# Analyzing the Effects of Urbanization on Regional Climate in the Chicago Metropolitan Area


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## Introduction

Widespread growth of metropolitan areas (MA's) and rapid modification of land use have driven many social and climate scientists to analyze urban impacts on regional climate (Cohen 2006; Lawler et. al 2014). The urban heat island (UHI), identified as a sharp, primarily nocturnal temperature gradient between the cooler rural and warmer urban regions, is one such effect that may be exacerbated by extremes in climate such as heat waves (Gutiérrez et. al 2015) (Figure 1). The July, 1995 heat wave, an event which produced record high daytime and nighttime surface temperatures and dew point temperatures approaching 80 F in the Chicago MA, claimed the lives of over 700 people and prompted further investigation into the probability of reoccurrence for climate anomalies in urban regions (Kunkel et. al 1996; Dematte et. al 1998; Karl & Knight 1997) (Figure 2). This study examines the urban influence on multiple meteorological variables of the energy budget during the Chicago heat wave of July, 1995.

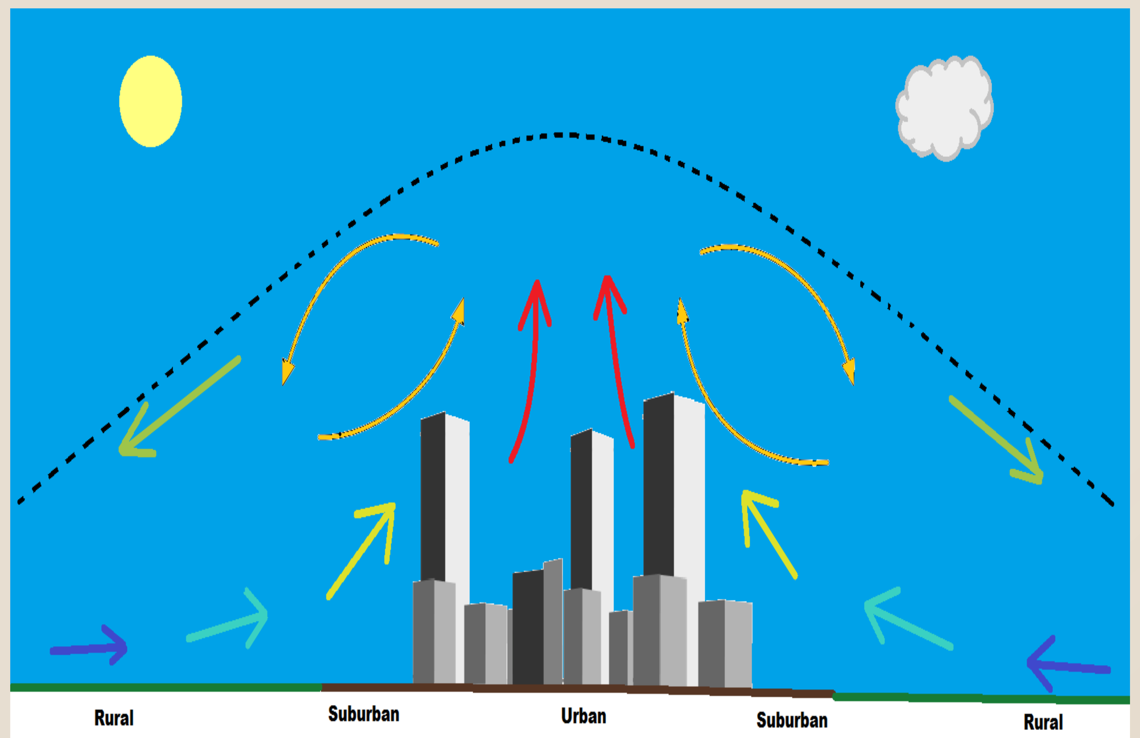


Figure 1. Example of the UHI Circulation, adapted from Hidalgo et. al (2010)

## July 14, 1995 – Synoptic Analysis

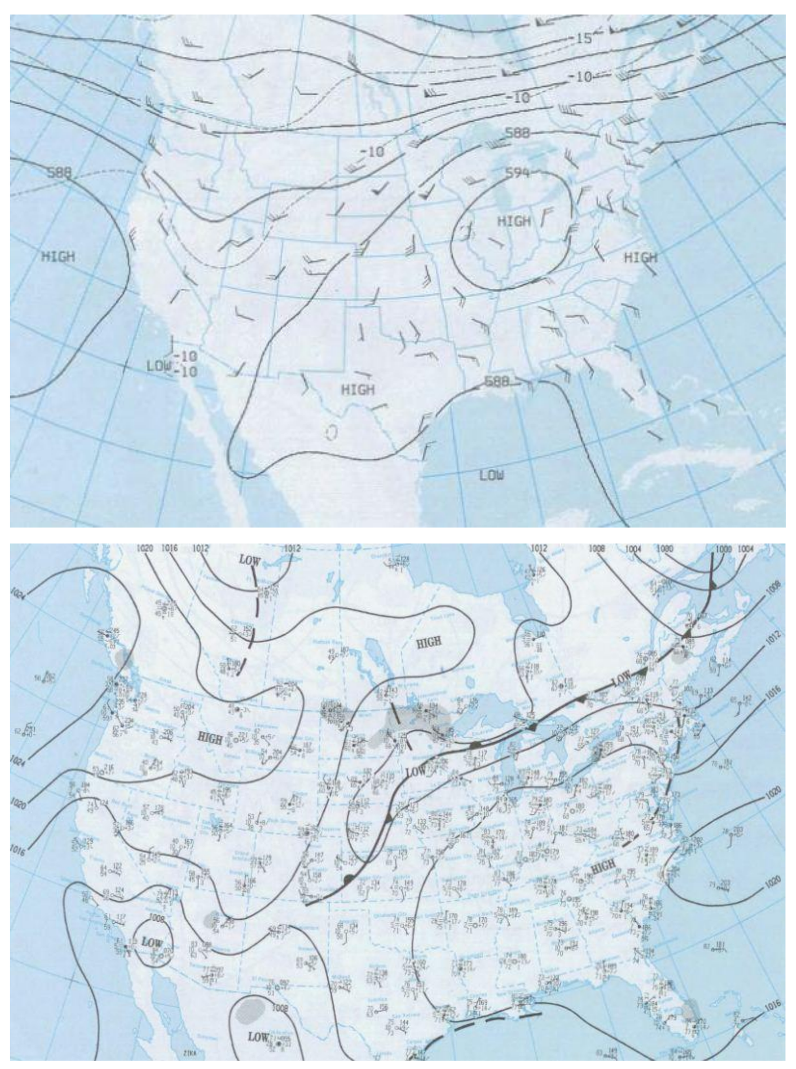

Figure 2. The large-scale setup for the event, depicting 500 mb heights and winds (top) and analysis of the surface (bottom).

## Methods and Model Setup

- ➢Numerical Model Simulations using the Advanced Weather Research and Forecasting Model (WRF-ARW)
- ➢The domain of the simulation area consists of a 288 x 252 km grid with a resolution of 3km per grid cell, centered at 42.0N, -88.0W (Figure 3).
- ➢Period of study: July 10 - 17, 1995
- ➢Simulation 1 (Control): Current USGS land use (Figure 4)
- ➢Simulation 2 (Modified): Removal of urban land use and subsequent insertion of grassland/cropland. (Figure 5) (Figure 4)
- ➢Analysis of difference between the urban and non-urban simulations using graphics generated by the National Center for Atmospheric Research's (NCAR) Command Language (NCL).

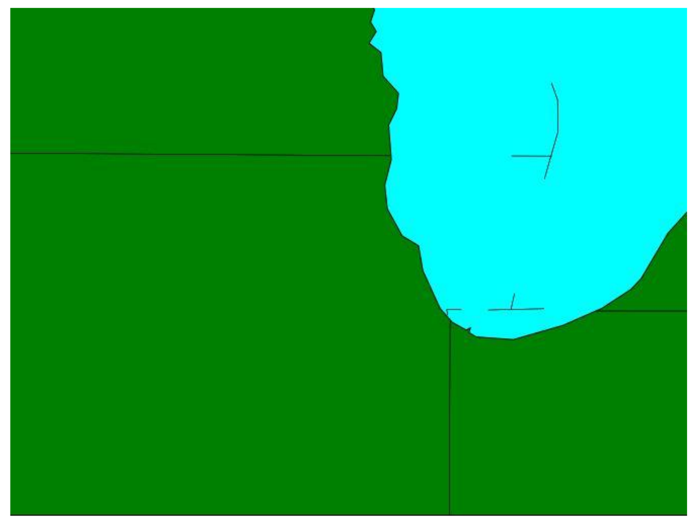

Figure 3. Simulation Domain – Resolution: 3km

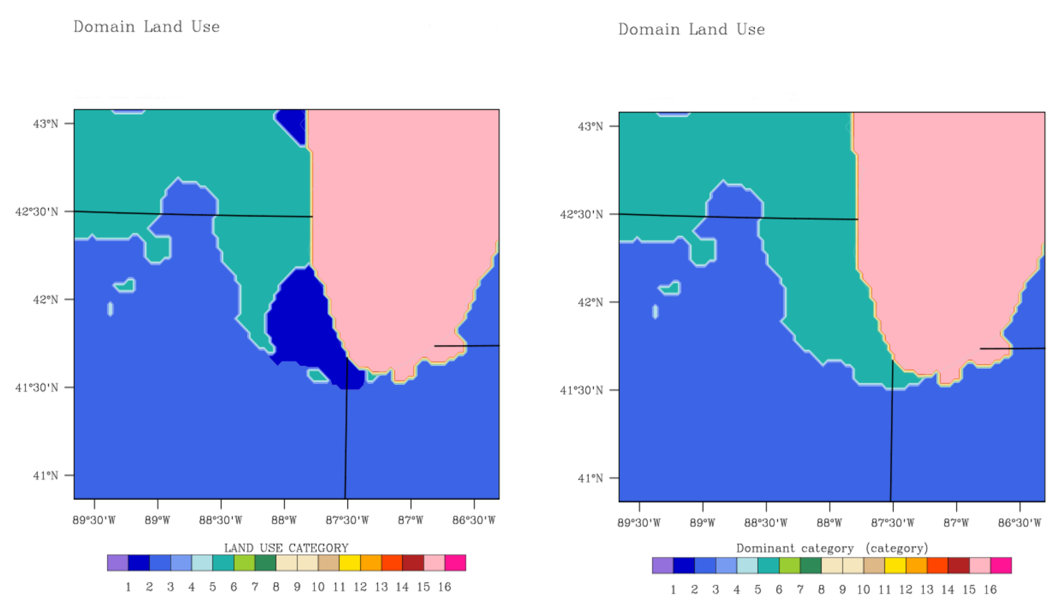


Figure 4. Simulation 1 – No land use change (left); Simulation 2 – Urban changed to grassland (right)

## Model Setup

- ➢WRF resolution: 3km
- ➢Input data
  - ❖ Meteorological: North American Regional Reanalysis (NARR)
    - ▪ Spatial Resolution: 32 km.
    - ▪ Period: July 10, 1995 00Z – July 17, 1995 21Z
    - ▪ Temporal Resolution: 3 hr.
  - ❖ Geographical: USGS 24-category land use
    - ▪ Spatial Resolution: ~18 km (10-minute)
    - ▪ Assume land use homogeneity per category

## Results of WRF-ARW Simulations

Five variables, key factors in the depiction of the energy budget, comprised the main analysis of the 7-day WRF simulations: Temperature (Figure 5), Latent Heat Flux (Figure 6), Relative Humidity (Figure 7), Sensible Heat Flux (Figure 8), and Albedo (Figure 9). Other variables such as Net Radiation, Ground Heat Flux, and Wind Speed were also noted. The date of July 15, 1995 was arbitrarily selected to represent the differences between the urban and non-urban simulations, though significant changes also occurred throughout a majority of the time period. Daytime and nighttime variations are shown.

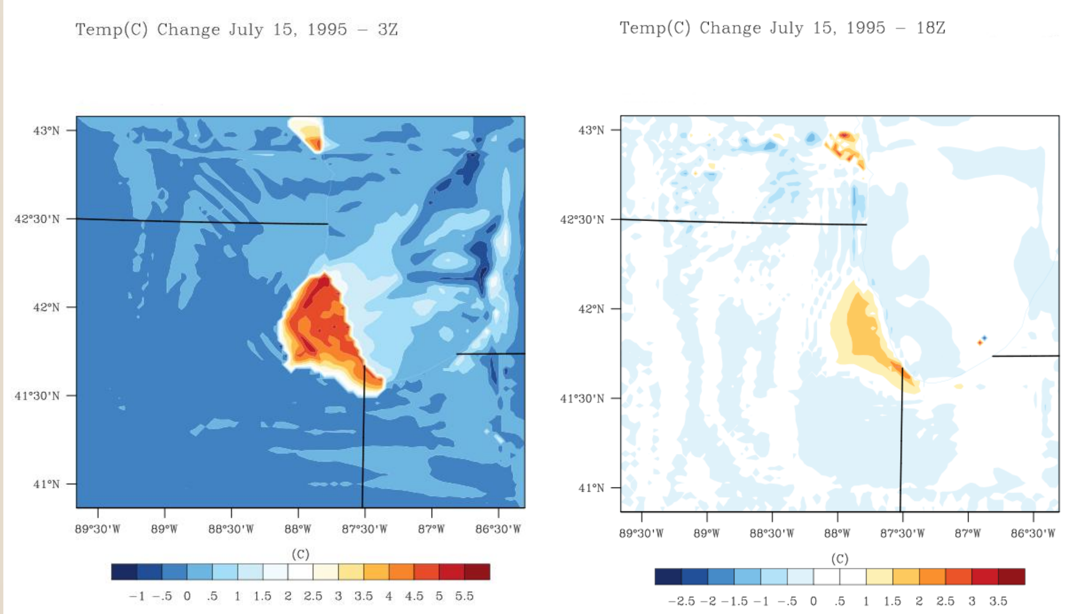


Figure 5. Temperature change at 3Z (left) and 18Z (right)

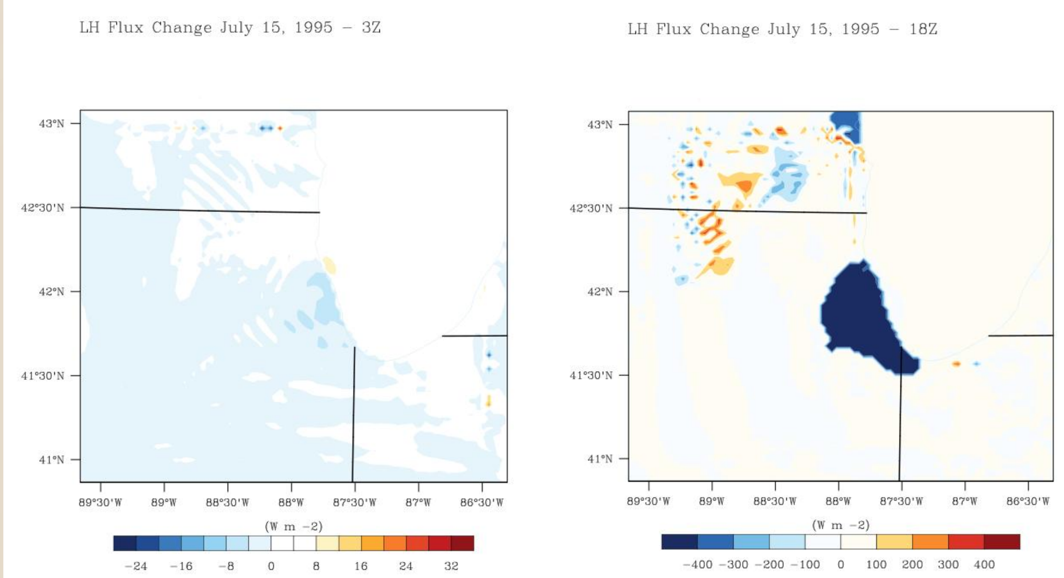


Figure 6. Latent Heat Flux change at 3Z (left) and 18Z (right)

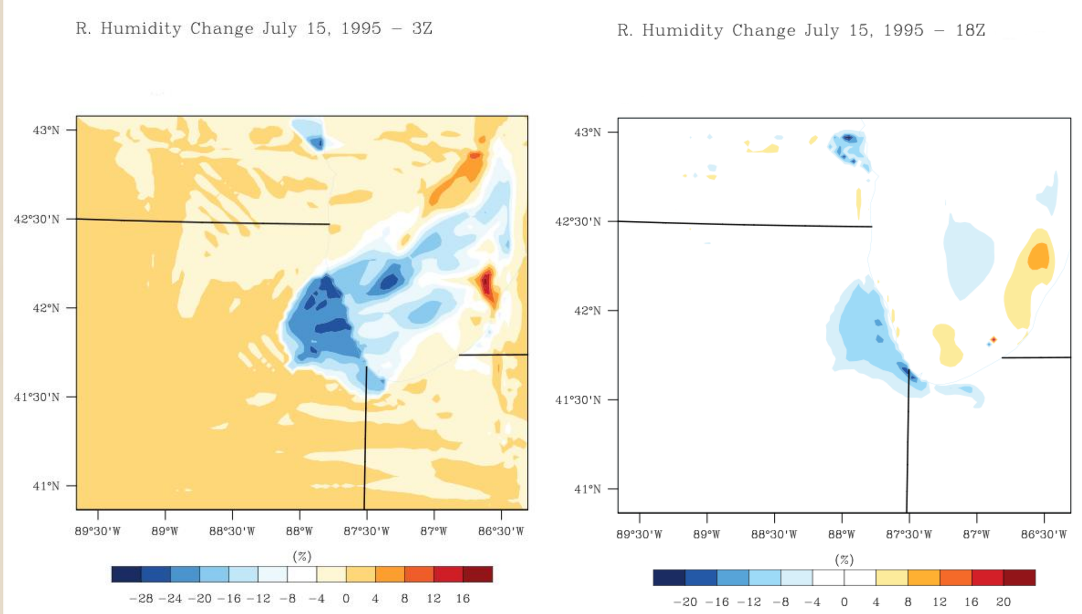


Figure 7. Relativity Humidity change at 3Z (left) and 18Z (right)

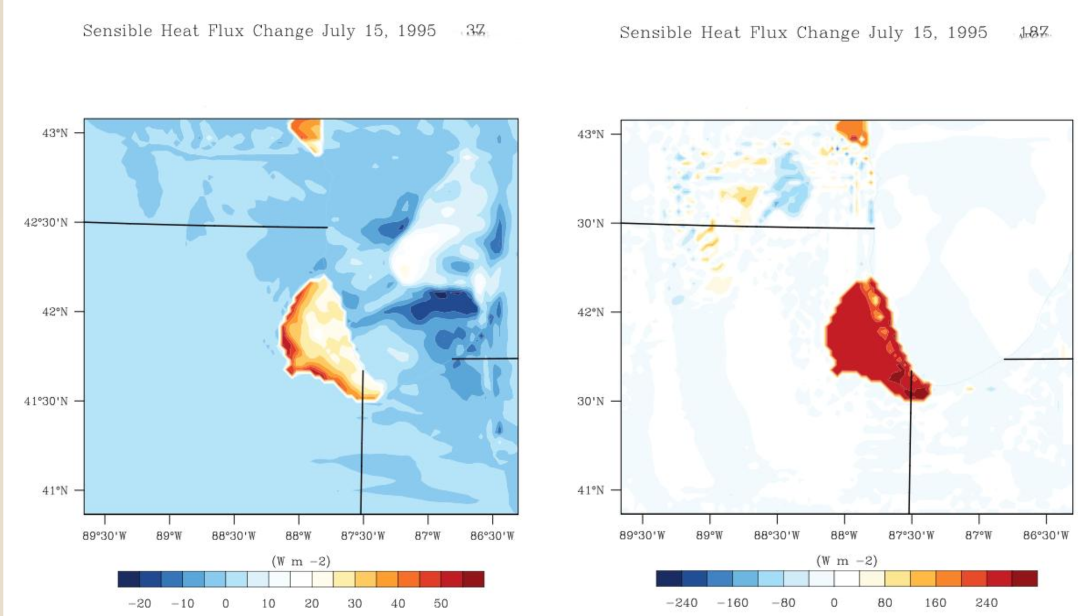


Figure 8. Sensible Heat Flux change at 3Z (left) and 18Z (right)

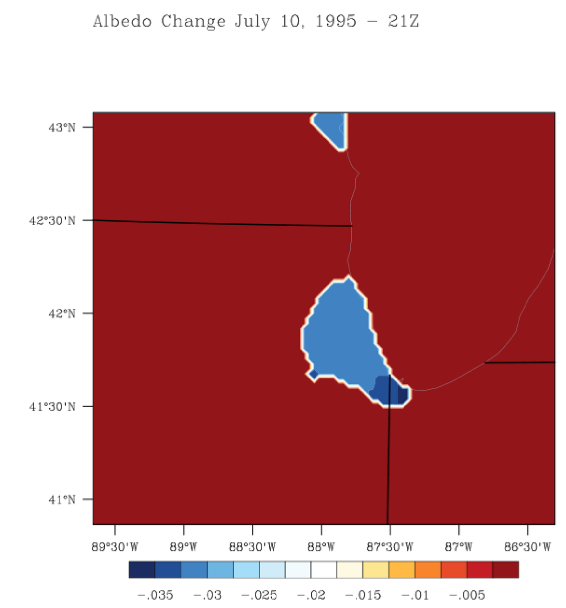


Figure 9. Albedo change at 21Z – July 10, 1995

## Discussion

- ➢Changes in Land Use (Urban to Non Urban) lead to major changes in Albedo.
- ➢Significant increase in Sensible Heat Flux over Urban Region
- ➢Significant decrease in Latent Heat Flux over Urban Region
- ➢Higher humidity values over grassland/cropland.
- ➢Overall higher temperatures over urban region, particularly at night (Urban Heat Island Effect)

## Conclusions

- ➢Rapid and widespread changes to the land surface alter the energy budget to a degree that may introduce new and different climate impacts to long term residents.
- ➢Anomalies in climate, such as the Chicago 1995 heat wave, may be exacerbated, particularly locally, in regions undergoing urbanization.
- ➢Numerical Climate Simulations that assess land use change may be beneficial to land planners and city developers focused on creating a comfortable, inexpensive, and relatively safe environment for future residents.

## References


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