Climatology

A STATISTICAL EVALUATION OF THE NEW YORK CITY—NORTHERN NEW JERSEY URBAN HEAT ISLAND EFFECT DURING SPRING AND AUTUMN

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ABSTRACT

Temperature differences between Central Park, New York City and twenty-two stations in northern New Jersey and New York for nights with strong radiational cooling during the 1970 to 1984 spring and autumn seasons are evaluated. The effect of urbanization on temperature is strongest in the area just to the west of New York City and diminishes rapidly with increasing distance from the metropolitan area. Results of this study are consistent with prior studies for the winter and summer seasons.

1. INTRODUCTION

Urban areas tend to generate and retain heat more than surrounding suburban and rural areas. The reasons include greater industrial activity, increase in atmospheric aerosols, elimination of evaporative and evapotranspirative surfaces, and changes in surface heat capacity. On nights favoring radiational cooling, temperatures are normally highest in and around urban areas and decline rapidly toward rural areas. This phenomenon is known as the urban heat island effect.

Several studies have been done on the New York City—northern New Jersey heat island recently. DeGaetano and Shulman (4) studied the effect of the urban heat island on winter minimum temperatures during the 10-yr period from 1972 to 1981. The criteria for the winter season study included no precipitation for the date, winds less than 5 kt at Newark, NJ; 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, PA at 1200 GMT. They found on the average a temperature difference of 16°F between Central Park and rural northern New Jersey on nights favoring radiational cooling. Kirkpatrick and Shulman (5) studied the effect of the heat island on mean minimum temperatures during the summer season. Criteria for the summer study included a slow-moving high-pressure system centered over the area, no precipitation over the region, clear skies at 1200 GMT at Central Park and Newark, winds less than or equal to 7 kt at Newark, and relative humidity less than or equal to 68% at Newark, NJ. A 16-yr period was studied from 1968 to 1983 and temperature differences between 12°–15°F were found between Central Park and rural northern New Jersey on nights favoring radiational cooling.

This study compared the effect of urban areas on mean minimum temperatures in the New York City—northern New Jersey area during the spring and autumn seasons for conditions similar to those in the studies of DeGaetano and Shulman (4) and Kirkpatrick and Shulman (5).

2. PROCEDURE

The New York City—northern New Jersey urban heat island was studied for daily spring and autumn season minimum temperatures over a 15-yr period from 1970 to 1984. The daily minimum temperatures were recorded for 23 stations (Fig. 1) on nights with favorable radiational cooling.

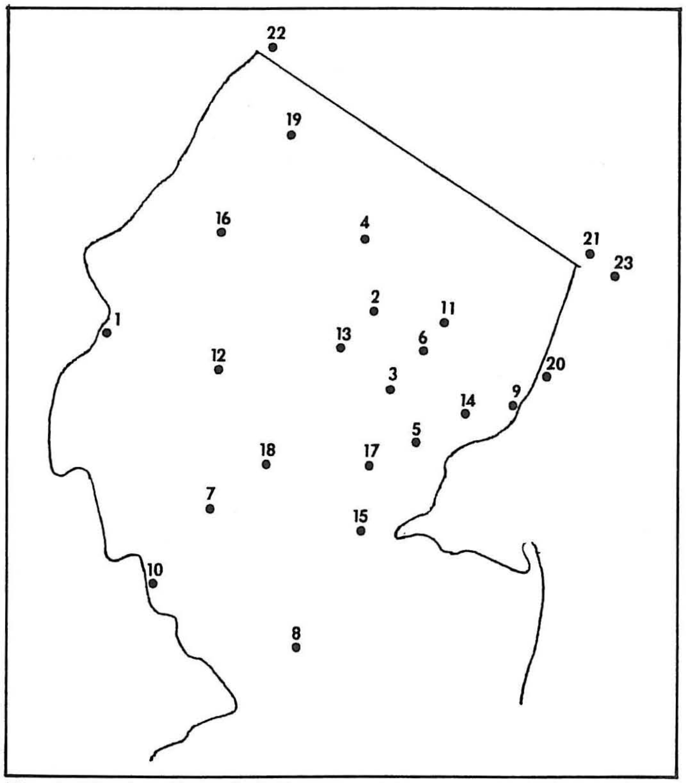

Fig. 1. The location of stations used in study. An index to these stations is given in Table 1.

By inspection of the Daily Weather Map Series (6), the Climatological Data for New Jersey (7) and New York (8) and the Local Climatological Data for Newark, NJ (9), we were able to determine nights on which maximum radiational cooling would occur using the following criteria:

1. A slow-moving high-pressure system centered over the area. A closed isobar must encompass the area for at least a 24-hr period from 1200 GMT to 1200 GMT.
2. No precipitation over the area for the past 24 hr.
3. Clear skies observed at 1200 GMT at Central Park, New York City and Newark, NJ.

4. Winds less than or equal to 7 kt at 1200 GMT at Newark, NJ.

For spring, 47 days over the 15-yr period met the criteria and 38 days met the criteria for autumn.

Temperature differences between Central Park and all other stations were recorded, averaged (Table 1) and plotted (Figs. 2 and 3). The warmest temperatures were observed near and in the city with cooler temperatures to the west of the city

Table 1. Stations used with identifying number, Latitude/Longitude, Elevation (ft.), County and 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. A subscript of s or f refers to the spring and fall season respectively.

Station	Station Number	Lat/Lon	Elev (ft)	County	M_s	M_f	$\bar{T}_s$	$\bar{T}_f$	t_s	t_f
Belvidere	1	40°50′/75°05′	275	Warren	43	34	33.86	39.53	6.36	4.91
Boonton	2	40°54′/74°24′	280	Morris	47	38	37.51	39.24	4.67	5.26
Canoe Brook	3	40°45′/74°21′	180	Essex	47	38	33.42	38.66	6.87	5.55
Charlotteburg	4	41°02′/74°26′	760	Passaic	47	38	33.61	36.31	6.52	6.38
Cranford	5	40°29′/74°18′	75	Union	47	38	36.61	39.95	5.31	4.89
Essex	6	40°50′/74°17′	350	Essex	44	38	35.93	39.18	5.39	5.40
Flemington	7	40°31′/74°18′	140	Hunterdon	47	34	33.97	36.91	6.54	6.09
Hightstown	8	40°16′/74°34′	100	Mercer	47	38	36.61	41.87	5.20	4.09
Jersey City	9	40°44′/74°03′	135	Hudson	40	38	44.10	49.29	1.08	0.85
Lambertville	10	40°22′/74°57′	60	Hunterdon	47	38	35.23	41.71	5.94	4.17
Little Falls	11	40°53′/74°14′	150	Passaic	47	37	38.42	41.49	4.23	4.18
Long Valley	12	40°57′/74°47′	550	Morris	47	38	32.27	35.66	7.44	6.52
Morris Plains	13	40°50′/74°30′	400	Morris	47	37	35.34	37.46	5.61	6.01
Newark	14	40°42′/74°10′	30	Essex	47	38	44.82	48.82	0.84	1.05
New Brunswick	15	40°28′/74°26′	125	Middlesex	47	38	38.06	41.92	4.38	4.04
Newton	16	41°02′/74°48′	600	Sussex	44	38	31.15	34.42	7.63	7.23
Plainfield	17	40°36′/74°24′	90	Union	47	38	36.97	41.03	5.06	4.64
Somerville	18	40°36′/74°38′	160	Somerset	47	38	34.42	39.26	6.27	5.25
Sussex	19	41°12′/74°36′	390	Sussex	47	38	31.72	35.16	7.65	6.88
Central Park	20	40°47′/73°58′	47	New York	47	38	46.34	51.11		
Dobbs Ferry	21	41°01′/73°52′	240	Westchester	47	31	40.74	45.50	2.91	2.52
Port Jervis	22	41°23′/74°41′	470	Orange	47	32	32.19	37.34	7.29	5.88
Scarsdale	23	40°59′/73°48′	199	Westchester	47	31	37.63	41.50	4.53	4.16

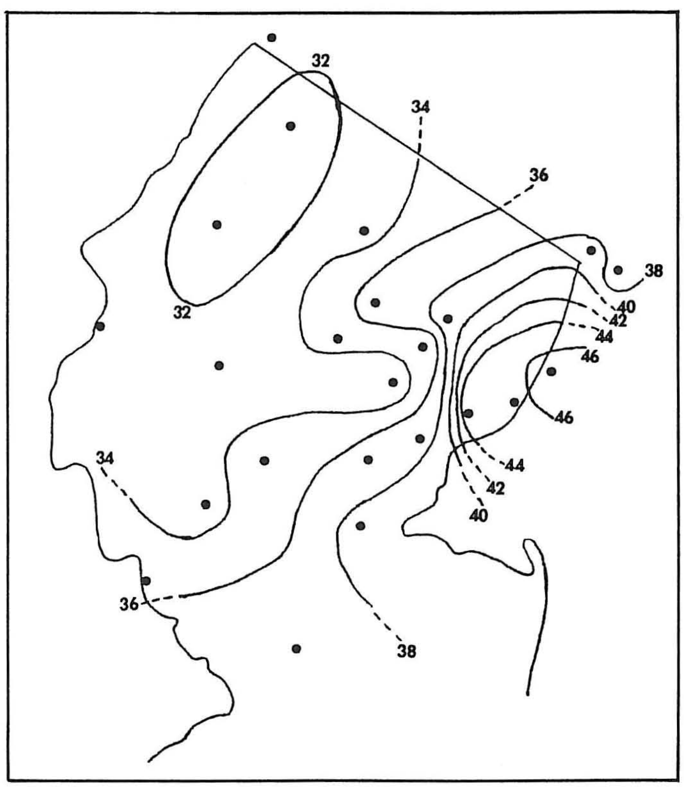

Fig. 2. Isotherms showing the calculated mean minimum temperatures (°F) for the spring season on nights with strong radiational cooling.

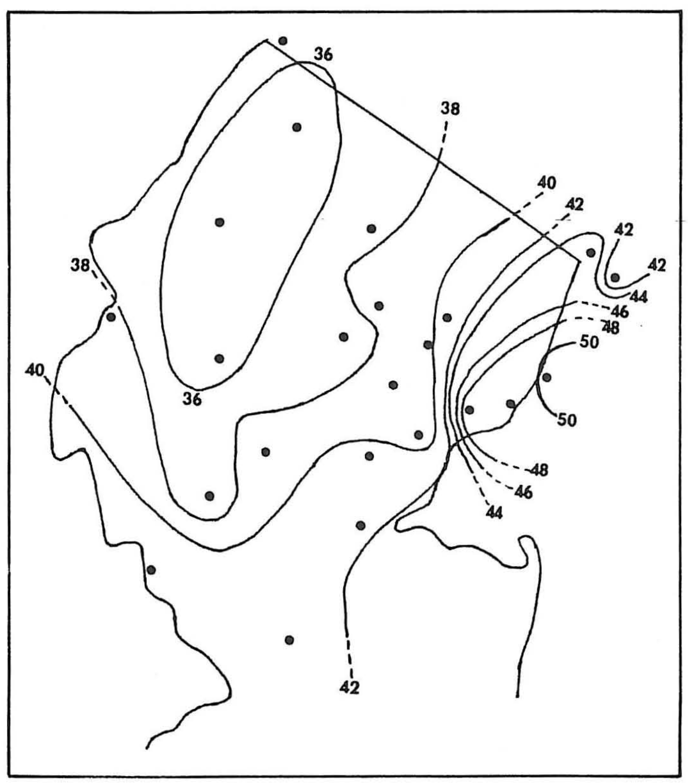

Fig. 3. Isotherms showing the calculated mean minimum temperature (°F) for the autumn season on nights with strong radiational cooling.

and the coolest temperatures in a pocket located in northwestern New Jersey.

A t-test was run on the mean minimum temperatures between Central Park and the twenty-two other stations to see if statistically significant differences existed. The following test statistic t was used (10,11):

$$t = \frac{(\overline{Y} - \overline{X})}{S_p \sqrt{\frac{1}{M} + \frac{1}{n}}}$$

Where $\overline{Y}$ is the mean minimum temperature for the cases at Central Park and $\overline{X}$ is the mean minimum temperature at every other station. The sample size at Central Park is n and M is the sample size at every other station. The value for S_p^2 is defined as the pooled standard deviation, is given as:

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

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

3. RESULTS

The results of the t-test performed on data from the spring and autumn seasons indicate that the mean minimum temperatures of all stations, with the exception of Newark and Jersey City, are significantly different from the mean minimum temperature of Central Park (Table 1). The t values for the spring season are isoplethed in Fig. 4; while, the t values for autumn are isoplethed in Fig. 5. The t value of 2.3 (Figs. 4 and 5) shows the boundary of statistical significance at the one-percent level with infinite degrees of freedom. The hatched area includes t values less than 2.3 (Figs. 4 and 5). Stations with t-test values of less than 2.3 are well within the urban

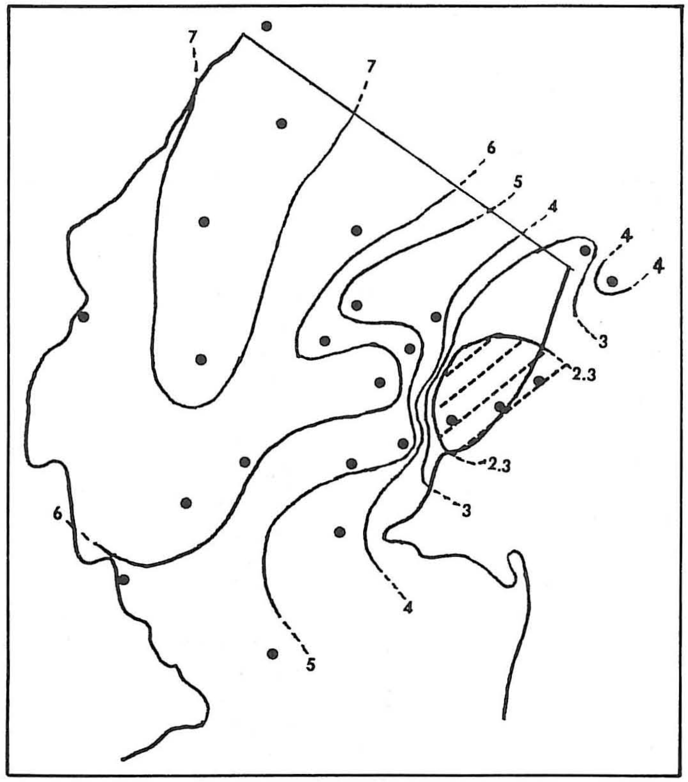

Fig. 4. Isopleths of t values for spring season data. Hatched region includes t values less than 2.3.

Table 2. Temperature departures from Central Park by season on nights favoring radiational cooling. *DeGaetano, A.T., and Shulman, M.D. (4) data; **Kirkpatrick, J.S., and Shulman, M.D. (5) data.

Station	Winter*	Spring	Summer**	Autumn
Belvidere	11.79	12.48	10.68	11.58
Boonton	9.37	8.83	10.19	11.87
Canoe Brook	12.32	12.92	11.85	12.45
Charlotteburg	12.24	12.73	12.93	14.80
Cranford	8.43	9.73	9.65	11.16
Essex	8.14	10.41	10.17	11.93
Flemington	11.45	12.37	12.15	14.20
Freehold	7.25	—	9.39	—
High Point	10.48	—	—	—
Hightstown	—	9.73	—	9.24
Jersey City	2.00	2.24	1.53	1.82
Lambertville	9.63	11.11	9.83	9.40
Little Falls	7.18	7.92	8.35	9.62
Long Valley	12.89	14.07	14.45	15.45
Morris Plains	10.81	11.00	12.61	13.65
Newark	2.79	1.52	0.30	2.29
New Brunswick	7.31	8.28	7.59	9.19
Newton	16.24	15.19	15.15	16.69
Plainfield	7.06	9.37	8.99	10.08
Somerville	10.79	11.92	10.90	11.85
Sussex	15.69	14.62	15.49	15.95
Dobbs Ferry	—	5.60	5.80	5.61
Port Jervis	—	14.15	12.81	13.77
Scarsdale	—	8.71	9.42	9.61
MEAN	**9.69**	**10.22**	**9.57**	**11.00**

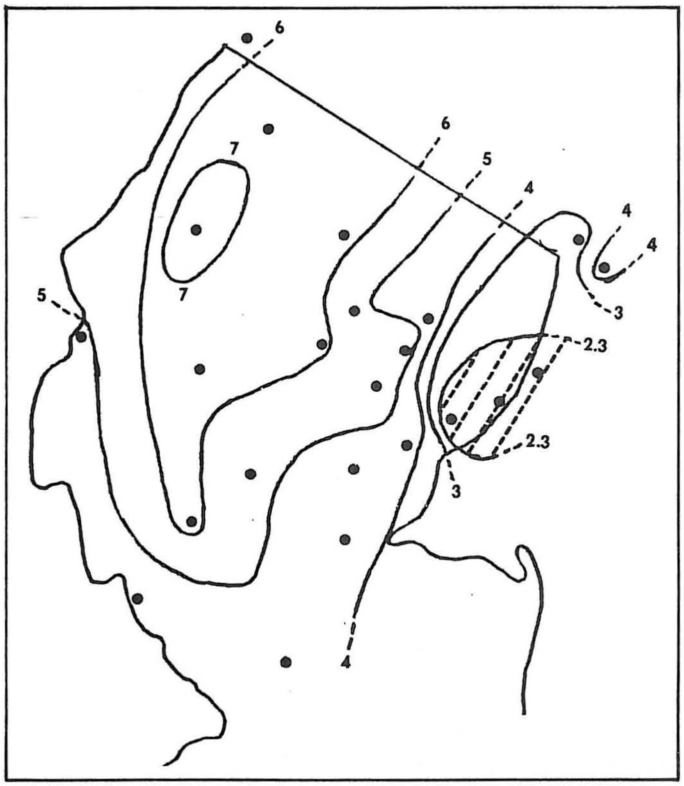

Fig. 5. Isopleths of t values for autumn season data. Hatched region includes t values less than 2.3.

heat island; therefore, their mean minimum temperatures are not significantly different from Central Park. The t values for spring and autumn are similar in isopleth pattern and numerical range.

Mean minimum temperatures for spring and autumn are shown in Figs. 2 and 3 respectively. With increasing distance from Central Park, the mean minimum temperatures decrease. The lowest mean minimum temperature for spring and autumn can be found in Newton, Sussex, and Long Valley, New Jersey. The Studies by DeGaetano and Shulman (4) for winter, and Kirkpatrick and Shulman (5) for summer, show the lowest mean minimum temperatures to occur at the same stations. This is expected since these are rural high-elevation stations. The modifying effect of the Delaware River Valley at Belvidere and Lambertville, and of the Hudson River Valley at Dobbs Ferry, is reflected in higher mean minimum temperatures than at the nearby stations of Long Valley, Flemington, and Scarsdale.

Spring season nights that meet conditions for strong radiational cooling show mean minimum temperatures in central New Jersey to be about 9°F cooler than Central Park, while northwestern New Jersey averages about 14°F cooler than Central Park. Autumn season nights favoring radiational cooling yield mean minimum temperatures in central New Jersey about 11°F cooler than Central Park, while northwestern New Jersey averages 15°F cooler than Central Park. These differences in temperature are in agreement with previous studies by DeGaetano and Shulman (4) and Kirkpatrick and Shulman (5). Winter season mean minimum temperatures in central New Jersey were about 8°F cooler than Central Park and northwestern New Jersey averaged 16°F cooler than Central Park (4). During the summer season, mean minimum temperatures were 8°–11°F cooler in central New Jersey, and about 12°–15°F cooler in northwestern New Jersey as compared to Central Park (5). Taking all seasons into account, the results are similar. There appears to be a sharp transition zone between the heat island and the interior of northern New Jersey. Mean minimum temperature departures from Central Park and seasonal averages from this and previous studies, under synoptic conditions favoring radiational cooling appear in Table 2. Not all stations were used in each study. Mean minimum temperature departures from Central Park are greatest during the autumn and least during the summer.

4. CONCLUSIONS

In conclusion, this evaluation of the urban heat island effect during the spring and autumn seasons, is in agreement with the results obtained for winter by DeGaetano and Shulman (4) and summer by Kirkpatrick and Shulman (5). On nights favoring strong radiational cooling, temperatures in and around cities will be considerably higher than the temperatures of suburban and rural locations, with an apparent sharp transition zone delineating the urban heat island.

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NOTES AND REFERENCES

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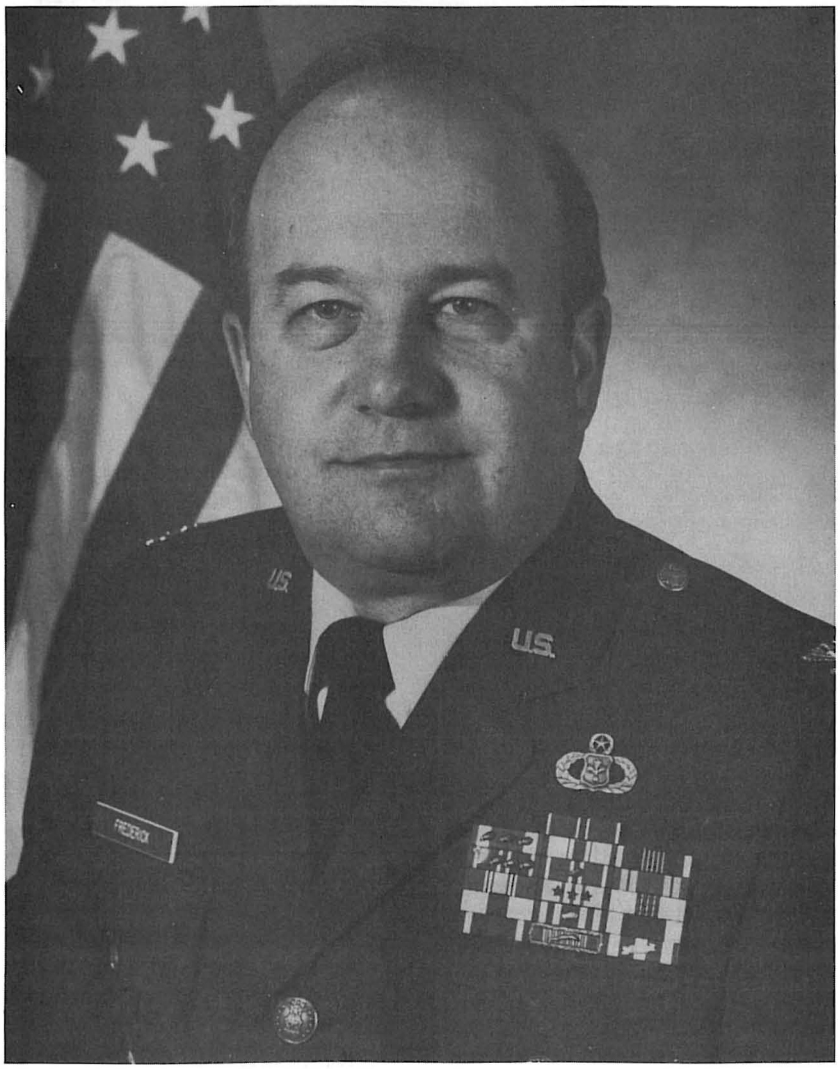
NEW COMMANDER FOR THIRD WEATHER WING



George L. Frederick, JR, Colonel, USAF assumed command of the Third Weather Wing this past July in a ceremony held at Offutt Air Force Base, Nebraska. Colonel Frederick graduated from the United States Air Force Academy in 1963 with a Bachelor of Science degree in Engineering Sciences. He studied undergraduate meteorology at the University of California at Los Angeles and completed his Masters of Science in meteorology at the University of Wisconsin in 1969. The Third Weather Wing is part of Air Weather Service, Military Airlift Command, and is responsible for operational environmental services to the Strategic Air Command, the U.S. Army Alaska, and other customers. A veteran of over 25 years service, Colonel Frederick is a charter member of the National Weather Association and has served as National Vice President (1981), and President (1986). Colonel Frederick was also honored as the Member of the Year in 1986.