

THE EFFECT OF JET AIRCRAFT ON AIRPORT TEMPERATURE RECORDS

by

Glenn Schwartz

National Hurricane Center
National Weather Service, NOAA
Miami, Florida 33124

ABSTRACT

During the past 15 years, numerous studies have verified the "urban heat island effect," and, in some cases, how it has influenced temperature records. Temperature records at Miami International Airport indicate significant changes since 1970. However, the possible cause of many of these changes is different, and has been investigated in this study. The results of this study may have far-reaching implications on temperature records at cities anywhere into which large jets have been or will be flying.

1. INTRODUCTION

The "urban heat-island effect" is something that meteorologists have known for a long time. Mitchell (1961) has indicated that the first documentation of this phenomenon was by Luke Howard in 1818.

As concrete and asphalt have replaced grass in cities, large temperature differences (up to 20°F) have been observed at night between downtown areas and suburban sections, only a few miles away. The sharpest differences occur with little or no wind (the left-over heat from the city remains over the city, rather than getting spread around by the wind). Chandler (1963), in his study of London, found that "wind speeds below 10-12 kt (5-6 m/s) are necessary for development of sharp urban-rural temperature contrasts. The thermal effect of the city is entirely eliminated by wind speeds greater than about 22 kt (11-12 m/s)." Smaller cities, he said, require less wind to eliminate the heat island.

Mean temperature differences of 3-4°F (particularly in winter minimums) were found by Landsberg (1956) and Chandler (1963) between urban and rural locations.

These temperature increases are likely to be gradual, increasing as the city grows. One would expect this to hold true in Miami also (a moderate sized, not very industrialized city), but the evidence does not corroborate this.

2. THE EVIDENCE

While compiling a climatic atlas for the Miami area in 1976, I came upon some surprising statistics:

A. Half of the existing records for the highest minimum temperatures had been set since 1970 (using records starting in 1939-40), and 258 such daily records had been set or tied between 1970 and 1975.

B. Of the 31 warmest winter nights during the period of record, 24 had occurred since 1970.

C. Table 1 compares the changes in minimum temperatures from 1970-1975 with the previous six years' readings for Miami, Miami Beach, and Homestead. Readings averaged over the most recent period, were 1.7°F warmer than the previous six year period at the Miami Airport, but were only 0.7°F warmer at Miami Beach and Homestead.

D. Table 2 shows the departures from normal of the maximum and minimum temperatures at the Miami Airport from 1939-40 to 1975-76, during the winter months of November-March. The symbol ΔT represents the difference in departures of these two figures. Note that all but one ΔT between 1945-46 and 1970-71 was less than 2°F, but a dramatic, sudden increase occurred starting in 1971-72. (Also note the dramatic difference in ΔT in years prior to 1945-46 ... this can possibly be attributed to the rapid urbanization of the area after WW2.)

Table 1

Average Minimum Temperature Change in Miami Area (1964-69 vs. 1970-75)

Year	MIAMI AIRPORT			MIAMI BEACH			HOMESTEAD		
	Normal	Actual	Departure	Normal	Actual	Departure	Normal	Actual	Depart.
1975	67.9	70.8	+2.9	71.2	71.9	+0.7	63.1	65.1	+2.0
1974		71.0	+3.1		71.5	+0.3		64.7	+1.6
1973		70.0	+2.1		70.2	-0.9		64.3	+1.2
1972		69.6	+1.7		72.4	+1.2		65.0	+1.9
1971		69.9	+2.0		71.2	0		63.4	+0.3
1970		69.4	+1.5		70.3	-0.9		62.9	-0.2
AVERAGE	1970-75	70.1	+2.2		71.3	+0.1		64.2	+1.1
1969	67.9	68.8	+0.9	71.2	69.9	-1.3	63.1	63.7	+0.6
1968		67.4	-0.5		69.3	-1.9		62.2	-0.9
1967		68.8	+0.9		71.3	+0.1		63.9	+0.8
1966		67.3	-0.6		70.0	-1.2		63.5	+0.4
1965		68.8	+0.9		71.1	-0.1		63.1	0
1964		70.0	+2.2		71.9	+0.7		64.4	+1.3
AVERAGE	1964-69	68.4	+0.5		70.6	-0.6		63.5	+0.4
AVERAGE	1970-75	70.1	+2.2		71.3	+0.1		64.2	+1.1
Difference	1970-75								
vs.	1964-69		+1.7			+0.7			+0.7

Based on minimum temperatures over 6 year periods ... or 2191 days.

Table 2

Winter (November through March) Maximum and Minimum
Temperature Departures From 1941-70 Normals

YEAR	DEPARTURE			YEAR	DEPARTURE		
	MAX	MIN	ΔT		MAX	MIN	ΔT
1975-76	-0.8	+2.3	+3.1	1955-56	+0.2	-0.6	-0.8
1974-75	+1.5	+4.3	+2.8	1954-55	-0.9	-2.2	-1.3
1973-74	+1.2	+5.0	+3.8	1953-54	0	+0.8	+0.8
1972-73	-0.2	+3.4	+3.6	1952-53	+1.0	+1.7	+0.7
1971-72	+1.1	+5.0	+3.9	1951-52	+1.7	+1.8	+0.1
1970-71	+0.4	+0.9	+0.5	1950-51	-1.4	-3.2	-1.8
1969-70	-2.7	-1.3	+1.4	1949-50	+1.2	+2.3	+1.1
1968-69	-1.8	-1.5	+0.3	1948-49	+3.6	+3.4	-0.2
1967-68	-2.6	-1.1	+1.5	1947-48	+2.4	+3.0	+0.6
1966-67	+0.5	+0.8	+0.3	1946-47	+0.6	+0.8	+0.2
1965-66	-0.6	+1.0	+1.6	1945-46	+0.6	-0.2	-0.8
1964-65	+1.2	+3.4	+2.2	1944-45	+0.6	-3.3	-3.9
1963-64	-1.5	-0.2	+1.3	1943-44	+0.8	-1.8	-2.6
1962-63	-1.9	-1.4	+0.5	1942-43	+1.0	-1.8	-2.8
1961-62	+1.2	+0.9	-0.3	1941-42	0	-2.6	-2.6
1960-61	-0.4	+1.1	+1.5	1940-41	-0.9	-2.9	-2.0
1959-60	-1.0	-0.6	+0.4	1939-40	-2.6	-6.6	-4.0
1958-59	+1.4	+3.1	+1.7	ΔT = Difference in departures of maximum and minimum temperatures.			
1957-58	-3.6	-2.5	+1.1				
1956-57	+1.7	+0.6	-1.1				

3. THE EXPLANATIONS

Three possible causes of this anomaly are: (1) the climate of the area is getting warmer; (2) some change has occurred in the instrumentation; or (3) changes in the surrounding environment have significantly affected the minimum temperatures since 1970.

A. Changing Climate. The so-called urban heat island effect undoubtedly has some contribution to this disparity ... most cities have warmed up at night. However, the change at the Miami airport has been a very sudden and sharp one, while the urbanization of the area has increased gradually over the last 15-20 years. Furthermore, as indicated in A. and B. of the previous section, a major difference seems to be that the warm nights are getting warmer. Since at least a moderate ocean breeze is required for very warm night time readings, and the "urban heat island effect" is least important with brisk winds, some other factors must be producing the increase in temperature.

B. Changes in Instrumentation. The temperature instrument did change, but in 1965 (to a Bristol H061), and has remained the same since then. Calibration and comparative checks are done regularly, and the readings are within the allowable tolerances of the instrument. On a 10 day trial test at 5 AM, April 6-16, 1976, the temperature at the H061 averaged 1.8°F warmer than the shelter thermometer at the weather office a mile to the east; it is not known whether this reflects instrument errors or true temperature differences at those locations, or whether this difference existed prior to 1976.

C. Changes in Surrounding Environment. Three major changes have occurred since 1970, each probably having some effect on the minimum temperature reading. Figure 1 shows a plan of Miami International airport as of 1974. It was obtained from Mr. I. H. Carr, Planning and Section Head of the airport.

(1) A "satellite station" was constructed about 1750 feet northeast of the instrument in late 1973. The associated 1 million sq. ft. of asphalt has replaced a similar amount of grass.

(2) A large asphalt parking lot was constructed in the winter of 1969-70 about 1 mile east of the instrument. The associated 1 million sq. ft. of asphalt has replaced a similar amount of grass.

(3) An increase in the amount of heat and air is reaching the instrument from aircraft taxiing down a ramp only 150 ft. from it, and taking off from a runway only 850 ft. south and east of the instrument. The total number of night

time flights along this runway and taxiway have not changed, but the type of aircraft has. More "wide body" jets are now in use (DC10's and 747's and L1011's), which produce twice as much thrust and affect nearly twice the area surrounding the airplane with the exhaust than the older types (see Figure 2). The change-over to these newer, larger, more turbulent and heat-producing jets occurred in 1970, the same year the temperature anomaly appears to have begun (source of this data: Peter Reavely, "Airport Consultant," and Mr. Marinello, Assistant Chief of Operations at the tower of Miami International Airport).



Figure 1. Aerial plan view of Miami International Airport showing instrument shelter, taxiing, parking lot (lower right), and illustrating size of "jumbo" and conventional jet aircraft relative to taxiing.

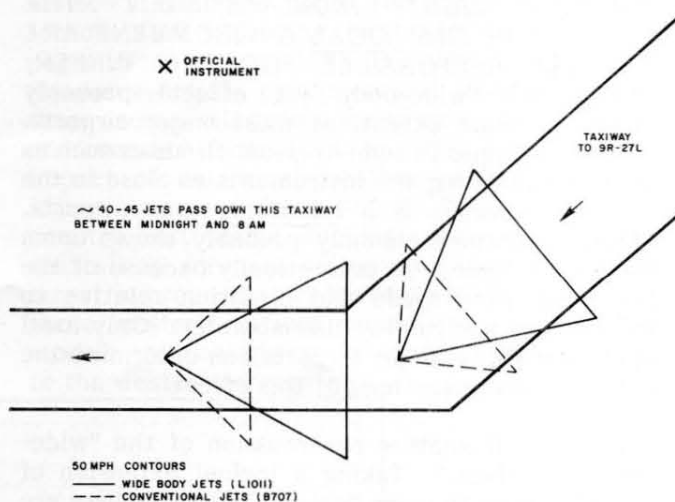


Figure 2. Scaled diagram of section of Figure 1 showing the difference in thrust between "jumbo" and conventional jets relative to instrument shelter.

Since the parking lot (b) and the wide body jets (c) came into existence around 1970 (the same year the temperature anomaly began), it is natural to examine these factors as the probable causes. Dr. Subrata Sengupta of the Mechanical Engineering

Department of the University of Miami has indicated that it is likely that under moderate to strong easterly winds, the left-over heat from the parking lot will have some influence in raising night time temperatures. Obtaining accurate, detailed figures would require a major study of the area. Since at least moderate east to southeast winds during the night are necessary for very warm temperatures in Miami, and under these conditions the parking lot is upwind from the instrument, it is apparently playing a significant role during some of the warmest nights.

The emergence of the wide-body jets, and their proximity to the instrument can affect the readings even more often, causing the average minimum temperatures to increase so much. The prevailing wind direction in Miami is east-south-east, so again, the taxiway is only 150 ft. upwind from the instrument on most nights. With the addition of heat and mixing of the air so close to the instrument, this undoubtedly is more of a factor than when the smaller, less thrust-producing jets passed down the taxiway before 1970.

The "satellite station" has probably also had some effect during northeast wind conditions.

4. CONCLUSIONS

THE CONCLUSION IS THAT THE CLIMATE IS NOT CHANGING AS MUCH AS THE TEMPERATURE RECORDS AT MIAMI INTERNATIONAL AIRPORT MIGHT INDICATE, BUT THE CHANGES IN THE LOCAL ENVIRONMENT ARE LARGELY RESPONSIBLE FOR THIS DIFFERENCE. This "wide-body jet effect" probably exists, to some extent, at most major airports, particularly ones in semi-tropical climates such as Miami's. Locating the instruments so close to the taxi and runways is a requirement at airports. This temperature anomaly probably shows up in the Miami records so dramatically because of the prevailing wind speed and direction relative to the taxiway and runway thermometer. Only local studies at other major airports can determine the existence and magnitude of this effect.

There is still another repercussion of the "wide-body jet effect." Taking a logical extension of Table 2, when the new "normal" temperatures are computed for Miami for the period 1951-80, a very large change in the minimum temperature figures will occur. Not only will the unrepresentatively warm 1970's be adding to the difference, but the cooler 1940's will be extracted. Natural conclusions about a change in the Miami climate may be inferred if these numbers are used without a qualification. To a somewhat lesser extent, this may also occur in other cities. Such local environmental influences interfere with the efforts to determine the climatic change over large metropolitan areas. Unfortunately, for the most

part, airport records are the "official" records for the area, as well as the most detailed and widely used.

5. SUMMARY

Numerous studies have illustrated the fact that the "urban heat island effect" has heated up cities at night. However, the rise in night time temperatures at Miami International Airport since 1970 can only partially be attributed to this effect. In particular, it is the windy nights that have been getting warmer, and the "urban heat island effect" is least important when it is windy.

The instruments at the airport have been checked, and were found to be within the tolerance of the equipment, so some other influences must be causing this dramatic rise in minimum temperatures. Two of the most plausible explanations are:

A. A large parking lot that was constructed in 1970 at a location that is 1 mile upwind from the instrument on many warm nights.

B. "Wide-body" jets were introduced to the Miami airport in 1970. These aircraft produce much more heat and stir up the air much more than conventional aircraft. They taxi down a ramp about 150 feet upwind from the instrument on most warm nights, and takeoff from a runway only 850 feet away.

These artificial, local effects have raised the night time temperatures at the airport much more than they normally would have. This effect probably exists at many major airports around the world where the official thermometer is so close to the taxi and runways. Therefore, studies of climatic change involving such airports are "corrupted" by these anomalous readings.

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National Weather Digest

YES - THERE IS AN IMPROVEMENT IN FORECASTS

by

Charles H. Pierce, Retired
Weather Service Forecast Office
Boston, Massachusetts

C. S. Ramage in an article in the *Bulletin of the American Meteorological Society*, January 1978, says that "in spite of great strides in better observations, faster communications and greater computer power in the past ten years, forecasts had not improved." He adds that many meteorologists agree with him. The forecasters at WSFO Boston have shown that Ramage's premise is not right.

In the year just ended, the public forecasts at Boston have just made the highest skill score ever in forecasting precipitation. The average for the year was 0.549. The previous high was 0.535 in 1971. What makes the score of 1977 more significant is that it occurred in a year when the frequency of precipitation was 24%. With two exceptions, the highest in 18 years. Never before has the skill score been above 0.500 when the frequency has been so high. If the forecasters at Boston could keep their same proficiency in precipitation forecasting at the 20% frequency level, the score would go to 0.569 and the percent correct to 87%.

It should be explained that the high score this past year was helped considerably by a good showing in the summer months (April - September). It was 0.516 compared to 0.360 in 1973 - an improvement of 43%.

A graph of skill scores for Boston from 1954 through 1977 shows a peak in 1957, a higher peak in 1964, another higher peak in 1968, yet another in 1971 and now this one in 1977. Thus since 1967, we have reached new highs three times. A definite trend in improving forecasts.

The increase in forecast skill at Boston has continued right into the first month of 1978. In January, the skill score was an amazing 0.808 - another record. The number of hits was 92%. The frequency of precipitation for 12 hour periods was 32%. The previous record was 0.751 and 94% in January 1973 when the frequency was only 15%.

In the past ten years, the five year running mean of the skill scores at Boston has increased from 0.468 to 0.508 - a significant improvement of 8.5%. If Ramage needs further proof that the forecasts are improving, he should turn back a few pages in the January 1978 *Bulletin* to Figure 7 in Shuman's article on Numerical Weather Predictions and he will note a sharp upswing in accuracy of forecasts from 1974 to 1976. The greatest impact of numerical weather prediction on the improvement of forecasts so far has been the country east of the Rockies. However, the fact that all 52 forecast offices in Figure 7 showed a larger improvement in the last two years than the three eastern offices would suggest that the models are now giving more help than previously to the western forecasters.

