Urban Heat Island Effect: Analyzing the Correlation Between the Intensity of Sunlight and Temperature in Manhattan

Louis Waxman[1,3], Awolou Sossa[2,4], Dr. Brian Vant-Hull[2,4], and Dr. Reza Khanbilvardi[2,4]

[1]Ardsley High School, [2]CUNY CREST, [3]NSF CREST REU, [4]The City College of New York

Abstract

Cities may experience a higher air temperature at ground level compared to their rural surroundings in a phenomenon known as the Urban Heat Island (UHI) effect. The objective of this study is to analyze the relationship between the intensity of sunlight and ground-level air temperature on a summer day in Manhattan. The sun not only radiates visible light, but among other things, also heat energy. This analysis is done using data collected during summer 2013 from sensors placed as a part of the Manhattan Urban Heat

Urban Heat Island Effect

Urban areas often experience a higher air temperature at ground level compared to outlying, more rural areas. This is due to the fact that manmade structures such as buildings and roads absorb more heat than vegetation and radiate it back into the air after sunset. In addition, buildings change winds that may dissipate heat and their reflective surfaces may increase the efficiency of the sun's warming radiation during the day. The increased temperature in an urban heat island, particularly during the summer, can diminish the local environment and quality of life. Negative impacts include:

- Increased energy consumption due to increased demand for air conditioning;
- An increase in energy consumption often leads to more air pollutants and greenhouse gases being put into the atmosphere by power plants;
- Ground-level ozone more readily forms at higher temperatures;
- A decrease in quality of life as a result of warmer days and nights leading to general discomfort, respiratory

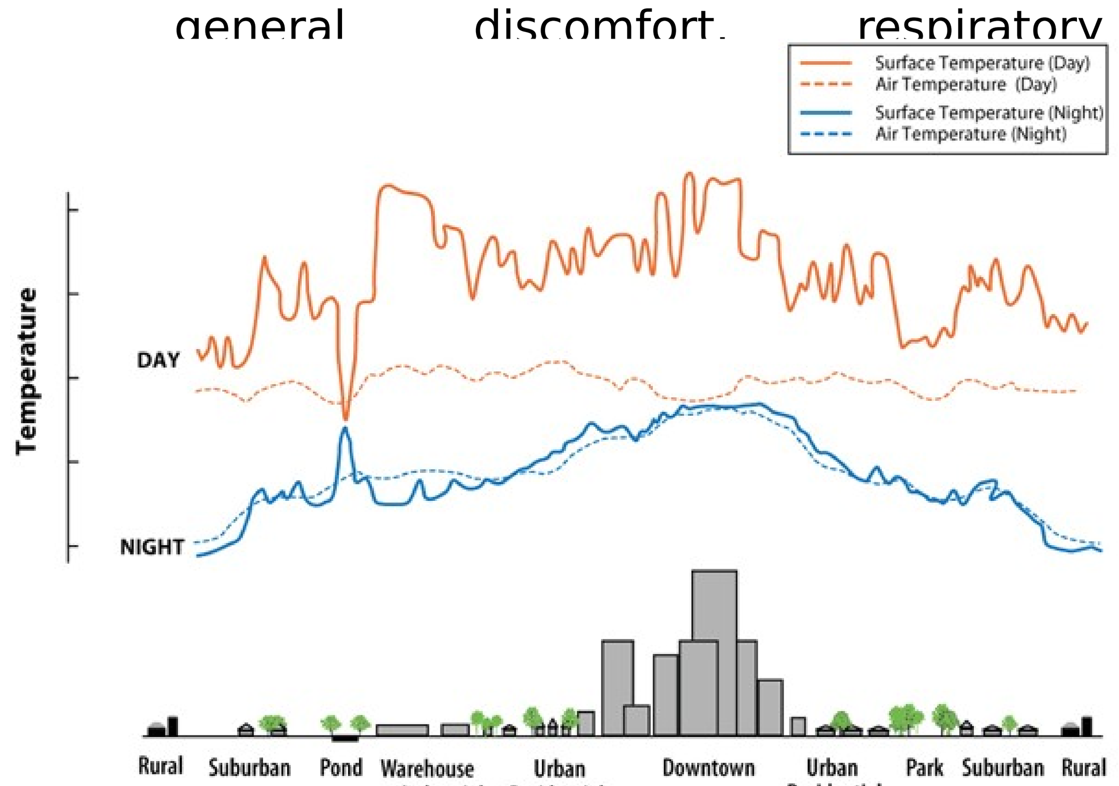

Figure 1

Data Collection

Between June 24 and September 20, 2013, ten sets of temperature, relative humidity, and illumination sensors were placed on lampposts around Manhattan between 3.1 – 3.9 meters above street level with the approval of the New York City Department of Transportation. These se… …ata…

Figure 2

A typical sensor installation

Figure 3

Sensor Locations:

145th St.
120th St. West
120th St. East
81st St.
57th St. West
57th St. East
35th St.
14th St.
Prince St.
Reade St.

Analysis Method

The data were downloaded from the Manhattan Urban Heat Island Project at the City College of New York (URL: http://glasslab.engr.ccny.cuny.edu/u/brianvh/UHI/datapage.html). Three stations were selected to be analyzed: 145th St., 81st St., and Prince St. In addition, three dates were selected: June 24, July 25, and September 20, 2013. Each of these nine data sets of temperature (degrees Celsius) and light intensity (Watts/meters squared) were then plotted against each other using MATLAB. Additionally, these data were smoothed with MATLAB using a moving average filter centered on each hour (20 samples). This was done to remove insignificant changes in order to obtain a stronger and more accurate correlation. Using thi… …on co… …vo da…

$$R = \frac{\sum_i[(x_i - \bar{x})(y_i - \bar{y})]}{\sqrt{\sum_i[(x_i - \bar{x})^2]\sum_i[(y_i - \bar{y})^2]}}$$

In order to measure the amount of time that it took for a change in light to lead to a change in temperature during the day, the lag correlation was also calculated.

Acknowledgments

This research was funded by NOAA CREST (NOAA CREST – Cooperative Agreement No: NA11SEC4810004) and supported by The Pinkerton Foundation.

I would also like to thank my mentors Awolou Sossa, Dr. Emiko Morimoto, Dr. Brian Vant-Hull, Dr. Shakila Merchant, and Dr. Reza Khanbilvardi for assisting me with my research.

Results and Discussion

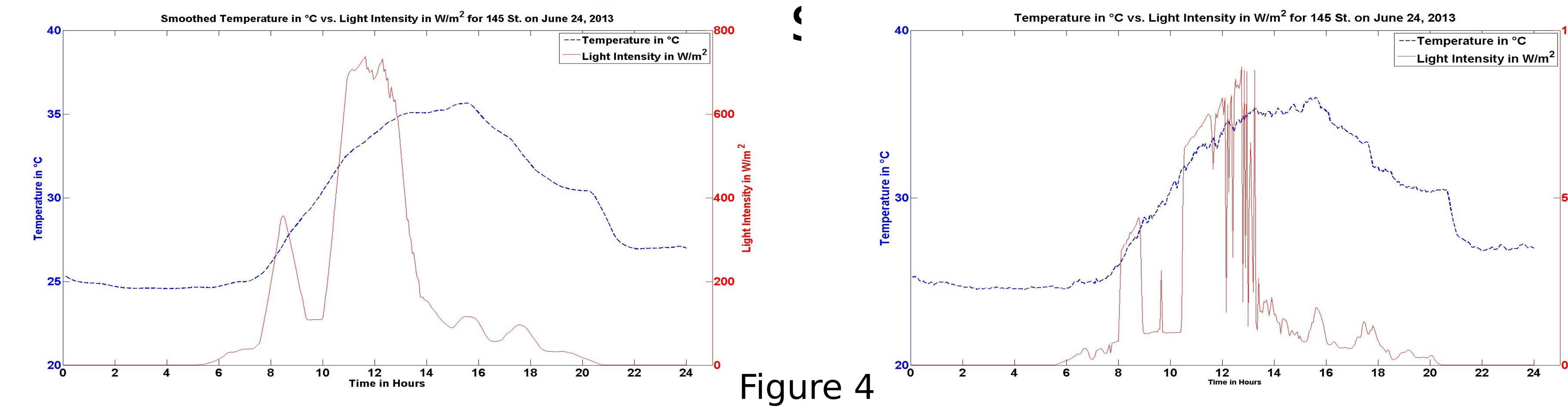

Figure 4

Graphical Comparison Between Raw and Smoothed Data

	Correlation for 6/24/13 (Clear day)	Correlation for 7/25/13 (Cloudy day)	Correlation for 9/20/13
W 145 St.	0.5256	-0.5102	0.3294
	Daytime Correlation for 6/24/13	**Daytime Correlation for 7/25/13**	**Daytime Correlation for 9/20/13**
W 145 St.	0.2915	-0.2009	0.0639
W 81 St.	0.1901	-0.3257	0.2753
Prince St.	0.4040	-0.3643	-0.1706

A correlation of 1 equals a perfect positive relationship, -1 is a perfect negative relationship, and 0 is no relationship. A correlation value of +/- 0.7 equals a significant correlation.

Date	Daytime Lag Correlation
6/24/2013 (Clear day)	0.3519 (3 samples/9 minutes)
7/25/2013 (Cloudy day)	-0.3461 (10 samples/30 minutes)

The negative lag correlation for July 25, 2013 was likely due to the time delay, causing positive and negative changes to be misaligned.

There is a weaker correlation between temperature and light when calculating for just the daytime (6:00 a.m. – 8:00 p.m.) in contrast to the entire day. This may be due to the fact that manmade structures such as buildings and roads absorb heat during the day and release it into the atmosphere later at night.

On July 25 for all three stations, there was a negative correlation between temperature and light. One possible explanation for this is that the cloud cover on this day was very important in relation to the amount of sunlight reaching the ground. There could be other possible explanations such as the wind speed and pattern.

Using the temperature and light data for a clear day (June 24), it was calculated that the strongest lag correlation had a delay of 9 minutes. This was done by shifting the temperature data 1-15 samples from the light data and it was found that the strongest 'r' value was when the data was shifted by 3 samples. Using this same method for an overcast day (July 25), it was found that the strongest correlation was shifted by 10 samples, thus there was a delay of 30 minutes. This is due to the fact that clouds absorb some of the light coming from the sun and act as a damper on temperature changes near ground level as they trap air under them. In short, it was found that a change in light led to a noticeable temperature change 9 minutes later for the sample clear day and 30 minutes for the sample overcast day.

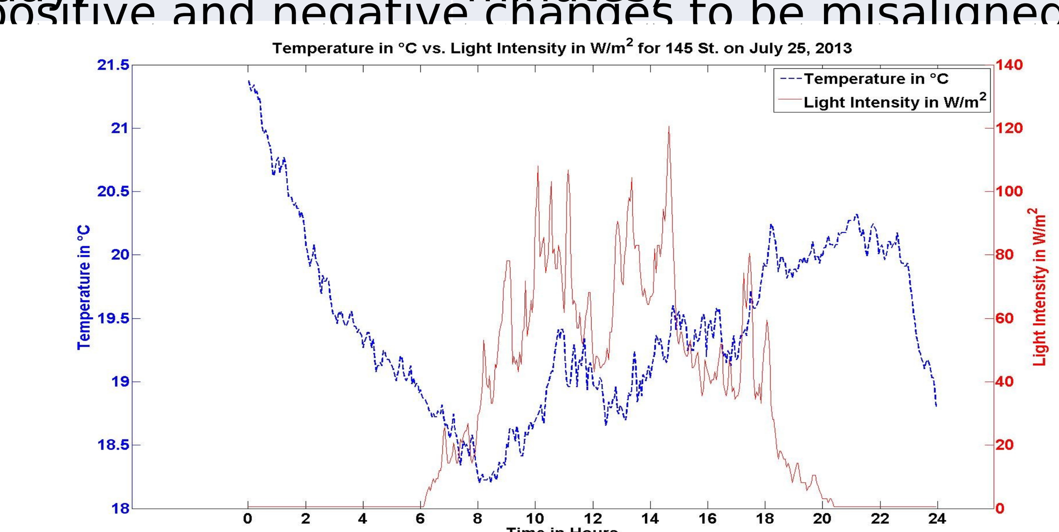

Figure 5

Graphical Representation of Light and

Conclusions and Future Work

Our results show that there is a noticeable correlation between light and temperature on a clear summer day in Manhattan and a weaker correlation on an overcast day.

Further work will need to be done so that more data sets can be analyzed in order to produce a more accurate average correlation for days with different weather and cloud cover. Of

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