

PARKS AND THE URBAN HEAT ISLAND: A LONGITUDINAL STUDY IN WESTFIELD, MASSACHUSETTS

Robert S. Bristow
Geography and Regional Planning
Westfield State College

Robert Blackie
Westfield State College

Nicole Brown
Lyndon State College

Abstract.—Urban landscapes often have warmer temperatures than the surrounding countryside, a phenomenon known as the urban heat island (UHI) effect. This study compares and contrasts temperatures across Westfield, Massachusetts, a moderate size New England city, and considers the influence that the city's parks and protected areas have on the local microclimate. The data show a clear urban heat island in the downtown area of Westfield and show that the urban heat island grew larger between 1993 and 2009.

1.0 INTRODUCTION

Urban landscapes often have warmer temperatures than the surrounding countryside. Known as the urban heat island (UHI) effect, this phenomenon was first identified by meteorologist Luke Howard in 1818. UHIs were first studied by medical doctors because of the connection between urban air quality, air temperatures, and health. Later, scientists were able to distinguish the environmental factors that cause warmer temperatures in urban areas. Today artificial surfaces including pavement, sidewalks, and buildings, plus traffic and related infrastructure contribute to warmer urban temperatures (Braham 1977, Martin and Powell 1977). Paved surfaces typically cover up to 30 percent of the land in cities. This “asphalt jungle” absorbs solar energy received during the day and releases heat into the atmosphere at night. Additional

heat is generated by vehicles and by heating and ventilation units on buildings.

There has been a lot of past research on parks and climate change. Parks are usually mostly unpaved open space and are known to mitigate the consequences of climate change by providing cooling effects and carbon sequestration (Alig 2009, Braham 1977, MacDonald 2009, Spronken-Smith and Oke 1998). Urban parks have also long served local residents as enclaves of relief from the summer heat. Some research has found that an increased chance of thunderstorms and other precipitation is directly tied to human-induced higher urban temperatures (Bornstein 1968, Bornstein and Lin 2000, Kim and Baik 2005). Dixon and Mote (2003) found low-level moisture to be important in producing precipitation, but they also acknowledge that the UHI effect is an important factor.

The UHI effect is not limited to midlatitude or major cities. Barrow, Alaska (lat. 71° N) has a known UHI with increased temperatures of as much as 2 °C that can affect the city's permafrost (Hinkel et al. 2003). Midsized cities like Columbia, Missouri (population 84,000) have found that temperatures can be 1 to 2 °C warmer than in the suburbs. While these differences may seem minor, even a one-degree change can mean the difference between rain and snow.

In contrast, arid landscapes experience only a mild UHI effect. Principally this is because the built-up urban center absorbs and releases heat in much the same way as the surrounding desert. When an area is naturally-forested, a pronounced UHI can occur as city features replace the forests (Carlowicz 2010).

Fortunately, not all parts of an urban area are built up. Urban parks and open spaces such as riparian corridors (Endreny 2008, Martin and Powell 1977), forested lands (Heisler et al. 2007), and grassy fields (Murphy

et al. 2007) have been observed to mitigate warmer surrounding urban temperatures. Urban forests also mitigate the deleterious effects of UHIs (Alig 2009) and improve air quality in urban landscapes (Nowak 1995). The American Planning Association's City Parks Forum has identified these four ways that urban parks help mitigate UHIs:

- Parks moderate artificially higher temperatures from the urban heat island effect through shading and evapotranspiration.
- Parks enhance local wind patterns in cities through the park breeze (cooler air over parks replaces warmer air in adjacent city neighborhood).
- Parks mitigate local precipitation anomalies amplified by the urban heat island effect.
- Parks sequester carbon and other pollutants trapped by the urban heat island that may otherwise alter local and global atmospheric composition. (MacDonald 2009)

Finally, heat waves kill more people in the United States than hurricanes, tornados, earthquakes and floods combined (Golden et al. 2008). Since urban areas have the bulk of the world's population, especially in the developing world, mitigating UHIs may help reduce the health impacts of global climate change at the local scale.

1.1 Case Study

Westfield is a 46 square-mile city located in Hampden County in Western Massachusetts. Also known as "Whip City," Westfield was incorporated in 1669 and grew from an agricultural community to a small industrial city by the mid-1800s. Westfield was once well known for producing bricks, whips, cigars and many other products. According to historic U.S. Geological Survey topographic maps, there was a major expansion of the city center outward and a concentration of neighborhood roads between 1895 and the 1940s. As this road and building construction occurred, the downtown area began to have less greenery and trees. During this time, the city designated thirty parks and playgrounds. The historic Westfield Commons was set aside in 1732.

The city is bounded by higher elevations on the east and west borders. The Westfield River drains the Berkshire Mountains and bisects the town into a northern section and a southern section. Currently there are about 40,000 residents in the city.

2.0 METHODS

This study used two sampling schemes to collect air temperature data in Westfield. The entire city was sampled since Westfield's land use pattern deviates from a theoretical model of concentric circles. Following Murphy et al. (2007), data were collected using fixed-height thermometers starting on the outskirts of the community. Both mobile and pedestrian data collection methods were employed. Three automobiles drove east to west, north to south, and on an eastern loop to collect data at $\frac{1}{4}$ to $\frac{1}{2}$ mile intervals. This transect method, also employed by Melhuish and Pedder (1998), does not permit simultaneous data collection at all sampling points but is still relevant since the goal was to measure differences between the urban core and the outlying suburban and rural landscapes.

Research by Kim and Baik (2005) found the highest UHI effect occurred overnight at 0300 local time, while Bornstein (1968) collected temperatures at predawn. For our study, data were collected during the predawn hours to obtain the coolest temperatures for the region.

The first data set was obtained on 23 November 1993 (Bristow and Mullens 1996). Sites for air temperature readings were randomly selected for the entire city. In order to compare current conditions with those from the earlier study, an updated inventory was repeated 16 years later on 6 November 2009. In addition to collecting temperature readings for the outskirts of the city, sampling in the downtown area included oversampling in built-up areas and several urban parks.

3.0 RESULTS

Both the 1993 and 2009 studies found a pronounced UHI effect in the center of the city. In 1993, the

temperature range across the city was 6 °F. Cooler temperatures were found along the Westfield River and along the eastern and western boundaries of the city (which are at higher elevations). In the 2009 data, the downtown area also experienced warmer UHI temperatures, although temperatures in the park areas were somewhat cooler.

Figure 1 shows the absolute temperature readings for 1993 and 2009. In 1993, there is a clear heat island in the downtown area on both the north and south sides of the Westfield River. The isotherms (lines of equal temperature) show warmer temperatures in the built-up downtown area and cooler temperatures in rural farmland away from commercial development. While cooler temperatures would be expected in the riparian

corridor, the data collected in 1993 were too coarse to permit such an analysis.

In Figure 1, the temperature scale is the same for each year; that is, a quick look at the two years suggests that there was a tremendous increase in temperature over the 16 years. Actually, the weather conditions were quite different during the two sampling periods and the 2009 data were collected 17 days earlier in November than the 1993 data. In an effort to standardize the UHI findings, a median temperature was calculated for the two time periods. Median temperatures rather than mean were used to offset the oversampling of downtown data points in 2009. In 1993, the average temperature in the data set was 33 °F. In the milder fall of 2009, the average temperature was 38 °F. Since the

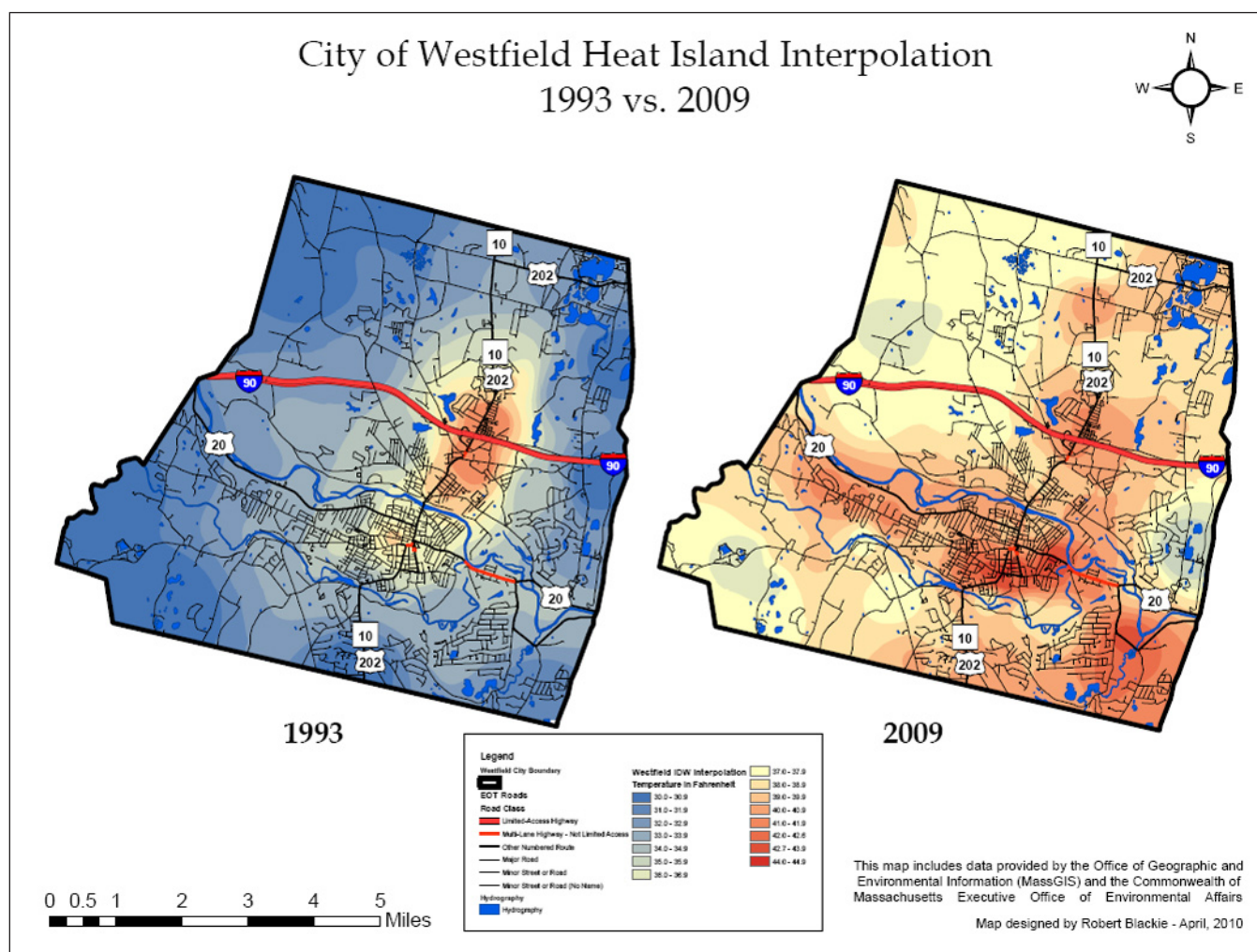


Figure 1.—Raw temperature data of Westfield with geographical information system (GIS) interpolation for years 1993 and 2009.

difference in relative temperature is the most important element of UHI, these averages, while different, can still be used to identify the UHI effect in Westfield.

Figure 2 shows UHI maps for 1993 and 2009 with the differences in absolute temperatures standardized – where it is hotter than the median temperature (in red) and where it is cooler (in blue). The UHI effect appears to have expanded to a larger area of downtown over the sixteen years.

In 2009, several pedestrian researchers canvassed the downtown area to obtain finer-grain temperature data at 100-foot intervals (Figure 3). The additional air temperature data shows the UHI effect at a finer scale.

It is interesting to note the bifurcated temperatures on the north side versus the south side of the city.

The cooler temperatures in the north may be caused by the eastward flow of the Westfield River from the highlands in the west. In addition, north of the river, higher elevations gradually climb toward the hill town of Montgomery. The cooling effect of the river may be “pushed” by a mountain breeze as cool air drains from the higher elevations. For the southern portion of downtown, temperatures were 4-5 °F warmer, perhaps because of large parking areas and a small industrial park.

Finally, it is important to note that there are cooler temperatures around the city green in the 2009 data (blue spot in the center of Figure 3). This small area, known as Park Square, was acquired by the city in the 1835. Citizens planted trees in 1859 and today the park is still well used, hosting farmer’s markets and local festivals. It is clear that the grassy grove of

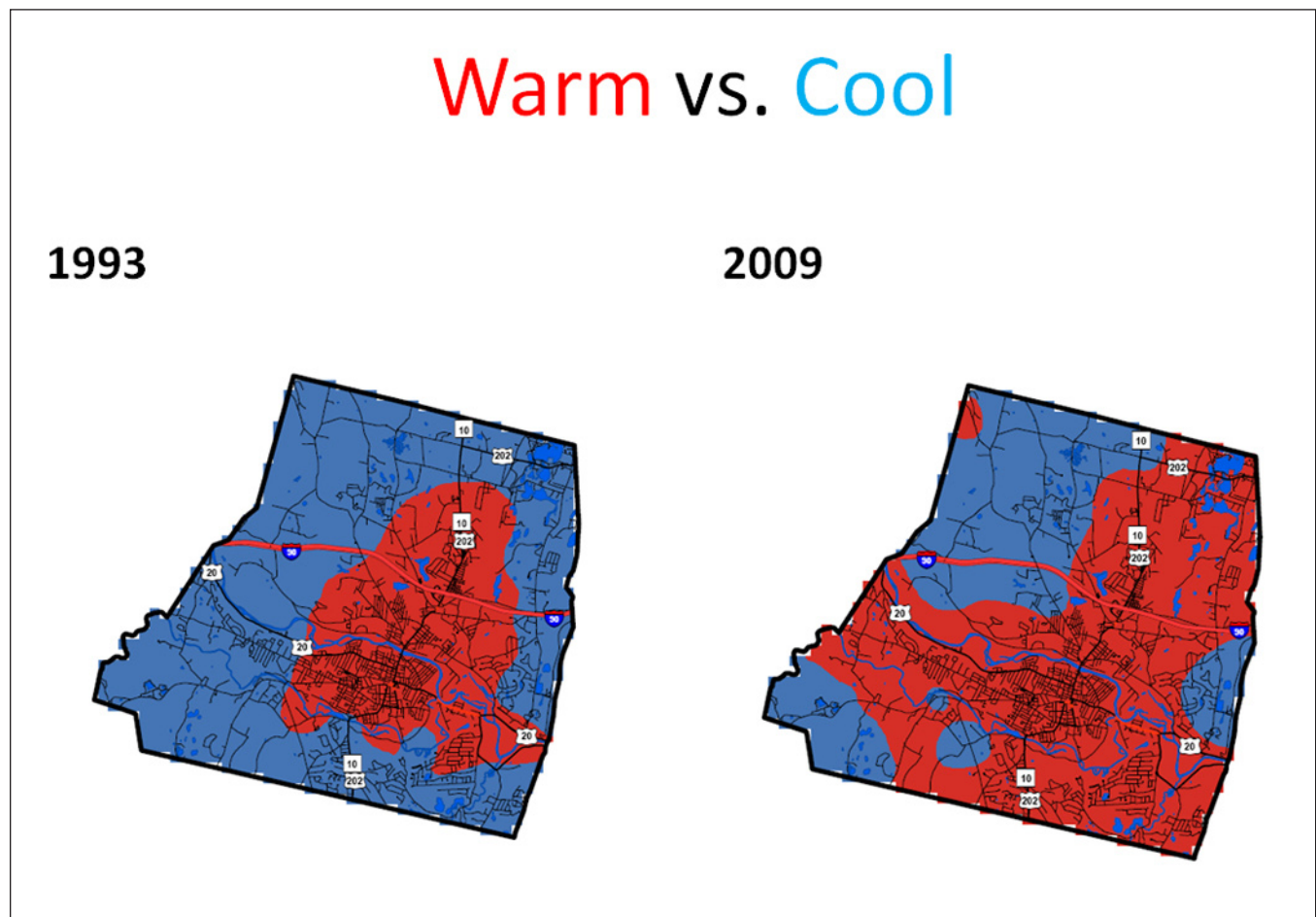


Figure 2.—Standardized urban heat island (UHI) maps for 1993 and 2009.

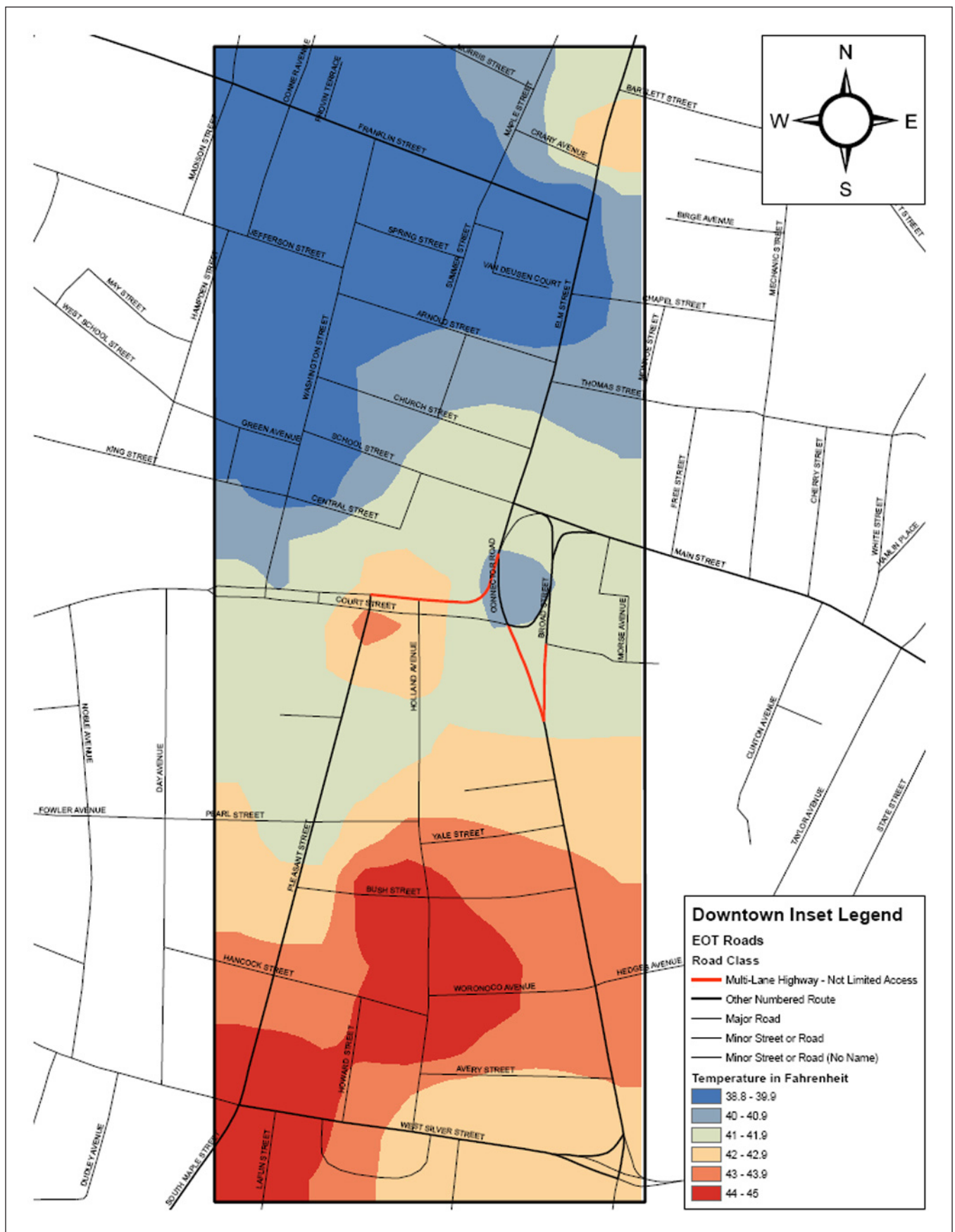


Figure 3.—The downtown urban heat island (UHI) and cooler park area.

trees mitigates the UHI since it is at least one degree Fahrenheit cooler than the pavement surrounding it. As Pinho and Manso Orgaz (2000) caution, the lack of parks in cities only adds to UHI effects.

4.0 DISCUSSION AND CONCLUSIONS

Two important findings of this study warrant discussion. First, even when data are standardized for the different climatic conditions between 1993 and 2009, the UHI effect has apparently expanded outward from the city core. A modest population growth during this time period may offer some explanation, but increased vehicular traffic has probably also exacerbated the problem.

Second, the finer-grained 2009 data highlights the positive benefit of the small green in mitigating the warmer downtown temperatures. This research demonstrates the positive environmental benefits of urban green spaces, which help improve microclimatic conditions.

Urban forests include many smaller parks and protected areas that may go unnoticed and unused by thousands of people who drive by them. Beyond the occasional festival or fair, these urban parks provide a place for urban residents to recreate or socialize. This research suggests that even small urban parks can provide a vital climate control against the effects of urban heat islands.

Several questions remain for further research. First, the Westfield River and down-slope drainage of cooler air from the hills may influence the cooler temperatures north of Park Square, but further research is needed on the impact of the river and varied elevation levels on nearby temperatures. Second, it would be useful to study what happens to urban air temperatures when parks are deforested. In May 2010, the Park Square trees were cut down as part of an urban redevelopment plan, so the authors will explore the impact of these actions on nearby air temperatures in November 2010.

Finally, more research is needed on how changes in land cover and urbanization affect global temperatures since most studies to date have concentrated on atmospheric and ocean temperature exchange (Carlowicz 2010). For example, what impacts do urban heat islands have on the global or regional temperature changes, and how much can urban parks and other open spaces mitigate these changes? The small temperature differences found in our study (both across the city and over the 16-year period between data collections) might suggest broader affects if we could replicate the findings for each city on the planet.

5.0 ACKNOWLEDGMENTS

The authors wish to thank the students in GARP0346 Quantitative Methods (Fall 2009) for their help with the data collection. We also wish to thank Dr. Carsten Braun for his review of this manuscript.

6.0 LITERATURE CITED

- Alig, R. 2009. **We're all in this together: decisionmaking to address climate change in a complex world.** Science Findings. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 116: 1-2.
- Bornstein R. 1968. **Observations of urban heat island effect in New York City.** Journal of Applied Meteorology. 7: 575-582.
- Bornstein, R.; Lin, Q. 2000. **Urban heat islands and summertime convective thunderstorms in Atlanta: three case studies.** Atmospheric Environment. 34: 507-516.
- Braham, R. 1977. **Overview of urban climate.** In: Heisler, G.; Herrington, L. eds. Proceedings of the conference on metropolitan physical environment. Gen. Tech. Rep. NE-25. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 3-17.

- Bristow, R.; Mullens, J. 1996. **Environmental education: a geographical approach**. In: Middlekauff, B., ed. *Proceedings of the New England St. Lawrence Valley Geographical Society*. Plymouth State College. Vol. 25.
- Carlowicz, M. 2010. **Ecosystem, vegetation affect intensity of urban heat island effect**. *The Earth Observer*. 22(1): 36-37.
- Dixon, P.; Mote, T. 2003. **Patterns and causes of Atlanta's urban heat island-initiated precipitation**. *Journal of Applied Meteorology*. 42: 1273-1284.
- Endreny, T. 2008. **Naturalizing urban watershed hydrology to mitigate urban heat-island effects**. *Hydrologic Processes*. 22: 461-463.
- Golden, J.; Hartz, D.; Brazel, A.; Luber, G.; Phelan, P. 2008. **A biometeorology study of climate and heat-related morbidity in Phoenix from 2001 to 2006**. *International Journal of Biometeorology*. 52(6): 471-80. Available at <http://www.springerlink.com/content/j20r26199m664074/>. (Accessed October 2009).
- Heisler, G.; Walton, J.; Yesilonis, I.; Nowak, D.; Pouyat, R.; Grant, R.; et al. 2007. **Empirical modeling and mapping of below-canopy air temperatures in Baltimore, MD and vicinity**. In: *Proceedings of the seventh urban environment symposium; September 10-13, 2007; San Diego, CA: American Meteorological Society*. 7 p.
- Hinkel, K.; Nelson, F.; Klene, A.; Bell, J. 2003. **The urban heat island in winter at Barrow, Alaska**. *International Journal of Climatology*. 23: 1889-1905. Available at: <http://www.geography.uc.edu/~kenhinke/uhi/HinkelEA-IJOC-03.pdf>. (Accessed October 2009).
- Kim, Y.; Baik, J. 2005. **Spatial and temporal structure of urban heat island in Seoul**. *Journal of Applied Meteorology*. 44: 591-605.
- MacDonald, J. 2009. **How cities use parks for climate change management**. City Parks Forum Briefing Papers #11. American Planning Association. Available at: <http://www.planning.org/cityparks/briefingpapers/climatechange.htm>. (Accessed October 2009).
- Martin, F.; Powell, G. 1977. **The urban heat island in Akron Ohio**. In: Heisler, G.; Herrington, L., eds. *Proceedings of the conference on metropolitan physical environment*. Gen. Tech. Rep. NE-25. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 94-97.
- Melhuish E.; Pedder, M. 1998. **Observing an urban heat island by bicycle**. *Weather*. 53: 121-128.
- Murphy, D.; Hall, M.; Hall, C.; Heisler, G.; Stehman, S. 2007. **The relationship between land-cover and the urban heat island in Northeastern Puerto Rico**. In: *Proceedings of the seventh urban environment symposium; September 10-13, 2007; San Diego, CA: American Meteorological Society*.
- Nowak, D. 1995. **The effects of urban trees on air quality**. Washington, DC: U.S. Department of Agriculture, Forest Service. Available at: www.fs.fed.us/ne/syracuse/gif/trees.pdf. (Accessed November 24, 2009).
- Pinho, O.; Manso Orgaz, M.D. 2000. **The urban heat island in a small city in coastal Portugal**. *International Journal of Biometeorology*. 44: 198-203.
- Spronken-Smith, R.; Oke, T. 1998. **The thermal regime of urban parks in two cities with different summer climates**. *International Journal of Remote Sensing*. 19(11): 2085-2104.

The content of this paper reflects the views of the author(s), who are responsible for the facts and accuracy of the information presented herein.