Heat and Human Health

Preparing for More Extreme Heat Events in New York City

Motivation

Climate change is increasing the frequency and intensity of extreme heat worldwide. Heat-related illnesses may result in organ damage, permanent disability, or death. In the United States, extreme heat events are a leading cause of extreme weather-related deaths. Thus, there is a need to investigate the relationship between heat and human health so communities can better prepare for extreme heat events.

Urban areas located in middle latitudes have high heat vulnerability. Previous studies about heat and human health have primarily analyzed mortality data to identify vulnerable populations to extreme heat. Research involving morbidity data is lacking but could provide more spatial insight than mortality data about this environmental health issue.

New York City (NYC) is a middle latitude city with over 8 million residents. Using emergency medical services (EMS) incident dispatch data and local climatological data, zip codes in which there was a significant increase in EMS incidents on extreme heat days relative to nonextreme heat days were determined ("hotspot" zip codes). A geographic information system (GIS) was then used to assess spatial trends in the distribution of "hotspot" zip codes. Land cover, green infrastructure (GI), and patient care centers were mapped to analyze differences in land cover, GI, and proximity to patient care centers between "hotspot" and "non-hotspot" zip codes. Additionally, "high-risk, hotspot" zip codes, which were entirely more than 1 mile from a patient care center, were identified.

Methodology

EMS data were only available for 2018. Therefore, only data between May–September 2018, which was when extreme heat days were most likely to occur, were used for analysis.

Identifying Extreme Heat Days

Any day that met at least one of the following criteria was considered an extreme heat day:

- Heat wave: The high temperature was at least 90˚F
- Heat advisory, category 1: The heat index reached 95˚ to <100˚F
- Heat advisory, category 2: The heat index reached 100˚ to <105˚F
- Excessive heat: The heat index reached or exceeded 105˚F

Identifying "Hotspot" Zip Codes

Using Microsoft Excel, the number of EMS incidents on each nonextreme heat day ($n = 136$) and extreme heat day ($n = 17$) was counted for each unique zip code in the zip code boundaries dataset. One-sided, two-sample t-tests ($df = 16$) were used to identify zip codes in which the average number of EMS incidents was significantly higher ($p < 0.05$) on extreme heat days compared to nonextreme heat days. Such "hotspot" zip codes were distinguished using a Boolean true value. Additionally, the average percent change in EMS incidents on extreme heat days relative to nonextreme heat days was computed for each zip code. Any zip codes with zero EMS incidents, on average, on both extreme and nonextreme heat days were assumed to not report EMS incident data. EMS incident statistics were joined to the zip codes boundaries spatial dataset to map "hotspots" and investigate spatial patterns.

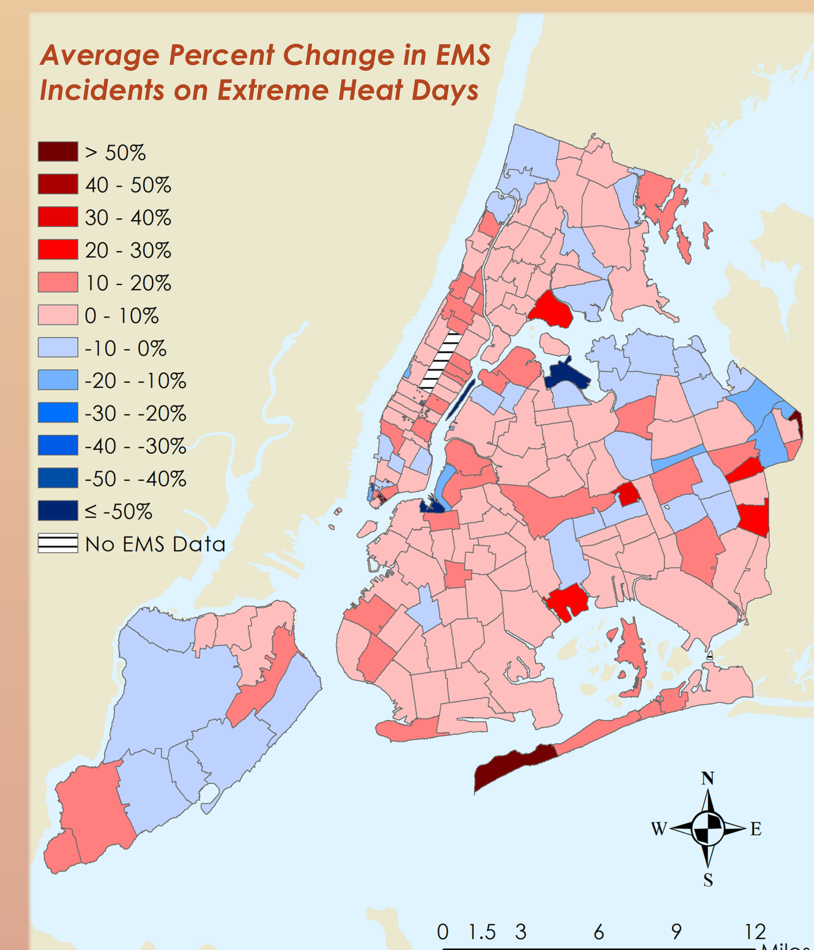
Investigating Spatial Patterns

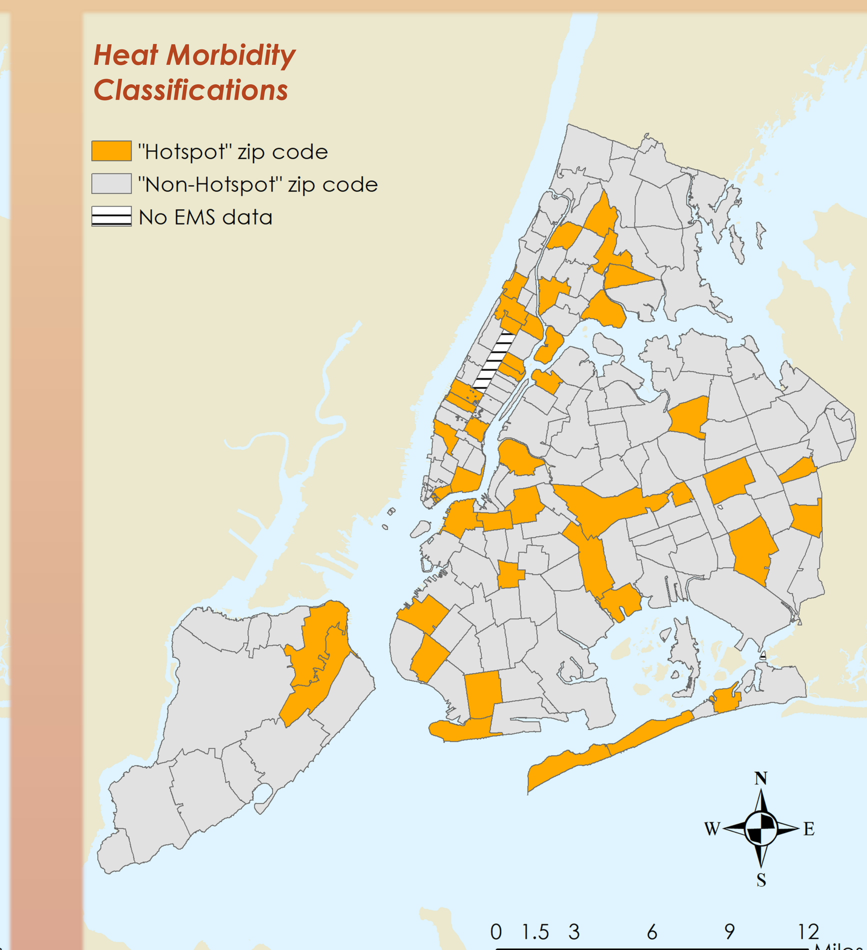
The zonal histogram tool and land cover raster (clipped to NYC zip codes) were used to determine the percentage of total land that each land cover type accounted for in "hotspot" versus "non-hotspot" zip codes. A one-to-one, "contains" spatial join was used to count the number of GI points in each "hotspot" and "non-hotspot" zip code. From there, the number of GI points was divided by the zip code area. A one-sided Wilcoxon rank-sum test was conducted using R to assess whether the density of GI was lower in "hotspots" compared to "non-hotspots". Lastly, a 1-mile buffer was created around each patient care center. Nursing homes were excluded because these facilities only provide care to individuals currently admitted in the facility. Using the "near" tool, the distance between the boundary of each "hotspot" and "non-hotspot" zip code and the nearest patient care center was computed. A one-sided Wilcoxon rank-sum test was conducted using R to assess whether the distance to the nearest patient care center was greater for "hotspots" compared to "non-hotspots". "High-risk, hotspots" were identified as more than 1 mile from a patient care center.

Results

Between May 1–September 30, 2018, 17 extreme heat days (136 nonextreme heat days) occurred. On average, more zip codes experienced an increase in EMS incidents on extreme heat days versus a decrease in EMS incidents. There did not appear to be an obvious trend in the location of zip codes that experienced an increase in EMS incidents on extreme heat days. Among the 248 unique zip codes, there were 43 "hotspot" zip codes, 184 "non-hotspot" zip codes, and 21 zip codes without EMS data. There did not appear to be an obvious trend in the location of "hotspot" zip codes.

Water and bare earth comprised a very small proportion of total land cover in both "hotspots" and "non-hotspots". "Hotspots", collectively, had more built land cover (buildings, other paved surfaces) than "non-hotspots" which, collectively, had more natural land cover (tree canopy, grass/shrub, water). High densities of GI seemed to appear in some "non-hotspot" zip codes but not in the adjacent "hotspot" zip codes, especially in Brooklyn, Queens, and the Bronx. Despite this, the data did not provide sufficient evidence to suggest that the median density of GI was lower in "hotspots" compared to "non-hotspots" ($p = 0.9265$). Lastly, the data did not provide sufficient evidence to suggest that the median distance to the nearest patient care center was higher for "hotspots" compared to "non-hotspots" ($p = 0.9995$). Some "hotspot" zip codes were partially more than 1 mile away from a patient care center; 11 of the 43 unique "hotspot" zip codes were entirely more than 1 mile away from a patient care center ("high-risk, hotspots").





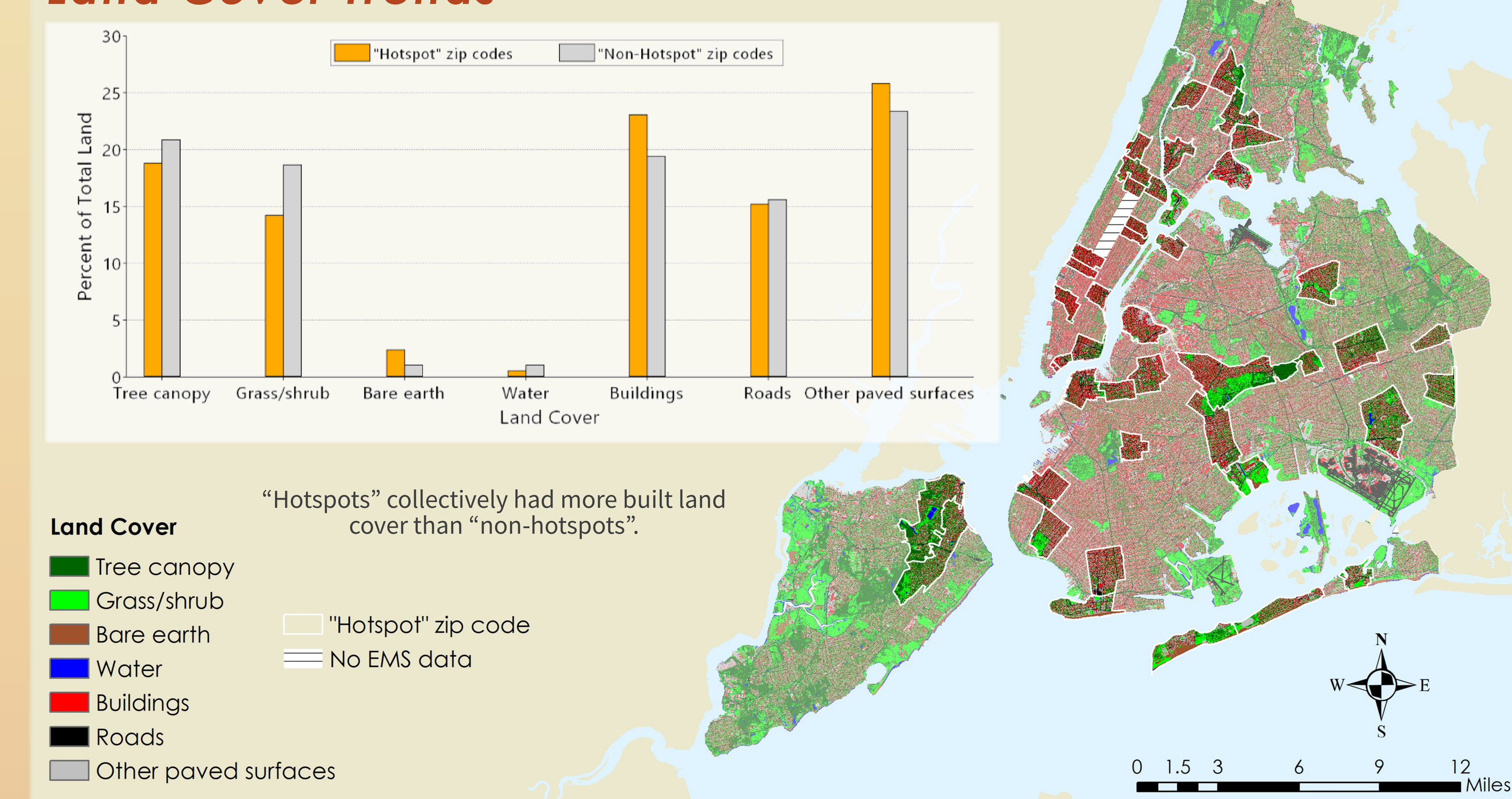
Conclusions

The GIS analysis demonstrates how morbidity data can be used to gain spatial insight about the impact of heat on human health and help cities better prepare for extreme heat events.

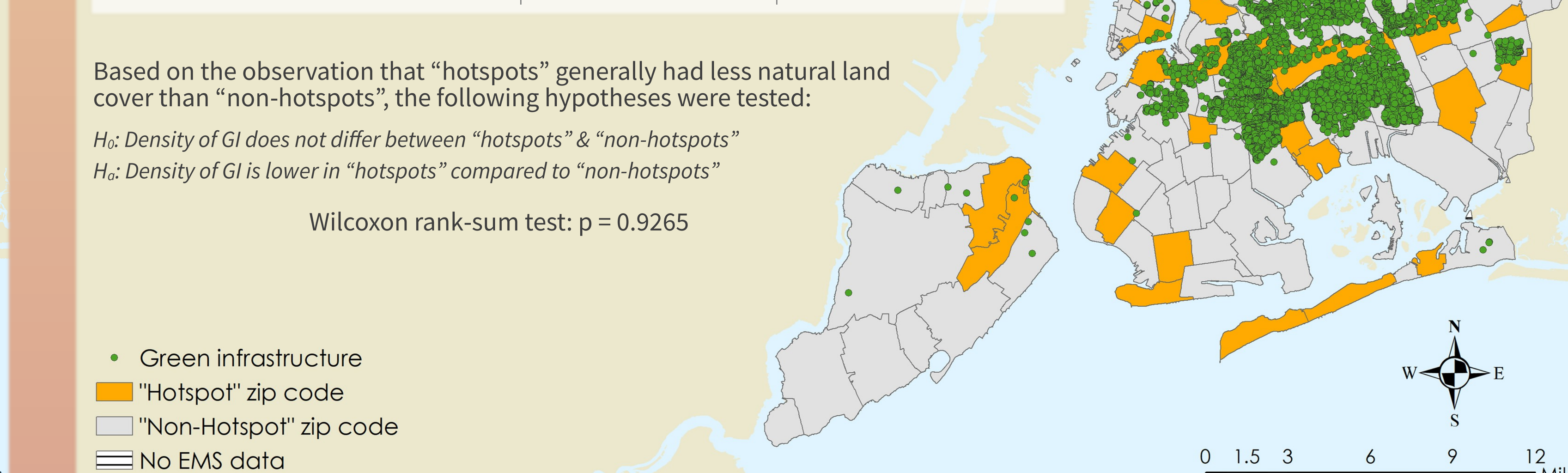
Because dark, built surfaces enhance the urban heat island effect, elevated temperatures in heavily built regions, which increase morbidity risk, may explain the higher proportion of built land cover in "hotspots" compared to "non-hotspots". This may suggest that incorporating natural land cover can reduce heat morbidity. GI is one strategy that incorporates more natural land cover. Although the data did not support the hypothesis that "hotspots" had less GI than "non-hotspots", there may have been confounding factors, such as bylaws that limit GI construction in certain zip codes. The data also did not support the hypothesis that "hotspots" were further from a patient care center than "non-hotspots". Patient care centers more often provide health services *after* heat morbidity has occurred. Therefore, far distance to a patient care center is likely not a risk factor of heat morbidity. Instead, far distance more likely influences the severity of *existing* heat morbidities. Thus, NYC should consider stationing health personnel in "high-risk hotspots" on extreme heat days to ensure that care is timely provided to individuals experiencing heat morbidity.

Next steps include assessing if "hotspots" differ on weekday versus weekend extreme heat days and if the location of "hotspots" is correlated with demographic variables that vary spatially. Similar analysis may be conducted in the future to assess differences between "hotspots" and "non-hotspots" for other factors that may affect heat vulnerability.

Land Cover Trends



Green Infrastructure Trends



Density of Green Infrastructure (GI)

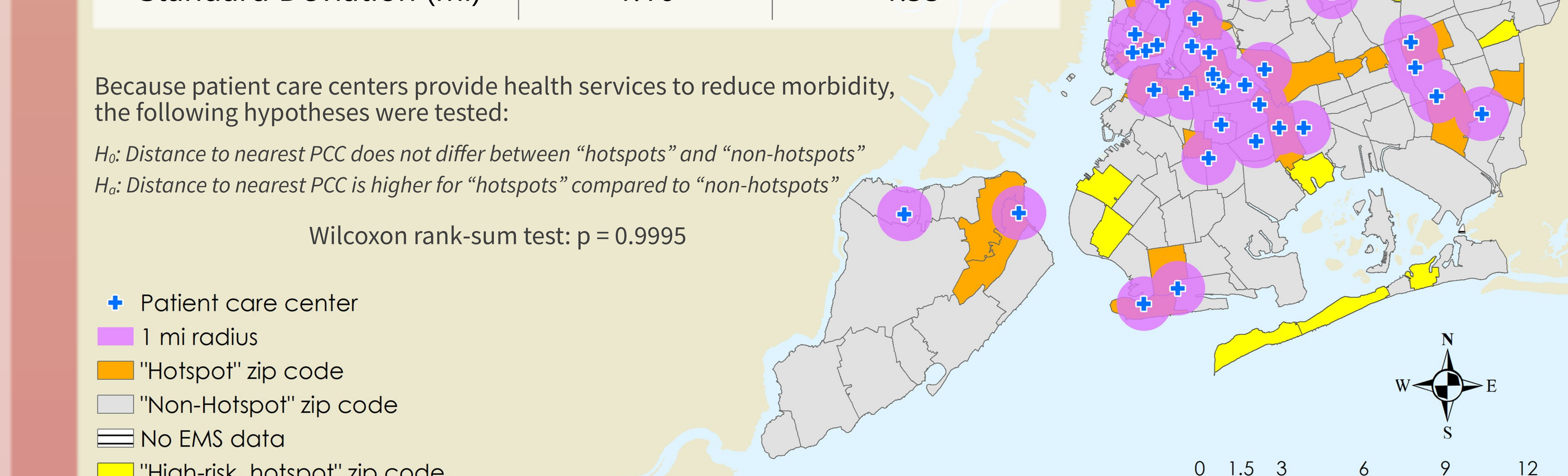
	"Hotspots"	"Non-Hotspots"
Mean (GI/mi²)	19.74	34.17
Median (GI/mi²)	1.80	0.00
Standard Deviation (GI/mi²)	38.30	80.92

Based on the observation that "hotspots" generally had less natural land cover than "non-hotspots", the following hypotheses were tested:

H_0: Density of GI does not differ between "hotspots" & "non-hotspots"
H_a: Density of GI is lower in "hotspots" compared to "non-hotspots"

Wilcoxon rank-sum test: $p = 0.9265$

Proximity to Patient Care Centers



Distance to Nearest Patient Care Center (PCC)

	"Hotspots"	"Non-Hotspots"
Mean (mi)	0.76	1.20
Median (mi)	0.29	0.87
Standard Deviation (mi)	1.16	1.33

Because patient care centers provide health services to reduce morbidity, the following hypotheses were tested:

H_0: Distance to nearest PCC does not differ between "hotspots" and "non-hotspots"
H_a: Distance to nearest PCC is higher for "hotspots" compared to "non-hotspots"

Wilcoxon rank-sum test: $p = 0.9995$

Tufts University School of Engineering

Cartographer: Elana Chan

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Data Sources: NYC Open Data, NOAA (JFK International Airport), ESRI 2018
Projection: NAD 1983 State Plane New York Long Island FIPS 3104 Feet