Fiker Zewdie

**Introduction.**

Extreme heat is a major health hazard during summer in many regions around the world(Lowe 2015). One example was the 2003 heat wave in Europe during July 2003, which killed as many as 70,000 people(Robine et al. 2008). Impacts from heat waves are amplified by urbanization, a phenomenon known as the Urban Heat Island phenomenon(Voogt et al. 2003). The urban heat island is the idea that urban areas warmer than surrounding suburban areas. This occurs because anthropogenic heat release from urban activity, low surface albedo (absorbing more energy from the sun), and better retention of heat by urban infrastructure (which can then release that heat back to the evironment) (Rizwan). Other studies have found that areas with a higher concentration of people in an area could have a higher relative temperatures than their surrounding rural areas (Chapman). Because of UHI, many people in urban areas are subject to higher temperatures than their surrounding suburban areas, especially during extreme heat events.

In the latter half of the 1900s, there has been a sharp increase in temperatures worldwide due to global warming(Alexander et al. 2006). Further, this warming has increased the risk of heat extremes and heat waves in many regions (Kovats 2008). And while it is known that the urban heat island causes higher temperatures in urban relative to less urbanized areas, but the interaction between the urban heat island and rising temperatures due to global warming for is less well understood, especially as it is related to heat extremes. In order to understand the extent of the effects of heat increase, these is a need for the tracking and modeling of these temperatures. Recent studies that have tracked heat waves have looked into measuring the trends of heat waves, but have excluded New York as a part of their study (Habeeb).

The goal of this research is to investigate how extreme heat days are changing over time, Times Square, an urbanized area of Manhattan and Ardsley, a suburban area in Westchester County, NY. This research is aimed to answer if urbanization amplifies warming trends in Times Square more than it does in Ardsley by comparing daily maximum temperatures during the summer (June-July-August) between the two locations. Questions that will be addressed include: “Are the number of days with maximum temperature above the 90th percentile increasing?”, “Are they increasing at a faster rate in Times Square than they are in Ardsley?”, “How different are median and 90th percentiles summer maximum temperatures between Times Square and Ardsley?”, “how have the median and 90th percentiles in each location changed between the first 30 years and last 30 years of the available data?”, and “how sensitive are the number of extreme heat days in each location to seasonal average summer temperature?” Finally, we use the available data to estimate what extreme heat will look like at these locations in 2050, if past warming trends continue.

**Methods.**

Daily maximum temperature data were taken from the TopoWx dataset (REF), for years 1950-2016. To track differences in urban areas and suburban areas in the New York area, we used two sample locations: Times Square (a highly urbanized area of Manhattan) and Ardsley (a suburban area in Westchester County, NY). All analyses were performed using Python, including the Matplotlib and NumPy packages.

In climate science, an extreme heat day is generally defined broadly as a day when temperatures reach higher than normal. This research aims to understand the intensity, changes, frequency, and timing of extreme heat days. For the purpose of this research, the 90th percentile of temperatures from 1951-1980 is used as threshold to define the minimum temperature for a day to be considered an extreme heat day in both locations. The use of the 90th percentile allows for the use of a threshold appropriate for local climatic variability (CCSP 2008).

To understand the interaction between the urban heat island and global warming trends, temperatures were divided into two 30-year time periods:1951-1980 and 1987-2016. The temperature distribution was plotted for both 30-year time periods in both locations. These time periods were used to track the shift in temperatures over time and the impact of global warming on both locations, as well the impact that the Urban Heat Island has on Times Square temperatures in comparison to Ardsley temperatures. Probability distributions (kernel density plots) were plotted for Times Square’s two time periods, Ardsley’s two time periods, and a comparison between the two locations’ temperature distributions during the years 1950-2016. The number of extreme heat days was also tracked based on the 90th percentile as an extreme heat day threshold. Similarly, the temperature for the hottest day of the year was tracked to see if there was an increase in these temperatures overtime as expected due to the urban heat island and global warming. To track the timing of these events, a linear regression model was also used to draw a trend line as a predictor for timing in the future.

Finally, to predict what extreme heat days will look like for the future, linear regression models were used with the Python library SciPy to estimate how many extreme heat days would occur in 2050 if current warming trends continue. The timing of these extreme events was also plotted and by using a linear regression model, a linear model can be used as a predictive method to understand how early in the year the first day above the 90th percentile threshold will fall. This linear regression model works as a predictor for future trends related to average summer temperatures and the number of extreme heat days for a given temperature. By using the linear predictor for average summer temperatures, this can help interpret the number of extreme heat days for a given temperature.

References:

Alexander, L. V., et al. “Global Observed Changes in Daily Climate Extremes of Temperature and Precipitation.” *Journal of Geophysical Research*, vol. 111, no. D5, 2006, doi:10.1029/2005jd006290.

Kovats, R. Sari, and Shakoor Hajat. “Heat Stress and Public Health: A Critical Review.” *Annual Review of Public Health*, vol. 29, no. 1, 2008, pp. 41–55., doi:10.1146/annurev.publhealth.29.020907.090843.

Lowe, Scott A. “An Energy and Mortality Impact Assessment of the Urban Heat Island in the US.” *Environmental Impact Assessment Review*, vol. 56, 2016, pp. 139–144., doi:10.1016/j.eiar.2015.10.004.

Robine, Jean-Marie, et al. “Death Toll Exceeded 70,000 in Europe during the Summer of 2003.” *Comptes Rendus Biologies*, vol. 331, no. 2, 2008, pp. 171–178., doi:10.1016/j.crvi.2007.12.001.

Sheridan, Scott C., and Shao Lin. “Assessing Variability in the Impacts of Heat on Health Outcomes in New York City Over Time, Season, and Heat-Wave Duration.” *EcoHealth*, vol. 11, no. 4, 2014, pp. 512–525., doi:10.1007/s10393-014-0970-7.

Voogt, J.a, and T.r Oke. “Thermal Remote Sensing of Urban Climates.” *Remote Sensing of Environment*, vol. 86, no. 3, 2003, pp. 370–384., doi:10.1016/s0034-4257(03)00079-8.

~~To understand the temperature anomalies in both Times Square and Ardsley, the threshold for normal was set as the average of all summer temperatures for each respective location. If the plotted line fell above the threshold, it represented how many degrees warmer in Celsius Times Square is in comparison to Ardsley. If the urban heat island intensity is represented by a positive number, then Times Square is warmer than Ardsley.~~

New and improved intro:

Climate change is the global phenomenon that says that global temperatures are increasing with due to increased release of CO2 in our atmosphere and the continuous release of harmful gasses. Climate change has the potential to impact many of the earth’s natural processes, including extreme heat events. Due to climate change, there is an expected increase in the intensity, duration, and frequency of heat waves. In the latter half of the 1900s, there has been a sharp increase in temperatures worldwide due to global warming (Alexander et al. 2006). Furthermore, this warming has increased the risk of heat extremes and heat waves in many regions (Kovats 2008). Heat waves are responsible for more deaths than any other extreme weather event combined (source).

Impacts from heat waves are amplified by urbanization, a phenomenon known as the Urban Heat Island (Voogt et al. 2003). The urban heat island is the idea that urban areas are warmer than their surrounding suburban areas. This occurs because anthropogenic heat release from urban activity, low surface albedo (absorbing more light and heat energy from the sun), and better retention of heat by urban infrastructure (which can then release that heat back to the evironment) (Rizwan). Other studies have found that areas with a higher concentration of people in an area could have a higher relative temperatures than their surrounding rural areas (Chapman). Because of UHI, many people in urban areas are subject to higher temperatures than their surrounding suburban areas, especially during extreme heat events.

Extreme heat is a major health hazard during summer in many regions around the world (Lowe 2015). A prime example of a heat-related mortality event was the 2003 heat wave in Europe during July of 2003, which killed as many as 70,000 people (Robine et al. 2008). Recent studies have shown that extreme heat, [drought](https://www.sciencedirect.com/topics/social-sciences/drought) and other climate-related events are projected to increase([Handmer et al., 2012](https://www.sciencedirect.com/science/article/pii/S0264275118311934" \l "bb0355)). As climate change projections show that there is an increase in the frequency and severity of extreme weather events, health impacts are expected to get worse ([Austin et al., 2015](https://www.sciencedirect.com/science/article/pii/S0264275118311934" \l "bb0070)) In the US, there are an estimated 670 - 1300 deaths annually.(Berko Heat events are expected to have a more detrimental impact on older populations aged 65 and over (Flynn et al. 2005). Recent research estimates that the world population of people above 65 will only increase, subsequently increasing the population that is susceptible to health impacts. Climate change’s impacts have not only affected health but have also created an impact on food security in developing nations (Ropo et al., 2017). Another highly susceptible group to this change in the frequency of extreme heat events would be low-income residents of urban areas. In areas such as these where the urban heat island interacts with global warming, the population of people that are not able to gain access to proper air conditioning systems and comfortable living conditions would be worst affected by the heat. Those who live in more heat-prone areas may not be able to afford the costs of running air conditioning as well (Sheridan 2007). Recent studies have studied the urban heat island and climate change’s interaction, but have failed to include NYC as a part of their study (Habeeb et al., 2014). These concerns prompt current research about urban areas like NYC and its surrounding suburban areas to understand the susceptibility of urban populations to a warming temperatures.

Implications of climate variability and change on urban and human health

References:

Alexander, L. V., et al. “Global Observed Changes in Daily Climate Extremes of Temperature and Precipitation.” *Journal of Geophysical Research*, vol. 111, no. D5, 2006, doi:10.1029/2005jd006290.

Kovats, R. Sari, and Shakoor Hajat. “Heat Stress and Public Health: A Critical Review.” *Annual Review of Public Health*, vol. 29, no. 1, 2008, pp. 41–55., doi:10.1146/annurev.publhealth.29.020907.090843.

Lowe, Scott A. “An Energy and Mortality Impact Assessment of the Urban Heat Island in the US.” *Environmental Impact Assessment Review*, vol. 56, 2016, pp. 139–144., doi:10.1016/j.eiar.2015.10.004.

Robine, Jean-Marie, et al. “Death Toll Exceeded 70,000 in Europe during the Summer of 2003.” *Comptes Rendus Biologies*, vol. 331, no. 2, 2008, pp. 171–178., doi:10.1016/j.crvi.2007.12.001.

Sheridan, Scott C., and Shao Lin. “Assessing Variability in the Impacts of Heat on Health Outcomes in New York City Over Time, Season, and Heat-Wave Duration.” *EcoHealth*, vol. 11, no. 4, 2014, pp. 512–525., doi:10.1007/s10393-014-0970-7.

Voogt, J.a, and T.r Oke. “Thermal Remote Sensing of Urban Climates.” *Remote Sensing of Environment*, vol. 86, no. 3, 2003, pp. 370–384., doi:10.1016/s0034-4257(03)00079-8.