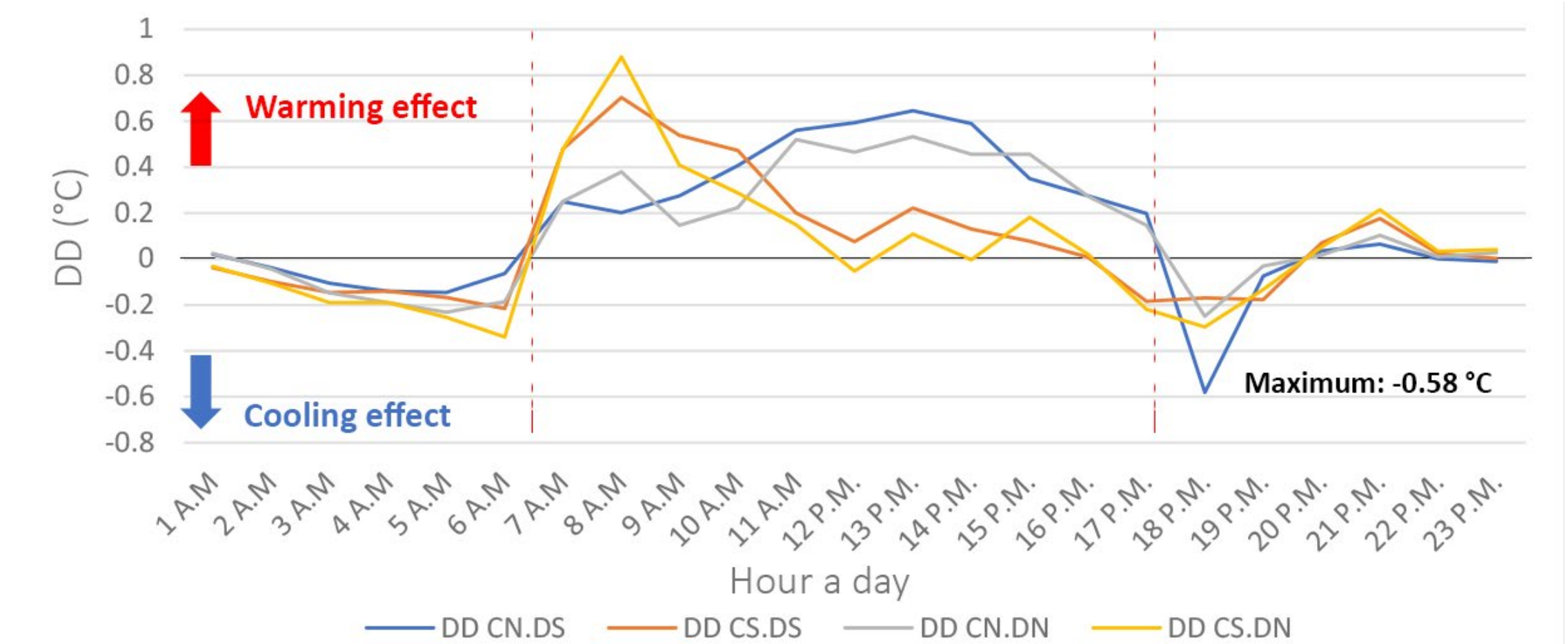


Fig. 4: Line graph showing hourly air temperature differences between sensor pairs, through calculating DD ($\Delta_{post} - \Delta_{pre}$).

Aspirated Sensor

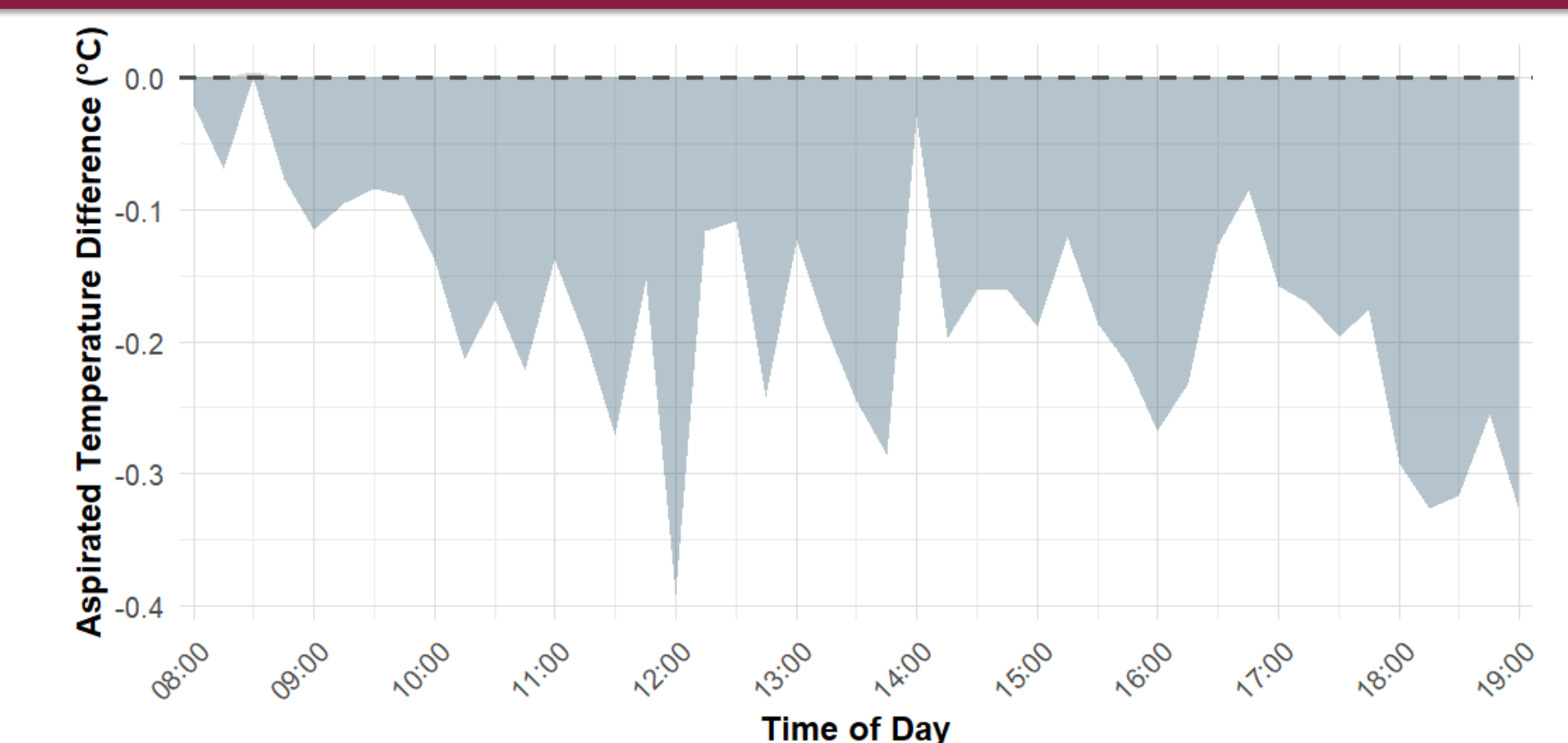


Fig. 5: Avg. hourly T_{air} difference (cool – dark), aspirated sensors, June 25–July 15.

Aspirated sensor results:

- Fixed aspirated sensors: ~0.4 °C cooling above cool pavement around noon
- No daytime warming detected with aspirated sensors
- Confirms daytime warming from unaspirated sensors was an artifact of reflected radiation warming sensor enclosures

Unaspirated sensors can introduce bias in T_{air} measurements, consistent with previous studies reporting apparent warming effects of 0.1–3 °C [1,2].

Conclusions

- Cool pavement produces meaningful T_{air} reductions of 0.4–0.6 °C during late afternoon and evening hours
- Slight overnight cooling (0.3–0.4 °C) due to reduced heat storage in cool pavement
- Apparent daytime warming in standard sensors was a measurement artifact caused by reflected shortwave radiation
- Aspirated measurements showed net cooling once radiative bias was removed
- These results highlight the importance of aspirated sensing for evaluating cool pavement performance in hot, arid urban environments

Acknowledgments

This research was supported by the ASU Urban Climate Research Center. We thank Desert Ridge Marketplace management for site access and the City of Phoenix for supporting this cool pavement pilot.

References

- [1] Erell, E., Leal, V., and Maldonado, E. (2005). Measurement of air temperature in the presence of a large radiant flux. *Boundary-Layer Meteorology*, 114(1), 205–231.
- [2] Nakamura, R. and Mahrt, L. (2005). Air temperature measurement errors in naturally ventilated radiation shields. *J. Atmos. Oceanic Technol.*, 22(7), 1046–1058.