An Analysis of Observed Urban Heat Island in Greenville, NC and Its Implication on Energy Consumption and the Environment

Linwood Hall and Hong-Bing Su
Department of Geography, East Carolina University

Introduction:

Urban Heat Island (UHI): Air temperatures in the core of a city are higher than those in surrounding suburban and rural areas. The temperature difference is a measure of UHI strength.

Significance of UHI: energy consumption, air and water quality, public health.

Rationale: Previous studies of UHI have focused on large cities (population more than 100,000). Greenville, NC is a smaller city (population 76,058 in 2007). However, Greenville's population has steadily grown by 69% over past 18 years.

Objectives:

To quantify the magnitudes and climatology (diurnal and seasonal characteristics) of UHI in Greenville.

To quantify the relations between the strength of UHI and weather conditions (solar radiation, wind speed).

To quantify the relations between energy consumption and weather data.

To develop simple models for the prediction of energy demand for the City of Greenville.

Weather and Electricity Data:

The Department of Geography at East Carolina University developed and maintains two automated weather stations. The BIF (urban) station is located in the core of the City of Greenville, and the WRC (rural) station is located on the outskirt of the city. Wind speed and direction, air temperature and relative humidity, barometric pressure and incoming solar radiation are measured every 10-s while the precipitation is continuously measured. 5-min averages and totals of these measurements are archived. For this study, hourly averages of the weather data are used to match the hourly electricity data provided by Greenville Utilities.

The time period of these weather and electricity data reported here is from July 17 to October 31, 2008.

Hourly electricity data were recorded at 24 sub-bus stations for various sections in the City of Greenville, and 2 stations in the City of Winterville which is next to Greenville.

http://www.ecu.edu/cs-cas/geog/CurrentWeather.cfm

Thomas Harriot College of Arts and Sciences
Department of Geography

Weather Station at Blount Intramural Field (BIF)

Weather Station at West Research Campus (WRC)

Contact:

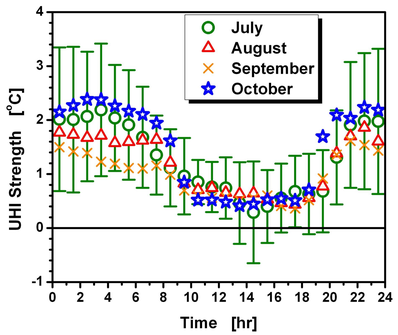
Dr. Hong-Bing Su
Department of Geography
Office Phone: 252-328-1040
Email: suh@ecu.edu

Current Weather Conditions

Date and Time	Station	Avg Temp	Relative Humidity	Barometric Pressure	Solar Radiation	Wind Speed	Wind Direction
2008-11-20 13:55:00	BIF	13.5 C 56.3 F	32%	1012 mb 29.87 in	474.6 w/m^2	3.4 m/s 7.6 mph	NWW
2008-11-20 13:55:00	WRC	12.9 C 55.2 F	31%	1011 mb 29.85 in	463 w/m^2	4.8 m/s 10.7 mph	SWW

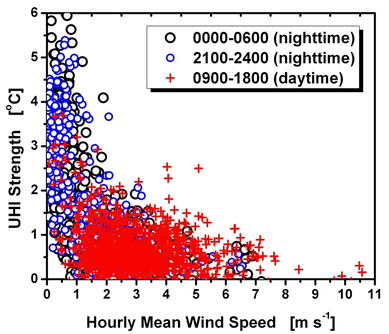
Results: UHI

Seasonality of the Diurnal Pattern of UHI



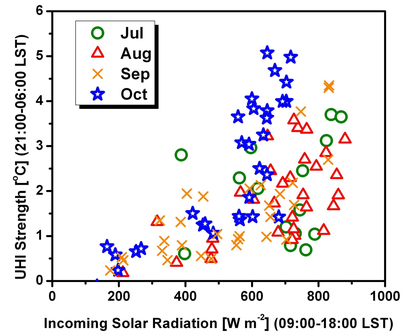
• UHI is stronger at night than in the daytime.
• UHI becomes weaker from July to September, but this trend reverses in October.

Influence of Wind Speed on UHI



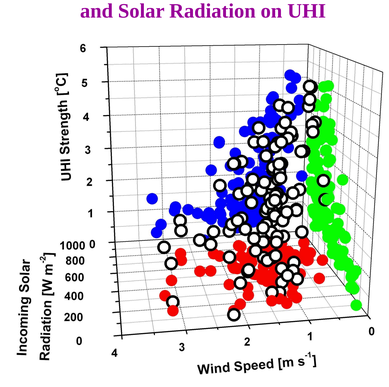
• UHI increases with decreasing wind speed.
• Maximum UHI strength is as great as earlier observations in many big cities.

Influence of Solar Radiation on UHI

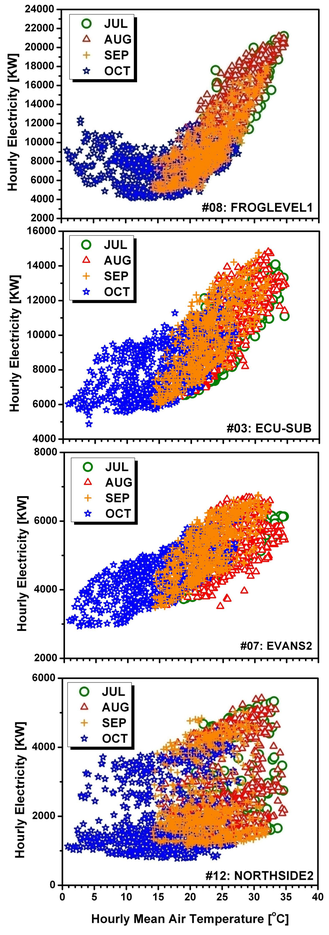


• The greater incoming solar radiation in the daytime, the stronger UHI at night.

Combined Effects of Wind Speed and Solar Radiation on UHI



Results: Relation between Electricity Use and Air Temperature



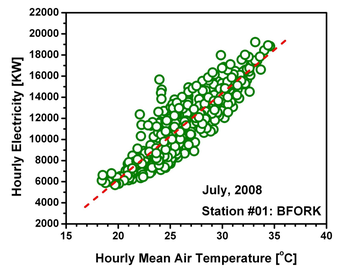
• Air temperature is the predominant factor influencing electricity use.

• Electricity use increases with increasing air temperature nearly in a linear fashion from July to September.

• However, this relation is more complicated (non-linear) in October, which also varies spatially.

• A linear regression is applied to monthly data for July – September.

Linear Regression: Y = A + B * X
Y – hourly electricity use
X – hourly mean air temperature



Slope B: indicates the amount of increase in electricity (KW) consumption per 1 °C increase in air temperature for different sections of Greenville.

The seasonality of this slope is such that it decreases from July to September in most sections of Greenville, except station 07.

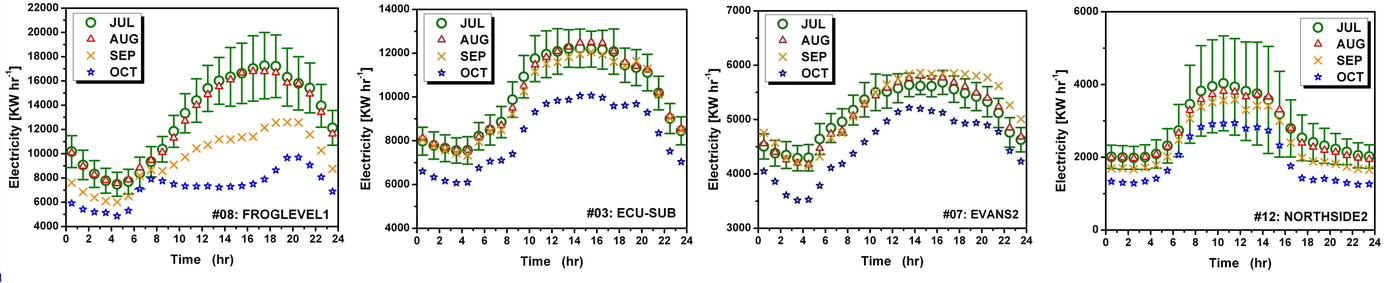
The spatial variations of the slope are also evident.

Station No.	July	August	September
01	820	734	617
02	539	480	416
03	457	437	396
04	476	429	377
05	679	613	527
06	422	402	373
07	124	126	145
08	957	855	619
09	581	521	417
10	514	443	368

Results: Electricity Use

Seasonality and Spatial Variability

• Seasonality is illustrated by the differences in the magnitudes, peak hours and number of peaks.
• Spatial variability is shown by the differences among different stations of the monthly averaged diurnal patterns.



Future Work:

- Full seasonality (over a year) of UHI.
- Spatial variations of land cover types/uses.
- Spatial and temporal variations of albedo.
- Spatial variations of air temperature in various sections in the City of Greenville.
- Types of electricity consumptions.
- Types and ages of houses, income levels.
- Gas consumptions and water uses.

Acknowledgement:

We thank Roger Jones at Greenville Utilities for the electricity data, Ron Mitchelson, Patrick Pease, Sol Wuensch and many others for helping building the two weather stations.