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Climatology

AN EVALUATION OF THE NEW YORK CITY— NORTHERN NEW JERSEY URBAN HEAT ISLAND EFFECT

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ABSTRACT

Temperature differences between Central Park and 20 stations in northern New Jersey for nights with strong radiational cooling during a 10-year period are evaluated. The effect of urbanization on temperature is strongest in the area adjacent to New York City, and diminishes with increasing distance from the metropolitan area.

1. INTRODUCTION

Urban areas tend to develop unique microclimates different from more rural environments. The concentration of people and industrial activity in urban areas increases temperature since greater local heat sources exist and nocturnal heat loss is often reduced. These temperature increases are the result of an increase in atmospheric aerosols, elimination of evaporative and evapotranspirative surfaces, and changes in surface heat capacity. The cumulative effect of these factors produces what is known as the urban heat island.

Theoretically, during synoptic conditions favoring radiational cooling, temperatures are normally highest near urban centers, decline gradually into the suburbs, and drop off rapidly in rural areas. This has been shown through the use of infrared satellite photographs of New York City and Philadelphia (3), and by recording temperature differences between weather stations at varying distances from Bellingham, Washington (4). The extent of the heat island produced by Quebec City, Canada, was shown to be limited by distance from the warmest points and land use (5).

Under favorable synoptic conditions, temperatures were found to be 6°F to 14°F warmer in central Akron, Ohio than in rural areas outside of the city (6) and a nocturnal heat island was documented over Austin, Texas using the auto traverse method (7).

This paper will examine the magnitude of the urban heat island in New York City and determine its extent into northern New Jersey.

2. PROCEDURE

Since the temperature difference between urban and rural areas reaches a maximum during periods of strong radiational cooling, data were collected from New Jersey Climatological Data (8) for selected stations (Fig. 1) for days meeting the following criteria: no precipitation; winds less than 5 knots at Newark, New Jersey; clear skies; a stationary or slow-moving high-pressure system centered over the area; and a temperature difference of at least 5°F between New York City and Scranton, Pennsylvania at 7 a.m. EST. Data from Scranton was used for convenience since it was readily available on the Daily Weather Map Series (9), and it served as a measure of temperature decrease from the New York City area. In this study, a high-pressure system was considered stationary if at least one closed isobar remained over the area for three consecutive days.

Since the intensity of the heat island is greatest during the longer night period of the year and is best developed for minimum temperatures (10), this study was limited to 24-hour minimum temperatures for the months of December, January, and February. A 10-year period from 1972 to 1981 was used and 51 days met the above criteria. There were no station moves during the period of study with the exception of Newton. Newton changed its location from 41° 03'N, 74° 45'W; to 41° 02'N, 74° 48'W in May 1974, and its elevation increased 35 feet. This was not considered a significant move.

Temperature differences between Central Park and all other stations were recorded, averaged (Table 1), and plotted (Fig. 2). The warmest temperatures were observed near and in the city.

A t-test was run on the mean minimum temperature differences between all stations and Central Park to determine if statistically significant differences existed. The following test statistic, t', given in (11) was used:

$$t' = \frac{(\bar{Y} - \bar{X})}{S_p\sqrt{1/m+1/n}}$$

where Y is the mean minimum temperature for the 51 days at Central Park and X is the mean minimum temperature at every other station. While the sample size at Central Park was 51 (n), the sample size at several stations was less than 51 and is given by m (Table 1). S_p is the pooled standard deviation defined as:

$$S_p^2 = \frac{\sum X^2 - \frac{(\sum X)^2}{m} + \sum Y^2 - \frac{(\sum Y)^2}{n}}{m+n-2}$$

Here again, Y and n correspond to Central Park while X and m are values for the stations being tested.

The test statistic was evaluated (12) and significant temperature differences were said to exist if it was greater than the threshold value for the 1-percent significance level (Table 1). Infinite degrees of freedom were used since the distribution is assumed normal for sample sizes greater than 30 (12).

3. RESULTS

The results of the t-test show that temperatures at all stations with the exception of Newark and Jersey City are significantly different from those at Central Park (Table 1), where a value of 2.3 indicates significance at the 1-percent level.

This analysis indicates that, in general, temperatures decrease with increasing distance from Central Park (Fig. 2). Urban areas adjacent to New York City, including Newark and Jersey City, lie within the heat island and minimum temperature differences are not significant. The hatching in Figure 3 includes the area with t' values of less than 2.3. West of the metropolitan heat island, a strong temperature gradient exists with temperatures decreasing rapidly in rural areas further west (Fig 2).

During winter nights with strong radiational cooling, temperatures in extreme northwestern New Jersey average 16°F lower than those at Central Park. These differences result from anthropomorphic modifications of the urban areas, intensifying factors that enhance urban-rural temperature differences. In suburban central New Jersey, minimum temperatures average about 8°F cooler than those in Central Park, and result from the intermediate location of the area. This indicates a modified form of the urban heat island.

Weather forecasters tend to be urban oriented and their forecasts often fail to accurately assess minimum temperatures in outlying areas. In agricultural regions, good minimum temperature forecasts are critical. Greater attention should be given to minumum temperature forecasts beyond the urban fringe.

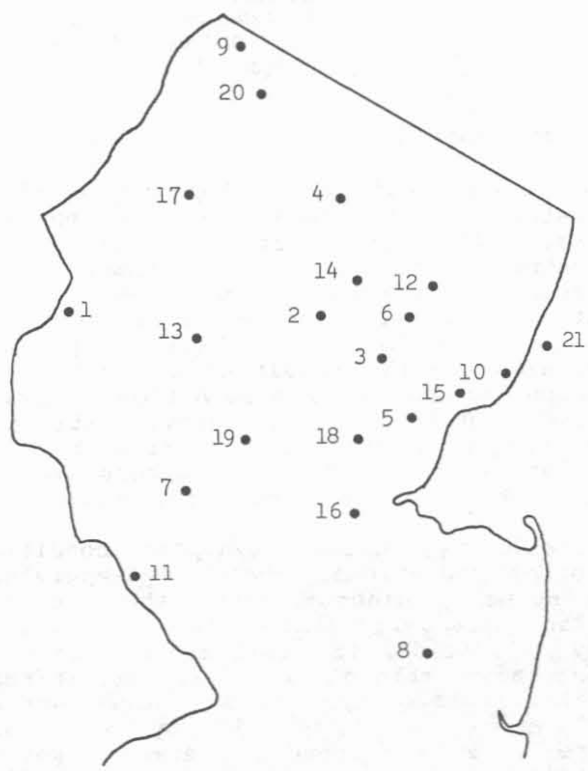

Figure 1. Stations included in this study. An index to these stations is given in Table 1.

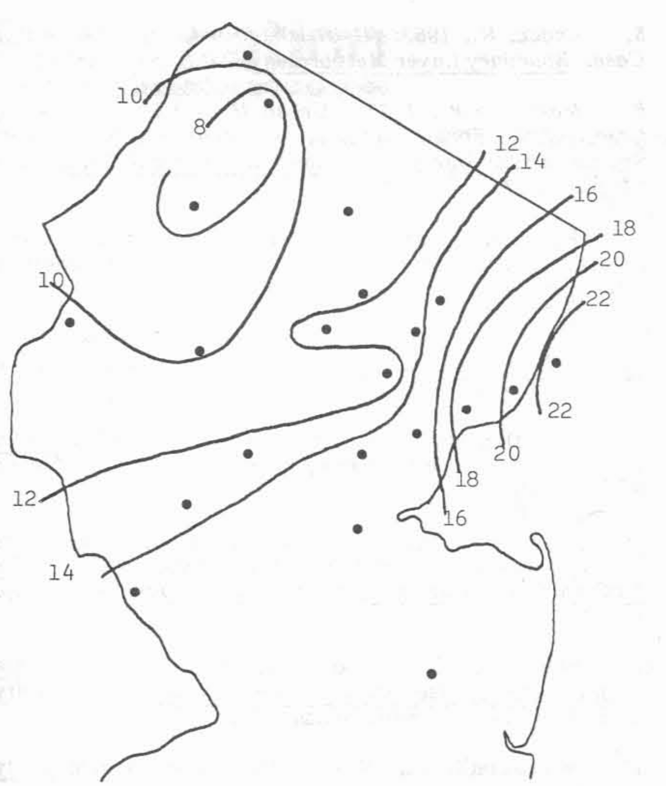

Figure 2. Isotherms of mean minimum temperatures during conditions favoring enhanced nocturnal radiation.

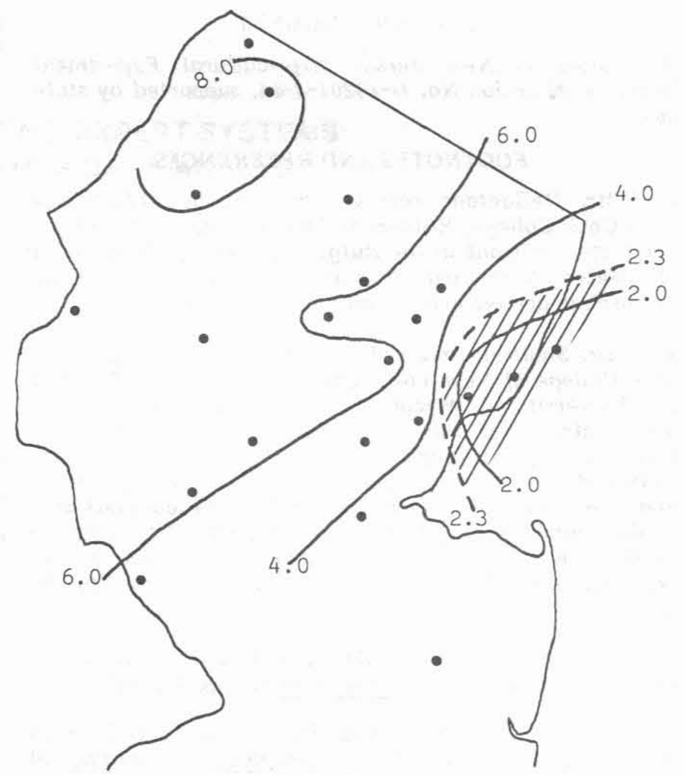

Figure 3. Isoplethed map of t' values. Hatched area indicates t' values less than 2.3.

Station	County	Latitude	Longitude	Elevation	m	T	t'
1. Belvidere	Warren	40° 51'	75° 05'	275	45	10.78	6.41
2. Boonton	Morris	40° 54'	74° 24'	280	49	13.20	5.27
3. Canoe Brook	Essex	40° 45'	74° 21'	180	51	10.25	6.55
4. Charlotteburg	Passaic	41° 02'	74° 26'	760	51	10.33	6.58
5. Cranford	Union	40° 39'	74° 18'	75	51	14.14	4.87
6. Essex	Essex	40° 50'	74° 17'	350	49	14.43	4.81
7. Flemington	Hunterdon	40° 31'	74° 48'	140	51	11.12	6.17
8. Freehold	Monmouth	40° 16'	74° 15'	194	37	15.32	3.88
9. High Point	Sussex	41° 18'	74° 40'	1410	32	12.09	5.36
10. Jersey City	Hudson	40° 44'	74° 03'	135	49	20.57	1.07
11. Lambertville	Hunterdon	40° 22'	74° 57'	60	49	12.94	5.46
12. Little Falls	Passaic	40° 53'	74° 14'	150	51	15.39	4.09
13. Long Valley	Morris	40° 47'	74° 47'	550	50	9.68	6.08
14. Morris Plains	Morris	40° 50'	74° 30'	400	51	11.76	6.11
15. Newark	Essex	40° 42'	74° 10'	30	51	19.78	1.93
16. New Brunswick	Middlesex	40° 29'	74° 26'	125	51	15.26	3.83
17. Newton	Sussex	41° 02'	74° 48'	600	46	6.33	8.03
18. Plainfield	Union	40° 36'	74° 24'	90	51	15.51	4.17
19. Somerville	Somerset	40° 36'	74° 38'	160	51	11.78	6.07
20. Sussex	Sussex	41° 12'	74° 36'	390	51	6.88	8.04
21. Central Park	New York	40° 47'	73° 58'	47	51	22.57	

Table 1. Stations used by county, elevation, latitude, longitude, and elevation with values of m (number of observations), T (mean minimum temperature), and t' (test statistic).

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FOOTNOTES AND REFERENCES

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3. *Matson, M., 1978: Satellite Detection of Urban Heat Islands. Monthly Weather Review, pp. 1725-1734.*

4. *Fonda, R.W., 1971: Heat Islands and Frost Pockets in Bellingham, Washington. American Meteorological Society Bulletin, 52(7), pp. 552-555.*

5. *Leduc, R., 1982: Heat Island in Quebec: a Winter Case. Boundary Layer Meteorology, 21(3), pp. 315-324.*

6. *Martin, F.P., 1977: Urban Heat Island in Akron, Ohio. U.S. Forest Service, Northeastern Experiment Station, Upper Darby, PA., General Technical Report NE-25, pp. 94-97.*

7. *Wood, J.L., 1981: Nocturnal Heat Island in Austin, Texas. Texas University, Austin College of Engineering, Atmospheric Science Group Report, Number 28.*

8. *U.S. Department of Commerce, 1972-1981: New Jersey Climatological Data. Asheville, N.C., National Climatic Center.*

9. *U.S. Department of Commerce, 1972-1981: Daily Weather Maps, Washington, D.C., U.S. Government Printing Office.*

10. *Colacino, L.M., 1983: Evidence of the Urban Heat Island in Rome by Climatological Analysis. Archives for Meteorology, Geophysics, and Bioclimatology, 31(1/2), pp. 87-89.*

11. *Panofsky, H.A., and G.W. Brier, 1968: Some Applications of Statistics to Meteorology. University Park, Pa., The Pennsylvania State University.*

12. *Mendenhall, W., 1979: Introduction to Probability and Statistics. North Scituate, Mass., Duxbury Press.*

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