Characterizing Temperature Variations Due to the Urban Heat Island for Climate Health Impacts In New York City

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Introduction

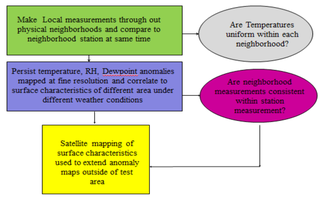
The uneven surface heating in the urban environment causes variations in temperature between neighborhoods. As the heat has been increasing over the years, human exposure to excessively warm weather, especially in crowded city like New York, becomes an important public health problem. Some neighborhoods have great exposure to heat stress depending on their physical characteristics and sparse vegetation. The Consortium for Climate Risk in the Urban Northeast (CCRUN) at Columbia University have a five year mission to Leverage their research to create new products of interest to climate stakeholders, including the health sector . They are attempting to package air quality, heat, and water events for short term and climatic forecasts to assess the climate impact on urban areas to neighborhood or regional scale.

In collaboration with CCRUN, we are planning on downscaling of weather forecasts to predict temperature/wind on neighborhood scale based on surface observations, vertical profiles, and satellites to find Correlations between health (hospital statistics) and fine scale observed temperature to relate Weather/Climate Forecasts to Health.

As a part of the study we are comparing the temperature between different neighborhoods of New York City and current weather stations.

Object

Identify and validate Thermal Neighborhoods – do uniform physical characteristics result in a uniform temperature bias throughout the neighborhoods?



Weather Stations in NYC

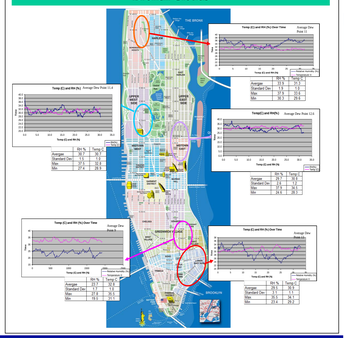
To compare our data to weather station data, several routes were designe to include weather station locations. Of the weather station located in Manhattan, Midtown-Central Park, Midtown East- 46 Street, Lower East side- Mott Street were chosen as stops for the neighborhood routes.

Selected Neighborhoods and sample measurement

Five neighborhoods have been picked through out Manhattan for sampling. The heat temperature and relative humidity of all five areas were taken in six different days. Most days were sunny to partially cloudy with 40% to 60% clouds and few overcasts.

Temperature and Relative Humidity Measurements in various neighborhood of NYC, July 15, 2011

Broken Clouds



Methodology

Student were given a map route for every trip and were Sent out simultaneously to walk designated routes. Every route was a thirty minute walk which consist of three stops; beginning, end and midpoint. Measurements were taken every 10 seconds for 30 minutes. Three of the routes had routes' stop at the surface stations. Students were supplied with Data Logger, Relative Humidity Sensor and Air Temperature sensor. The start time for the 30 minute walks bracketed 2 pm. Sensors covered by Styrofoam cups and cardboard to provide thermal isolation and all devices were mounted at the same height.

Data Collection and Analysis Device

Data Logger- Portable data collection and analysis device (*Figure 1*).

Air Temperature Sensor- used for low thermal mass and measure temperature range -25 to 125 C (*Figure 2*).

Relative Humidity Sensor- used to measure the relative humidity over the range 0 to 95% (*Figure 3*)

Preliminary Results For Summer Campaign

Comparison to Weather Stations

To see the accuracy of surface station data which are mounted on rooftops, neighborhood average temperatures and dew points at 2:00 pm from three different areas; Midtown- West, Midtown-East, and Lower East side are each compared to surface station of the same area. The data show that the surface station data are about 2 to 4 degrees off from the manual readings done by students.

July 15, 2011

Central Park Area	Temp	Dew Point	Wind Speed
MetNet Station, 2:00 pm	29	13	8
Labquest Reading, 2:00 pm	32	12	
Area's Average Temperature	31	12	

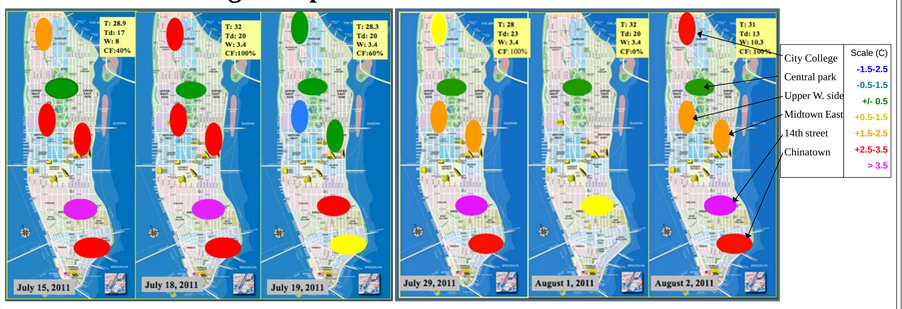
Midtown- East	Temp	Dew Point	Wind Speed
MetNet Station, 2:00 pm	29	10	0
Labquest Reading, 2:00 pm	33	14	
Area's Average Temperature	31	11	

Lower East Side	Temp	Dew Point	Wind Speed
MetNet Station, 2:00 pm	29	11	1
Labquest Reading, 2:00 pm	31	14	
Area's Average Temperature	31	13	

Preliminary Results For Summer Campaign

In comparing the neighborhoods, the average temperature, and relative humidity of all areas were calculated. The maximum and minimum temperature and relative humidity for each neighborhood are shown on the map. The color scales show temperature differences from Central Park. For Example, in comparing the neighborhoods, 14th Street location shows the highest temperature in compare to all other locations for all the measurements taken at different dates.

Average Temperature Differences from Central Park

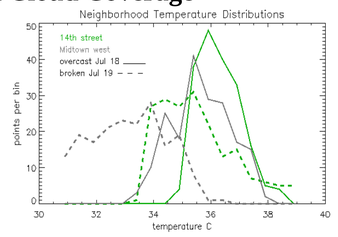


The colored ovals indicate where the field measurements were made, with colors indicating the temperature difference relative to the Central Park surface station in increments of 1 C. The red end (including violet) of the spectrum is warmer, blue colder, green neutral. As expected, tree filled Central Park is almost always the coolest location. The warmest location is 14th street, perhaps due to low buildings and more exposure to the sun. The City College and Chinatown locations have similar building heights and vegetation, but were always cooler than 14th street, perhaps because both locations are closer to large bodies of water. It should be noted that every other day in this series has a full cloud overcast, yet it doesn't seem to affect the general pattern, challenging the assumption that since surface temperature contrasts are driven by solar radiation, decreased irradiance should decrease the contrast.

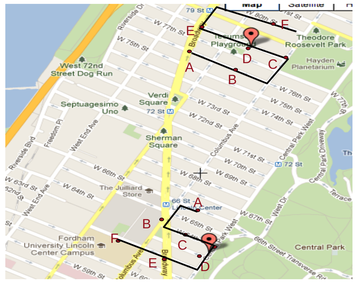
Selected Neighborhood and Comparison

Temperature Distributions and Cloud Coverage

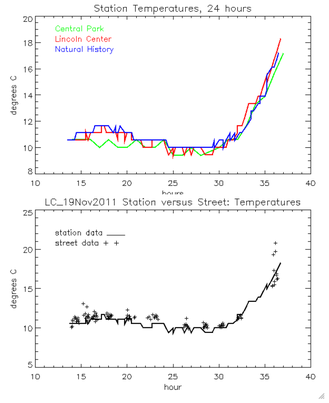
Two neighborhoods were compared on an overcast day (July 18, 2011: solid lines) and a partly cloudy day (July 19, 2011: dashed lines). 14th street (green) was generally the hottest of all the neighborhoods, while Midtown West (gray) was generally the most humid. The plots show temperature histograms in bins of 0.5 C. It is clear that the distributions are broader on days with broken clouds, almost certainly due to larger solar heating effects. The differences between average neighborhood temperatures follow the same pattern: 3.4 C difference on an overcast day compared to a 5.4 C difference on the day with broken clouds, despite the fact that the overcast day was several degrees warmer.



24 hour Station/Neighborhood Comparisons

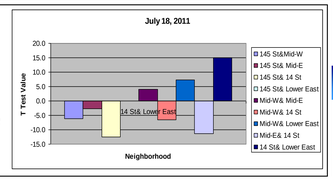


Street level measurements in the vicinity of two weather stations were made roughly every 2 hours at the locations shown on the map to the right. The measurements start at 2 pm (14 hours) on November 19 and continue until 12 pm (36 hours) the next day. These street measurements were generally 1 to 2 degrees warmer than the station measurements, a pattern that continued throughout the night.



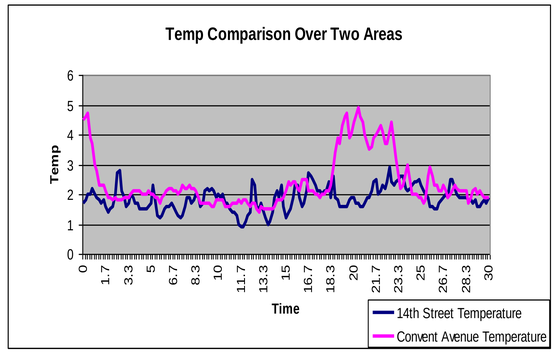
T-Test

In order to find if the differences between neighborhoods are meaningful, for each day a T-test is performed between all possible pairs of neighborhoods. For data sets of this size, T-test values greater than 2 indicate the differences between the average values are statistically significant at the 5% level. Most neighborhood temperature averages are statistically distinct from each other (selected examples are show to the right), but a few neighborhoods are very similar. For most days 145th street and the Lower East Side neighborhoods are statistically indistinguishable.



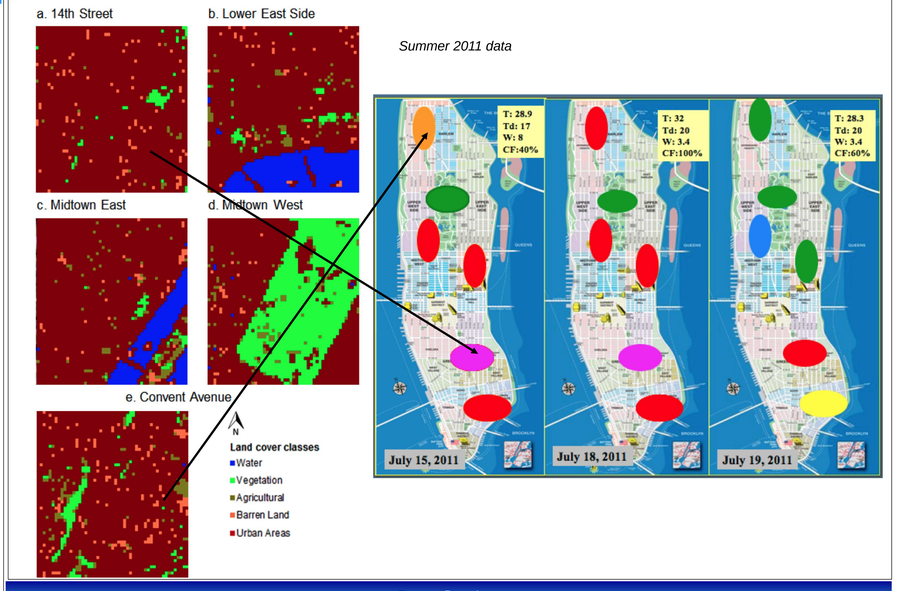
Winter Comparison

The greatest temperature difference during summer was seen between 14th Street and Convent Avenue area, so a winter comparison was done to see if the same pattern held during the winter. The figure on the right shows this comparison of the temperature measurements in the two neighborhoods. In contrast to the summer, there was very little difference between the two temperature averages in the winter. This may be due to the absence of transpiration effects in the winter (the convent avenue area has more trees) or to comparatively warmer river temperatures nearby. The sudden jumps in the temperature around the CCNY campus occurred in the vicinity of a metallic sided building; when these are removed the two neighborhoods increases.



Surface Characterization

LandSat data can classify the surface at resolution comparable to the field measurements. Landsat data is being used to find types of ground cover from building density to water to types of vegetation. We can see that the East 14th Street hotspot corresponds to low vegetation density, the cooler spot near city college could correspond to patches of vegetation.



Conclusion

In heat island effect campaigns conducted with portable instrumentation in Manhattan, some preliminary results show the following:

- Various neighborhoods show warm temperature biases of several degrees compared to the Central Park weather station.
- These biases were consistent on several days.
- Temperature differences tend to decrease on overcast days, and in the winter.
- The temperature contrasts within neighborhoods decreased with cloud cover.
- LandSat data classifies the surface at resolution comparable to the field measurements.

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