J3.7

HEATING AND COOLING DEGREE DAYS FOR OKLAHOMA CITY

Peter K. Hall, Jr.* and Jeffery B. Basara
Oklahoma Climatological Survey
University of Oklahoma, Norman, Oklahoma

1. INTRODUCTION

Numerous studies have shown variations in meteorological variables between urban and rural environments (e.g. Lowry 1974; Oke 1987, 1988; Grimmond and Oke 1999a; Hall 2004). The most notable urban and rural differences have regarded air temperature in the form of the urban heat island (UHI; Bornstein 1968; Vukovich 1975; Nkemdirim 1980; Kidder and Essenwanger 1995; Lu et al. 1997; Oke 1987, 1988). Urban areas have significant heat storage and the thermal inertia from this process is believed to be instrumental in creation of the urban heat island effect (Grimmond and Oke 1999b). However, anthropogenic heating and heating from pollution can add to the thermal increase in urban areas depending on the time of year (Bornstein 1968). These two factors allow the air temperatures to be larger in an urban area than in the surrounding rural landscape.

Heating Degree Days (HDD) and Cooling Degree Days (CDD) are values compiled daily to assess how much energy may be needed to heat or cool buildings. In fact, energy companies determine the daily power load based on average air temperature and degree days. To determine HDD or CDD, the average temperature is calculated for a given day. If the daily average is less than 18.3 degrees Celsius, the average is subtracted from 18.3 to yield HDD. Conversely, 18.3 is subtracted from a daily average temperature greater than 18.3 degrees Celsius to yield CDD. HDD or CDD can be compiled daily or totaled for an entire month or season.

Based on climatological records, Oklahoma City averages 564 CDD from July to August and 1282 HDD from December through February (U.S. Environmental Data Service, 1973). The purpose of this work is to illustrate the significant difference between HDD/CDD calculated in rural areas (including the official climate record for Oklahoma City) and values calculated inside the central business district (CBD) of Oklahoma City.

2. INSTRUMENTS AND DATA

The Oklahoma Mesonet, an automated network of over 110 permanent meteorological stations dispersed across the state of Oklahoma (Brock et al., 1995), was used to determine ambient atmospheric conditions at the surface in locations outside of Oklahoma City (Figure 1). In particular, this study used observations of air temperature at 1.5 and 9 meters above ground level. The measurements of these variables were collected at five-minute intervals and averaged across the six sites. Seasonal HDD/CDD were calculated from six-site average.

As part of a preliminary study for Joint Urban 2003, Portable Weather and Information Display Systems (PWIDS; Vernon et al., 2004) sites were installed in and near the CBD of Oklahoma City for nearly a year beginning in July 2002. The PWIDS sites measured wind speed, wind direction, temperature, and relative humidity. Thirteen of the PWIDS Sites (P1-P8 and P11-P15) were mounted atop street light/traffic light poles, approximately ten meters above ground level, all within four blocks of each other. The other two PWIDS sites (P9 and P10) were located on a building rooftop approximately 1 kilometer south of the CBD. Ten-second PWIDS data were converted first to five-minute data, then the five-minute values were used to compute seasonal CDD/HDD. Figure 2 depicts a typical PWIDS site in the CBD.

* *Corresponding author address:* Peter K. Hall, Jr., Oklahoma Climatological Survey, Univ. of Oklahoma, 100 E. Boyd St., Suite 1210, Norman, Oklahoma 73019-1012; e-mail: pkhjr@mesonet.org.

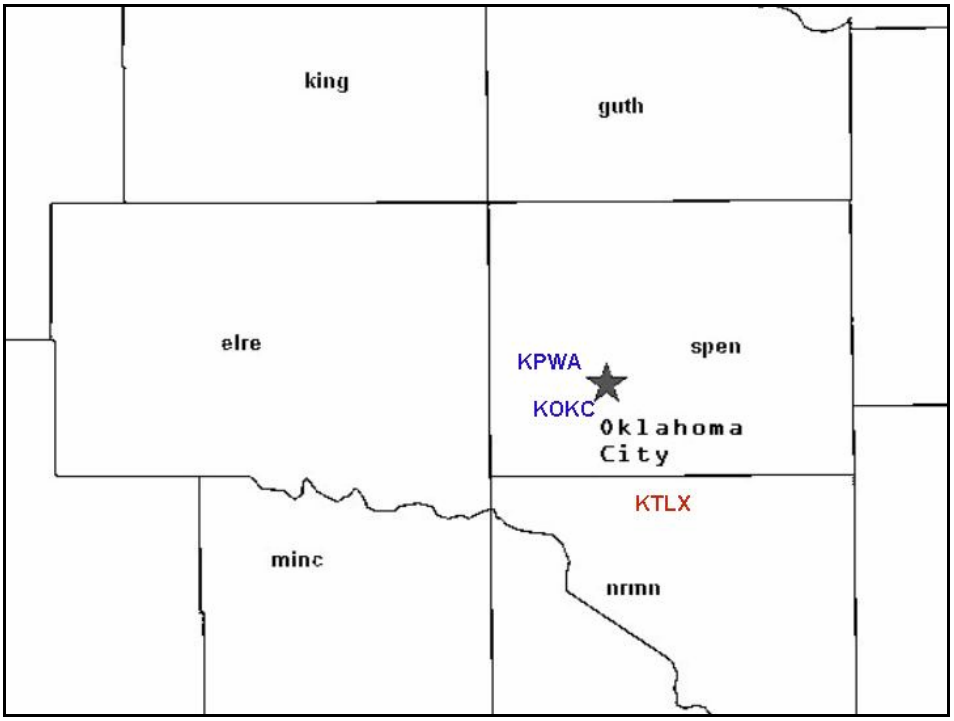

Figure 1. Central Oklahoma Mesonet sites used in this study. Additionally, location of ASOS (KPWA and KOKC) and the operational weather radar (KTLX) are noted. The Central Business District of Oklahoma City is denoted with a star.


Figure 2. Picture of a representative PWIDS site.

3. HEATING AND COOLING DEGREE DAYS

Because the summer is dominated by CDD and the winter by HDD, two seasons were created for this study. Season 1 encompasses July and August of 2002, while Season 2 occurred from December 2002 through February 2003. Seasons 1 and 2 were examined for differences between the *official* CDD/HDD measured by the KOKC Automated Surface Observing System (ASOS) and the values computed within the CBD and at Mesonet sites (Figs. 3 – 4). Because CDD/HDD are dependent on average daily temperature, both provide an approximate comparison of average temperatures between all sites.

During the summer months (Season 1; Fig. 3.) the Mesonet average at 1.5 meters and the KOKC CDD were exactly equal at 545 degrees, while the averaged values for 9 meters at Mesonet sites and P10 (elevated PWIDS site) were the lowest at approximately 530 CDD. As for the CBD (P2-8) the range of CDD was 590 – 615 degrees for this season. As such, the differences observed were 45 to 70 degrees from *official Oklahoma City values* to urban areas. In other words, on average, the urban area was nearly one CDD warmer per day than KOKC during the summer. Thus, more energy would have been expended for cooling purposes than planned based on the climatological reference point (i.e. KOKC).

The winter (Season 2) revealed similar patterns as the summer. While more CDD were present in urban areas during the summer (i.e., warmer), less HDD were calculated for the winter in urban areas (also warmer; Fig. 4). The average of central Oklahoma Mesonet sites at 1.5 and 9 meters and the official tabulations from the KOKC yielded HDD of 1300 to 1325 degrees, with the 1.5 meter Mesonet average recording the most HDD. Conversely, PWIDS HDD (not including rooftops) ranged from 1175 to 1210 degrees. During the period, a difference of 90 to 125 HDD was calculated between urban sites and the *official* record – more than 1 HDD different per day during the season. Thus, urban sites were again warmer than the surrounding terrain. However, the warmer urban areas would require less energy to heat buildings and less energy would be used than planned based on the official climatological record.

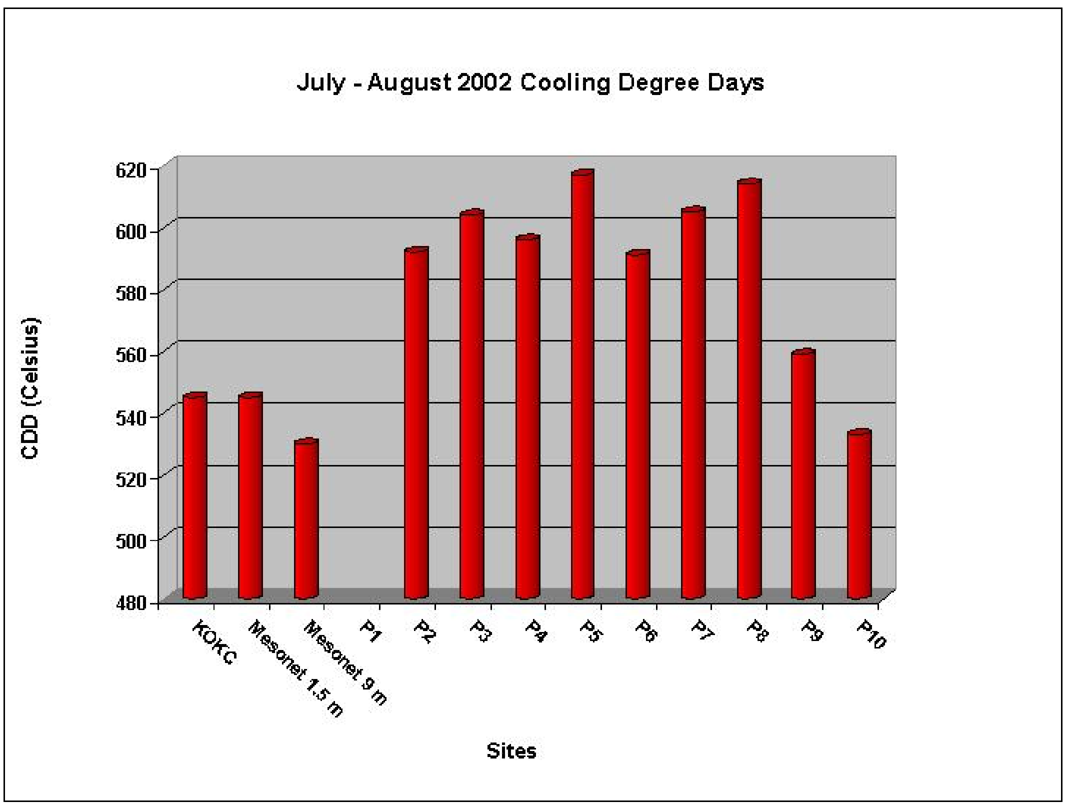

Figure 3. Season 1 Cooling Degree Days for KOKC, Mesonet, and PWIDS sites.

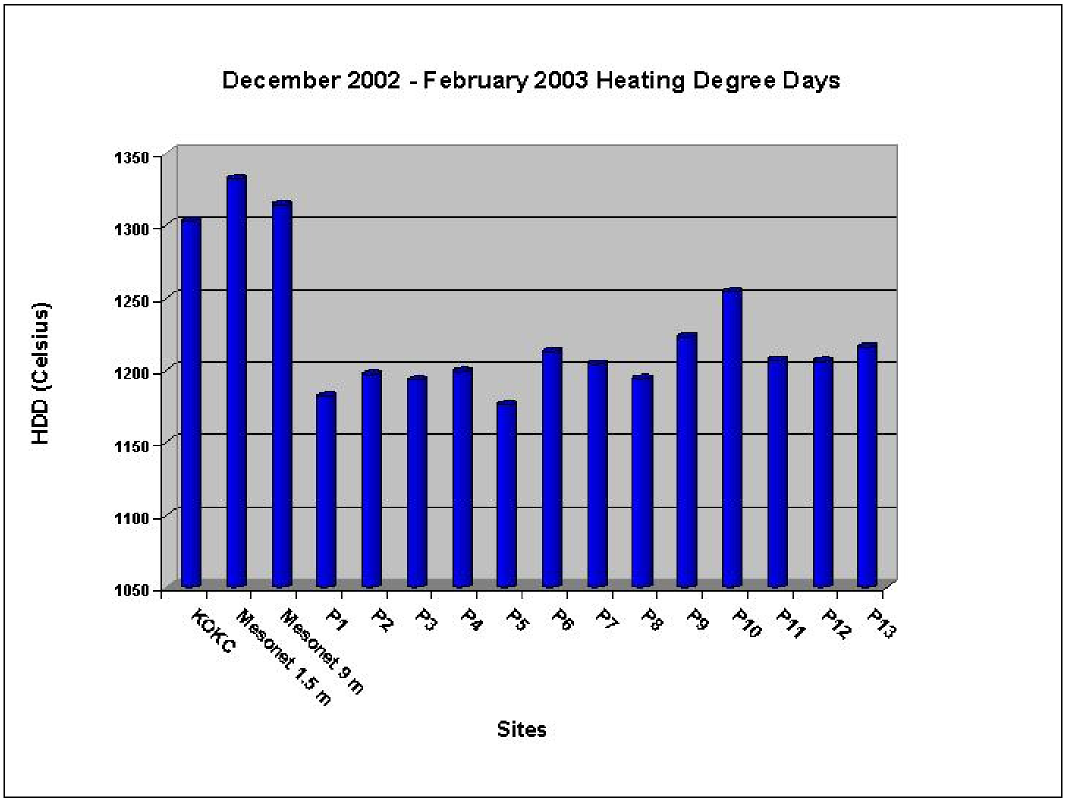

Figure 4. Season 2 Heating Degree Days for KOKC, Mesonet, and PWIDS sites.

4. DISCUSSION

Differences were observed between 1.5-meter rural CDD/HDD and PWIDS CDD/HDD. These differences were apparent despite the height difference of 7.5 meters. Comparing the 9-meter Mesonet CDD/HDD to the PWIDS CDD/HDD still showed a difference of approximately 1 degree day per day.

The difference between urban and rural temperatures can have a strong impact on the energy industry. For example, an electric company bases its electric output by what the average temperature would be in an area for a given day. If the electric company bases its temperature forecasts and calculations on weather stations in rural areas, there is a strong chance that the electric company could over or under produce electricity. Based on the results from Oklahoma City, an electric company could perfectly predict the average temperature at KOKC but still be at least one degree day off of the actual occurrence within the urban area. During the winter there would be an overproduction of energy while in the summer an underproduction. These mis-productions can cost energy companies significant amounts of money over a season or a year.

The results of this study appear significant as Oklahoma City includes a relatively modest CBD and urban extent. Yet, significant thermal variability existed between the urban core and the surrounding rural area. Further studies, through permanent urban observatories, will allow scientists to better quantify the CDD and HDD differences. Furthermore, integration of energy demands and urban observations will benefit providers and consumers of energy and make production more efficient.

5. ACKNOWLEDGEMENTS

This study was made possible, in part, by funding from the Defense Threat Reduction Agency. The authors would like to thank Donny Storwald for providing the PWIDS Data.

6. REFERENCES

Bornstein, R.D., 1968: Observations of the Urban Heat Island Effect in New York City. *J. of Appl. Meteor.*, **7**, 575-582.

Brock, F.V., K.C. Crawford, R.L. Elliott, G.W. Cuperus, S.J. Stadler, H.L. Johnson, and M.D. Eilts, 1995: The Oklahoma Mesonet: A Technical Overview. *Journal of Atmospheric and Oceanic Technology*, **12**, 5-19.

Grimmond, C.S., and T.R. Oke, 1999a: Aerodynamic Properties of Urban Areas Derived from Analysis of Surface Form. *J. of Appl. Meteor.*, **38**, 1262-1292.

_____, 1999b: Heat Storage in Urban Areas: Local-Scale Observations and Evaluation of a Simple Model. *J. of Appl. Meteor.*, **38**, 922-940.

Hall, P.K., 2004: The Urban Environment of Oklahoma City: A Spatial and Temporal Analysis of the Meteorological Conditions. M. S. Degree Thesis, University of Oklahoma.

Kidder, S.Q, and O.M. Essenwanger, 1995: The Effect of Clouds and Wind on the Difference in Nocturnal Cooling Rates between Urban and Rural Areas. *J. of Appl. Meteor.*, **34**, 2440-2448.

Lowry, W.P., 1974: Project METROMEX: Its History, Status, and Future. *Bull. Amer. Meteor. Soc.*, **55**, 87-88.

Lu, J., and S. P. Arya, 1997: A Laboratory Study of the Urban Heat Island in a Calm and Stably Stratified Environment. Part I: Temperature Field. *J. of Appl. Meteor.*, **36**, 1377-1391.

Nkemdirim, L.C., 1980: A Test of Lapse Rate/Wind Speed Model for Estimating Heat Island Magnitude in an Urban Airshed. *J. of Appl. Meteor.*, **19**, 748-756.

Oke, T.R., 1987: *Boundary Layer Climates*. Routledge, 435 pp.

Oke, T.R., 1988: The Urban Energy Balance. *Progress in Physical Geography*, **4**, 471-508.

U.S. Environmental Data Service, 1973: *Daily Normals of Temperature and Heating and Cooling Degree Days 1941-1970*, Climatography of the United States, No. 84, pp. 650.

Vernon, E.N., D.P. Storwold, F.W. Gallagher III, S.F. Halvorson, and J.F. Bowers, 2004: An Analysis of Urban Surface Meteorology Data Collected Prior to the Joint Urban 2003 Dispersion Experiment, *Fifth Symposium on Urban Environment*, Vancouver, British Columbia, Canada, American Meteorological Society, CD ROM.

Vukovich, F.M., 1975: A Study of the Effect of Wind Shear on a Heat Island Circulation Characteristic of an Urban Complex. *Mon. Wea. Rev.*, **103**, 27-33.