Climatology

A STATISTICAL EVALUATION OF THE NEW YORK CITY-NORTHERN NEW JERSEY URBAN HEAT ISLAND EFFECT ON SUMMER SEASON DAILY MINIMUM TEMPERATURES

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ABSTRACT

Temperature differences between Central Park and 22 stations in northern New Jersey and southeastern New York state for summer season nights experiencing favorable radiational cooling conditions during a 16-year period are evaluated. The effect of urbanization on temperature differences is strongest in the region adjacent to Central Park and diminishes with increasing distance from the urban area. Also, the modifying effect of river valleys on temperature is evident along both the Hudson and Delaware river valleys where mean minimum temperatures are warmer than adjacent stations.

1. INTRODUCTION

Many studies have investigated urban-rural temperature differences. The bulk of these studies have investigated the urban heat island as determined by minimum temperature differences between urban and rural areas during the winter months (December through February). These studies have shown that, under favorable radiational cooling conditions, temperature differences between the urban area and its surrounding rural area vary by 10°F or more. Bornstein (3) investigated the New York City urban heat island by obtaining observations taken near sunrise from an instrumented helicopter on 42 predetermined test mornings from July 1964 through December 1966. He found that the average intensity of the urban heat island, measured by the magnitude of the temperature differences between urban and rural sites, was a maximum (1.6° C) below 25 meters elevation. Martin (4) found a 6°F to 14°F temperature difference between central and rural Akron, Ohio for dates experiencing favorable radiational cooling nights. Recently, DeGaetano and Shulman (5) investigated the New York City-northern New Jersey urban heat island finding average temperature differences of 16°F between extreme northwest New Jersey and Central Park, New York and an 8°F difference between central suburban New Jersey and Central Park, New York. Zois and Sandoval (6) observed the Newark, New Jersey nocturnal heat island by a series of 42 instrumented automobile runs conducted through Newark during the period of 5 January 1976 and 18 December 1976. Results showed that on each of the 42 nights a discernable heat island was present ranging in intensity between 2°F under normal conditions to 16°F under extreme conditions.

There have been few investigations on the urban heat island effect on summer season minimum temperatures. Lyall (7) investigated the London, England heat island during June–July 1976 finding statistical significant differences of temperature between London and surrounding rural sites encompassing the urban center. Price (8) through the use of satellite data assessed the New York City-New England area urban heat island finding temperature differences between urban and rural sites in excess of 4°C. Finally, Katsoulis and Theoharatos (9) analyzed 22 years of monthly temperature data for the Athens, Greece basin. Results showed the presence of an urban heat island during the winter and summer months. The summer months display lower monthly mean minimum temperature differences between urban and rural stations with higher monthly mean minimum temperature differences observed during winter months.

This study will examine the intensity of the summer season New York City urban heat island and its extension into northern New Jersey.

2. METHODOLOGY

Investigation of the New York City-northern New Jersey urban heat island was studied for daily summer season minimum temperatures experiencing favorable radiational cooling conditions. The summer season is defined as the months of June, July, and August. Data were collected from New Jersey (10) and New York (11) Climatological Data records. Twenty-three stations (Fig. 1) were used for a sixteen year period from 1968–1983 (Table 1). The daily minimum temperatures used were those which occurred on nights with favorable radiational cooling. The

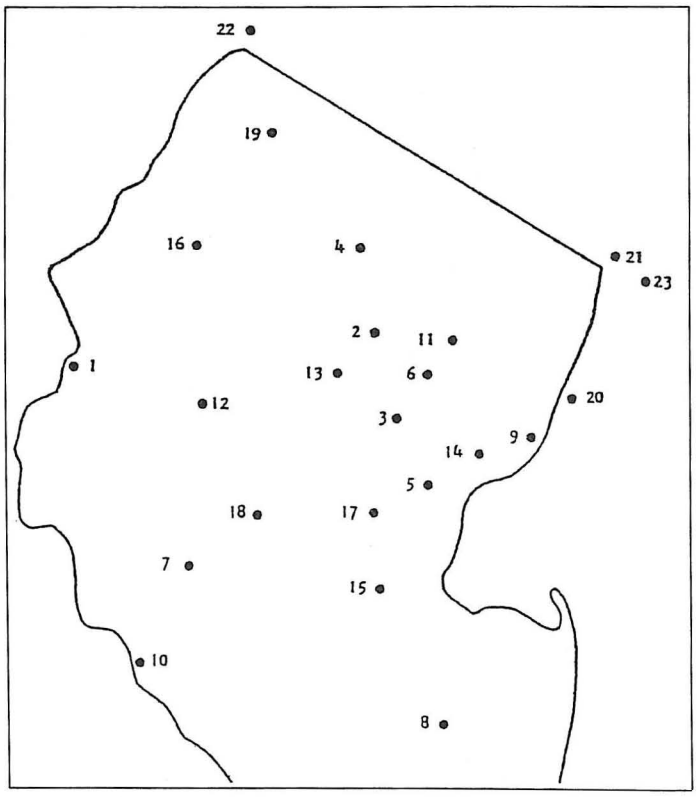

Fig. 1. Location of stations used in study. An index to these stations is given in *Table 1*.

Table 1. Stations used by Latitude/Longitude, Elevation (ft), and County with values of m, T, and t where m is the number of recorded observations, T is the mean minimum temperature (°F), and t is the test statistic.

Station Name	Station Number	LAT/LON	Elev (ft)	County	m	T	t
Belvidere	1	40° 50′/75° 05′	275	Warren	57	52.36	10.52
Boonton	2	40° 54′/74° 24′	280	Morris	57	52.85	10.71
Canoe Brook	3	40° 45′/74° 21′	180	Essex	57	51.19	12.33
Charlotteburg	4	41° 02′/74° 26′	760	Passaic	57	50.11	12.81
Cranford	5	40° 29′/74° 18′	75	Union	51	53.39	9.60
Essex	6	40° 50′/74° 17′	350	Essex	54	52.87	9.56
Flemington	7	40° 31′/74° 18′	140	Hunterdon	54	50.89	12.03
Freehold	8	40° 16′/74° 15′	194	Monmouth	48	53.65	9.41
Jersey City	9	40° 44′/74° 03′	135	Hudson	51	61.51	1.46
Lambertville	10	40° 22′/74° 57′	60	Hunterdon	57	53.21	10.09
Little Falls	11	40° 53′/74° 14′	150	Passaic	57	54.69	8.78
Long Valley	12	40° 57′/74° 47′	550	Morris	57	48.59	14.96
Morris Plains	13	40° 50′/74° 30′	400	Morris	51	50.43	13.58
Newark	14	40° 42′/74° 10′	30	Essex	57	62.74	0.32
New Brunswick	15	40° 28′/74° 26′	125	Middlesex	57	55.45	7.75
Newton	16	41° 02′/74° 48′	600	Sussex	54	47.89	16.25
Plainfield	17	40° 36′/74° 24′	90	Union	57	54.05	9.27
Somerville	18	40° 36′/74° 38′	160	Somerset	57	52.14	12.35
Sussex	19	41° 12′/74° 36′	390	Sussex	57	47.55	15.93
Central Park	20	40° 47′/73° 58′	47	New York	57	63.04	—
Dobbs Ferry	21	41° 01′/73° 52′	240	Westchester	57	57.24	6.06
Port Jervis	22	41° 23′/74° 41′	470	Orange	57	50.23	12.49
Scarsdale	23	40° 59′/73° 48′	199	Westchester	57	53.62	8.78

criteria used to obtain nights experiencing favorable radiational cooling conditions were:

1. Slow moving high pressure system centered over the area
2. No precipitation over the area
3. Clear skies observed at 0700 hours at Central Park and Newark
4. Winds less than or equal to seven knots measured at 0700 hours at Newark
5. Relative humidity value less than or equal to 68% measured at 0700 hours at Newark

These particular conditions were chosen so as to obtain a large sample size experiencing favorable radiational cooling conditions during the summer season. Definitions for the selected conditions follow.

Condition (1), slow moving high pressure system centered over the area, was used to select dates of occurrence by inspection of the *Daily Weather Map Series* (12) at 0700 hours. For qualification, a closed isobar was needed to encompass the general area of New Jersey, southeastern New York state, western Long Island, and eastern Pennsylvania for the 24 hour period ending at 0700 hours. If this condition was met, then that particular day was included in the sample. For condition (2), precipitation totals for the previous 24 hour period were noted from both the *Daily Weather Map Series* and local climatological data to make certain no precipitation had occurred over the area. The criteria for condition (3) was checked against the *Daily Weather Map Series* model plot for New York City and against local climatological data for Newark. A value of 7 knots for condition (4) was chosen as the threshold wind speed. If the threshold were lowered to 5 knots, for example, only 32 of 75 total cases would result. The 7 knot wind value used increased the sample size to 57 resulting in an adequate sample. Finally, the 68% relative humidity value for condition (5) was used to obtain a quantitative measure of the dryness of the ambient air. Again, this represented a compromise allowing for a sufficient sample size of 57. For example, when an initial value of 65% was used only 48 of 75 total cases met this condition.

Temperature differences between Central Park and all other stations were recorded, averaged (Table 1), and plotted (Fig. 2). The warmest temperatures were observed in and near the city with cooler temperatures west of the metropolitan area. A t-test

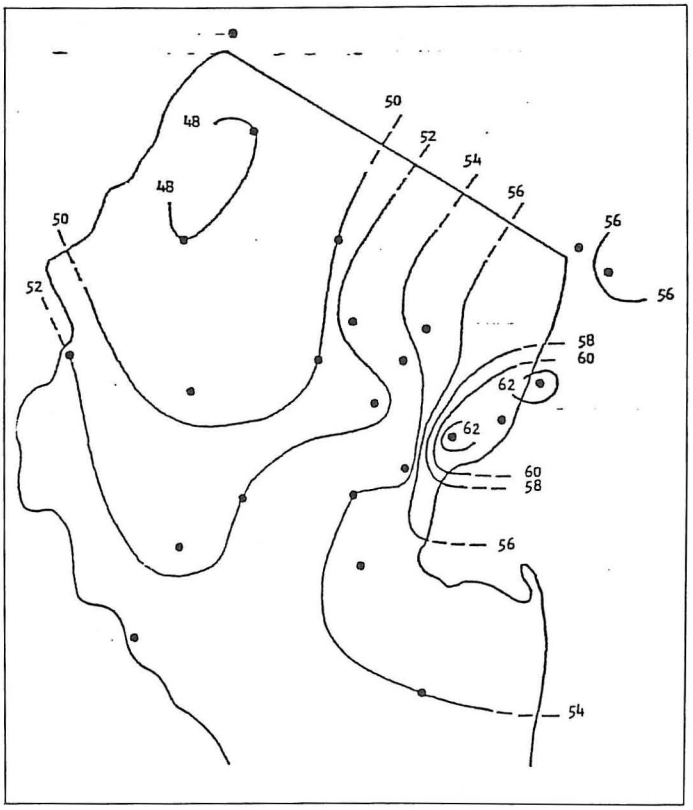

Fig. 2. Isotherms of Mean Minimum Temperatures (°F) using recorded data during conditions favoring nocturnal radiation.

was run on the mean minimum temperature differences between Central Park and all stations to determine if statistically significant differences existed. The following test statistic t (13) was used:

$$t = \frac{\bar{Y} - \bar{X}}{S_p \sqrt{\frac{1}{m} + \frac{1}{n}}}$$

where Y is the mean minimum temperature for the 57 cases at Central Park and X is the mean minimum temperature at the other station. The value for S_p^2, defined as the pooled standard deviation, is given as:

$$S_p^2 = \frac{\sum X^2 - \frac{[\Sigma x]^2}{m} + \sum Y^2 - \frac{[\Sigma y]^2}{n}}{m + n - 2}$$

where n is the sample size at Central Park and m is the sample size at every other station.

The test statistic was evaluated and significant temperature differences existed if t values were greater than the threshold value at the one-percent significance level. Infinite degrees of freedom were used since the distribution is assumed normal for sample sizes greater than thirty.

3. RESULTS

Results of the t-test show mean minimum temperatures at all stations, with the exception of Jersey City and Newark, are significantly different from those at Central Park (Table 1). The t value of 2.3 isoplethed in Fig. 3 indicates statistical significance at the one-percent level with infinite degrees of freedom; the hatched region includes the area with t values less than 2.3.

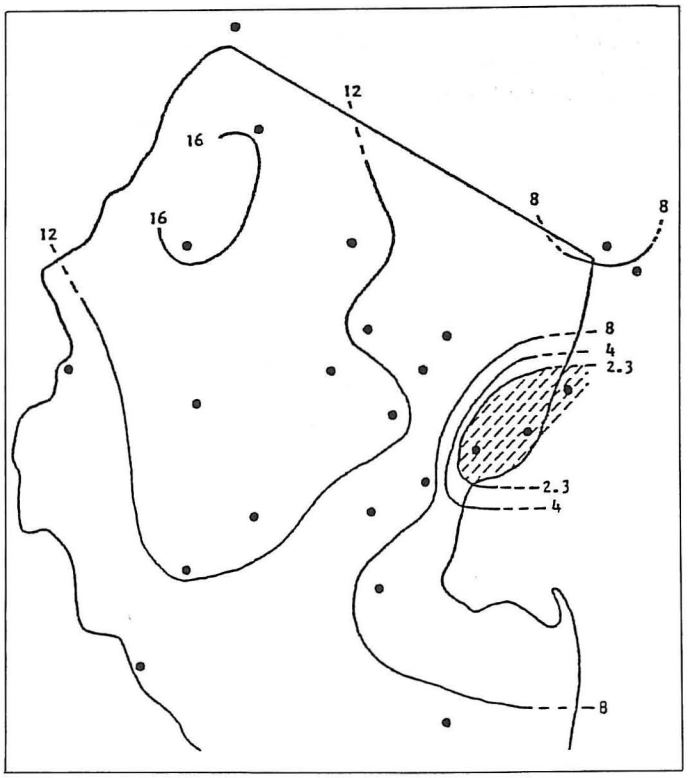

Fig. 3. Isopleths of t values. Hatched region indicates statistical significance at the one-percent level.

Urban areas adjacent to New York City, including Jersey City and Newark, lie within the heat island and minimum temperature differences are not significant.

Isotherms of mean minimum temperatures (Figure 2) display temperatures which decrease with increasing distance from Central Park. The modifying effect of river valleys on temperatures is evident along the Delaware River valley (Belvidere and Lambertville) and the Hudson River valley (Dobbs Ferry) where mean minimum temperatures are warmer than at adjacent stations. In addition, the higher more rural stations in northwest New Jersey have the lowest mean minimum temperatures (Newton, Sussex, and Long Valley). Finally, Central Park and Newark display similar mean minimum temperatures since they share a uniformly urban environment. This observation agrees with Zois and Sandoval (6) concluding that Newark exhibits its own urban heat island under favorable radiational cooling conditions.

During summer season nights experiencing strong radiational cooling, mean minimum temperatures in central suburban New Jersey average 8–11°F cooler than Central Park and are indicative of a transition area between the urban heat island and northwest New Jersey. The mean minimum temperatures in west/northwest New Jersey average 12–15°F cooler than those observed at Central Park. These values are in close agreement with winter season mean minimum temperatures observed by DeGaetano and Shulman (5).

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NOTES AND REFERENCES

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Folklore

WEATHER TIPS FROM KERMIT

by Sue Mroz

There are several old weatherlores that center around frogs and toads. Probably the most well-known of the sayings has to do with the frogs' announcement of the arrival of spring. Reportedly, when you hear the first "peepers" sing their song in the spring, the ground is thoroughly thawed. This information was given to me by a lady who has lived out in the country for years and is quite accustomed to listening for these noisy little harbingers of spring. There are other sayings, however, which may take a naturalist to discern. . . . for example, the croaking of frogs is said to mean rain is on the way, and if you hear tree frogs, likewise, expect showers. And finally, this one would really take a trained eye . . . if toads venture further than usual from their habitat or are restless, look for rain. So if you find jittery toads in the shopping center, better buy an umbrella.