A Novel Method for Assessing the Health Impacts of Urban Heat

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INTRODUCTION

Extreme heat is among the leading causes of weather-related mortality and morbidity in the United States[1]. Reducing the incidence of heat-related deaths and illnesses is often cited as a motivation for urban heat mitigation strategies[2]. Despite the intuitive claim that urban residents are at higher risk of these health events because of higher temperatures in cities, the literature demonstrating such an association is quite limited. We aimed to understand if an association exists between **urban heat intensity** and heat-related deaths in Maricopa County, Arizona, separately from the well-established link between temperature as measured at one site and heat-related deaths[3].

MATERIALS AND METHODS

Health Data

Daily counts of heat-related deaths were obtained from the Maricopa County Department of Public Health (MCDPH) for 2006– 2015. MCDPH operates an advanced heat mortality and morbidity surveillance programs in which health events suspected of being influenced by environmental heat are subject to additional review. 760 cases were reported over the study period. More details about the MCDPH heat surveillance program are available at heataz.com.

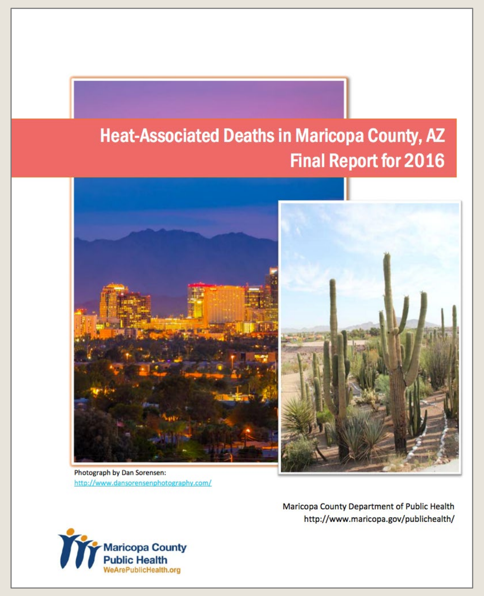

Figure 1 (above): Cover of MCDPH 2016 heat mortality report

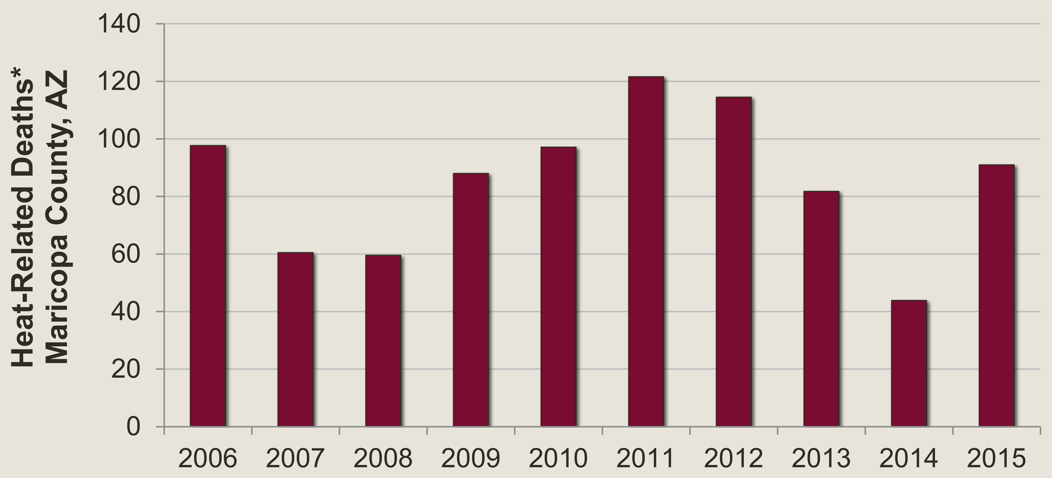

Figure 2 (to left): Annual heat-related deaths reported by MCDPH, 2006-2015. *Annual totals have been adjusted by total annual mortality in the county to account for long-term trends in population size and composition and health status.

Weather Data

Hourly and daily temperature observations were obtained from the National Centers for Environmental Information, Maricopa County Air Quality Department, and the Arizona Meteorological Network (AZMET). The analysis shown on this poster is based on data from Phoenix Sky Harbor Airport, located within five miles of downtown Phoenix, and the Queen Creek AZMET station, located more than 35 miles from downtown. The Queen Creek station falls outside the extent of continuous urban development.

Statistical Modeling

We modeled heat-related deaths as a function of daily mean temperature at Queen Creek station (QCmean) and urban heat intensity (UHI), defined as the difference in daily mean temperature between the two stations. The model took the form:

Log(scaled_heatdeaths) = s(QCmean, k=4) + s(UHI, k=4)

where *scaled_heatdeaths* is the standardized daily count of heat-related deaths and *s* is a natural penalized thin plate smoothing spline with *k*-1 degrees of freedom. The model was run in R using the *mgcv* package.

RESULTS

Consistent with extensive previous research, **we found substantial differences in daily mean temperatures between an urban core site (Sky Harbor Airport) and an urban fringe site (Queen Creek)** (Figures 3 and 4)[4]. On average, temperatures at Sky Harbor were 6.3°F higher than at Queen Creek, and reached a maximum difference of 12.5°F. This difference (UHI) was positive on all but 11 of the 3,649 days for which observations were available from both stations. Many of the highest UHIs were observed on the hottest days in the study period, and hotter days were associated with stronger UHIs on average (Figure 5). For example, the average UHI on days with temperatures above 100°F was nearly 0.8°F larger than on days with temperatures in the range 90-100°F.

We also found a similarly strong association between daily mean temperature and heat-related deaths as reported elsewhere (Figure 6). The statistical model estimated **a sharp increase in heat-related deaths beginning at daily mean temperatures near 90°F**, at which approximately one death per day would be expected. Risk nearly doubled at daily mean temperatures of 95°F and even more rapidly increased at higher temperatures. The effect estimate on the hottest days was more than seven heat-related deaths.

Daily urban heat intensity was positively associated with risk of heat-related deaths (Figure 7). The lower confidence interval of the effect estimate exceeded 1.0 at a UHI of 7.0°F and nearly linearly increased toward higher UHIs. The model estimated a relative risk of more than 1.5 for the highest UHIs observed over the study period. Nearly 300 fewer heat-related deaths (a reduction of 34%) were predicted over the study period in a model with UHI values limited to a maximum of 6°F, suggesting that urban heat countermeasures could reduce the health burden associated with high temperatures.

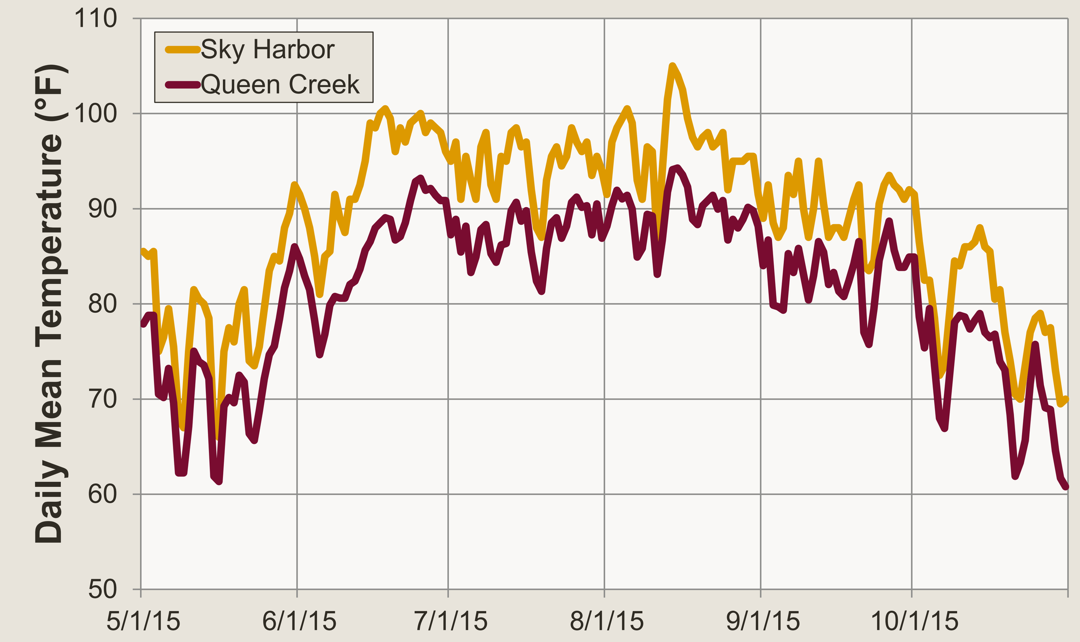

Figure 3: Daily mean temperature observations at Sky Harbor Airport and the Queen Creek AZMET station. Data are shown for summer 2015 only for demonstration purposes.

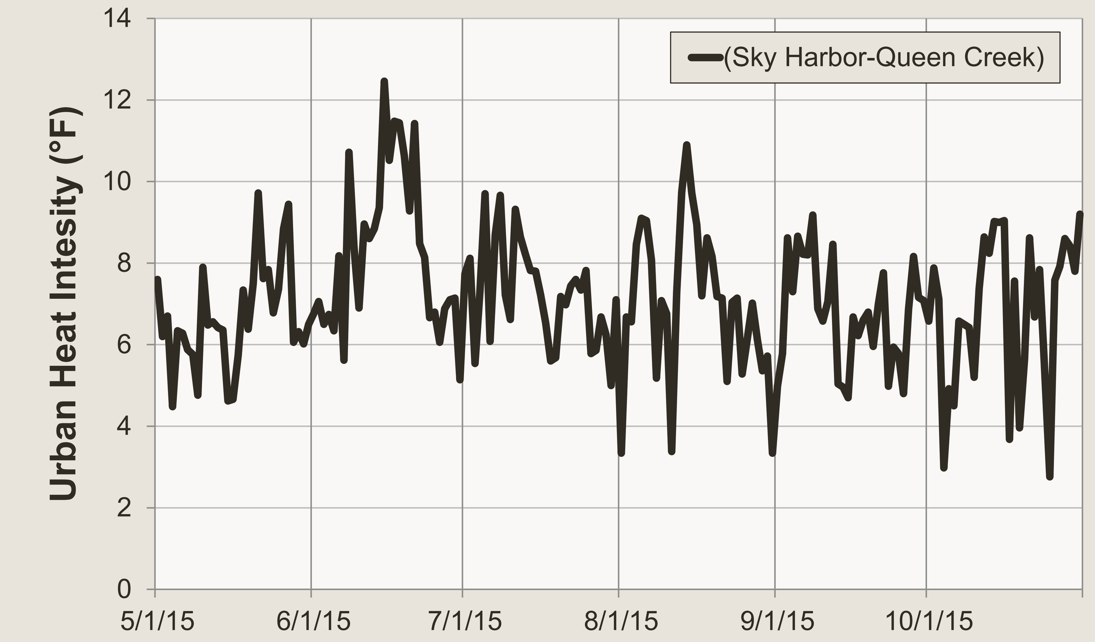

Figure 4: Daily urban heat intensity in Maricopa County, AZ, as measured as the difference between Sky Harbor Airport and Queen Creek. Data are shown for summer 2015 only for demonstration purposes.

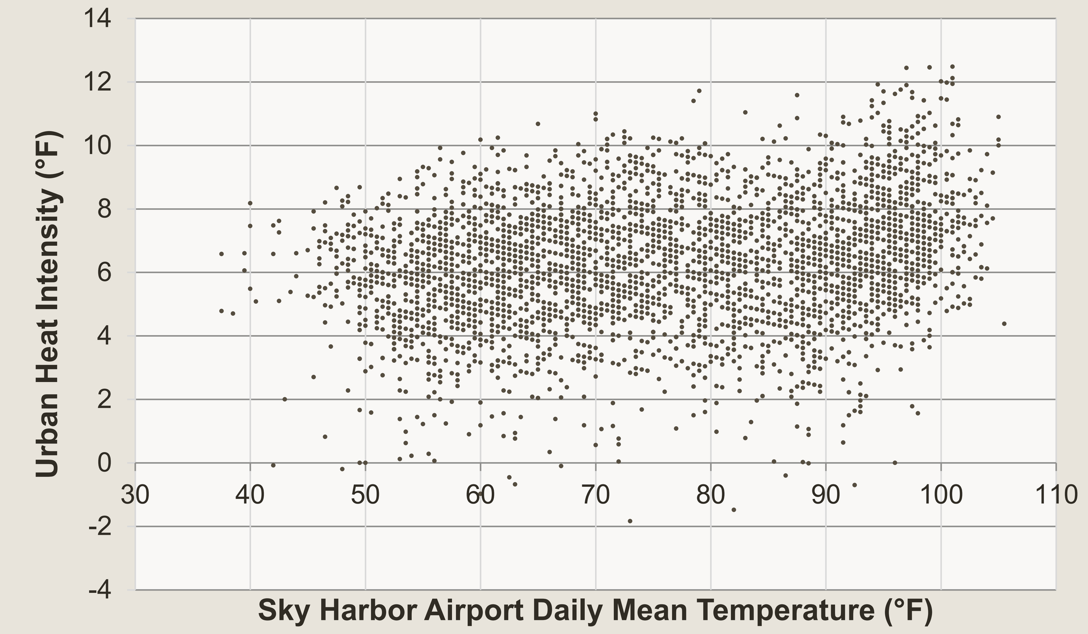

Figure 5: Scatterplot showing the association between daily mean temperature as measured at Sky Harbor Airport and daily urban heat intensity in Maricopa County, AZ, over the period 2006–2015.

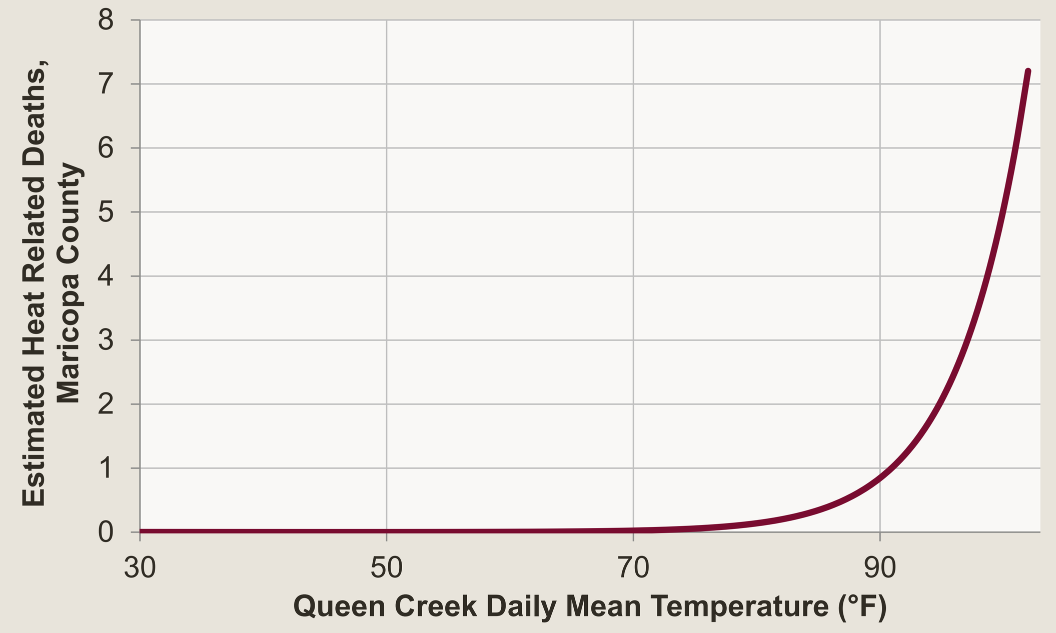

Figure 6: Estimated association between daily mean temperature at the Queen Creek AZMET station and the number of heat-related deaths in Maricopa County, AZ, 2006-2015.

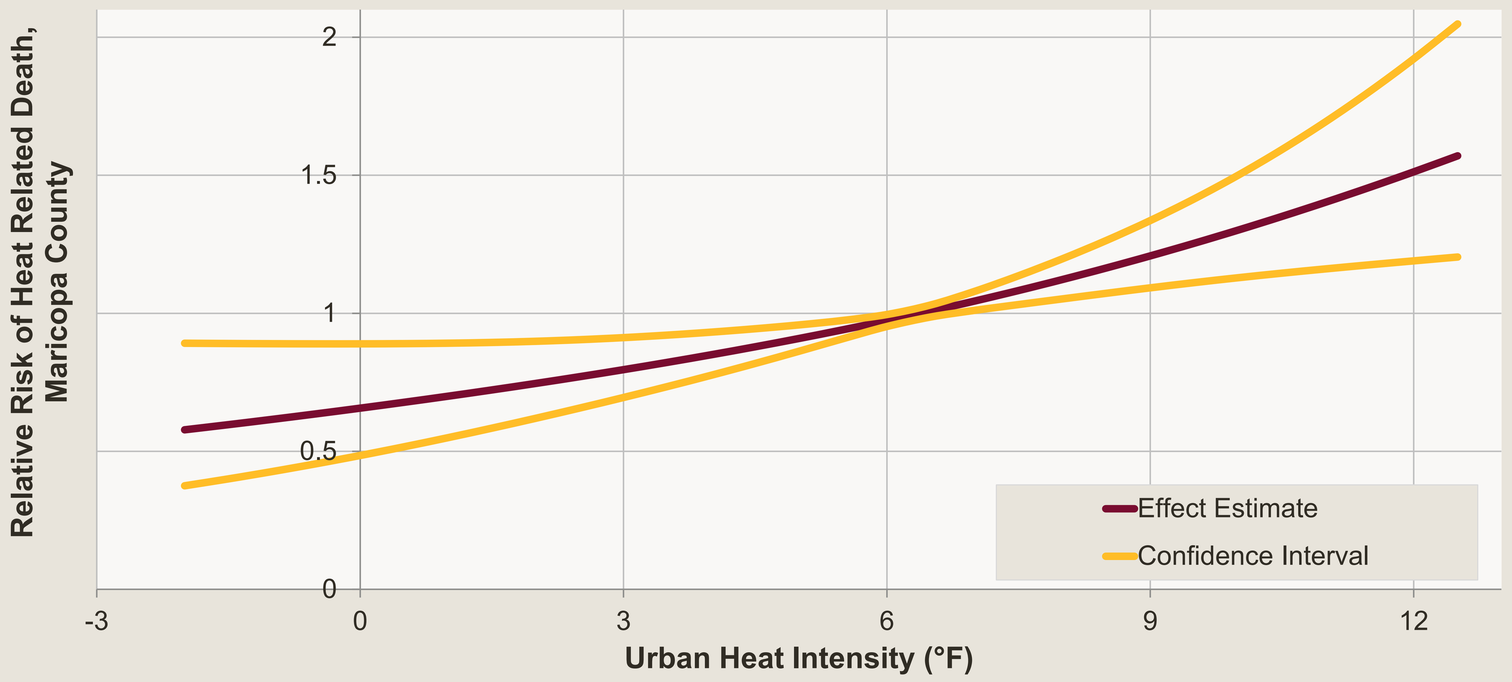

Figure 7: Estimated association between daily urban heat intensity, measured as the difference between Sky Harbor Airport and Queen Creek station, and the relative risk of heat-related death in Maricopa County. The maroon line shows the effect estimate and the gold lines show the 95% confidence interval.

CONCLUSION & DISCUSSION POINTS

In our analysis days with a more intense urban heat effect were associated with a higher risk of heat-related death than those with a less intense effect. Temperatures as measured at a fixed-point site outside of the urban core likely underestimate the exposure for the entirety of the metropolitan population. We observed a similar (but reverse) effect when the model was based on temperatures measured at Sky Harbor Airport instead of Queen Creek.

Additional work is needed to test for confounding factors and effect modifiers including humidity, air quality, solar radiation, and mortality displacement. Further research demonstrating that personal heat exposure is higher for residents of the urban core would also strengthen the findings. If confirmed, our results demonstrate that urbanization-driven warming in Maricopa County has been a driver of heat-related mortality.

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