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DO INDIANAPOLIS AIRPORT TEMPERATURES REPRESENT INDIANA'S ENERGY NEEDS?

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ABSTRACT: Air temperature data from the National Weather Service at the Indianapolis International Airport are used by the heating industry to estimate heating degree days and the corresponding heating fuel needs for most of Indiana. Although the airport is located southwest of the main metropolitan area (climatologically the windward side and least subject to urban heating), the city heat island may cause unrepresentatively high temperatures at the airport and correspondingly lower estimates of the heating fuel needs of Indiana. This concern is addressed in this paper. Temperature records from 1955 to 1993 at the airport were compared with those from the rural climatological station at Whitestown, about 19 miles north of the airport. The temperature variables examined for both stations were the January, July, and annual mean daily maximum and minimum temperatures and their respective differences. The airport-Whitestown differences for the July and mean annual daily maximum temperatures showed statistically significant upward time trends. Using the 1961-1990 temperature normals adjusted to a midnight observation base, the north-south gradients of the mean daily maximum and minimum temperatures for each month were compared with an average of those for three pairs of rural climatological stations. The mean daily temperatures at the airport averaged about 0.8° F higher for the year than those in rural settings. The corresponding annual heating degree day total was estimated to be about 251 heating degree days (or 4%) too low for predicting the heating needs of rural Indiana.

KEYWORDS: Heating degree days, heating fuel needs, Indianapolis airport, temperature gradients, time of observation temperature bias, urban heat islands.

INTRODUCTION

Air temperature data from the National Weather Service at the Indianapolis International Airport are used by the heating industry to predict the heating fuel needs for most of Indiana. The airport has 24-hour temperature records as well as the maximum and minimum for each day ending at midnight. Although the airport is located southwest of the city (climatologically the windward side and least subject to urban influences), some concern exists that the urban heat island and possibly the increasing airport runway pavement mass may cause unrepresentatively high temperatures at the airport and, therefore, lower estimates of the heating degree days and fuel needs than would be indicated by temperature data from rural climatological stations. Heating degree days (HDD) are derived from the daily mean temperatures $(\overline{T})$, assuming no heating needs when the daily mean temperature is 65° F or higher (*i.e.,* HDD = 65 - $\overline{T}$ and HDD = 0 for $\bar{T} \geqslant 65°$ F). The daily heating degree days are summed and correlated with fuel use for any period.

The existence of the urban heat island has been well documented (Landsberg, 1981; Oke, 1978). Although the effect of single residences, farm buildings, and small towns on climate is minor, larger towns and cities develop a climate of their own, due to the changes in atmospheric composition and energy balance caused by air pollution, concrete building and pavement masses, and decreased evaporation. Annual mean temperatures in cities average at least 1° to 2° C higher than those in surrounding rural areas; the greatest temperature differences occur in the winter heating season and in periods of calm, clear weather under stagnant high pressure cells.

Our overall objective in this study was to estimate the effect of the Indianapolis urban heat island on airport temperatures and the adjustments required to obtain "rural" daily mean temperatures and respective heating degree days for the airport. The representativeness of airport temperatures for predicting Indiana fuel needs can be estimated using at least two different approaches: 1) by comparing the observed fuel use with the usage predicted from the airport temperature and the derived heating degree days; and 2) by comparing the airport temperatures with those from adjacent rural climatological stations. Since we do not have the observed and predicted fuel use data, we are limited here to the second approach.

Since few, if any, climatological stations have homogeneous records over periods sufficiently long to provide unadjusted temperature "normals," our first objective was to examine the station histories, select the best rural control station, and adjust its records *a priori* for changes in location, instrumentation, and time of observation. Our second objective involved the comparison of airport temperature trends with those of the adjusted control station, using the daily maximum and minimum temperatures for January, July, and the year. Our last objective was to compare the north-south temperature gradients between the airport and the control station for each of the calender months with those of several other rural pairs in west-central and central Indiana.

DATA AND PROCEDURES

The Indianapolis International Airport is located on the southwestern corner of Indianapolis, and, with the exception of increasing runway pavements, nothing but grass and agricultural land occurs from south through west to north of the airport weather station. Given the prevailing southwesterly winds, little urban influence should occur, except for occasions of calm weather and air flow from the northeast to southeast, when urban warming might be expected. The air temperature at the airport was measured with a hygrothermometer (HO-60 to 1983 and HO-83 to the present) at the same exposure in the runway complex (1.8 m above sod) since 1 September 1959 (National Climatic Data Center, 1993, Indianapolis Station Location; personal communication, Roger Kenyon, Cooperative Program Manager, National Weather Service, and Jerry Reed, National

Weather Service Electronics Supervisor, Indianapolis, as well as Ann Lazar, National Climatic Data Center, Asheville, North Carolina). From 24 December 1954 to 1 September 1959, telepsychrometer equipment was used, effectively providing a homogenous record of maximum and minimum temperatures for days ending at midnight from 1955 to the present (a total of 39 years through 1993).

The rural climatological station selected for our control was Whitestown, Indiana. Whitestown lies 30 km north of the airport. While this rural station is in town (population 460), the station is surrounded by agricultural land and is considered a rural site. Epperson and Dale (1984) described this station as one of the most homogeneous climatological stations in Indiana, but a few minor moves did occur along with two changes in the time when the once-daily temperature observation was made. Epperson and Dale (1984) adjusted the 1909 to 1965 daily mean maximum and minimum temperatures from a 6 P.M. to a 7 A.M. observation day base (the 7 A.M. schedule began on 1 October 1965). On 1 September 1986, the liquid-in-glass maximum and minimum thermometers, which had been exposed in a Cotton Region Shelter since 1909, were replaced with an electronic Maximum-Minimum Temperature System and the observation time was changed from 7 A.M. to 5 P.M. EST. The change required adjusting the 1 September 1986 to December 1993 mean daily maximum and minimum temperatures at Whitestown to provide a homogeneous 7 A.M. observation day temperature through 1993. The change was made by the method described by Epperson and Dale (1984) using data from the West Lafayette 6NW Indiana climatological station at the Purdue University Agricultural Research Center located about 80 km northwest of Whitestown.

The West Lafayette station has had an 8 A.M. observation time since 1953. The method of adjustment for each monthly mean daily maximum and minimum temperature is summarized below for the two periods of record, before and after the change in equipment and the time of observation at Whitestown on 1 September 1986:

(1) 1 July 1967 through 31 August 1986:

Whitestown: 7 A.M. observation time; liquid-in-glass thermometers, Cotton Region Shelter.

West Lafayette 6NW: 8 A.M. observation time; liquid-in-glass thermometers, Cotton Region Shelter.

(2) 1 September 1986 through December 1993:

Whitestown: 5 P.M. observation time; Maximum-Minimum Temperature System.

West Lafayette 6NW: 8 A.M. observation time; liquid-in-glass thermometer, Cotton Region Shelter.

The method for computing the Whitestown (WHT) adjustments for each monthly mean daily maximum and minimum temperature from the homogeneous West Lafayette 6NW (WLF) record was:

$WLF_{1-2} = WLF_1 - WLF_2$ = Assumed climate change from period 1 to period 2 at both West Lafayette (WLF) and Whitestown (WHT; not shown in this equation).

$WHT_{1-2} = WHT_1 - WHT_2$ = Climate change + non-climatic change caused by changes in observation time and instrumentation at Whitestown.

Temperature adjustment at Whitestown 1 Sept. 1986 to 31 Dec. 1993 $= WHT_{1-2} - WLF_{1-2}$ = (Climate + Observation change) - Climate change

These estimated adjustments (Table 1) were applied to the September 1986 through December 1993 records from Whitestown to create a homogeneous 7 A.M. series. Since the airport temperature series is based on midnight observations, the Whitestown 7 A.M. series (1 January 1955 to 31 December 1993) was then adjusted (see Karl, *et al.,* 1986) to a midnight observation base with the time of observation bias adjustments given for the nearest 7 A.M. stations (Kokomo 7SE, Greencastle 1E, and Elwood) provided in the Indiana Monthly Station Normals (National Climatic Data Center, 1992). No adjustments were made to the airport records.

The airport and adjusted Whitestown data series (1955-1993) were used to regress January, July, and mean daily maximum and minimum temperatures on year. The differences between each of the data series were also regressed on year. A simple linear regression program was used with the years coded by their last two digits (55, 56,....., 93) to minimize roundoff errors. The slope of the regression line for the temperature differences between the airport and Whitestown on year should reveal any linear trends in the urban heat island effect at the airport over the last 39 years, assuming that the heat island effect does not reach Whitestown.

Using the 1961-1990 National Climatic Data Center (1992) normals, the 30-km north-south temperature gradients between the airport and Whitestown for the mean daily maximum and minimum temperatures for all months and the year were compared with those calculated for an average 30-km north-south temperature gradient in western and central Indiana. Three pairs of rural climatological stations having 30-year normals and time of observation bias adjustments were used to define the average rural north-south temperature gradient: Terre Haute 8S to Perrysville 4WNW; Greencastle 1E to West Lafayette 6NW; and

Table 1. Adjustments to published (U.S. Weather Bureau from 1909 to June 1965 and the U.S. Department of Commerce from July 1965 to 1993) mean daily maximum and minimum temperatures (°F) for Whitestown, Indiana, used to obtain a 7 A.M. observation day base for the indicated month and years as well as adjustments (National Climatic Data Center, 1992) to the 7:00 A.M. series (*) to obtain a series with a midnight (MID) observation base.

	Adjustments For							
	Mean Daily Maximum Temperature To Convert To A 7:00 A.M. Observation Base				Mean Daily Minimum Temperature To Convert To A 7:00 A.M. Observation Base			
Month	1/1/09[1] - 9/30/65	10/1/65 - 8/31/86	9/1/86 - Present	7 A.M. to MID Base*	1/1/09[1] - 9/30/65	10/1/65 - 8/31/86	9/1/86 - Present	7 A.M. to MID Base*
January	- 0.6	0	- 0.9	0.2	- 2.5	0	- 3.1	1.2
February	- 1.2	0	- 2.0	0.4	- 2.5	0	- 3.7	1.7
March	- 1.9	0	- 2.7	0.4	- 1.7	0	- 3.2	1.1
April	- 1.3	0	- 1.8	0.4	- 1.5	0	- 2.7	0.0
May	- 1.1	0	- 0.9	0.3	- 1.0	0	- 2.0	- 0.6
June	- 0.7	0	- 1.6	0.2	- 0.5	0	- 1.1	- 0.5
July	- 0.2	0	- 1.5	0.0	- 0.5	0	- 1.0	- 0.4
August	0.0	0	- 1.2	0.0	- 1.0	0	- 2.0	- 0.3
September	0.2	0	- 1.0	0.0	- 2.0	0	- 2.6	- 0.4
October	- 0.3	0	- 1.6	- 0.1	- 0.9	0	- 2.9	0.5
November	- 0.6	0	- 1.3	0.0	- 1.4	0	- 3.0	1.0
December	- 0.4	0	- 0.4	0.0	- 1.7	0	- 2.5	0.7
Year	- 0.7	0	- 1.4	0.2	- 1.4	0	- 2.5	0.3

[1] Epperson and Dale, 1984

Greenfield to Elwood. The locations of these station pairs are shown on Figure 1. Higher elevations in eastern Indiana make the north-south temperature gradients there less representative of the airport to Whitestown area. All station normals were adjusted to a midnight base using the time of observation bias estimates provided with the National Climatic Data Center 30-year normals.

The difference between the airport to Whitestown north-south temperature gradient and the average north-south gradient for the three rural station pairs for the mean daily maximum and minimum temperatures for each month were used to estimate temperature adjustments to the airport data to provide more representative "rural" temperatures. Heating degree day normals for each month at the airport were then computed from the airport's adjusted mean daily temperature using the rational method developed by Thom (1954) for truncated (at the 65° F base) normal distributions:

$$N \bar{D} = N(65 - \bar{T} - l\, s_{\bar{T}} \sqrt{N})$$

where N is the number of days in the month, $\bar{D}$ is the daily mean heating degree days for the month, 65° F is the base of the heating degree days, $\bar{T}$ is the

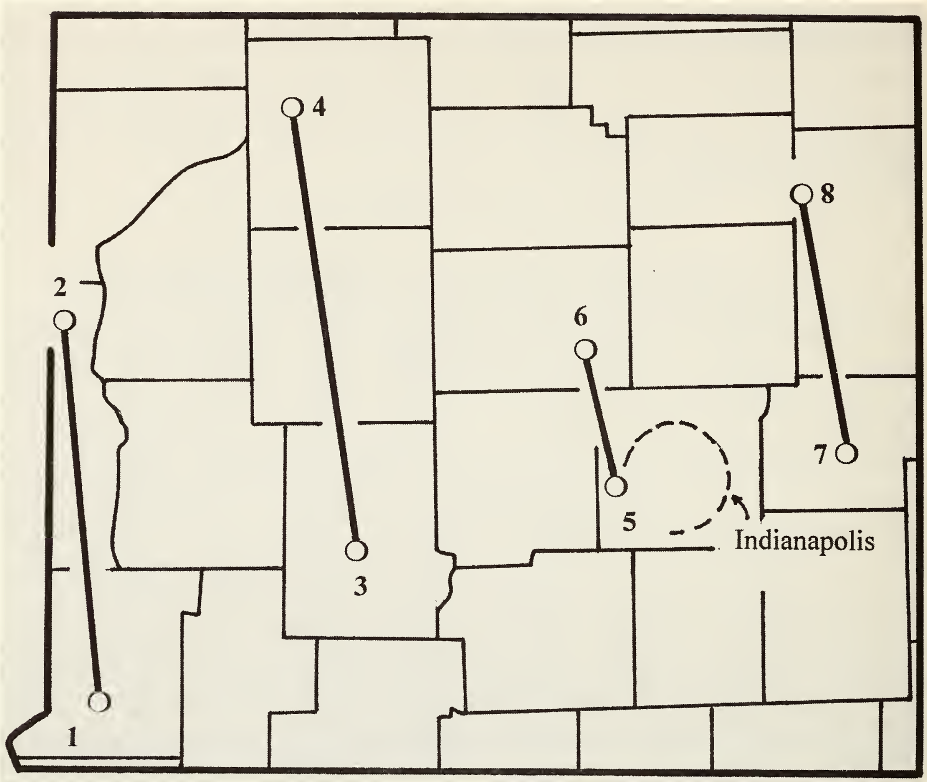

Figure 1. The location of the climatological stations with 30-yr normals used to determine the rural north-south temperature gradient adjustments to Indianapolis International Airport temperatures (1 = Terre Haute 8S; 2 = Perrysville 4WNW; 3 = Greencastle 1E; 4 = West Lafayette 6NW; 5 = Indianapolis International Airport; 6 = Whitestown; 7 = Greenfield; and 8 = Elwood). The major urban area of Indianapolis is shown by the dashed circle.

mean temperature estimated as the mean of the daily mean maximum and minimum temperatures, l is an empirical function of h (see Table 1 in Thom (1954)), h is calculated as $(65 - \bar{T})/s_{\bar{T}}\sqrt{N}$, and $s_{\bar{T}}$ is the standard deviation of the mean monthly temperature as interpolated from the National Atlas Charts (Thom, 1955).

RESULTS AND DISCUSSION

The *a priori* temperature adjustments made to the Whitestown control station temperatures before comparison with the Indianapolis Airport's temperatures are shown in Table 1. For example, in March after 1 September 1986 (5 P.M. observation time), 2.7° F must be subtracted from the published mean daily maximum and 3.2° F from the daily mean minimum temperatures before comparing them with those from the same station when it had a 7 A.M. observation time (from October 1965 through August 1986). In addition, for temperatures before October 1965 (6 P.M. observation time), 1.9° F must be subtracted from the March daily mean maximum and 1.7° F from the mean daily minimum temperatures before comparing them with those in the 1965-1986 time period. (Note that these two time of observation bias adjustments for 5 P.M. (since September 1986) and 6 P.M. (before 1965) signal the discrepancy in "climate" which occurs in areas which go on Daylight Savings Time from April through October, unless the observer changes his time of observation (say from 5 P.M. EST to 6 P.M. EST).) Finally, to compare the new 7 A.M. adjusted mean temperature series to the midnight-based airport mean temperatures, 0.4° F must be added to the March mean daily maximum at Whitestown and 1.1° F to the mean daily minimum.

Regression analysis of the airport and Whitestown temperature variables for January, July, and annual on year (1955-1993) are summarized in Table 2. Of the 12 regressions, the only significant time trend ($\alpha = 0.05$) was the airport's annual mean daily minimum temperature with a trend of 0.04° F (± 0.02)/year or an estimated warming of 1.5° F in the last 39 years.

Two significant trends emerged in the six regressions of the airport to Whitestown gradient on year, the July, and annual mean daily maximum temperatures. The July average daily mean maximum temperature differences have increased 0.04° F (± 0.01)/yr or 1.6° F in the last 39 years. July, of course, does not affect the heating degree days but does affect cooling degree days (not discussed here). The annual mean daily maximum temperature difference has increased an average of 0.02° F (± 0.01)/yr or 0.8° F in the last 39 years. No significant time trends were found in the airport to Whitestown differences for the January mean daily maximum and minimum temperatures or for the annual mean daily minimum temperatures (Table 2), but the annual mean daily minimum temperature at the airport averaged 2.8° F (± 0.8) above that at Whitestown. Since any climatic change should be reflected in the temperature at both the airport and Whitestown, these significant trends in the temperature differences suggest increased urban heat island and/or increased upwind runway pavement area effects at the airport.

The comparison of the north-south temperature gradients between the airport and Whitestown with the averaged gradients from the three rural station pairs for the 30-year normals (1961-1990), adjusted to a midnight observation base, are shown in Table 3. The standard deviations are also included to show that the average gradients were usually beyond two standard deviations. For example, in March (Table 3), the airport to Whitestown gradient is 1.4° F for the mean daily maximum and 2.6° F for the mean daily minimum temperatures compared to the rural average of 1.0 ± 0.2 and 1.0 ± 0.4, respectfully, resulting in a - 0.4° F adjustment to the airport's March mean daily maximum, -1.6° F to the mean daily minimum, and -1.0° F to the daily mean temperature. "Rural adjustments" to the airport's mean daily maximums are minor, averaging 0.2° F for the year, but they are consistently negative for the mean daily minimums, averaging - 1.8° F and - 0.8° F for the mean. The temperature gradients in west-central and central rural Indiana averaged 0.7° F for the mean daily maximum and 0.9° F for the mean daily minimum per 30 km.

Table 2. Simple linear regression statistics for the Indianapolis International Airport, Whitestown, Indiana, and the temperature gradient between them on year, 1955-1993.

Station	Variable	Mean °F ± Std Dev	Slope ± Std Error	*r*	*F*
Indianapolis International Airport	January Mean Daily Maximum	34.2 ± 5.3	0.06 ± 0.08	0.12	0.5
	January Mean Daily Minimum	18.0 ± 5.8	0.10 ± 0.08	0.19	1.3
	July Mean Daily Maximum	85.2 ± 2.5	0.05 ± 0.04	0.24	2.3
	July Mean Daily Minimum	65.2 ± 2.1	0.04 ± 0.03	0.25	2.4
	Annual Mean Daily Maximum	62.0 ± 1.2	0.03 ± 0.02	0.25	2.0
	Annual Mean Daily Minimum	42.5 ± 1.3	0.04 ± 0.02	0.34	4.8*
Whitestown	January Mean Daily Maximum	32.8 ± 4.9	0.04 ± 0.07	0.08	0.3
	January Mean Daily Minimum	16.1 ± 6.3	0.14 ± 0.09	0.25	2.4
	July Mean Daily Maximum	85.3 ± 2.4	0.01 ± 0.03	0.04	0.1
	July Mean Daily Minimum	61.7 ± 2.0	0.05 ± 0.03	0.29	3.4
	Annual Mean Daily Maximum	61.5 ± 1.3	0.01 ± 0.02	0.06	0.2
	Annual Mean Daily Minimum	39.7 ± 1.2	0.03 ± 0.02	0.28	3.1
Airport to Whitestown Gradient	January Mean Daily Maximum	1.4 ± 1.1	0.02 ± 0.02	0.19	1.4
	January Mean Daily Minimum	1.9 ± 1.7	-0.04 ± 0.02	-0.28	3.1
	July Mean Daily Maximum	0.0 ± 1.0	0.04 ± 0.01	0.53	14.6**
	July Mean Daily Minimum	3.5 ± 1.3	-0.01 ± 0.02	-0.07	0.2
	Annual Mean Daily Maximum	0.5 ± 0.6	0.02 ± 0.01	0.35	5.2*
	Annual Mean Daily Minimum	2.8 ± 0.8	0.01 ± 0.01	0.14	0.7

* $F_{0.05\,[1,\,37]} = 4.11$.
** $F_{0.01\,[1,\,37]} = 7.37$.
r = Correlation coefficient.
F = Calculated value of *F*.

The calculated adjustments for a rural environment to the monthly and annual heating degree days at the airport are shown in Table 4. The adjustments to the daily mean temperature (the last column in Table 3) have been reproduced in the third column of Table 4 to obtain the rural gradient adjusted mean daily temperature normals. The l column in Table 4 is a measure of the truncation of the normal distribution of the daily mean temperatures due to the transition of daily mean temperatures across the 65° F threshold of the heating degree days. For example, in January, February, March, November, and December, the mean is sufficiently below the 65° F bound that no daily temperatures within the month are above 65° F, and l is 0. In other months, however, l is not 0, and the truncated portion, $l\, s_{\bar{T}} \sqrt{N}$, has to be added to the 65 - $\bar{T}$ component. Our results showed

Table 3. Average 30-km north-south temperature gradients (°F, 1961-1990 normals) between the Indianapolis International Airport and Whitestown, Indiana, and the mean gradients with their standard deviations for three rural station pairs in western and central Indiana (Terre Haute 8S to Perrysville 4WNW; Greencastle 1E to West Lafayette 6NW; and Greenfield to Elwood) with the estimated rural temperature adjustments for the airport. All normals were adjusted to a midnight observation base. The 30-yr normals from 1961 to 1990 for Whitestown were calculated from the same adjusted temperature series used in the airport to Whitestown regressions, but the normals used for the other 6 (3 pairs) of rural stations were obtained from the National Climatic Data Center (1992).

	Mean Rural Gradient		Airport to Whitestown Gradient		Adjustments To The Airport For A Rural Environment		
Month	Mean Daily Maximum ± Std Dev	Mean Daily Minimum ± Std Dev	Maximum	Minimum	Maximum	Minimum	Mean
January	0.9 ± 0.1	0.9 ± 0.3	1.3	1.9	- 0.4	- 1.0	- 0.7
February	1.1 ± 0.2	1.0 ± 0.4	0.9	2.3	0.2	- 1.3	- 0.7
March	1.0 ± 0.2	1.0 ± 0.4	1.4	2.6	- 0.4	- 1.6	- 1.0
April	0.7 ± 0.3	1.0 ± 0.2	0.7	3.1	0.0	- 2.1	- 1.0
May	0.6 ± 0.3	1.0 ± 0.3	0.1	3.3	0.5	- 2.3	- 0.9
June	0.5 ± 0.3	0.8 ± 0.4	- 0.1	3.1	0.6	- 2.3	- 0.8
July	0.6 ± 0.2	0.9 ± 0.4	- 0.1	3.5	0.7	- 2.6	- 1.0
August	0.7 ± 0.3	1.1 ± 0.3	0.0	3.7	0.7	- 2.6	- 1.0
September	0.5 ± 0.3	1.1 ± 0.3	- 0.4	3.9	0.9	- 2.8	- 1.0
October	0.6 ± 0.2	1.0 ± 0.2	0.3	2.3	0.3	- 1.3	- 0.5
November	0.6 ± 0.2	0.8 ± 0.4	0.9	1.6	- 0.3	- 0.8	- 0.6
December	0.8 ± 0.1	0.7 ± 0.3	1.2	2.0	- 0.4	- 1.3	- 0.8
Annual	0.7	0.9	0.5	2.8	0.2	- 1.8	- 0.8

that the annual total of the monthly heating degree day adjustments is 251, or about 4% above the published heating degree day annual normal of 5615 for the airport. Grant (personal communication, R.H. Grant, Agronomy Department, Purdue University, 5 July 1994) compared the seasonal heating degree day total computed with Thom's method with those computed from the actual daily mean temperatures for the airport (1955-1993) to find that Thom's method underestimated the seasonal heating degree days by about 50 heating degree days. This additive methodological bias brings the estimated seasonal heating degree day bias to 301 (about 5% too low).

We do not know whether or not this heating degree day adjustment will create any significant changes in the methods of estimating total gas use during the heating season in Indiana. Also, some segments of the heating industry use population-weighted heating degree days for estimating fuel use. Perhaps unknow-

Table 4. Calculated adjustments to the heating degree day (HDD) normals for the Indianapolis International Airport with adjusted mean "rural" temperature normals from 1961 to 1990.

	Mean Daily Temperature (F)							
Month	Present Normal	"Rural" Temp. Adjust.	Adjusted Rural Normal	Standard Error[1] s_T	l[2]	"Rural"[3] HDD Normal	Present HDD Normal	"Rural" HDD Adjusted
January	25.5	- 0.7	24.8	5.7	0	1246	1225	21
February	29.6	- 0.7	28.9	5.0	0	1011	991	20
March	41.4	- 1.0	40.4	5.3	0	763	732	31
April	52.4	- 1.0	51.4	3.2	0.01	413	378	35
May	62.8	- 0.9	61.9	3.6	0.13	177	165	12
June	71.9	- 0.8	71.1	3.2	0.41	33	5	28
July	75.4	- 1.0	74.4	2.6	0.66	5	0	5
August	73.2	- 1.0	72.2	2.7	0.51	15	6	9
September	66.6	- 1.0	65.6	3.3	0.21	96	58	38
October	54.7	- 0.5	54.2	3.5	0.02	347	338	9
November	43.0	- 0.6	42.4	3.5	0	678	660	18
December	30.9	- 0.8	30.1	4.8	0	1082	1057	25
Annual	52.3	- 0.8	51.5			5866	5615	25

[1] From the isoline charts of Thom (1955).
[2] $l = f(h)$, Table 1 in Thom (1954); $h = (65 - \bar{T}) / s_{\bar{T}}\sqrt{N})$.
[3] Monthly heating degree days = $N\bar{D} = N(65 - \bar{T} + l s_{\bar{T}}\sqrt{N})$.

ingly, the airport heating degree day bias may provide something of a population-weighted heating degree day prediction! These questions are for the heating industry to answer.

CONCLUSIONS

The urban heat island effect at the Indianapolis International Airport is small but measurable. The bias is found primarily in the mean daily minimum temperature, which for the year averages about 1.8° F higher than would be expected in a more rural setting. Also, of the 12 temperature regressions on year examined, only the airport's annual mean daily minimum had a significant (α= 0.05) upward time trend, possibly due to the greater frequency of urban air pollution and heat backing to the airport under the typically calmer conditions of the night and early morning hours. The temperature differences between the airport and Whitestown showed the greatest upward time trends for the annual and July mean daily maximum temperatures, the only significant time trends in the six gradient variables. These trends may be caused by the increased mass of runway pavement upwind of the hygrothermometer. The mean temperature for the year at the airport was estimated as 0.8° F above that of a "rural" setting. This difference produces a downward bias in the seasonal heating degree days (base 65° F) of about 251 heating degree days for the year. If we add to this the 50 seasonal heating degree day bias found by Grant (personal communication, 1994), the total bias becomes 301 or about 5% of the published seasonal heating degree day normals for the airport.

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