Localizing urban heat island at microclimate scale: Evidence from Philadelphia

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1. Introduction

With the increasingly greater threat of climate change and the rapid growth of urbanization, the Urban Heat Island and Urban Pollution Island effects are further exacerbated. These two phenomena describe the effect of urban environments experiencing higher temperatures and greater concentrations of air pollutants compared to the surrounding rural areas (Santamouris, 2015; Crutzen, 2004). This difference can be explained by urban morphology that shape the urban microclimate, a small, localized area that experiences unique conditions that differ from the surrounding region. While this microclimate scale can capture the effects of UHI and UPI, urban researchers commonly use Typical Meteorological Year (TMY) data to describe the city. However, TMY data does not accurately reflect the weather conditions experienced in the urban environment (Shen et al., 2021). This is a research gap that must be explored.

Research Question: How do local buildings and urban features represent exhaustively for Urban Heat Island intensity at the microclimate scale?

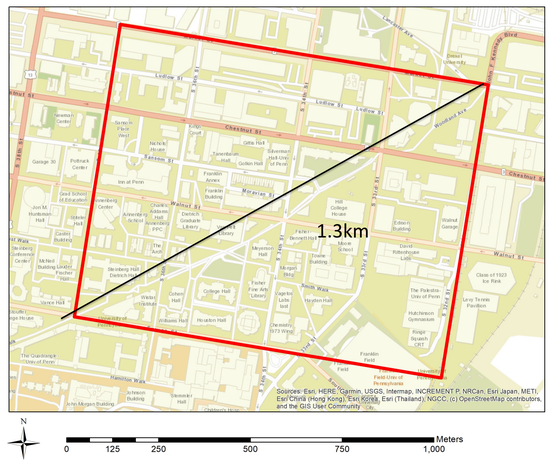
1) How large is the intra-urban variability in urban microclimate as well as that of outdoor thermal comfort and air pollutant (e.g., PM2.5) distribution, and to what extent are they linked?
2) To what extent is this variability determined by local features?
3) What is the relative importance of the urban landscape parameters in explaining microclimate, thermal comfort, and air quality?

2. Literature

- TMY data is widely used in urban research and is created by taking historical weather records gathered from rural airport weather monitors to represent the typical yearly weather of a location (Parker, 2021)
    - Variables collected by TMY data and local weather stations that can measure for the effects of UHI and UPI include outdoor air temperature, relative humidity, wind speed, gust speed, dew point temperature, solar radiation, and PM 2.5
- Microclimate research has increased over the concern of the use of TMY data yielding inaccurate representations of the urban environment
    - Many building models and simulations use TMY data to satisfy their weather parameter. Studies that compared the use of TMY data in these models with the use of microclimate weather data found that predictions using TMY data were less accurate than predictions that used microclimate data (Li et al., 2018).
- The built environment of cities has distinct characteristics that create unique microclimates that affect localized weather conditions (Zhao et al., 2021)
    - Some urban landscape characteristics that researchers typically analyze include vegetation coverage, tree coverage, building height, site coverage ratio, glazing ratio, albedo, and emissivity of the building surface

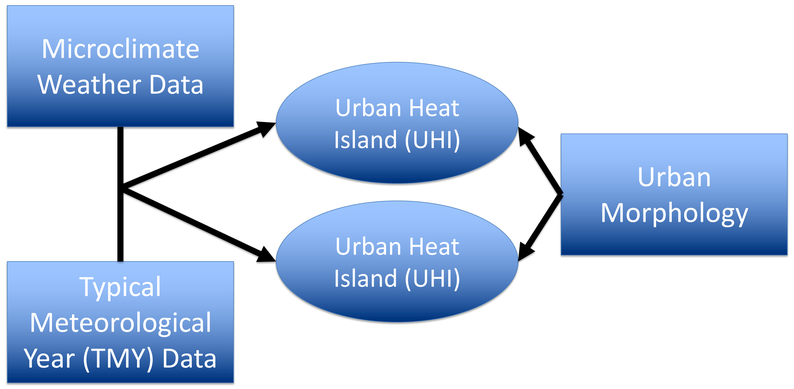
3. Sample Region

- Our University City sample region defined in the figure below will be used to study the UHI and UPI effect in a localized microclimate
- It is bounded to the north and south by Market St. and Spruce St. and to the east and west by 32nd St. and 37th St.

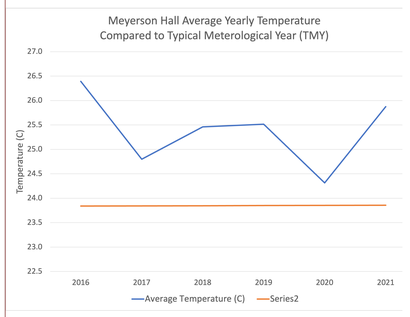


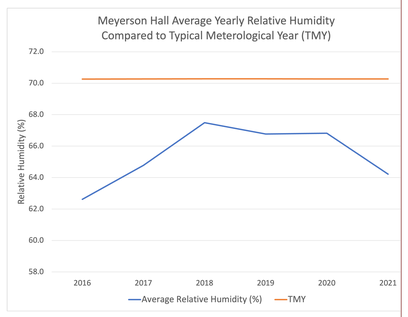
4. Methodology

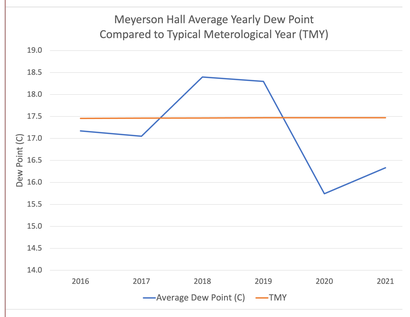
- This study examines UHI and UPI using two different types of datasets to 1) analyze the variation between using microclimate versus TMY weather data, 2) access the intensity of UHI and UHI, and 3) determine how urban morphology account for these two phenomena
- Microclimate and TMY weather data will be compared against each other to study the differences in actual conditions experienced in the city that is not captured by TMY data
- This difference in reported weather conditions will illustrate UHI and UPI intensity.
- Urban morphology will be analyzed to determine how they affect UHI and UPI



5. Results







- Microclimate weather data was collected in June, July, and August from 2016 to 2021
- Yearly averages were calculated for the temperature, relative humidity, and dew point data collected by the microclimate weather station (shown in blue)
- An average for each of these variables was calculated for the summer months recorded by the TMY data (shown in orange)
- TMY data consistently underestimated temperature and overestimated relative humidity experienced in the sample region and does not precisely reflect the dew point

6. Policy Implications and Conclusions

- Urban researchers widely use TMY data instead of microclimate data to study the city. However, this leads to inaccurate representations of the conditions experienced by those living in the city
- Urban designers and city planners rely on this research and these building models when creating buildings and cities. This leads to building choices that are made underestimating the severity of the UHI and UPI effects
- The use of microclimate weather data would better represent urban conditions and lead to building design choices that promote better conditions for those living there
- Understanding the effect that different urban characteristics have on the urban microclimate can help city planners design spaces that mitigate the effects of UHI and UPI
- To increase thermal comfort, many urban design choices could be made to lower air temperatures such as the reflectiveness of high albedo building materials and the cooling effect of water surfaces and green spaces (Ragheb et al., 2016; Sabrin et al., 2021).

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Selected References

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