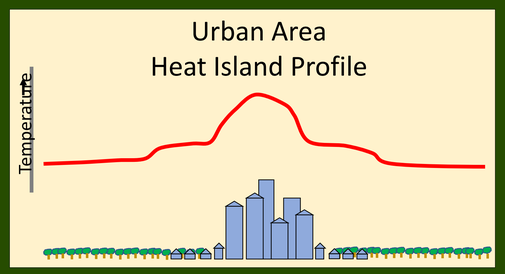
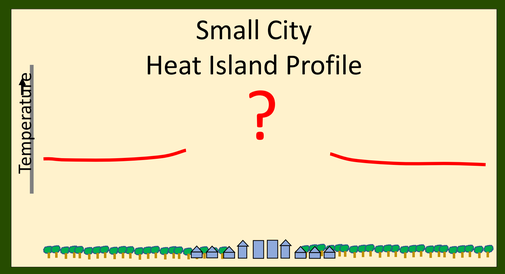
John McIntosh, Northeastern State University

Urban Heat Islands ... Small Cities Too???





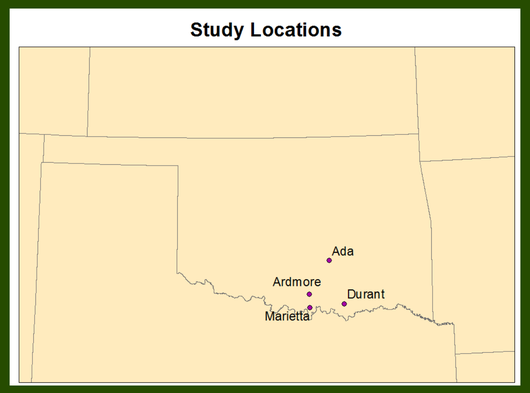
Introduction

Urban heat islands occur when urban areas experience warmer temperatures than nearby rural areas. The difference in temperature observed in rural and urban areas is from human activities, primarily a result of how well the surfaces in each of these environments absorb energy from the sun during the day and hold heat. Rural areas typically have more plant cover than urban areas and the associated transpiration cools down the air. Urban areas on the other hand have a much higher proportion of the surface covered with buildings, roads, parking lots and other impervious surfaces. These surfaces tend to absorb sunlight and radiate sensible heat into the environment. Even vegetated areas within urban areas are warmer than similar areas outside of the heat island.

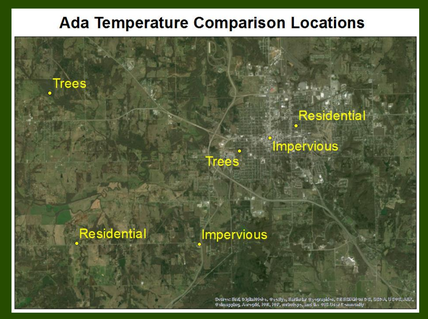
Modest temperature increases of even a few degrees can impact human health, energy consumption, pollutant emissions, and water quality. Mitigations such as application of coatings to lighten streets and roofs, plants on rooftops and other measures have been advocated to reduce the urban heat island effect. Most of the research on urban heat islands has focused on large urban areas. Is there a significant urban heat island in smaller cities that should, or could, be mitigated? This poster reports the analysis of the urban heat island effect on four small cities in Oklahoma. The urban heat island effect was analyzed using land surface temperatures derived from Landsat imagery

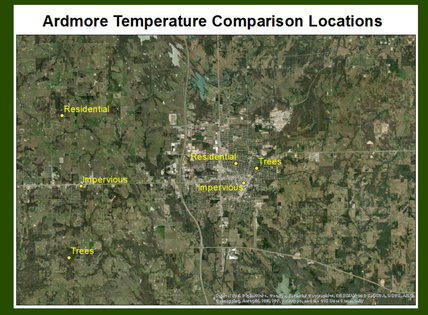
Study Area

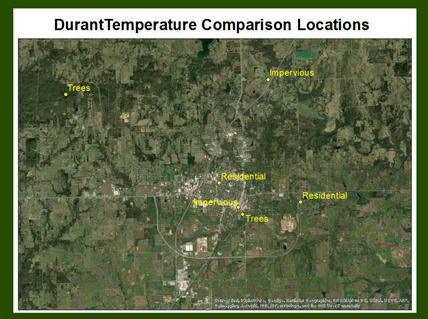
The study area includes the cities of Marietta, Ardmore, Durant and Ada in South Central Oklahoma. The cities range in size from about 3000 up to about 25000 people providing a range of city sizes to review. The cities are relatively close together and are covered by the same Landsat scene (path 125, row 208) providing consistency in weather conditions for the analysis day.

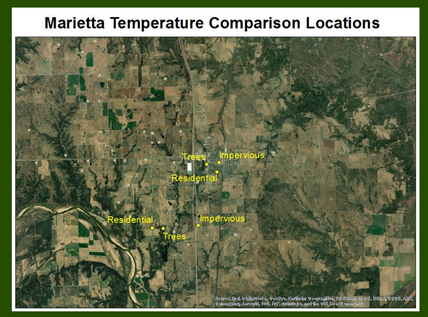


Measurement Locations









City-Rural Temperature Pair Results

City	Type	Site Characteristics	Temp C
Ada	City	Impervious	17
Ada	Rural	Impervious	15
Ada	City	Residential	16
Ada	Rural	Residential	15
Ada	City	Trees	15
Ada	Rural	Trees	14
Ardmore	City	Impervious	18
Ardmore	Rural	Impervious	17
Ardmore	City	Residential	17
Ardmore	Rural	Residential	16
Ardmore	City	Trees	16
Ardmore	Rural	Trees	15
Durant	City	Impervious	17
Durant	Rural	Impervious	16
Durant	City	Residential	16
Durant	Rural	Residential	15
Durant	City	Trees	15
Durant	Rural	Trees	15
Marietta	City	Impervious	17
Marietta	Rural	Impervious	17
Marietta	City	Residential	16
Marietta	Rural	Residential	15
Marietta	City	Trees	16
Marietta	Rural	Trees	15

Methods

This study uses nighttime Landsat derived land surface temperature estimates. Satellite measurements provide finer spatial resolution than available climate records. Night time images were used because urban heat island effects tend to be more pronounced during the evening and land surface temperatures closer to actual air temperature.

Steps

1. Download Landsat scenes from the United States Geological Survey's Earth Explorer website for June 13, 2019

2. Calculate the TOA (Top of Atmosphere) spectral radiance for Band 10
   $TOA = M * Q_{cal} + A$

   Where TOA = Top of Atmosphere Spectral Radiance, M = Band 10 multiplicative rescaling factor from the metadata , Q_{cal} = Band 10 value, A = Band 10 additive rescaling factor from the metadata

3. Convert TOA to Brightness Temperature (C°)
   $BT = (K2 / (\ln (K1 / TOA) + 1)) - 273.15$

   Where BT = Brightness Temperature, K1 = Band 10 specific thermal conversion constant from the metadata, K2 = Band 10 specific thermal conversion constant from the metadata

4. Calculate the land surface temperature (C°)
   $LST = (BT / (1 + (0.00115 * BT / 1.4388) * \ln(\varepsilon)))$

   Where LST=Land Surface Temperature, Emissivity (ε) is from the June 13, 2019 Analysis Ready Data

5. Compare calculated land surface temperatures between city and rural sites for each of the cities.
6. Prepare a profile of going through the city centers to view overall temperature trends.

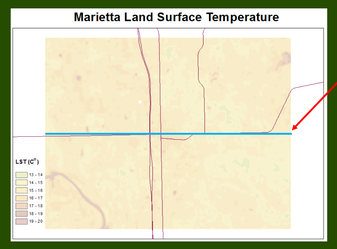
Results

The day was relatively mild for a June day. It was either sunny or mostly sunny with air temperature between 27 and 30 C in the study area cities. Each of the cities exhibited some degree of increased heating in the city center. However, the increased temperature was only one or two degrees Celsius and for some cities and site characteristics there was no difference.

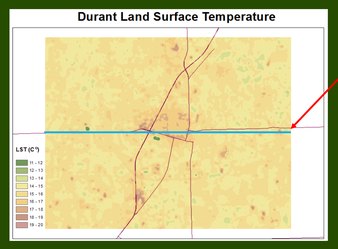
While this study shows a modest urban heat island effect in the towns studied, there are some limitations. Urban heat islands are climatological phenomena, or weather averaged over time. This study just considered a single day and may not be representative of climate averages.

The literature suggests the most significant temperature variations during the evening. The literature also suggests that land surface temperatures closest to air temperature in the evening. Both the higher temperature differences in the evening and the similarity of land surface temperature and observed air temperatures are not tested for the study area.

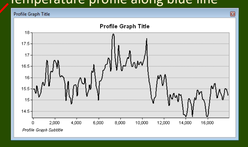
Temperature and Profiles through the downtown

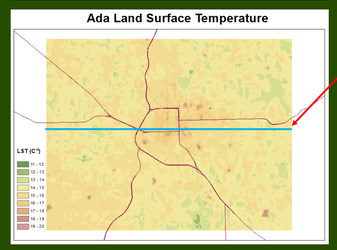


Temperature profile along blue line

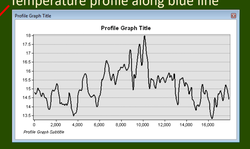


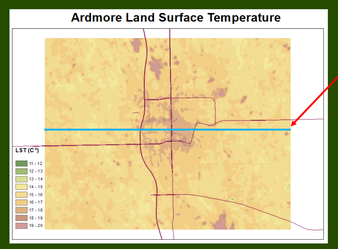
Temperature profile along blue line





Temperature profile along blue line





Temperature profile along blue line