An Investigation of the Surface Temperature Distribution in the Detroit Region

Smith

Follow this and additional works at: https://scholarworks.wmich.edu/masters_theses

Part of the Climate Commons, and the Geography Commons

Recommended Citation
https://scholarworks.wmich.edu/masters_theses/4280
AN INVESTIGATION OF THE
SURFACE TEMPERATURE DISTRIBUTION
IN THE DETROIT REGION

by

Allen R. Smith

A Thesis presented to the
Faculty of the School of Graduate
Studies in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
August, 1966
ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation to his advisor, Dr. Val Michenlaub, and to Rainer R. Erhart of the Western Michigan University Geography Department, for their guidance in assembling this report.

Acknowledgement is also made of the assistance of Dr. Richard Kopec of Wayne State University, Lt. Col. Elvin of the U.S.A.F., the staff members at Willow Run, Wayne, Windsor and City Airport’s Weather Stations, and the staff of the reference department of Windsor Public Library, all of whom assisted in the compilation of data and information.

Allen R. Smith
TABLE OF CONTENTS

ACKNOWLEDGEMENTS ..................................................... 11
LIST OF TABLES ............................................................. v
LIST OF ILLUSTRATIONS ....................................................... vi

CHAPTER

I INTRODUCTION ............................................................. 1
Climate and the City ...................................................... 1
Reasons for this Study ................................................... 3
Techniques Employed ..................................................... 5

II PREVIOUS STUDIES ON THE TEMPERATURE DISTRIBUTION WITHIN CITIES .... 8
Studies in Europe ......................................................... 9
Studies in the United States .......................................... 15
Summary ................................................................. 20

III THE CITY, THE REGION AND THE LOCATIONS OF STATIONS .......... 21
Major Temperature Controls ........................................... 24
United States Recording Stations .................................... 26
Canadian Stations ......................................................... 32
Support Stations .......................................................... 35
<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>THE DISTRIBUTION OF SURFACE TEMPERATURES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>The Summer Average Temperature Distribution</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>The Winter Average Temperature Distribution</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Variations in the Average Monthly Temperatures between the Nine Stations</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>53</td>
</tr>
<tr>
<td>V</td>
<td>THE DIFFERENCE OF TEMPERATURES BETWEEN CITY AND WAYNE AIRPORT</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Comparison Between Wayne and City Airport</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Cool Season</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Warm Season</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>66</td>
</tr>
<tr>
<td>VI</td>
<td>THE OCCURRENCE OF FIRST FROST IN FALL AND LAST FROST IN SPRING</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>First Frost of Fall</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Last Frost of Spring</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>70</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>72</td>
<td></td>
</tr>
</tbody>
</table>

iv
LIST OF TABLES

<table>
<thead>
<tr>
<th>Tables</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Detroit Area Weather Stations</td>
<td>34</td>
</tr>
<tr>
<td>2. Average Monthly Maximum Temperatures</td>
<td>56</td>
</tr>
<tr>
<td>3. Average Monthly Minimum Temperatures</td>
<td>59</td>
</tr>
<tr>
<td>4. Differences Between the Average Monthly Maximum and Minimum Temperatures</td>
<td>61</td>
</tr>
<tr>
<td>5. Airport and City Temperatures at Detroit, Michigan</td>
<td>64</td>
</tr>
<tr>
<td>6. Deviations from City Airport's First Frost Average</td>
<td>78</td>
</tr>
</tbody>
</table>
LIST OF ILLUSTRATIONS

Figures

1. Monthly Temperature Variations Between the Nine Stations ............................................. 55
2. Frequency of Differences of Daily Extremes at City and Wayne Airports, 1964 ....................... 67
3. A comparison of the Average Hourly Temperature at City and Wayne Airports ................. 72

Maps

1. The Detroit Region .............................................. 23
2. July Temperature Distribution—Southeastern Michigan ..................................................... 39
3. Average Summer Maximum Temperature Distribution ...................................................... 40
4. Average Summer Minimum Temperature Distribution ...................................................... 43
5. January Temperature Distribution—Southeastern Michigan ................................................ 47
6. Average Winter Maximum Temperature Distribution ....................................................... 48
7. Average Winter Minimum Temperature Distribution ....................................................... 50
8. Last Frost Day of Spring ........................................ 81
CHAPTER I

INTRODUCTION

Climate and the City

Studies made of temperature in and around cities have shown the climate of the city to be anomalous in relation to its regional climate. The extent of this anomalous condition and the reasons for its occurrence vary from city to city and from season to season. So many variable factors are present in the generation or regeneration of heat within the city that no study has yet satisfactorily explained the total factors involved, or has indicated the percentage for which any one factor might be responsible. This being the case, the only objective investigation that can be carried out, without breaking new ground or lapsing into pure conjecture, is to delimit the extent of the anomaly and observe the spacial distribution of its seasonal variations.

The anomaly that does exist is one most commonly represented by higher temperatures within the city than those temperatures recorded in the surrounding
countryside. In many cities such differences have been dismissed as being products of the variations in thermometer siting. However, research has shown that given two locations that have the same physical landform and experience the same external climatic factors, and assuming one is in its natural, undisturbed state while the other is a sizeable modern city, the interaction between the individual locations and the external influences acting upon them will be noticeably different. The city, therefore, becomes a modifier of climate, and in particular, temperature. During the winter the city experiences less severe temperatures than the surrounding countryside and in the summer it experiences greater temperatures than the nearby rural areas. The degree to which these variations are present in a city will depend upon the location of the city, its size, its function, and the external climatic factors of the region.

There are three basic causes for the changes in temperature when an area becomes urbanized. The first is the alteration in surface. This may be very radical as in the case of the removal of dense forest and the construction of stone, brick and cement edifices. Moist areas such as swamps and ponds may be drained
and aerodynamic changes will probably occur due to the variety of structures built. Secondly, the city itself produces heat in various ways ranging from that produced by factories, home furnaces, and automobile engines down to that produced by the human and animal metabolisms. Finally, there are released into the atmosphere over the city large volumes of inert solid matter, gases, and active chemicals which, apparently, can affect the climate even beyond the city's confines. At no point in this study were these factors analyzed or isolated so that the phrase "city heat" refers to the temperature resulting from any combination of these variables and others which are not so easily identified.

Reasons for this Study

The purpose of this study is to investigate the surface temperature distribution in a region dominated by a large urban-industrial complex, to isolate the anomalous areas, to find the areas of heat concentration, and to study the seasonal variation in

---

temperature throughout the region. The city of Detroit was selected as the center of the study area in this investigation for the following reasons: First, the writer's familiarity with the region and his unquantified observations of the locational variations in the city's temperature. Second, there had not been any studies of this kind conducted in the Detroit region, although investigations of temperature variation, both horizontally and vertically, had been made in several other major cities in the United States. Finally, in a recent article published in the Bulletin of the American Meteorological Society, Detroit was shown as having a higher continentality index than comparable locations at the same latitude and greater than many locations in Michigan, some more centrally located and at higher latitudes. This is to say that Detroit experiences a greater annual temperature range than locations surrounding it, and thus can be considered an anomaly in the region.

---

2Richard J. Kopec, "Continentality around the Great Lakes," Bulletin of the American Meteorological Society, XLVI (February, 1965), 54-57. Kopec used the modified Conrad formula for continentality in which
\[ K = 1.7 \frac{A}{\sin(\theta + 10)} - 14 \]
where \( K \) is the index of continentality, \( A \) the annual range of temperature in degrees centigrade and \( \theta \) the degrees of latitude.
Techniques Employed

The techniques used in investigations of this type have varied from study to study. No two studies seem to have had identical purpose or treatment, so no standard procedure has been established. The technique used here is neither unique nor all-inclusive, but the best available to this researcher. It required the compilation of various data supplied in published form by the United States Department of Commerce, Weather Bureau, and Canada's Department of Transport, Meteorological Branch.\(^3\) Both of these sources supplied the daily maxima and minima (which were the bulk of the data used) for established stations within a twenty-five mile radius of Detroit, in addition to some stations beyond that range which were used for interpolation purposes.

The time period studied begins in June, 1958, and concludes in May of 1965. This time period was chosen because of the availability of the data in the Western

---

Michigan University library. Also, changes in a city can make longer periods of data less valid unless they are used in groups of years to show changes in the temperature pattern.

The daily maxima and minima for this seven-year period were processed several times to produce mean monthly maximum and minimum and seasonal average maximum and minimum temperatures. The process was basically one of simple averaging, summing and dividing into seasonal groups. For these computations and compilations a Friden SW automatic calculator was used almost exclusively. Besides these computed statistics, selected specific conditions were also studied. An analysis of the surface distribution throughout the region was made after plotting the seasonal average temperatures on maps. The occurrence of first frost in the fall and last frost in spring was reviewed for the seven-year study period. The variations in the average monthly maximum and minimum temperature between the nine stations were graphed.

and arranged in table form; and the variations between a city location and a rural location were examined for a twelve-month period to ascertain how much effect the city had upon the temperature. The purpose throughout was to show the existence of city heat and to delimit, with the data available, the location of this thermal cell.
CHAPTER II

PREVIOUS STUDIES ON THE TEMPERATURE DISTRIBUTION WITHIN CITIES

Since 1933 more than three hundred studies have been published which deal, in some way, with the climate of urban places. Most of these studies were concerned with the effects of the urban industrial growth upon the environment of a location and focused on such factors as air pollution, smog, and fog. Also, many studies were concerned with only certain variables of climate, such as snowfall or wind direction while others were limited in duration, covering only a specific year or a certain storm. In some cases temperature distributions were isolated and studied, but in most they were either a small part, a by-product of the study, or not included at all.

The following is a review of some of the more important studies concerned specifically with temperature distribution or having within them sections devoted to this phenomenon. Most of those mentioned cover a year or more of investigation.
Studies in Europe

In the year 1833 the first studies of urban climate were published in England by Howard,¹ and were the result of the author's compilation and analysis of the data collected at various suburban stations around London between 1806 and 1830. The temperature of the region was an important part of the three volumes and temperature variations between the city and suburban areas were noted. Twenty-two years later a Frenchman named Renou added to the knowledge of city temperature distribution with a series of studies between 1855 and 1868.² These were all done in Paris and compared the city temperatures with those recorded in the surrounding countryside.


Renou used several techniques in his studies such as comparing his stations at three-hour intervals to develop patterns in the diurnal variations between the locations. He also used a five-year study period in one paper and divided the time in hour segments to derive average variations over an extended time period. Finally, he noted that the city experienced fewer frost-days than did the open country, and made a study of this phenomenon. Renou showed clearly that the city had a higher minima on most days than those recorded at the outside station and that the city generally experienced a smaller diurnal range.

The Austrian and German meteorologists did not begin to write in this field until 1885, but rapidly became the most prolific authors on the subject. In both countries studies of the urban climates were conducted using weather records as a source of data. Paris, Prague, Trieste, Berlin and Vienna, as well as many minor cities, were studied in this way and the results were published in the academic and scientific journals. The German publication, Meteorologische Zeitschrift, has published more of these studies than
any other journal.\textsuperscript{3} Most of the Austrian and German studies covered periods of a year or a decade, but some attempted to cover all years for which records were available.\textsuperscript{4}

Many of the early studies were apt to have built-in errors or biases owing to the poor location of the recording instruments, such as close proximity to buildings. In an attempt to overcome this problem two men separately devised the method of collecting data while maintaining a uniformity of the recording equipment. This method involved the equipping of an automobile as a "moving laboratory"\textsuperscript{5} and traversing the city making frequent returns to a check point in order to screen out the influence of temporary

\textsuperscript{3}Reference to these studies included in Brooks, \textit{op. cit.}, pp. 736-773.

\textsuperscript{4}One example of these long surveys is Otto Behre's \textit{Das Klima von Berlin}, (Berlin: Otto Salle, 1908), which covers the period between 1719 and 1907, giving a very broad coverage to all aspects of temperature variation including some of the earliest published work in micro-climatology. Cited by Brooks, \textit{op. cit.}, p. 739.

temperature change. Schmidt\textsuperscript{6} made the first investigation of this kind in Vienna in 1927 using a mercury thermometer. Schmidt’s main concern was with frost limits. Peppler\textsuperscript{7} of Karlsruhe improved the method somewhat in 1919 using an Assmann aspirated thermometer. Peppler’s contribution to research technique was his method of traveling around a city and comparing his recorded data later with that recorded on a thermograph that had remained at a fixed location within the city. He also devised the method of quick runs in north-south and east-west directions crossing at a central location.

\textbf{The Köppen-Geiger Handbuch der Klimatologie.}


published in 1930, included a chapter in which Geiger reviewed the works of Schmidt and Peppler. Geiger's own contribution to urban climatology came soon after when he allied his work on urban temperature variations with his studies of microclimates. He wrote a paper which dealt specifically with urban influences and in the second edition of his 1927 book, Das Klima der Bodennahen Luftschicht, Geiger had also included a chapter on city climates.

During the 1930's many studies were made throughout the world in almost every climatic zone in which large urban complexes are found, and in 1937 Father Kratzer, a Benedictine priest, developed a comprehensive survey of all previous literature on the subject.


10Cited in Geiger, The Climate Near the Ground, op. cit., p. xiv, which is the English translation.
as part of his Munich doctoral dissertation.\textsuperscript{11} Kratzer not only chronicled the work that had been done, but also speculated upon the multi-variables that caused the city's heat. This had been done before for individual cities, but here all the previous studies were brought together for analysis.

Most studies of the European city climate published since Kratzer have been devoted to specific weather phenomena and do not bear repeating here with the exception of the Sundborg study\textsuperscript{12} at Uppsala, Sweden. Here the data were collected using the automobile traverse method, and an attempt was made to quantify the underlying causes of city heat and the external effects upon it. Sundborg apparently met with some success in deriving formulae to express both


night and day variations. However, though similar formulae can be written for other cities, no one set of equations is suitable for all cities.\textsuperscript{13}

\textbf{Studies in the United States}

In the United States recognition of possible modification of climate due to man's activity was noted quite early. Thomas Jefferson, in a letter dated July 16, 1824,\textsuperscript{14} suggested that climatic surveys "should be repeated once or twice in a century to shew (sic) the effect of clearing and culture towards changes of climate." However, nothing was published regarding the climate of cities until 1893 when a bulletin was published on Chicago's climate.\textsuperscript{15}

\textsuperscript{13}H. E. Landsberg, \textit{op. cit.}, 596, 597.

\textsuperscript{14}Thomas Jefferson in a letter to Dr. Lewis C. Beck of Albany, New York, (July 16, 1824), quoted by H. E. Landsberg, \textit{op. cit.}, p. 584.

\textsuperscript{15}Henry A. Hazen, "Climate of Chicago," as mentioned by Henry J. Cox and John H. Armington, "The Weather and Climate of Chicago," \textit{Geographic Society of Chicago Bulletin}, No. 4 (1914), 4. Publisher or publication not named.
After the turn of the century, various writers began to examine this field, publishing either two and three page articles or great tomes on the various aspects of climate. The two major works are Fassig's study of Baltimore, and Cox and Armington's study of Chicago. Both are sizable books which deal with numerous aspects of climate, and both devote a large portion to temperature. Neither deal with the surface distribution very thoroughly, though both note the presence of city heat. The Chicago study, for instance, compares the data recorded at the central city station, located on the top of the Auditorium Tower, with the temperature records for La Grange, 13 miles to the west, with its equipment located "a few feet above the sod." From these records La Grange appears as having a warmer maximum and a lower minimum throughout the year, but only had a higher monthly mean during the warmer months.


17 Cox and Armington, op. cit.

18 Ibid, p. 52.
More to the point, but extremely brief in themselves, were the articles appearing in the *Monthly Weather Review* during 1911. The Mindling study\(^{19}\) sought to explain how fuel consumption in cities was influencing the urban climate by comparing two ten-year periods at New York and New Haven. The reply to this was supplied by Palmer\(^{20}\) who claimed his study of Boston showed no appreciable degree of change had occurred.

The last of the early publications on temperature in cities came in 1919 when Redway\(^{21}\) did a small study of New York. Again, the suburbs experienced warmer temperatures during the day and cooler at night. All the published studies that followed for the next thirty years were concerned with other aspects of climate and particularly with smoke, fog, smog, or other health hazards affected by climate.

---


However, in the last 15 years several small studies have been made in various major cities of the United States. The best known of these is probably the Duckworth and Sandberg study\textsuperscript{22} of San Francisco, San Jose and Palo Alto. In studying these cities the automobile traverse system of data collection was used. Temperature distributions were plotted and the deviations were noted. The ultimate goal seemed to be to quantify the variables so that predictions of variations in the urban temperature could be made. Each of the cities showed the presence of heat islands over the urban regions.

The most recent study published was made on the Washington, D. C. area by Woollum.\textsuperscript{23} Here the writer used the data compiled at substations in the region and divided the data into four five-year study periods. He developed from this an extremely comprehensive set of maps showing the distribution of temperature and


\textsuperscript{23}Woollum, \textit{op. cit.}
the modifications that occurred both seasonally and in each study period. The investigation that follows is patterned in part on Woollum's technique.

Summary

From the previous research in this field it is apparent that the city experiences different temperatures than those of its suburbs and the surrounding countryside. It seems apparent that these differences usually show the city as being warmer than the surrounding stations though this may vary with the time of day or with individual cities. Many of the early studies show discrepancies in the siting of the apparatus that could have produced biases or misinterpretation of recorded data. In many cases city thermometers were located at higher altitudes than at rural stations, and thus tended to nullify the presence of heat that could have existed at ground level in the city.

No two cities are subject to exactly the same weather phenomena and no two cities have the same physical characteristics; therefore, very little of the knowledge gained by these researchers could be transferred from one location to another. Method of
investigation is the only real transferable element, and here there was variety, dependent upon the goals of each researcher, the availability of data and the equipment and finances available to the researcher. The approach used in the original publication by Howard and the latest publication by Woollum seems the most valid and economically expedient and is the basis upon which the following investigation was conducted.
CHAPTER III

THE CITY, THE REGION AND THE LOCATIONS OF STATIONS

The city of Detroit is located on the Detroit River, southwest of Lake St. Clair and twenty miles north of Lake Erie. The majority of the land on which the city is located and the part of lower Ontario across the river were once the bottom of a glacial lake and now appear as flat plains areas. To the northwest of Detroit the terrain becomes one of gently rolling hills of relatively low relief.

Originally established as a control point from which lake traffic could be surveyed,¹ Detroit has grown into a large metropolitan center of more than 3,000,000 population. Having little in its favor besides cheap water transportation, Detroit, through historical coincidence, became the center of the world's largest automobile industry. However, Detroit is not the large industrial conglomeration that one

¹Almon Ernest Parkins, The Historical Geography of Detroit, (Lansing: Michigan Historical Commission, 1918), 49.
would expect, for the three major companies and the numerous supply companies are not centralized in any one place but are, in fact, dispersed throughout the city and its suburbs and even into the surrounding countryside. The residential areas, too, are not concentrated but extend from the very center of the city out into the countryside in all directions except where prevented from doing so by the presence of Lake St. Clair, the Detroit River and the Canadian border. The greatest extent of this residential growth is to the north and west while the southern extension and the Canadian annex at Windsor are under-developed as yet. (See Map 1).

Grand Circus Park is the center of the study area. From here a radius of twenty-five miles was measured to delimit this region which takes in much more than the city and its outer suburbs. The area also includes a large part of Essex county in Ontario, two-thirds of Lake St. Clair, the cities of Livonia and Pontiac, and extends as far west as Willow Run. Slightly less than one quarter of this area is water and just more than one quarter is heavily developed. The rest is open country used mainly for agriculture and pasture and having only light tree covering.
Map 1
THE DETROIT REGION

- Weather Stations
- Heaviest Urban Concentrations
Major Temperature Controls

The region falls between latitude 41°55' and 42°40' which places it in the belt of the prevailing westerly winds. The area fluctuates from year to year between the Köppen humid microthermal climatic classifications of Daf (warm summers) and Dbf (cool summers). At times some stations fall within one group while the rest fall within the other depending upon whether their warmest monthly mean exceeds 71.6°F. There are also years when the lake shore and eastern Detroit locations experience a Caf (humid mesothermal) climate.²

To the west, north, east and southeast of the region lie the Great Lakes, and these act as modifying influences upon the general region throughout the year. Among these influences are the modifications upon the northwest cold waves during the cooler months by Lake Michigan and the moderating effect of Lakes Huron and

²Frank Himmler, and George C. DeLong, "The Mesothermal Climates of Michigan, 1951-60," Papers of the Michigan Academy of Science, Arts and Letters, XLVIII (1963), 413-417. This would be so if the Köppen coolest monthly mean of 26.6°F was used as in this article, but not so if the Trewartha modification (coolest month above 32.0°F) was used.
Erie during the warmer months that prevent extremely high temperatures. Extreme temperatures are rare in the general area of Detroit in contrast to locations at similar latitudes in the plains states to the west which experience great ranges in temperature.

The air masses affecting Detroit are most commonly Continental Polar in origin with the southern Maritime Tropical next in importance. In winter Continental Arctic air will occasionally blanket the region.

The elevation of the region is not very significant as a temperature control. There are no elevational barriers on this glaciated surface and the relative relief over the whole study area would fall within 560 and 930 feet.

An important secondary temperature control over the region is Lake St. Clair. This body of water, east of the city, acts as a modifier upon the temperature over a large portion of the region throughout the year. The actual extent of its influence is difficult to delimit, the degree of landward penetration varying with diurnal cooling and the seasons. It does, however, act as a cooling agent during the warm months and a warming agent during the cooler months, particularly along the eastern side of the city. This
secondary control will interact at times to diminish and at other times to augment the temperature modifying effects of the city. Hence, with any evaluation of the urban effect, this factor must be considered.

United States Recording Stations

The stations in the area are divided into two types: first, U. S. Weather Bureau Offices (commonly known as first-order stations), which are staffed by meteorologists who record numerous aspects of the weather throughout each day; second, the Weather Stations (commonly known as sub-stations), which are operated by observers who are not skilled in meteorology and are required only to keep a daily record of the temperature and precipitation at their location. In the latter case these stations are most commonly located at state operated facilities or at city utilities and the observer is usually an employee.

A knowledge of the siting of the equipment throughout the region is important in evaluating the data used. For this reason visits were made to each

---

of the stations in the region.

First order stations

Three first order stations are used in this study. The main weather station of the Detroit region is the one located at City Airport, approximately five miles northeast of Grand Circus Park. The recording equipment is located in a fairly open space at the south end of the airport near Gethsemane Cemetery. However, the land surrounding the airport and the cemetery is heavily developed with residential and commercial buildings and several small concentrations of industries border the field.

Until 1934 the official weather station for Detroit had been on top of the ten story Federal Building in the business section of the city. The move was made to the airport in an attempt to eliminate the effect of the city upon the recording equipment shelter. Detroit's Weather Bureau office was the first city station in the country to make this kind of move, and today we find that almost all major cities in the country have their recording stations at their airports.  

The second first-order station is at Willow Run Airport at the extreme west of the study area. This station is twenty-four miles west-southwest of Grand Circus Park. The terrain in this area is generally flat to gently rolling with only moderate tree covering. The location is more than 30 miles from either Lake St. Clair or Lake Erie and has an elevation of 700 feet (about 100 feet higher than Detroit proper).

The temperature measuring equipment is located on the grass near the center of the airfield, more than 1000 yards from any buildings. There are several large industrial complexes around the perimeter of the airfield, but these factories are not clustered and there are no large residential conglomerations in close proximity to the airport.

The third first-order station was established in 1959 at Wayne Airport, more commonly known as Detroit Metropolitan. This station is located approximately twenty miles southeast of Grand Circus Park and is at a thirty foot greater elevation. The terrain here is generally flat to gently rolling with local relief seldom exceeding ten feet. The trees and shrubs are sparse and there is not a well developed residential area within two miles of the terminal. Surrounding
the airport are several small industrial plants of a type usually associated with aircraft or services. The equipment for measuring temperature is located on the grassed area near the main runway, well away from any buildings.

Each of the above stations record hourly observations of various aspects of the weather including such things as temperature, wind direction and speed, relative humidity, precipitation, pressure, and ceiling, which are published monthly by the Department of Commerce.\(^5\)

At all three stations mentioned above the temperature is measured by telespsychrometers placed four feet above the ground. The temperature and dew point are relayed from the instrument to the station that could be as much as a mile away from the site of the equipment shelter. The sitings at Wayne and Willow Run are free from strong cultural influences while City Airport's equipment is located much closer to the heavily urbanized district with its temperature modifying factors, and to Lake St. Clair.

Sub-stations

Three of the other four Weather Bureau stations in the study area are sub-stations where the only temperature measurements each day are taken from a maximum and minimum thermometer. The monthly records of these two daily temperatures are sent to the central agency at Asheville, North Carolina, for compilation and publication. 6

The Dearborn sub-station is located at Greenfield Village, eleven miles west of Grand Circus Park. The equipment is located directly behind the Henry Ford Museum and to the side of a maintenance building used for restoring old vehicles. The thermometer enclosure is about 125 feet from either building. The area surrounding the village complex is basically parkland with abundant tree cover for a distance of 1000 yards or more in all directions. However, the village is located within two miles of the large Ford Motor Company plant at River Rouge and surrounded by the suburban cities of Dearborn, Allen Park, and Melvindale.

The Pontiac sub-station is located twenty-five miles northwest of Detroit and is on the grounds of the State Hospital. This is on the western fringe of the city of Pontiac, but still within its suburbs. The thermometer enclosure is located at the rear of the hospital complex and in front of the power plant. There are about 100 feet between the white thermometer box and the nearest building. The terrain is quite hilly with a local relief of about 50 feet while the altitude at the station, one of the higher locations, is 380 feet greater than Grand Circus Park. There are several small lakes to the west of the hospital and several large industrial complexes within a few miles east. This is the most northern of the stations in the study area and is also farther from the influence of any large water body than the other stations.

The Grosse Pointe Farms sub-station is located approximately 50 feet behind the city's filtration plant over a grass surface at an elevation of 613 feet or approximately 50 feet above Lake St. Clair and 550 feet to the west of it. The general area to the south, west and north is covered with private homes, but they are spaced farther apart than in most suburbs and there are large areas of lawns and parkland. While
this is not the most easterly station, this site is located directly to the leeward of the city.

A fourth sub-station is located on the United States Air Force station at Selfridge Field east of the city of Mount Clemens and about 20 miles northeast of Grand Circus Park. The area surrounding the station is only slightly developed with suburbs to the south and west, open country to the north and Lake St. Clair's Anchor Bay to the east. The area is flat and open with only light tree covering; temperature measuring equipment is located in the middle of a grass-covered area near the center of the main runway. The equipment used here is a telepsychrometer operated by the Air Force meteorologists.

Each of the sites appeared to be good locations for their immediate area although proximity to buildings and wind breaks varies greatly at each station.

Canadian Stations

The two Canadian stations are located in the western portion of Essex county and fall within the meteorological records division of Lake Erie and Niagara counties. The Windsor station is located at the Windsor Airport, approximately six and one-half miles...
miles southeast of Grand Circus Park. The equipment for measuring temperature is located about 60 feet in front of the terminal building and is a similar device to that used at the other airports. The proximity of the equipment to the terminal may seem like bad siting, but there is no other building within close proximity and the green lawn on which the equipment is located is exposed to the elements moving across the extremely flat and open plain.

Unlike Windsor, which is a meteorological station, Harrow, in southern Essex county is an Agricultural Climatic Station which is somewhat equivalent to the sub-station of Michigan. This is the most southern and most rural station of the study area. The recording equipment is located in an open field behind the Canadian Department of Agriculture station one mile east of Harrow. The equipment shelter is approximately 500 feet from any buildings, while the general area surrounding it for many miles is remarkably flat, unpopulated and open. Harrow, itself, is a very small town four miles from its nearest neighbor which is even smaller and three and one-half miles from Lake Erie. As in the Michigan sub-stations, the equipment for temperature measurement is maximum and minimum
<table>
<thead>
<tr>
<th>Location</th>
<th>Years&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Altitude</th>
<th>Temperature Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detroit City AP</td>
<td>32</td>
<td>42°24' N</td>
<td>83°00' W</td>
<td>619 ft</td>
<td>Telepsychrometer</td>
</tr>
<tr>
<td>Gratiot and Conner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wayne AP</td>
<td>7</td>
<td>42°14' N</td>
<td>83°20' W</td>
<td>633 ft</td>
<td>Telepsychrometer</td>
</tr>
<tr>
<td>Middlebelt Road</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willow Run AP</td>
<td>20</td>
<td>42°14' N</td>
<td>83°32' W</td>
<td>711 ft</td>
<td>Telepsychrometer</td>
</tr>
<tr>
<td>Mt. Clemens AFB</td>
<td>24</td>
<td>42°36' N</td>
<td>82°49' W</td>
<td>587 ft</td>
<td>Telepsychrometer</td>
</tr>
<tr>
<td>Selfridge Field</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dearborn</td>
<td>14</td>
<td>42°18' N</td>
<td>83°14' W</td>
<td>610 ft</td>
<td>Maximum-Minimum</td>
</tr>
<tr>
<td>Greenfield Village</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pontiac State Hospital</td>
<td>58</td>
<td>42°38' N</td>
<td>83°16' W</td>
<td>935 ft</td>
<td>Maximum-Minimum</td>
</tr>
<tr>
<td>Grosse Point Farms</td>
<td>15</td>
<td>42°23' N</td>
<td>82°54' W</td>
<td>613 ft</td>
<td>Maximum-Minimum</td>
</tr>
<tr>
<td>29 Moross Road</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harrow</td>
<td>36</td>
<td>42°03' N</td>
<td>82°55' W</td>
<td>612 ft</td>
<td>Maximum-Minimum</td>
</tr>
<tr>
<td>Canadian Agricultural</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windsor AP</td>
<td>21</td>
<td>42°16' N</td>
<td>82°57' W</td>
<td>625 ft</td>
<td>Telepsychrometer</td>
</tr>
<tr>
<td>Jackson Blvd.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Time apparatus has been located at present siting.
thermometers. (See Table 1 for a comparison of stations.)

Support Stations

In describing the horizontal temperature distribution maps had to be constructed and isotherms used to show the variation and temperature gradient between each station. To support the data of the nine stations within the study area six outer stations were studied and used for interpolation between inner stations and the boundary of the study area. While some of the supporting stations fall close to the boundary, two are forty miles away from Detroit.

The three Michigan supporting stations are located at Willis, to the southeast of the study area and thirty miles from Grand Circus Park; at Milford at the General Motors proving ground, west of Pontiac; and at the Monroe Sewage Plant, thirty-six miles south of Detroit on the western shore of Lake Erie.

The Canadian stations are located in almost a straight north-south line along the eastern edge of the study area. The first station, Leamington, is located to the southeast of Detroit at a distance of thirty miles. It was used to interpolate across Essex county towards Windsor and towards Harrow. Wallaceburg, to
the northeast, was likewise used to interpolate across a large space in the form of Lake St. Clair in the direction of Mount Clemens and Grosse Pointe Farms. Lastly, Pelee Island represents a Lake Erie location for interpolation towards Harrow and towards the other outer stations of Leamington and Monroe.

Of the six supporting stations only the two most southern, Monroe and Pelee Island, were of relatively little value to the study. Their lake location often resulted in the presentation of temperatures that were not related to their nearest neighbor and could not be understood without the presence of intermediate stations. These two stations did, however, point out the existence of a thermal trough between themselves and the city heat during most days of the study period.
CHAPTER IV

THE DISTRIBUTION OF SURFACE TEMPERATURES

In this portion of the investigation the temperature data for all 15 stations were compiled into two seasonal groups—summer being represented by June, July and August (1958-1964) and winter represented by December, January and February (1958-1965). Both maximum and minimum temperatures were averaged for their respective twenty-one month periods to produce average winter maximum and minimum temperatures and average summer maximum and minimum temperatures. These four groups of statistics were then plotted upon base maps of the area and analyzed.

The four maps (Maps 3, 4, 6, 7) are presented here with accompanying text which attempts to point out the differences between the expected isotherm pattern, based on the natural physical characteristics of the region, and the actual isotherm pattern developed from the data. The problem basically was to plot and analyze the distribution of temperature throughout the region taking into consideration the effect of both city heat and the proximity of bodies of water.
in distorting the natural trend of the isotherms. (See Maps 2 and 5. These were the only available maps that showed the trend of the isotherms over the general area of southeastern Michigan. Both represent individual months rather than the seasons. They are also based upon twenty-one years of records, 1931-52. The variations in degrees of temperature between these maps and those developed by the writer are due to the difference between January or July and seasonal averages, and to the difference in time periods used.)

The Summer Average Temperature Distribution

**Maximum temperature**

During the summer months of the seven-year period, the average daily maximum temperature for the region was between 77°F and 83°F, with the largest portion of the city enclosed within the 80°F isotherm as seen on Map 3. We see here that the urban area had a temperature two to three degrees above the immediate surrounding area, and the temperature gradient between the rural and the urban areas was very steep. The natural tendency of the maximum isotherms during that period would be parallel in alignment in a north-south direction (see Map 2) over the study area with the city
Map 2
July Temperature Distribution
Southeastern Michigan

Map 3

Average Summer Maximum Temperature Distribution
area falling between the 81°F isotherm in the south and the 79°F isotherm in the north. The heat of the city distorted this natural alignment and forced the 78°F isotherm to skirt the northern edge of the urbanized area while the 80°F isotherm was pushed to the south. In order for the 78°F and 79°F isotherms to follow their natural tendency across or south of Lake Erie they appear as north-south lines across Essex county before becoming parallel again with the warmer isotherms.

The anomaly in the regional climate was the area surrounded by the 80°F isotherm. This enclosed most of the urbanized area in the southeast of the city and Pontiac to the north and extended over a portion of Lake St. Clair. The center of this maximum summer warmth was the area surrounding, and to the northeast of Dearborn, where the maximum daily temperature during the summer averaged slightly less than 83°F. This area is mainly one of private homes and is rural towards the west, but several large industrial plants do exist within the 82°F isotherm including the previously mentioned Ford River Rouge complex. Another factor to be weighed here was the location of the heat concentration in regard to the lakes. The eastern extent of the
area bounded by the 80°F isotherm lay equidistant from the two lakes near the narrowest part of the Detroit River. The northern extreme and the western-most corner of this inverted heart-shaped area lay almost the same distance inland from the nearest body of water. With the exception of its southwestern section, this heat island covered the most inland portion of the urbanized and industrial region. This would seem to indicate that at the time of maximum temperature Lakes Erie and St. Clair exerted a tempering effect upon the city heat for a distance of 10 miles or more inland from their shores, thus limiting the eastern and southern extension of the 80°F heat cell. Heat generated by the large industrial complexes along the Detroit River and in the eastern portion of the city were tempered somewhat by the water bodies during this time.

Minimum temperature

The average daily minimum temperature distribution varied greatly from that of maximum as shown on Map 4. The minimum temperatures averaged between seventeen and twenty-four degrees below their maximums. The natural trend of the isotherms across the region
Map 4

WEATHER STATIONS

Average Summer Minimum Temperature Distribution
is more east-west than the maximum's isotherms, (see Map 2) but they were once again displaced. The 58°F isotherm was forced northward from a position south-west of the city, skirting the city's western extremities and lay to the north of the study area. The major part of the city was enclosed by the 59°F isotherm which took an elongated shape stretching from west of Dearborn over into Lake St. Clair and into Canada. Windsor, Mount Clemens and most of Detroit were included within the oval. The heat center enclosed within the 60°F isotherm included most of the central city as well as a portion of Lake St. Clair.

At the time of minimum temperature the air in contact with the land cooled some 20°F, while the temperature of the air associated with water bodies would be expected to cool to a much lesser degree. Thus the heat island during minimum temperature seemed to be more a product of lake influence though it would be difficult to estimate how great this influence was or how much the heat of the city played in the distortion of the isotherms. The gentle and relatively even temperature gradients and the shallowness of the heat concentration indicated that the source of heat was neither concentrated nor dynamic, which would suggest lake influence.
Mean daily range

The greatest drops in temperature (23°F) between maximum and minimum occurred in the area where part of the maximum heat concentration had previously existed—inland over a heavily urbanized area. The least variation between maximum and minimum (17°-19°F) occurred along the eastern side of the study area over Lake St. Clair and lower Essex county. Both the variations held to the premise that temperature varies most over land and least over or near large water bodies. However, the variation over the city tended to be greater than at places further inland or to the immediate north.

On both Map 3 and Map 4 there was a clearly defined temperature concentration over the city area, though temperatures did not greatly differ from those of surrounding areas. Considering that these figures were arrived at from the averaging of 637 summer days, the few degrees difference occurring there were quite significant. Tests conducted on individual years showed similar patterns to those for the seven-year period with minor variations in degrees and location of the heat island. The greatest concentration of
heat was always towards the central-west of the study area where maximum temperatures were higher, while minimum temperatures were highest in the vicinity of East Detroit and the Lake St. Clair shoreline.

The Average Winter Temperature Distribution

During the winter months the natural trend (see Map 5) of the isotherms over southeastern Michigan is west-southwest to east-northeast. This trend was distorted by the city of Detroit which again appeared as an anomaly recording temperatures that were equivalent to those experienced in northern Indiana and northern Ohio, 50 to 100 miles to the south.

**Maximum temperature**

The average winter maximum temperature over the study area varied by as much as four degrees and the anomalous area encircled by the 30°F isotherm covered the majority of the study area and extended to the east, west and north of the region. (See Map 6). The important section of the isotherm pattern appearing on Map 6 was the area surrounded by the 32°F isotherm which indicated that on a great number of the days during the winter months the maximum must have been
Map 5
January Temperature Distribution
Southeastern Michigan

Average Winter Maximum Temperature Distribution
above freezing. The heat concentrations during this period were located in two separate places indicated by the areas enclosed within the 33°F isotherm. First, there was the area around Dearborn that experienced the highest maximum during the summer, and second, there was a smaller area along the Lake St. Clair shore. An explanation of these two heat islands was difficult and would seem to present a study in itself. Samples taken for individual years indicated that these two cells usually existed and that the area between them, in the vicinity of Detroit City Airport, averaged one or even two degrees less over the season. The area around Dearborn was more likely to be warmer by a half degree than at its rival heat island which sometimes resulted in their being encircled within different isotherms.

Minimum temperatures

The average winter minimum temperatures during the study period followed a pattern not unlike the summer minimum. (See Map 7.) Once again it was a very shallow heat variation with widely separated isotherms and gently sloping gradients. The area which distinctly varied from the natural trend was
Average Winter Minimum Temperature Distribution
again enclosed in only two isotherms, but the area which was covered and distorted by the heat concentration was still very large.

The 17°F isotherm that would lie south of the city if it continued to parallel the 18°F isotherm became instead a line that skirted the outer limits of the urbanized region in the west and lay between the northern suburbs and Pontiac in the north. The heat concentration was again characterized by a large elongated oval, which extended over the central and eastern portions of the urbanized area to the shore of Lake St. Clair. The heat island took the form of part of a small oval extending from the west of City Airport to the east of Grosse Pointe Farms. Again Lake St. Clair seemed to be an important influence on the location of the heat center. Inland location experienced distinct drops in temperature of 15°F or more, while the lake shore locations varied to a lesser degree.

Mean daily range

The variations between the average daily maximum and minimum temperatures at locations throughout the study area fell between 11° and 15°F with the greatest extremes occurring along the western edge of the
urbanized area and to the southwest and north of the study area. The least variation again occurred along the eastern edge of the study area and on the southern coast of Essex county. Dearborn and its surrounding area stood out as the location of maximum heat during the winter, rivaled only during this period by the second heat island over Grosse Pointe Farms which was also the location of the minimum heat island. The Grosse Pointe Farms area, therefore, must have experienced a higher mean temperature than anywhere else in the study area. The winter maximum heat island over the lake shore was, in part, a product of Lake St. Clair. The lake, which acted as a cooling influence during summer maximum, suppressing city heat, became a warming influence in winter complementing the city heat. The degree to which the city or the lake was responsible for such heating was extremely difficult to evaluate.

In regard to the four maps reproduced here the writer would like to point out that these represent his interpretation of the available data. Had the network of stations been greater or differently located the isotherms may well have varied from their position on these maps. The interpolation between
stations was carried out under the assumption that the isotherms falling between known data points were equally spaced which was the best available method and the least biased. However, this method can only be successfully used when the surfaces, over which interpolation takes place, are similar. For this reason the isotherms that passed over the water bodies were not drawn as their true location was not known.

Variations in the Average Monthly Temperatures Between the Nine Stations

From the preceding portion of the study two separate influences stood out as important factors in temperature variation between the stations of the study area. They were the distance from water bodies and degree of urbanization. These two influences reduce to some degree the other previously mentioned controls, such as latitude and altitude. To complicate this still further seasonal changes also influenced the degree of difference existing between the stations.

In this section an attempt is made to investigate the variations in the average monthly maximum and minimum temperatures between the nine stations.
In the upper portion of Figure 1 the graph illustrates the average maximum temperature variation which occurred between stations in the study area during each of the twelve months. The length of each line, measured in degrees, indicates the variation between the stations with the lowest and the highest monthly maximum temperatures while the vertical position of the line measured on the y axis indicates the values of the highest and lowest maximum temperatures.¹

To show the actual monthly average maximum temperature at each station Table 2 was developed and from this the following analysis was made. Throughout the year the highest monthly average maximum temperatures within the study area were recorded at either Dearborn or Grosse Pointe Farms; however, the latter was only higher by a small margin in December and only equal to Dearborn in January. For the other ten months Dearborn clearly stood out as having a higher maximum than all the other stations, often by more than a degree. Dearborn’s domination of the

¹The drawing of curved lines to indicate the trend at each station was discarded as the relatively small variation throughout the year and the seasonal variation between stations created a complex web of lines that became unreadable.
Figure 1
Monthly Temperature Variations Between The Nine Stations

<table>
<thead>
<tr>
<th>Average Monthly Maximum Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Monthly Minimum Variation</td>
</tr>
<tr>
<td>Station</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Dearborn</td>
</tr>
<tr>
<td>Detroit A.P.</td>
</tr>
<tr>
<td>Wayne A.P.</td>
</tr>
<tr>
<td>Willow Run A.P.</td>
</tr>
<tr>
<td>Grosse Pt. Farms</td>
</tr>
<tr>
<td>Mt. Clemens</td>
</tr>
<tr>
<td>Pontiac</td>
</tr>
<tr>
<td>Harrow</td>
</tr>
<tr>
<td>Windsor</td>
</tr>
</tbody>
</table>
maximum monthly average over stations farther removed from lake influence and stations nearer the lake implied that the urbanization was the main cause of this phenomena. The reasons for Grosse Pointe Farms' high temperatures during December and January were dealt with earlier.

The lowest average monthly maximum temperatures occurred at either Mount Clemens or Harrow. Both these stations are more than twenty miles from Grand Circus Park. Mount Clemens is in close proximity to Lake St. Clair which would tend to reduce the maximum temperature in the summer months while its northerly location would generally contribute to lower monthly maximums throughout the year. Harrow, however, is the southern-most station of the study area and is not a lake shore location but the flat open country of the area and the large water body in the form of Lake Erie, only a short distance away, must in fact have exerted a tempering effect upon the maximum temperature. The more northern Mount Clemens station recorded lower average maximum temperatures than Harrow on only three months—March, September, and October—and equaled Harrow's maximum in February. Throughout the early winter and early summer Harrow recorded the lowest
maximum temperatures in the study area.

The differences between the average monthly maximum for all nine stations was greater in the spring and summer months and least during the winter months. (See Figure 1.) This strengthens the belief that the lake influence and city heat worked as opposing factors during the warmer period of the year and complemented each other during winter months.

The lower portion of Figure 1 and Table 3 follow the same format as above in presenting the average monthly minimum temperatures for all nine stations of the Detroit region. Here we can see that the differences between minimum temperatures recorded at the various stations tended to be slightly greater in the late summer and fall than during the other months of the year. The table indicates that the highest minimum temperatures were recorded at City Airport and Grosse Pointe Farms. The airport dominated during the first eight months of the year while the shore location was either equal to, or recorded higher minimum temperatures during the last four months when lake effect was strongest. The lowest average monthly minimum temperatures were recorded at two distinct inland locations. Wayne Airport recorded the lowest minimum temperature
## TABLE 3

**AVERAGE MONTHLY MINIMUM TEMPERATURES OCCURRING IN THE DETROIT REGION**  
**JUNE 1958 - MAY 1965**

<table>
<thead>
<tr>
<th>Station</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dearborn</td>
<td>16.4</td>
<td>18.9</td>
<td>25.9</td>
<td>37.5</td>
<td>49.9</td>
<td>55.9</td>
<td>61.9</td>
<td>60.5</td>
<td>54.1</td>
<td>43.8</td>
<td>33.8</td>
<td>19.7</td>
</tr>
<tr>
<td>Detroit A.P.</td>
<td>17.9</td>
<td>19.0</td>
<td>26.6</td>
<td>38.7</td>
<td>50.6</td>
<td>57.8</td>
<td>63.2</td>
<td>62.0</td>
<td>55.6</td>
<td>45.5</td>
<td>34.9</td>
<td>21.2</td>
</tr>
<tr>
<td>Wayne A.P.</td>
<td>16.1</td>
<td>17.0</td>
<td>25.1</td>
<td>35.9</td>
<td>47.5</td>
<td>55.2</td>
<td>59.3</td>
<td>57.1</td>
<td>51.9</td>
<td>41.5</td>
<td>31.1</td>
<td>19.2</td>
</tr>
<tr>
<td>Willow Run A.P.</td>
<td>15.8</td>
<td>17.3</td>
<td>25.4</td>
<td>36.5</td>
<td>48.1</td>
<td>55.7</td>
<td>61.2</td>
<td>59.9</td>
<td>53.0</td>
<td>42.4</td>
<td>32.1</td>
<td>18.9</td>
</tr>
<tr>
<td>Grosse Pt. Farms</td>
<td>17.5</td>
<td>18.8</td>
<td>26.0</td>
<td>37.6</td>
<td>49.9</td>
<td>57.2</td>
<td>62.6</td>
<td>61.5</td>
<td>55.8</td>
<td>45.5</td>
<td>35.1</td>
<td>21.4</td>
</tr>
<tr>
<td>Mt. Clemens</td>
<td>16.8</td>
<td>16.6</td>
<td>24.6</td>
<td>36.3</td>
<td>48.0</td>
<td>56.0</td>
<td>61.7</td>
<td>60.6</td>
<td>54.1</td>
<td>43.3</td>
<td>32.7</td>
<td>19.4</td>
</tr>
<tr>
<td>Pontiac</td>
<td>14.3</td>
<td>16.3</td>
<td>23.9</td>
<td>36.2</td>
<td>48.7</td>
<td>55.7</td>
<td>60.8</td>
<td>59.6</td>
<td>53.7</td>
<td>43.4</td>
<td>32.9</td>
<td>18.6</td>
</tr>
<tr>
<td>Harrow</td>
<td>16.7</td>
<td>18.3</td>
<td>25.7</td>
<td>35.7</td>
<td>49.7</td>
<td>56.8</td>
<td>62.0</td>
<td>61.2</td>
<td>55.2</td>
<td>44.7</td>
<td>34.2</td>
<td>19.9</td>
</tr>
<tr>
<td>Windsor</td>
<td>16.1</td>
<td>17.5</td>
<td>25.1</td>
<td>36.5</td>
<td>48.5</td>
<td>56.4</td>
<td>61.4</td>
<td>60.2</td>
<td>54.4</td>
<td>43.4</td>
<td>33.0</td>
<td>19.0</td>
</tr>
</tbody>
</table>
from April through November while Pontiac was colder by more than a degree from December through March. For the most part these facts followed the same patterns as previously mentioned with Lake St. Clair playing an important part in the location of high minimum temperatures while the lowest minimum temperatures were located at stations far removed from the lake.

The differences between the average monthly minimums and maximums at each station is shown on Table 4. Here we can see that the average monthly difference at each station fell between 11° and 18°F during the five-month period of November through March, while the differences between the maximum and minimum during the other seven months fell between 17° and 25°F. The greatest differences occurred at Dearborn, Wayne Airport and Pontiac with the latter being most pronounced. The least differences occurred at Harrow through eleven months of the year with Mount Clemens being lower in April.
<table>
<thead>
<tr>
<th>Station</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dearborn</td>
<td>15.2</td>
<td>16.1</td>
<td>17.7</td>
<td>22.1</td>
<td>24.0</td>
<td>24.5</td>
<td>22.9</td>
<td>22.4</td>
<td>22.9</td>
<td>22.2</td>
<td>17.3</td>
<td>14.8</td>
</tr>
<tr>
<td>Detroit A.P.</td>
<td>12.4</td>
<td>13.9</td>
<td>14.9</td>
<td>18.6</td>
<td>20.6</td>
<td>20.6</td>
<td>19.9</td>
<td>19.2</td>
<td>18.9</td>
<td>19.0</td>
<td>14.6</td>
<td>12.0</td>
</tr>
<tr>
<td>Wayne A.P.</td>
<td>14.3</td>
<td>16.0</td>
<td>16.1</td>
<td>21.0</td>
<td>23.2</td>
<td>23.8</td>
<td>20.0</td>
<td>22.8</td>
<td>22.4</td>
<td>22.5</td>
<td>17.7</td>
<td>14.4</td>
</tr>
<tr>
<td>Willow Run A.P.</td>
<td>14.0</td>
<td>15.6</td>
<td>16.3</td>
<td>21.3</td>
<td>23.4</td>
<td>24.0</td>
<td>22.7</td>
<td>22.0</td>
<td>22.0</td>
<td>16.7</td>
<td>14.1</td>
<td></td>
</tr>
<tr>
<td>Grosse Pt. Farms</td>
<td>14.1</td>
<td>15.1</td>
<td>16.6</td>
<td>20.3</td>
<td>21.0</td>
<td>22.2</td>
<td>20.8</td>
<td>20.0</td>
<td>20.0</td>
<td>19.7</td>
<td>15.5</td>
<td>13.2</td>
</tr>
<tr>
<td>Mt. Clemens</td>
<td>13.1</td>
<td>14.7</td>
<td>14.2</td>
<td>18.3</td>
<td>20.3</td>
<td>20.7</td>
<td>19.6</td>
<td>18.6</td>
<td>18.2</td>
<td>18.7</td>
<td>14.9</td>
<td>12.3</td>
</tr>
<tr>
<td>Pontiac</td>
<td>14.3</td>
<td>16.3</td>
<td>17.6</td>
<td>22.0</td>
<td>23.3</td>
<td>23.7</td>
<td>23.0</td>
<td>21.7</td>
<td>21.4</td>
<td>21.1</td>
<td>16.3</td>
<td>13.9</td>
</tr>
<tr>
<td>Harrow</td>
<td>11.7</td>
<td>13.0</td>
<td>13.2</td>
<td>18.6</td>
<td>18.4</td>
<td>19.5</td>
<td>18.1</td>
<td>17.1</td>
<td>17.2</td>
<td>17.4</td>
<td>12.7</td>
<td>11.7</td>
</tr>
<tr>
<td>Windsor</td>
<td>13.0</td>
<td>14.0</td>
<td>14.9</td>
<td>19.1</td>
<td>20.7</td>
<td>20.6</td>
<td>19.7</td>
<td>19.2</td>
<td>18.6</td>
<td>19.5</td>
<td>15.1</td>
<td>13.2</td>
</tr>
</tbody>
</table>
Summary

Throughout this chapter various aspects of temperature distribution were analyzed. The maps and their accompanying explanation showed the existence of a heat island over the urbanized area and the effect of this upon the surrounding area. In the latter part of this chapter the average monthly maximum and minimum temperatures at each station were reviewed. In general the patterns followed were: the existence of a higher maximum over the city and away from the lake while the higher minimum occurred over the city, but toward the lake. The lowest average maximum temperatures recorded were at rural locations inland and to the west of the city. These patterns followed relatively acceptable and expected lines, but it was extremely difficult to justify the reason why some stations were consistently warmer or cooler in relation to neighboring stations or locations having similar characteristics. An example of this would be the existence of the lowest maximum temperature at either Wayne Airport or Pontiac when Willow Run Airport is farther away from the moderating lakes and the city heat.
CHAPTER V
THE DIFFERENCE OF TEMPERATURES
BETWEEN CITY AND WAYNE AIRPORTS

In the year 1933 the Weather Bureau Office at
Detroit was moved from the downtown Federal Building to
the City Airport five miles to the north. The equip-
ment shelter on top of the ten story building was not
taken down at that time, and the temperature was re-
corded there until at least 1938. In that year a short
comparative study was made of the variations between
the two stations over a 52-month period.\(^1\) Ignoring the
variations in altitude, it was found that the Federal
Building station recorded an average monthly maxima
lower than that recorded at City Airport except for the
month of June. However, this variation never exceeded
a monthly average of one degree. It was also found
that the Federal Building recorded consistently higher
monthly minima which averaged two degrees warmer than
the airport between May and October. (See Table 5.)

\(^1\)Root, op. cit.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Maximum</td>
<td>-0.8</td>
<td>-0.3</td>
<td>-0.1</td>
<td>-0.6</td>
<td>-0.2</td>
<td>0.0</td>
<td>-0.2</td>
<td>-0.3</td>
<td>-0.7</td>
<td>-1.0</td>
<td>-0.7</td>
<td>-0.8</td>
<td>-0.5</td>
</tr>
<tr>
<td>Average Minimum</td>
<td>+1.1</td>
<td>+1.5</td>
<td>+1.1</td>
<td>+1.2</td>
<td>+2.1</td>
<td>+2.5</td>
<td>+2.8</td>
<td>+2.6</td>
<td>+2.7</td>
<td>+2.2</td>
<td>+0.5</td>
<td>+1.4</td>
<td>+1.8</td>
</tr>
<tr>
<td>Average Mean</td>
<td>+0.2</td>
<td>+0.6</td>
<td>+0.5</td>
<td>+0.3</td>
<td>+1.0</td>
<td>+1.2</td>
<td>+1.3</td>
<td>+1.2</td>
<td>+1.0</td>
<td>+0.6</td>
<td>-0.1</td>
<td>+0.3</td>
<td>+0.6</td>
</tr>
</tbody>
</table>

In the averages mentioned above, the airport is considered as a base and the City Office values as plus or minus.
At the time of this writing the Detroit Station was once again being relocated with City Airport currently being phased out and closing down in late 1966 at which time Wayne Airport will become the main recording station for the area.2

Comparison Between Wayne and City Airports

For this portion of the investigation a comparison was made between City Airport, the most urban of the first-order stations, and Wayne Airport, the nearest first-order station with a rural location. These two stations are less than 25 miles apart, but are located in markedly different surroundings. City Airport is located in a highly developed urban-industrial area on the eastern (leeward) side of the city and within seven miles of Lake St. Clair. Wayne Airport, to the southwest of City Airport, is surrounded by open rural land. It is also to the windward of the city and is considerably farther inland from the lakes. The altitude variation between locations is less than 15 feet and, therefore, is not a significant factor.

2Personal Interview with John McKinna, Observer, City Airport Weather Station, Detroit, May 21, 1966.
Ignoring the urban-industrial complex and considering the two sites in relation to the natural physical features of the region, one might expect the more inland and windward location to be warmer in the summer and cooler in the winter than at the City Airport site. Likewise, one could expect that the close proximity to Lake St. Clair would have a moderating effect upon the temperature at the City Airport location throughout the year.

The year 1964 was chosen for this investigation and comparisons made of both maxima and minima variations for the warm months (May through October) and the cool months (November through April). In all four instances the City Airport stood out as being considerably warmer than Wayne. (See Figure 2).

Cool Season

During the cooler November through April period the maxima recorded at City Airport were between one and three degrees higher on more than fifty per cent of the days, and at times were as much as five degrees greater. On twenty-one per cent of the days the maxima recorded at both stations were the same. This usually occurred in relation to sudden drops in temperature
Figure 2.
Frequency of Differences of Daily Extremes at City and Wayne Airports, 1964

MAX
Nov.- April
CITY AIRPORT
WAYNE AIRPORT
WARNER
WARNER

MIN
Nov.- April
CITY AIRPORT
WAYNE AIRPORT
WARNER
WARNER

MAX
May - Oct.
CITY AIRPORT
WAYNE AIRPORT
WARNER
WARNER

MIN
May - Oct.
CITY AIRPORT
WAYNE AIRPORT
WARNER
WARNER

DEGREES FAHRENHEIT
over the whole region. Only on twelve per cent of the days did the maxima at Wayne read higher than at City Airport.

For the same time period as above the minima recorded at both stations reacted in a different way. The mode in this case occurred on days when both stations recorded the same minimum temperatures; however, this was only on fourteen per cent of the days. The range of temperature difference was much greater than with the maxima, but again, the City Airport was noticeably warmer than the other, sometimes as much as fifteen degrees higher. Usually the minima at the City Airport were between two and six degrees above that of Wayne and only on four per cent of the days did the latter record higher minima.

The reason for the presence of such marked variations between the two stations during the cooler months cannot be answered solely on the premise of nearness to water bodies. However, the influence of Lake St. Clair would be of significance and would complement the city heat present in the vicinity of City Airport. The combination of these two factors at City Airport and the lack of either at Wayne Airport account for the distinct difference in temperature that does exist.
Warm Season

During the warmer months the City Airport again recorded higher maxima than those occurring at Wayne. The maxima recorded at City Airport were between one and three degrees above Wayne on sixty-nine per cent of the days, and sometimes were as much as five or six degrees greater. The same maximum temperatures were recorded at both stations on fourteen per cent of the days. On one occasion the rural station had a maximum five degrees above that recorded at the city location.

The minima recorded during this May through October period were overwhelmingly higher at City Airport. Ninety-seven per cent of the days recorded higher minima at the city location with differences of as much as fifteen degrees existing between locations. 3

The City Airport minimum averaged between five and six degrees higher for the six-month period and

3 During the interview with John McKinna at City Airport he stated that he would expect his station would have warmer minima than Wayne Airport on more than 80 per cent of the days in any given year.
only on one per cent of the days did Wayne record higher minima.

Once again these variations can not be explained by the natural physical features of the two locations. If we disregard the urban complex we find City Airport in close proximity to Lake St. Clair which should have a moderating effect upon its summer temperatures. Wayne Airport, with its inland and windward location, would be expected to record higher temperatures than at City Airport during the summer months. When the maximum temperatures did register higher at Wayne than at City Airport, the dates were checked to find on what days these readings occurred. In all cases checked for the warm season, the days were either Saturday or Sunday in July or August. These would be days when the industrial plants throughout the city were not in full operation and vehicle movement in the vicinity would be much reduced from the normal weekday congestion.

In comparing the hourly temperature changes throughout the year at both stations it was noted that daily maximum temperatures were usually recorded at approximately the same time (within two or three hours of each other). However, the temperature at City Airport would remain close to the maximum for an extended
period after reaching it while the temperature at Wayne dropped steadily towards its minimum.\(^4\) (See Figure 3.)

Several factors could be responsible for this and one might surmise that heat loss from houses and factories helped maintain the temperature at a high level, or simply the tendency for the concrete paving and brick structures to hold heat for extended periods as opposed to the natural vegetation which gives up its heat more readily. Also, the presence of inert solid matter, gases, and active chemicals in the air over the City Airport would be likely to create inversions that would hold the surface heat at a higher temperature.

\(^4\) Observers at both stations stated that they expected the maxima on most days to occur between 1500 and 1800 hours and both had noted the tendency for City Airport to retain its heat for extended periods while at Wayne Airport the temperature moved almost steadily between its maxima and minima.
Figure 3
A Comparison of the Average Hourly Temperatures at City and Wayne Airports

Average Hourly Temperature
July 1964

Average Hourly Temperature
January 1964
Summary

In summing up the comparison between both stations it is apparent that the maxima averages about three degrees warmer throughout the year at City Airport. The City Airport also retains its heat for a longer period each day, and consequently records a higher daily minima, averaging four or five degrees in the cooler season and five to six degrees in the warmer season above the minima recorded at Wayne Airport.

This comparative study covers only the year 1964, and while the percentages and the degrees of variation would differ if another year or the full seven years had been used, one would not expect to see any great variation in the pattern. The results show that the station located at City Airport, surrounded by industrial and commercial buildings, records higher temperatures, even when Lake St. Clair exerts tempering influences upon it, than the more rural inland station at Wayne Airport. 8

8 For other studies of this nature see Landsberg, op. cit., pp. 599, 600.
CHAPTER VI

THE OCCURRENCE OF FIRST FROST
IN FALL AND LAST FROST IN SPRING

First Frost of Fall

The data used in this portion of the study were limited to one recorded date at each station for each of the seven years of the study period. These dates represented the first time the minimum temperature reached $32^\circ F$ or below in each of the seven autumns. Because this event fluctuated in both time of arrival and in order of arrival at each station, it was impossible to develop an average pattern which could be convincingly mapped. The problem stemmed from the fact that the first frost seemed to occur at random without regard to location of physical factors. Also, there were often several days or weeks between the recording of first frost in the region and the arrival of first frost at every station in the region. Nevertheless, the results of averaging the arrivals at each station did, in some ways, support the expected pattern.
The two central stations of City Airport and Grosse Pointe Farms were found to be the last to receive frosts in the fall, a day behind Dearborn, Pontiac and Windsor, and four days after Wayne Airport and Willow Run. This seemed to indicate that the city's heat, plus the influence of Lake St. Clair, has the ability to forestall the arrival of the first frost. However, the data for Harrow and Mount Clemens did not agree with the developed pattern. Both these stations recorded frost dates in one of the seven years that were completely out of relation with the other stations. Had the study period been longer, the extreme dates may well have been subdued, but with only seven years to work with they tended to distort their average and unbalanced the pattern. For example, in 1961 Harrow received a frost on September 29, but it was not until November 4 that the other inner stations recorded frost. Harrow's southern location would not be suspected of having frosts 36 days ahead of Detroit. The other case in question occurred on October 6, 1958, when five inner stations recorded frost while the more northern lake located Mount Clemens station was not affected until November 7. While the inner stations were difficult to work with,
the outer stations were almost impossible. Inland stations such as Willis recorded frosts a month or more ahead of the city while the lake location of Pelee Island was often a month behind.

Despite these variations that were sometimes present, there were occasions when remarkable homogeneity existed. In 1959 seven of the inner stations recorded minimums below 32°F on October 19; two of the outer stations were also in agreement with this date while one inner station and one outer station had recorded frosts on the 18th. Harrow on this occasion was nine days behind the other. In 1960 Harrow and five other inner stations recorded frosts on October 20, while City Airport and Mount Clemens did not record sub-freezing temperatures until the 24th. In the year of Harrow's extremely early frost (September 29, 1961) Willow Run recorded sub-freezing temperatures on October 15, six inner stations recorded them on November 4 along with several outer stations, leaving only Dearborn which did not record a temperature below 32°F until November 6.  

1In working with this particular data there is always the problem of disparity in the times of observation. First-order stations usually record their
As can be seen from these examples, there was no continuity or pattern in any of these years. Either the majority of the area was blanketed in the same twenty-four hour period or individual stations succumbed to local frosts. Only in the averaging did a pattern develop, and even then an incomplete one.

The ability of Lake St. Clair to forestall the first frost of fall was apparent here. Heat from the slowly cooling lake warmed the surface air over the faster cooling land. The pattern that could be developed from the averaging of data did tend to imply that Lake St. Clair had a strong control over the arrival of first frost, but this pattern was not pursued very far due to the lack of stations surrounding the lake.

For deviations from the average first frost date at City Airport see Table 6.

daily extremes based on the day beginning and ending at twelve midnight. Sub-stations' observation times are usually in the late afternoon. This disparity in time could result in a frost appearing in different daily records, although it may have occurred simultaneously at all stations. However, the writer expects that these frosts would most likely occur in the early mornings and thus fall into the same recording periods.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dearborn</td>
<td>-15</td>
<td>-2</td>
<td>-1</td>
<td>+16</td>
<td>+3</td>
<td>+9</td>
<td>-14</td>
<td>-1</td>
</tr>
<tr>
<td>Detroit A.P.</td>
<td>-15</td>
<td>-2</td>
<td>+3</td>
<td>+14</td>
<td>+3</td>
<td>+13</td>
<td>-14</td>
<td>0</td>
</tr>
<tr>
<td>Wayne A.P.</td>
<td>--</td>
<td>-3</td>
<td>-1</td>
<td>+14</td>
<td>+3</td>
<td>-7</td>
<td>-16</td>
<td>-4</td>
</tr>
<tr>
<td>Willow Run A.P.</td>
<td>-15</td>
<td>-2</td>
<td>-1</td>
<td>-6</td>
<td>+3</td>
<td>+9</td>
<td>-16</td>
<td>-4</td>
</tr>
<tr>
<td>Grosse Pt. Farms</td>
<td>-9</td>
<td>-2</td>
<td>-1</td>
<td>+14</td>
<td>+3</td>
<td>+9</td>
<td>-14</td>
<td>0</td>
</tr>
<tr>
<td>Mount Clemens</td>
<td>+17</td>
<td>-2</td>
<td>-1</td>
<td>+14</td>
<td>+3</td>
<td>-7</td>
<td>-16</td>
<td>+1</td>
</tr>
<tr>
<td>Pontiac</td>
<td>-15</td>
<td>-2</td>
<td>-1</td>
<td>+14</td>
<td>+3</td>
<td>+9</td>
<td>-16</td>
<td>-1</td>
</tr>
<tr>
<td>Harrow</td>
<td>-19</td>
<td>+7</td>
<td>-1</td>
<td>-22</td>
<td>0</td>
<td>-7</td>
<td>-14</td>
<td>-7</td>
</tr>
<tr>
<td>Windsor</td>
<td>-15</td>
<td>-2</td>
<td>0</td>
<td>+14</td>
<td>+3</td>
<td>+8</td>
<td>-14</td>
<td>-1</td>
</tr>
</tbody>
</table>
Last Frost of Spring

The last sub-freezing temperature recorded in the spring most often occurred on the same date at several area stations, and once again there seemed to be no pattern to any one year’s records. Any combination of the nine stations may experience last frost at the same time with absolutely no regard to environmental controls. An example of this was the occurrence of the same last frost dates at both Grosse Pointe Farms and Willow Run Airport for six of the seven years studied.

As in the case of the first fall sub-freezing temperature, all stations within the study area may receive their last spring frost within a 48-hour period. In 1960 Harrow experienced its last frost on April 18 and the other eight stations recorded it on the 19th. In 1962 the spread was only slightly greater with seven stations experiencing the condition on April 17 leaving Pontiac and Wayne Airport to record theirs on the 19th and 23rd, respectively. The complete randomness in regard to regional grouping or physical features was clearly demonstrated in 1963. In that year Dearborn, Windsor, City Airport,
and Harrow experienced their last frost on May 1st. While the first three stations mentioned share some common qualities such as proximity and nearness to the central city, Harrow does not. It was not until May 23 that the other stations in the area experienced last frost while the above stations remained above 32°F. The stations recording 32°F temperature or less on this occasion were located to the west, east and north of the first-mentioned stations and had both inland and lake shore locations.

A very distinct pattern was developed by averaging the dates of last recorded spring frost for each of the nine stations. Map 8 was developed from this data. However, the validity of such a statistical map is questionable for the reasons shown above and because of the limited study period used here. Based on the City Airport average last frost date of April 20, the isopleths represent two-day intervals in the arrival of the last frosts. The gradients throughout the study area were relatively gentle except for the steep eight-day gradient between City Airport and Grosse Pointe Farms. This particular gradient, while based entirely upon the seven year data, was far steeper than anticipated and could be expected to
Map 8

Last Frost Day of Spring
Averaged Between 1959-1965
(All days fall in April)
diminish somewhat with the addition of more years to the study period.

City heat seemed to have the most effect upon the pattern developed here. The lake at that time would be relatively cool as opposed to the land which would be warming rapidly. Lake St. Clair's influence was somewhat subdued and, as has been shown in the preceding chapters, the city heat was most pronounced when the lake's influence was reduced.

Summary

The patterns developed by averaging the dates of the occurrence of both first and last frosts of the cool season were in agreement, to some extent, with the expected pattern. Lake St. Clair seemed to exert control over delaying of the arrival of first frost in the fall while the city heat tended to produce an early departure of sub-freezing temperatures from the urban areas in the spring.

The occurrence of first frost at nearly all stations at one time during some years indicated the possibility of sudden drops in temperature associated with the passing of a cold front. On researching this point further it was found to be so. The November 4,
1961, example mentioned earlier was directly associated with the passing of a cold front and the positioning of a high pressure cell south of Detroit. The October 19, 1959, example was similarly associated with the passing of a front on October 17 and the location of a high pressure cell of Continental Polar air over the city of Detroit on October 19.

The data used here and the explanations given only apply to the study period. Further elaboration would tend to be pure conjecture at this stage.
CONCLUSIONS

A description and analysis of the distribution of surface temperature within the Detroit region has been presented in this paper. The accuracy of this description was slightly weakened by the location of the stations which left large areas of the region without adequate coverage. Interpolation between stations was done in the most objective way so as to produce the most probable temperature distribution.

The data used here showed Detroit suburban stations as having temperatures warmer than at stations north and west of them, and comparable temperatures to stations one hundred miles or more south of them throughout most of the year. Because of these warmer temperatures the natural trend of the isotherms lying across this region was distorted, producing circular arcs around the urbanized area. Enclosed isotherms showed the existence of heat islands within the region. Detroit was seen as having a temperature anomaly in relation to its latitudinal location.

The heat islands that existed in the Detroit region were found to have different diurnal and seasonal
locations. These were explained as being the result of two factors that at times complemented each other, while at other times were directly opposed. First, the city had a capacity to produce heat by various means. This warmed the surface air creating higher temperatures within the urbanized area. The second was the influence of Lake St. Clair upon the surface temperature within the region. This is known as the lake effect and was found to vary with the degree of difference existing between lake temperatures and city heat. During the times when the surface temperature in the urbanized area exceeded that of the surface temperature over the water, the lake acted as a cooling agent and reduced the temperatures over the eastern portion of the city. At times when the surface temperatures in the city fell below lake temperatures the air from the lake became a warming element raising the surface temperatures recorded along the shore and in the eastern portion of the city.

To separate the temperatures caused by city heat and those due to the lake effect was difficult and beyond the scope of this study. Nevertheless, the presence of both these factors was observed in the investigation. Had the city heat not been present
during the time of summer maximum, Willow Run would have been expected to register the highest temperatures in the study area while temperatures would have decreased towards the lakes. Instead it was found that temperatures increased over the western suburbs and then decreased as the location of the stations neared Lake St. Clair. At the time of winter maximum the reverse situation would have been expected, with Willow Run recording the lowest maximum temperature and Grosse Pointe Farms the highest temperature. Once again, there was an increase of temperature over the urbanized area, indicating the presence of city heat.

Through both summer and winter the city experienced higher maximum temperatures than both lake and interior stations. However, the highest minimum temperatures in both seasons seemed to be more the result of the lake effect which prevented stations within a reasonable distance of the lake from experiencing large diurnal ranges.

In comparing the differences in temperature between a central city location and a western fringe location (Chapter V), it was noted that in the year 1964 the station at City Airport experienced warmer
temperatures than the station at Wayne Airport on a large percentage of the days. While this could be expected during the winter months due to their relative distances from water bodies, the presence of higher temperatures through the warmer months indicated the existence of other heat sources in the vicinity of City Airport. It was also observed that the city location tended to hold its heat for longer periods of time experiencing slower diurnal cooling than at the more rural location.

The occurrence of the first and last frosts of the cool season showed the lake influence and city heat working as separate factors. During the fall the warm lake retarded the arrival of frost in the area while city heat hastened the departure of frost in the spring. Through these two factors the urbanised area experienced a longer period of frost-free days than stations in the region having a more interior and rural location.

While the purpose of this study was only to investigate the distribution of surface temperature, the underlying problem throughout has been to separate the two prime causes of the temperature anomaly existing in the region. Separating the degree to which
city heat and lake effect contribute to the climate of a city will prove to be a problem in many future studies of this nature. The reason stems from the fact that most cities of large population in this country have coastal or lake shore locations. Smaller cities of more than 100,000 population with interior locations would most likely experience city heat over their urbanized and commercial areas but would not have a network of weather stations within their region to supply the needed data to isolate this phenomena. It seems apparent that techniques must vary with the types of cities being investigated and that new techniques must be sought to separate the influences affecting temperatures in regions like Detroit.
BIBLIOGRAPHY

Public Documents


Books


**Articles and Periodicals**


Kraus, E. "Climate Made by Man," Royal Meteorological Society, Quarterly Journal, LXXI (1945), 397-412.


______. "Die Temperaturverhältnisse von Karlsruhe an heissen Sommertagen," Deutsches Meteorologisches Jahrbuch, Baden, LXI (1929), 59, 60.


Interviews


Willow Run Airport. Personal interview with members of the Weather Bureau Staff. May 20, 1966.

Windsor Airport. Personal interview with members of the Meteorological Branch Staff. May 20, 1966.