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Seasonal Temperature Patterns of Selected Cities in and Around Ohio[1]

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ABSTRACT. **A sinusoidal temperature model has been developed which describes maximum and minimum temperature patterns through a yearly cycle for the major cities in and around the state of Ohio. Thirty-year monthly means provide the basis for the calculation of model parameters that are used to analytically compare temperature patterns among the selected cities. An amplitude of 11.8°C for the minimum temperature cycle in Columbus implies that the average minimum temperature for January in this city was 23.6°C colder than the average summer minimum temperature for July. Larger amplitudes for the maximum temperature cycles imply a larger difference between average summer daily extremes than for average winter daily extremes. With minimum winter temperatures well below freezing over the state, the model indicates a period of over 100 days during winter where the average minimum daily temperatures are below 0°C.**

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INTRODUCTION

Temperature patterns affect the lives of Ohio's citizens and play an important role in guiding human and animal activities within the state. A study of temperature variation for the major cities in Ohio has been made to illustrate the subtle changes in climate that affect the environment in the state. To facilitate this study, mean monthly temperatures for 250 cities within the United States were obtained from the National Climatic Data Center in Asheville, North Carolina (National Oceanic and Atmospheric Administration, 1979). A plot of the mean monthly temperature for each city for a 30 year period (1941-1970) revealed a clear sinusoidal pattern. A structure was therefore developed to model the mean monthly temperature of each city with a sine wave, changing only the model parameters to accommodate different patterns between cities (McCloskey 1981). The purpose of this article is to expand the model to mean maximum temperatures and mean minimum temperatures for selected cities in the state of Ohio. A study of Ohio's extreme temperatures for the year 1981 revealed a sinusoidal pattern with considerable daily fluctuation along the temperature cycle (Hickcox 1984). Thirty-year means will provide a historical base for comparison of a given year's temperatures, and the model parameters for each city will provide a quantitative way of comparing temperature patterns among the cities.

METHODS

For each of the 12 cities given in Table 1 the mean monthly temperatures (T) were used to establish the parameters in the temperature model:

$$T = A + B \sin\left(\frac{2\pi x}{12} + C\right),$$

where x is an integer code from 1 to 12 to represent each month throughout the year. The parameter A is the mean yearly temperature for the given city, B the amplitude for the temperature variation, and C the phase shift parameter indicating the beginning of the temperature cycle. The three parameters were determined by the method of least squares and were calculated for both the minimum monthly temperature and the maximum monthly temperature cycles for each of the 12 cities. The standard deviation of the least squares fit is used as a measure of accuracy of the temperature model. For the minimum temperatures, the standard deviations ranged from 0.26 to 0.44°C for the 12 cities. For the maximum temperatures, the standard deviations ranged from 0.64 to 1.12°C.

RESULTS

The mean and amplitude parameters for the minimum and maximum temperature cycles are given in Table 1 for the 12 major cities in and around Ohio. The mean parameters show the general increasing trend when moving from north to south. An amplitude of 12°C implies that the maximum summer mean temperature is 12°C above the yearly mean, whereas the minimum winter mean is 12°C below the yearly mean. The largest amplitudes occur in cities from the northwestern part of the area; the smallest amplitudes occur in the southeast. This is consistent with the pattern that prevails throughout the United States, with the largest amplitudes recorded in the upper midwestern states. An amplitude of 11.8°C for the minimum temperature cycle in Columbus, Ohio implies that the average minimum temperature for January in this city was 23.6°C colder than the average summer minimum temperature for July. For the 12 cities in this study the difference between summer and winter minimums varied from 22.2°C in Huntington, West Virginia to 24.8°C in Fort Wayne, Indiana and Dayton, Ohio.

Another interesting point is that the amplitude for the minimum temperature cycle is smaller than the amplitude for the maximum temperature cycle in this area. This fact implies a larger span between average summer daily extremes than for average winter daily extremes. In

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TABLE 1
Model parameters for 12 cities in and around Ohio

City	Minimum Temperatures (°C)		Maximum Temperatures (°C)	
	Mean	Amplitude	Mean	Amplitude
1. Erie, PA	3.9	11.8	12.8	13.1
2. Cleveland, OH	4.9	11.5	14.7	13.8
3. Youngstown, OH	3.9	11.6	14.6	14.0
4. Akron, OH	4.3	11.9	15.2	13.9
5. Mansfield, OH	5.5	12.0	15.8	13.8
6. Fort Wayne, IN	4.6	12.4	15.2	14.5
7. Toledo, OH	3.9	12.2	15.2	14.7
8. Dayton, OH	5.8	12.4	16.3	14.0
9. Columbus, OH	4.9	11.8	16.7	13.8
10. Parkersburg, WV	6.8	11.3	18.2	12.8
11. Huntington, WV	7.1	11.1	18.7	12.3
12. Cincinnati, OH	7.3	11.7	18.1	13.3

Table 2, the amplitude has been added and subtracted from the yearly mean to provide the extreme summer and winter means for the temperature cycles. The difference between the average maximum and minimum summer temperatures for Columbus, Ohio was 13.8°C; the value for the average winter temperatures in Columbus was 9.8°C. This information implies a span between average summer daily extremes that is 4°C larger than that for average winter daily extremes in this city.

A study of the model parameters reveals that the phase-shift parameter is quite stable over Ohio, and that the temperature cycle starts roughly 33 days after the spring equinox. This indicates that the extreme summer mean temperatures would occur on July 24 and the extreme winter mean temperatures on January 23. Furthermore, the variation between these extremes throughout the year follows a nearly perfect sinusoidal pattern with the mean and amplitude as provided for each city.

The differences between the maximum and minimum temperatures given in Table 2 have been calculated for both the winter and summer extremes. These differences yield the mean daily temperature extremes for both the winter and summer months. These figures indicate that mean summer daily extremes are from 2.4 to 5.0°C more variable than mean winter daily extremes for the cities examined in this study.

TABLE 2
Differences in maximum and minimum winter and summer temperatures for 12 cities in and around Ohio

City	Summer Temperatures (°C)			Winter Temperatures (°C)		
	Max	Min	Diff	Max	Min	Diff
1. Erie, PA	25.9	15.7	10.2	−.3	−7.9	7.6
2. Cleveland, OH	28.5	16.4	12.1	0.9	−6.6	7.5
3. Youngstown, OH	28.6	15.5	13.1	0.6	−7.7	8.3
4. Akron, OH	29.1	16.2	12.9	1.3	−7.6	8.9
5. Mansfield, OH	29.6	17.5	12.1	2.0	−6.5	8.5
6. Fort Wayne, IN	29.7	17.0	12.7	0.7	−7.8	8.5
7. Toledo, OH	29.9	16.1	13.8	0.5	−8.3	8.8
8. Dayton, OH	30.3	18.2	12.1	2.3	−6.6	8.9
9. Columbus, OH	30.5	16.7	13.8	2.9	−6.9	9.8
10. Parkersburg, WV	31.0	18.1	12.9	5.4	−4.5	9.9
11. Huntington, WV	31.0	18.2	12.8	6.4	−4.0	10.4
12. Cincinnati, OH	31.4	19.0	12.4	4.8	−4.4	9.2

An attempt was also made to determine the number of days during which the minimum temperature cycle has a mean below 0°C (Table 3). This was done by setting the model temperature (T) = 0 for each city and solving the resulting equation for the months (x) where this temperature is achieved. The results were converted to dates and tabulated for each city. These dates identify the specific period during which the minimum daily temperature will be below 0°C more than 50% of the time. Table 3 also shows that the minimum temperature cycle remains below freezing for as many as 142.4 days in Toledo, Ohio to as few as 101.2 days in Huntington, West Virginia.

The number of days that the minimum temperature cycle is below 0°C generally decreases when moving to the south. This period in the cycle is illustrated for Columbus, Ohio in Figure 1. The city of Cleveland, Ohio shows a shorter mean freeze period than might be expected by its northern location owing to the moderating effect of Lake Erie. The state's geography also

TABLE 3
Number of days during which the minimum temperature cycle has a mean below 0 °C

City	Date Mean Below 0°C	Date Mean Above 0°C	Number of Days Mean Below 0°C
1. Erie, PA	Nov 16	Apr 2	140.8
2. Cleveland, OH	Nov 19	Mar 29	129.5
3. Youngstown, OH	Nov 13	Apr 4	140.8
4. Akron, OH	Nov 14	Apr 2	137.2
5. Mansfield, OH	Nov 20	Mar 26	125.3
6. Fort Wayne, IN	Nov 13	Mar 30	136.2
7. Toledo, OH	Nov 10	Apr 2	142.4
8. Dayton, OH	Nov 19	Mar 23	123.9
9. Columbus, OH	Nov 15	Mar 26	130.4
10. Parkersburg, WV	Nov 27	Mar 14	106.3
11. Huntington, WV	Nov 28	Mar 10	101.2
12. Cincinnati, OH	Nov 28	Mar 11	102.8

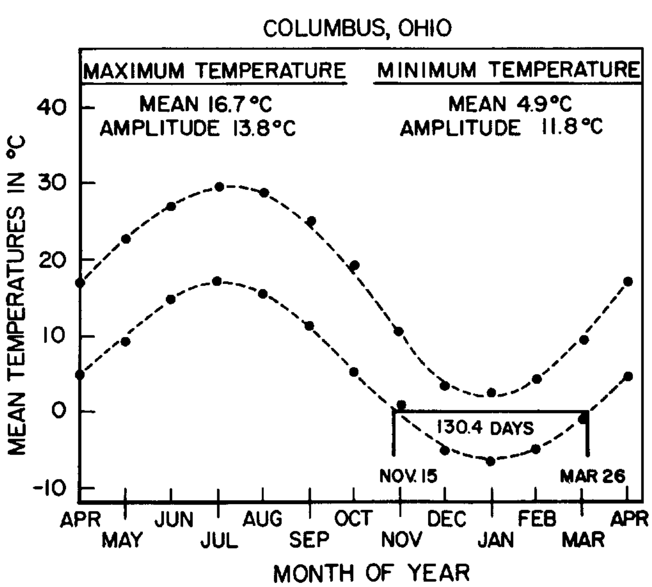

FIGURE 1. Temperature extremes for Columbus, Ohio

plays a role in producing somewhat colder temperatures at the higher elevations in northeastern Ohio (Strahler and Strahler 1978). The cities of Akron and Youngstown, Ohio show later mean freeze dates than might otherwise be expected for this latitude (Noble and Korsok 1975). Likewise, the moderating effect of the lowlands along the Ohio river in the southern part of the state produces a shorter mean freeze period in this area.

DISCUSSION

The sinusoidal temperature model provides an excellent fit to mean monthly temperatures for cities throughout the state of Ohio. This model can be used to study temperature variation from many different perspectives. Yearly means vary with elevation and latitude but provide only a limited measure of a city's climate. A study of temperature amplitudes provides a measure of the extremes that a city will experience and can be used to determine when and for how long these extremes are likely to be endured. The temperature model provides an analytical way to compare the temperature patterns among the cities in the study and provides a quantitative measure of these differences in climate. The model parameters can also be used as a basis for other comparisons with maximum or minimum temperatures not explicitly presented in this study.

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