Analysis of Weather Data Collected From Two Locations in a Small Urban Community

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Abstract:

The heat island effect is a well known feature in the microclimate of urban areas, and is considered to be the difference between the urban area and its surroundings. While this study only employs two instruments, the authors are not aware of any studies which examine the differences in temperature between an instrument inside a town the size of Sedalia and its surroundings by collecting hourly information. We attempt to infer here the impact of Sedalia, Missouri, the State Fair Community College campus, and the state fairgrounds on the temperature patterns for a small region of west-central Missouri. The two stations, one on the grounds of State Fair Community College and the other at the Sedalia Airport were used. Temperature, precipitation, cloudiness, and wind information were gathered hourly between 1 February and 31 March, 2005. The weather station at the regional airport was located 11 km (7 miles) northeast of the campus instrument. Our results indicate that the city has no discernable impact on the distribution of monthly precipitation totals. We found a distinct difference between the local surface temperatures as recorded by each instrument. For the Sedalia area, the temperature differences between the town center and the outside location were approximately 2 – 6°F (1.0 – 3.3° C) warmer, typically, than the surrounding environment, as inferred by these instruments. This difference was as much as 11° F (6°C) when comparing hourly temperature information. Additionally, the difference was larger for clear days and days during which there was little wind.

Key Words: *Heat island effect, climatology, microclimate, urban influences*

1. Introduction

The effect of urban environments on local temperature and precipitation distributions have been examined for large communities in the past (e.g., Changnon, 1981; Segal and Arritt, 1992; Karl and Knight, 1997; Melhuish and Pedder, 1998; Pinho and Manso-Orgaz, 2000; Baik and Kim, 2001; Rozoff and Cotton, 2001; Shepherd et al., 2002; Akyuz et al., 2004) and usually for cities that have very large populations. Melhuish and Pedder (1998), Pinho and Manso-Orgaz (2000), and Akyuz et al. (2004) however, examine the heat island effect in smaller urban areas. However, none of the urban areas studied above are as small as that of Sedalia, MO, which has a population of 20,000 – 25,000 residents.

The heat island effect is produced by many factors, which result in a change in the underlying energy budgets in the boundary layer due to urbanization. These include such effects as (e.g., Oke, 1982); an increase in sensible heating (e.g., due to changes in surface albedoes), an increase in thermal storage capacity of the underlying surface, decreased evapo-transpiration, and heat given off (generated) by urban structures. These processes then can have a large impact on the temperature field (see references above) and the precipitation field (e.g., Shephard et al., 2002). A few studies examined also the climatological (long-term) impact of heat islands including their variance by season (e.g., DeMarrais, 1975; Ackerman, 1985; Akyuz et al., 2004).

Published work (e.g., Melhuish and Pedder, 1998; Pinho and Manso-Orgaz, 2000; Akyuz et al., 2004) recently demonstrated that medium-sized and small urban areas may also be responsible for heat-island effects. Heat islands associated with medium-sized and smaller urban areas would not be expected to be as pronounced as those of larger cities, however, the heat island effect in the latter two studies was shown to be quite substantial (up to 7.5° C). Akyuz et al. (2004) demonstrate that the heat island effect was larger in the summer and during the daytime in their study, but smaller during the winter season, with the maximum difference found near morning. Sedalia, Missouri would be smaller than what most people consider to be an urban area in the United States. The town is composed of a downtown area, the State Fair Community College, and the State Fairgrounds.

The objective in this study was to infer the extent to which Sedalia, and the State Fair Community College may produce a heat-island effect. Two existing instrument sites were used; a unit which measures temperature, rainfall, and wind speeds deployed on the grounds of State Fair Community College (SFCC) and the Automated Surface Observation Station (ASOS) at the airport outside of the city, in order to measure the urban impact on the microclimate and the variation in the strength of the heat-island effect over a six-week period. In section two, we discuss the data and methodologies used, and we describe and discuss the study results in section three. In section four, the main conclusions are presented.

2. Data and Methods

The hourly data was collected at two sites within and near Sedalia, MO (Fig. 1) from 1 February to 31 March, 2005. One was located at Sedalia Memorial Airport (KDMO) on the northeast side of town (Fig. 1). This ASOS instrument was the National Weather Service observation station and data were collected courtesy of the NWS website (www.crh.noaa.gov/data/obhistory/KDMO.html, 2005). From this site we collected temperature, precipitation, wind speed, and cloud cover. The second location was at SFCC, which is on the southwest side of Sedalia (Fig. 1). The first author was able to connect a computer to the weather station at the college in order to obtain the data. Temperature data were collected on an hourly basis, and the unit is similar to that of a Campbell Scientific surface station, but the manufacturer is not known. The station has been in operation for many years on the SFCC campus. The precipitation data were collected in a plastic raised edge four-inch rain gauge.

The college and airport were approximately 11 km (7 miles) apart. The relative elevation between the two stations also was fairly comparable. Unfortunately, however, the SFCC site was stationed on top of a building. We cannot be certain how much the readings may have been influenced by heat released from the building. However, we felt that the influence may be similar to that of an instrument placed over a primarily asphalt or concrete surface inside a typical larger city, or even inside a town like Sedalia. Additionally, as only two instruments were used in this study, it is difficult to truly establish that we are measuring a true heat island effect. However, by comparing these results to other studies, and expected values for a heat island for a city of this size, we can infer the character of any potential heat island produced by Sedalia. However, the placement may exaggerate the effect that would be observed at a more representative (standard) site in the city. Finally, all temperature and precipitation data recorded here was reported in degrees Fahrenheit and inches, respectively, since these units are still the standard for surface data information in the United States.

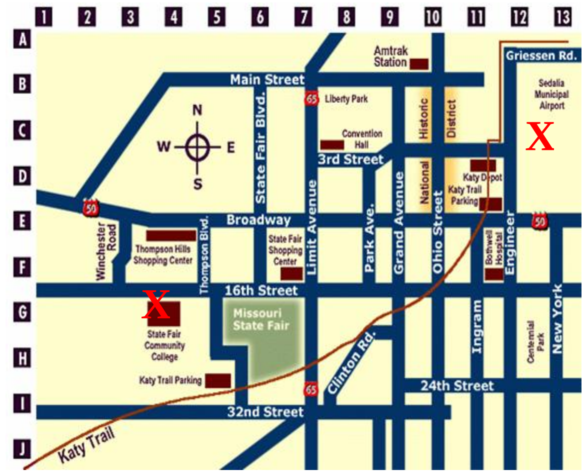

Figure 1. A map of Sedalia, MO. This map is not drawn to scale. The red letters "X" show the locations of the two instruments.

The temperature data were first compared between the two stations hourly in order to determine if any significant differences could be detected in the daily temperatures and if there was a diurnal signal in the hourly data. While using only two stations is not ideal, the station data was readily available and there was no budget for more instrumentation. However, other published studies have used only two stations for their study (e.g., Ackerman, 1985). Here, the difference was calculated by simple subtraction following Akyuz et al. (2004) calculation for the heat island;

$$HI = Temp(SFCC) - Temp(KDMO) \quad (1)$$

Following the above analysis, HI was then compared with wind speed, direction, and cloud cover in order to determine if these variables impacted the strength of the temperature difference. Akyuz et al. (2004) found that for Columbia, MO, clear days with little wind showed the largest values of HI, while cloudy, windy days showed no significant differences. They also demonstrated that the impact of wind direction was to "advect" the heat island effect into the quadrant downwind.

3. Results and Discussion

a. Temperature Variations

The mean value of temperature difference over the 6-week period of study was 2.6° F (1.5°C) and this is smaller than the maximum values for HI of 3 – 6° F (2.1 – 3.3° C) found for Columbia, MO (Akyuz et al., 2004). This is also smaller than the HI for Columbia (3 – 3.6° F, 2.1 – 2.5° C) when just using the February and March data. However, the value found here for Sedalia is still larger than the sensitivity for the type of instrumentation used in the study (see Akyuz et al., 2004). However, the temperature difference found here was consistent with Fig 14.8 in Aguado and Burt (2004, p 428) for an urban area with the population of Sedalia, MO. Thus, the inference of a heat island effect found here, even for a town the size of Sedalia, is likely real.

An examination of the differences for the hourly readings was then performed (Table 1). While the daily data could vary for the time of day when the largest and smallest HI values occurred, we discovered certain patterns emerged. These results showed that between 10:00 am and 12:00 pm, the hourly temperatures tended to run the closest together. This was a surprising result since, at this time, we felt that the building would have played a greater influence on the temperatures. However, it is possible that boundary layer mixing during the morning hours could provide for a similar temperature profile at each location. More information would be necessary to confirm this hypothesis. We also found that the greatest differences were most common between 6-7 am and between 8-9 pm. While the Akyuz et al. (2004) study did not have the time resolution to identify an early evening maximum in HI such as was found here, their study did identify a larger HI for the morning hours in general. Additionally, there is anecdotal evidence to suggest that there may be a large HI during the evening hours when looking at the difference between temperatures at Lambert Airport in Saint Louis versus temperatures in St. Charles, MO (on the order of 10 – 15° F, Lupo, personal communication).

Table 1. The number of observations in which a particular hour (top row) represented the maximum daily temperature difference (middle row) or the minimum daily temperature difference (bottom row).

	Morning (am)											
Time	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
ΔT_x (^oF)	**7**	**7**	**5**	**5**	**5**	**5**	**9**	**8**	**4**	**2**	**4**	**1**
ΔT_n (^oF)	**2**	**0**	**3**	**5**	**7**	**3**	**1**	**2**	**4**	**9**	**17**	**15**
	Afternoon (pm)											
Time	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
ΔT_x (^oF)	**1**	**2**	**0**	**1**	**0**	**0**	**2**	**4**	**10**	**10**	**3**	**8**
ΔT_n (^oF)	**12**	**7**	**7**	**5**	**7**	**7**	**2**	**1**	**1**	**0**	**3**	**4**

b. Sky Cover vs. Temperature

In this part of the study, the influence of cloudiness was examined, and only during the daytime hours. This study used a simpler classification of sky conditions than Akyuz et al., (2004). A day was considered to be cloudy (sunny) if 75% or more of the hourly observations were overcast (clear). The rest of the days were considered to be "mixed" cloudiness. During these two months it was found that there were 15 cloudy days, 26 sunny days, and 18 days of both sun and clouds.

With the 26 days of sunshine, we found that the average temperature difference was 6.3°F. This difference was as large as the maximum monthly means found for Columbia by Akyuz et al., (2004), but not as large as the maximum differences for sunny days in their study. For the 15 days of cloud cover, the average difference was only 3.7° F, while for the 18 days with a mixture of the sun and clouds, the difference was about 3.8° F. The overall mean daytime temperature difference was 4.9° F. Thus, not surprisingly, cloudy skies mitigated the temperature difference between Sedalia and its surroundings.

c. Wind Speed vs. Temperature

As with the cloud cover data, the KDMO wind speed data was stratified using a simpler scheme than Akyuz et al. (2004). The results were organized based on these three categories; a) daily wind speeds of generally less than 10 mph, b) daily wind speeds between 10-20 mph, and c) daily wind speeds that varied between the categories. The results found here were consistent with those of Akyuz et al., (2004) as well. When the speed of the wind was less than 10 mph at least 75% of the time, the average HI was 2.8° F. When, the wind was between 10-20 mph 75% of the time, the difference was smaller, or about 2.1° F. If the wind speed varied throughout the day, the difference was about 2.8° F. These data were not correlated versus the sky cover data due to the small sample size, but a similar pattern to Akyuz et al. (2004) emerged in that it is likely that clear and less windy days would reveal the largest temperature differences for Sedalia, MO. Such behavior for the temperature differences here is consistent with that of the heat island effect.

d. Wind Direction vs. Temperature

Here, we wanted to determine how the temperature differences were affected by the direction of the wind. This evaluation stratified the data into three categories based on wind direction in a given day. The first category was days with wind direction coming from the south or west at least 75% of the time. The second category was days with wind direction coming from the east or north. The third and final category was days with no set pattern of wind direction, but not including days where the wind speeds were calm. The results show here that wind direction did not produce as great a role in temperature differences as wind speed or cloud cover. When wind direction was coming from the south or west, the average temperature difference was about 1.9° F. When the wind direction was from the east or north, the average difference was about 1.7° F. If there was not a set wind direction, the average difference was approximately 1.9° F. This experiment, however, is likely complicated by the lack of station coverage around Sedalia.

e. Precipitation

An evaluation of precipitation data was also carried out here. The goal here was to determine what the differences, if any, there may be in precipitation amount between the two sites. Table 2 below shows the precipitation amounts for rainfall during three days of substantial rainfall during the period of study. There were no substantive differences found for these three events, and this may be expected as these events produced mainly stratiform rain. The same experiment performed during the convective season would likely yield larger differences, but as in Akyuz et al., (2004) there would be little evidence available to attribute such differences to an urban impact.

4. Summary and Conclusions

A study of the temperature difference between two instruments located in Sedalia, MO and outside the town was conducted between 1 February and 31 March 2005 using data collected from State Fair Community College and the Sedalia Airport National Weather Service station. This study followed similar procedures to Akyuz et al. (2004) for their study of the Columbia, MO heat island effect. Unfortunately, only two stations were available for this study, and this is similar to the Ackerman (1985) study. Thus, our conclusion was that there is a significant difference in the observed temperatures at a site within the city and one outside.

This study demonstrates that even a smaller community may exhibit small-scale variations in temperature observations much like their larger counterparts. Even though for the most part, the temperature readings only varied between 2-6°F, there was one hourly reading that showed an 11°F difference during the collection period. These values are consistent with those of Akyuz et al., (2004) and even more consistent with Aguado and Burt (2001) for an urban area with the population of Sedalia, MO.

Also, cloud cover and wind can play a role in temperature differences even in communities of fewer than 25,000 people. It was shown here that sunny and less windy days exhibited larger temperature differences, while cloudy or windy days were associated with smaller differences.

Thus, the magnitude and temporal behavior of the Sedalia, MO temperature differences found here were consistent with those in studies of the heat island effect. Finally, the precipitation study showed no substantial differences here. It is our intention to use this project as a basis toward a more in depth study in the future.

Table 2. The precipitation amounts (inches) at SFCC and KDMO for the three largest rainfall events that occurred during the study period.

Day	Precipitation at SFCC (in)	Precipitation at KDMO
Feb. 12-13	1.53	1.51
March 7	0.91	0.91
March 21-22	0.57	0.42

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