1. Introduction

Urban environments result in substantial changes to the roughness and radiative properties of the surface – these changes can affect local weather and climate within the urban canopy. The Chicago metropolitan area has experienced dramatic urban growth over the past few decades resulting in significant changes in land cover. The effects of this increasing urban environment are modeled to gain insight into the small scale thermal variations resulting from urban structures as well as possible mitigation strategies in present heat waves and late 21st Century business-as-usual climate scenarios.

Lynn et. al (2007) found that the Chicago area could see an increase in the average summer temperature of approximately 10 degrees Fahrenheit by 2080 as a result of anthropogenic climate change. This substantial baseline warming has profoundly negative implications for urban health. At this level of warming, a hot summer day now can be used as a proxy for a future “average” day and can thus be used to more closely examine the effects of the urban canopy on this environment.

2. Data and Methods

The conditions on 15 July 2006 (Fig 1) were examined as it represents a hot summer day in the Chicago metropolitan area (temperatures were in excess of 90 degrees Fahrenheit). High pressure centered over the Mississippi Valley kept winds light in the area.

Of additional meteorological interest, a notable lake breeze formed during the afternoon and advanced inland. No precipitation was reported but scattered cumuli formed along the lake breeze frontal boundary. This case will be used to represent conditions analogous to an average late 21st Century summer day in the business-as-usual scenario.

In effort to understand the spatial variation of temperature within the urban canopy, a thermal satellite image was obtained from Landsat TM 5 (Fig 2). The Landsat imagery along with standard surface observations at several sites across the domain were used to analyze model results and describe the thermal variations within the urban environment.

The WRF-ARW coupled with the Urban Canopy Model (UCM) introduced in WRFV2 was used to simulate this case. The single domain at 1 km grid spacing extends over the city of Chicago as well as...
surrounding areas. A basic run was performed in which all urban areas were classified as one category maintaining uniform properties and geometries across the urban portions of the domain. These areas were then reclassified using USGS 2001 National Land Cover Data in order to distinguish different types of structures within the urban canopy. 2001 NCLD contains four separate urban classifications that were reclassified according to the mapping documented for the UCM (Tewari et al. 2007). This resulted in three detailed urban categories consisting of low intensity residential, high intensity residential, and industrial/commercial. The reclassified domain was ingested into the WRF and the UCM was activated to account for the detailed geometries of the urban environment (Fig 3).

As a possible mitigation strategy, the impact of blanketing the Chicago metropolitan area with green roofs was examined by modifying UCM variables to represent the radiative properties of green roofs. Albedo values of the urban categories were increased based on studies done at Penn State University (Rosenzwieg et al. 2006) in order to mimic the radiative behavior of a vegetative rooftop.

3. Initial Results

When the three detailed urban categories and urban canopy structure is incorporated, an overall domain bias of 5 °C is obtained relative to the basic, single urban category scenario (Fig 4).

This is a significant warming effect related to the details of the urban environment itself on what is already a hot day. This also suggests that mitigation strategies might be gainfully employed. The spatial variation of temperature within the urban canopy shows a much warmer signature in locations where the domain is classified as low intensity residential, high intensity residential, or commercial/industrial. Localized hot and cool spots can also be seen in the thermal satellite images corresponding to areas of concrete or other forms of industrialization and vegetation such as parks, respectively.

The radiative properties of the urban classes were then modified to simulate 100% adoption of green roof technology in the urban domain, thereby representing a maximum impact mitigation strategy. Model results show 10-15 °F cooler conditions in the late afternoon and evening hours as a result of this adaptation (Fig 5).

4. Future Research

An additional component of business-as-usual is the ongoing growth of the urban area – the effects of continued urban sprawl have not been accounted for in the current study. Projected growth rates will be applied to the domain increasing the amount of urbanized area to simulate both the potential spatial urban coverage as well as density in 2100 assuming constant growth. Given a larger urban area, or more dense urban area, the impacts of the urban structures on a typical day in 2100 will be analyzed as well as a maximized green roof mitigation scenario.

Acknowledgments

This work was supported in part by the UW-Milwaukee RGI 1 01-0011.

References


Figure 1. Sea level pressure map – 12z on 15 July 2006. Obtained from the NWS Daily Weather Map archive.

Figure 2. Surface skin temperatures in City of Chicago. The image was acquired at 1630 UTC 15 July 2006. Surface skin temperatures were obtained from Band 6 with a resolution of 120 m x 120 m.
Figure 3. Land use of (a) basic run with 1 urban category and (b) UCM run with 3 detailed urban categories.
Figure 4. Bias between detailed three urban category run and basic single urban category run. 1.005 is equivalent to a warm bias of approximately 1.5 deg C.

Figure 5. Time series of temperatures at O’hare Airport (ORD).