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Temperature Influences of Lake Erie

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TEMPERATURE INFLUENCES OF LAKE ERIE

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INTRODUCTION

It is a generally accepted fact that large bodies of water exert a decided influence on the climate and on the cultural development in the immediate vicinity. Just how much and at what times this influence is most felt has always been more or less a matter of conjecture. There are many variables which force themselves into the picture to the extent that it is difficult to determinte which one is at work at a particular time. Among these variables might be mentioned distance from the lake, elevation of land above the lake, angle of incidence of the sun's rays, percentage of cloudiness, and wind directions.

Recently, Dr. John B. Leighly of the University of California has published a paper on the march of temperature along the California coast.[1] His method was to present a series of mathematical equations, the solution of which would give the time of maximum and minimum temperatures. In his work is included a simple drawing table construction which places approximately the time of occurrence of the extremes of temperature. The end product of all his work is a method of interpolation for points between those of the regular weather observation stations. The checks on his results indicate the very high percentage of conformity to the general equations which he has set down. The results of Dr. Leighly's investigation represent the culmination of several

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[1] Leighly, John B., Graphic Studies in Climatology, University of California Press, 1934.

years work and hence are far beyond the results hoped for in this investigation.

Among the many climatic factors, such as snowfall, barometric pressure, wind direction and cloudiness, perhaps the most discussed and the one which affects more people directly is temperature. It was therefore throught best to represent those phases of temperature in a graphical way so that its effects could be seen in a quantitative way as well as in a qualitative way. The series of maps and graphs included in this paper illustrate just when and to some degree how much the lake influences the temperature of the surrounding land area. The limitations placed on the "how much" part of the preceding statement are necessary because of the many other factors entering to affect the temperature at the same time the lake is casting its influence.

Temperature is perhaps the most important of the climatic elements, along with rainfall, in so far as the general population is concerned. A majority of the people depend upon the soil from which to gain their livelihood, and before the soil can produce a crop it is necessary to have sufficient rainfall, and of course minerals, for plant growth and the temperature must be such as to permit the growth of various products. As can be seen from a produce map of the United States it divides itself into sections in which temperature conditions especially, along with others of less import determine the crop grown. Thus we see clearly defined the palm belt, the citrus belt, the cotton belt, the corn belt, the spring wheat belt and the winter wheat belt.

Ordinarily, northern Ohio should be included in the grain and pasture belt as far as latitude and comparison with surrounding regions is concerned. But rather we find a conspicuous fruit belt extending across northern Ohio parallel to the shores of Lake Erie. The principal reason for this fruit region is the retardation of growing season in the spring and the prolongation in the fall, which will be shown in the chapter on the length of growing season. A late spring prevents the premature budding of trees and then, occasionally, the killing of the buds by the common late frost. The late frosts in autumn prevent frequent entire loss of crops by occurring after the crop of fruit has been harvested.

The temperature of a region reflects itself in a monetary way. The types of homes constructed are greatly influenced by the ruling temperature conditions. The disappearance of the "storm window" is a notable example of reduced expenses in home construction in northern Ohio. The late fall also reduces expenses in regard to fuels needed for heating the homes. This advantage is, however, partly overcome by the later warm weather in the spring.

Transportation is to some degree affected by the controls of temperature. Thus we see motor vehicle transportation carried on to almost a maximum degree along the south lake shore. Mild temperatures in fall prevent early blocking of highways by snowfall or by ice storms. A fairly early spring, with regard to "above freezing" temperatures also keeps highways open. Lake steamer transportation can be carried on until sometime in December. The importance of ice disappearing from the lake in spring is clearly shown by the rush to get the first boat through on the earliest possible date.

Temperature changes which occur very rapidly affect the health of the general populace and thus affect their efficiency. A large body of water tends to minimize these rapid changes and thus eliminates in part the occurrence of many minor health difficulties.

The wide range of interest in temperature and the importance to the daily affairs of the large majority of the populace is the reason for choosing it as the most influential element of the climate of northern Ohio. Of course, each of the other climatic factors could be treated in like manner and some perhaps more extensively, but by and large each would be a paper in itself. Hence, the following paper is just a treatment of one climatic element in itself, and this in turn would have to be correlated with treatments on the other phases of climate to give a complete picture of the influences of Lake Erie on the climate of northern Ohio.

GENERAL WEATHER CONDITIONS

Northern Ohio is located in the belt of prevailing westerly winds. As a result the expected winds throughout most of the year are from the west and southwest. With a variation in direction of the lower and higher terrestrial wind directions, secondary eddies are set up which result in the formation of passing highs and lows. These are driven by the prevailing lower winds, but are probably formed by conflict between the prevailing high winds and the prevailing low winds. Since the section under discussion lies in the prevailing westerly wind belt, the high and low pressure areas pass from west to east.

The variations in distribution of weather elements about the passing highs and lows causes a great daily variation in weather in northern Ohio. The distribution of weather elements about the highs and lows is so varied that the type of weather which a particular region will have depends to a high degree upon the location with respect to the centers of the cyclonic storms.

Location to the north of a passing low will result in clear skies, north winds and a comparatively low temperature. Location to the south will result in cloudy skies, rain, rising temperatures and a sudden change in temperature as the wind shift line is approached.

The size of the high and low pressure area is usually from 200 to 1000 miles in diameter and they move with a moderate rate of speed -- 30 to 40 miles per hour. Thus it is seen that next to the sun, which produces rather regular changes in temperature, the most influential determinant of temperatures of the section is the variable pressure sequence introduced as eddies passing from west to east and caused by conflicts between direction of upper air currents and those air currents nearer the surface.

Spring does not come on with a rush in the region of northern Ohio. The increase in temperature is slow and rather irksome. As is the case in the region of cyclonic storms the southerly winds bring rain and cloudy weather, but the north winds do not bring the clearing skies and bright sunshine. The north winds are usually cold and raw until the lake has undergone appreciable heating. Travelling toward the lake in the spring one notes an increasing percentage of cloudiness. Occasional snow storms and squalls are to be expected until the middle of April. A good general picture of northern Ohio's spring can be given by saying it is a good maple sugar region. That is, the evening temperatures drop below freezing and the day temperatures rise into the forties.

Conditions in the fall are usually just the reverse. With the cyclonic highs passing to the south of the lake the autumn days are warm and clear. Cloudiness does not increase on approach to the lake, but rather decreases as the air passes from the cooler land toward the warmer lake-controlled land temperatures as found nearer the lake.

The spring and autumn seasons are the times when the lake's influence is felt most. The stabilizing of temperatures continues through the summer, but is overcome by the far superior forces of sun elevation and prolonged heating of the surrounding land surface. In autumn the temperatures are directly affected until the appearance of ice on the lake which then acts as a body of land.

LENGTH OF GROWING SEASON

The growing season in Ohio varies from 150 days to 192 days.[1] The longer of these periods occurs in the extreme southwestern part of the state and along Lake Erie. The area included within the 192 day isopleth is much larger — about twice — along Lake Erie than in the southwestern part of the state, but in the lake region we have three isopleths running practically parallel to the lake shore. Thus we see a decrease in growing season as we progress from the southwestern part of the state toward the north and east and also a decrease as we go southward and away from Lake Erie.

The retarding influence of the lake is shown more clearly on the isopleth maps for the average dates of the first and last killing frosts.[2] The average progression of the dates of killing frost is about a mile per day in the region away from the lake. The regularity in the isopleths is broken after one gets about twenty-five or thirty miles from the lake. This apparently is about the maximum distance to which a body of water the size of Lake Erie would cast its influence over adjacent land masses. Of course there would be short periods of minor irregularities, such as a strong north wind, when the lake's influence would be felt for perhaps fifty miles and with a south wind there might be no influence at all.

The spring isopleths show a retardation in growing season, not as clearly as the prolongation indicated for the autumn. On the

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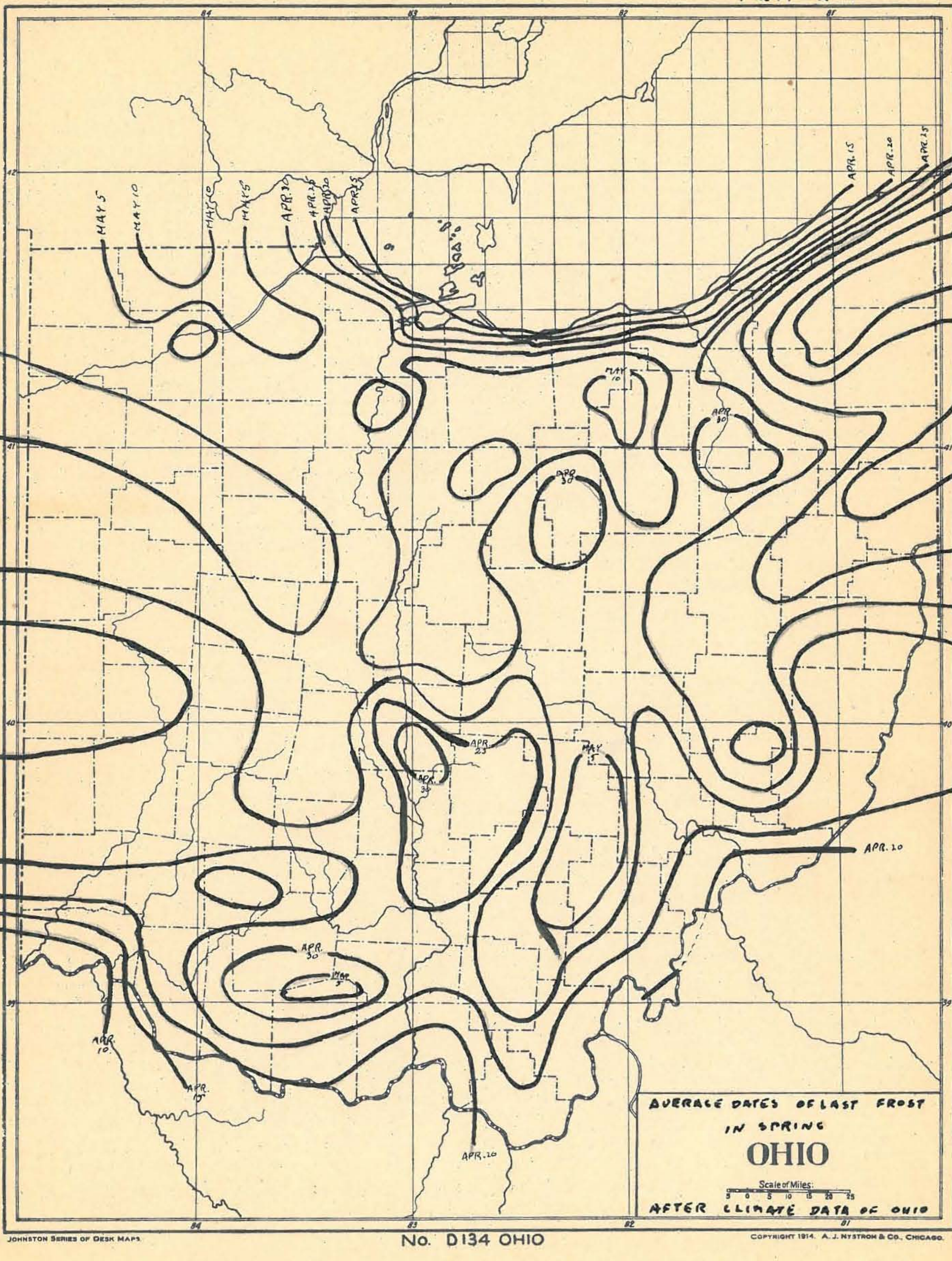
[1]See Plate III
[2]See Plates I and II

average the growing season near the lake is extended for at least ten days more than any other place in the state.

The peculiarities of weather along the lake shore is directly responsible for the type of crops grown in this region. Like many other marine influence regions typical crops grown are those which require a retardation in spring and a comparatively late fall for full maturing of the crop. Among these might be mentioned apples, peaches, plums, and grapes. Interesting comparisons could be made between the crops grown and the temperature curves, but the former would necessarily embody a paper in itself.

PLATE I



AVERAGE DATES OF LAST FROST IN SPRING
OHIO
Scale of Miles
AFTER CLIMATE DATA OF OHIO
MAY 5
APR. 30
APR. 25
APR. 20
APR. 15
APR. 10
MAY 10
MAY 15
MAY 20

PLATE A

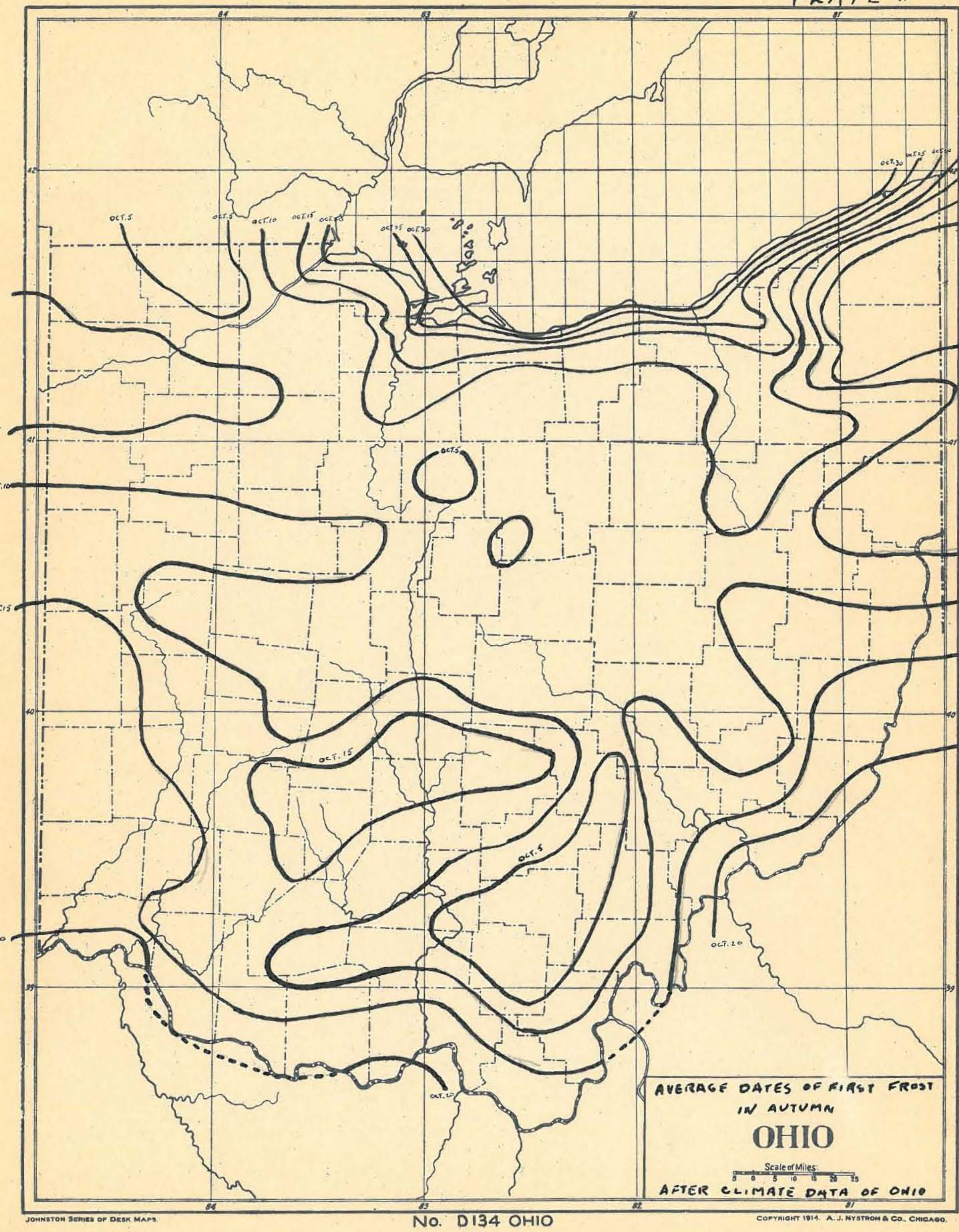

AVERAGE DATES OF FIRST FROST
IN AUTUMN
OHIO
Scale of Miles
AFTER CLIMATE DATA OF OHIO
OCT. 5
OCT. 10
OCT. 15
OCT. 20
OCT. 25
OCT. 30
SEPT. 30
JOHNSTON SERIES OF DESK MAPS.
No. D134 OHIO
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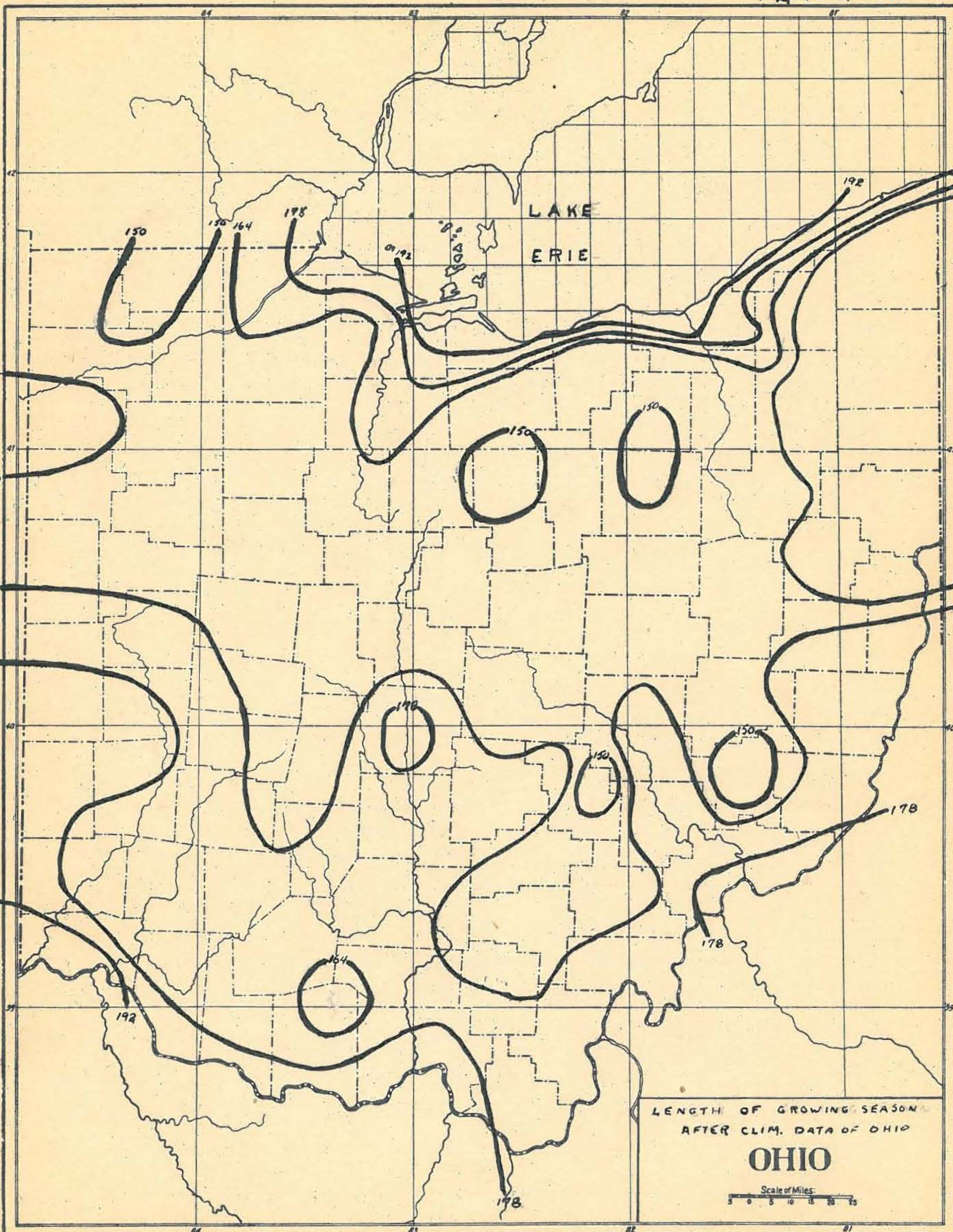
PLATE III



JOHNSTON SERIES OF DESK MAPS. No. D134 OHIO COPYRIGHT 1914. A. J. NYSTROM & CO., CHICAGO.

MARCH OF TEMPERATURE

The march of temperature represents the progression of temperature fron one season to the next, due to variability in the insolation received on the particular land area as a result of increase or decline in the elevation of the sun. The curves represented are of the usual order with a minimum in either January or February and a maximum in July or August. It is not until the temperatures curves, of various stations on a line drawn at right angles to the lake, are placed side by side that inferences can be drawn as to the relative effect of the presence of a large body of water. The curves clearly show the retardation of temperature increase of stations located near the lake and rapid increase of those pregressively farther from the lake. The maximum temperatures for all of the stations occur during the month of July which is an indication that by the time of greatest heating of the land surface, the lake has been warmed enough to eliminate practically all influence which it might noticeably have upon the surrounding land.

Ashtabula[1] is located 2.22 miles from Lake Erie. With it are compared the stations of Warren which is 31.6 miles from Lake Erie and Canfield which is still farther south. The ordinates of the graphs have been purposely exaggerated to illustrate more clearly and conveniently the temperature differences which do occur even though they are within five degrees at the most. Actual temperatures have been plotted introducing an error of about 1.6

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[1] See Plate IV

degrees for every three hundred feet difference in elevation. The greatest differences (320 feet) occur on the first plate of this group, the remaining two have much less variation.

The most significant things to be discussed in this chapter are the crossing of curves in the early spring, mid-summer, and winter, and along with this the resultant reversal of vertical distribution of temperatures for each of the three plates at the above mentioned times.

On Plate IV the difference in rate of heating of land and water is clearly shown in the spring. Warren and Canfield have temperatures of from two to five degrees higher than Ashtabula. This might at first glance be attributed to the more southerly location, but in the fall the two inland stations have lower temperatures than Ashtabula which is nearer the lake.

Put-In-Bay has an irregularity that is hard to explain. The average temperature for March is several degrees above the normal. Thus the march of temperature curves[1] are irregular. As can be clearly seen if the curves for Put-In-Bay were smoothed out, the same conditions as in Plate III would exist. One explanation may be the presence of the local high pressure area formed over the lake proper at the time the land surface is just beginning to heat. With the high pressure area would be found clearer skies and increased solar insolation in comparison to the more cloudy regions farther from the lake. The land surface near Put-In Bay

[1] See Plates V and VI

would be heated to such a degree that it would be noticeable in recordings of instruments located five feet above the ground. Ashtabula[1] also indicates a marked increase in the temperature for March, but since it is located 2.2 miles from the lake the effect is not enough to place the curve above those of Warren and Canfield.

These conditions would exist only as long as a local high pressure remains over Lake Erie and, as shown by the curves, it does disappear fairly rapidly. A more definite conclusion concerning this anomoly could be drawn were a careful investigation made of such factors more likely to influence the local conditions, such as, wind direction, barometric pressures and percentage of cloudiness.

The temperatures for the stations away from the lake remain above those nearer the lake until after the sun has reached its maximum elevation on June 21 and begins to decline. Thus we have temperature curves crossing and reversal of temperature conditions at or about the time of summer solstice. The curves for the stations near the lake remain parallel to each other while those farther away take a sharp drop in slope. However all of the stations experience a maximum of temperature in July.

In mid-summer the curves recross. This is because the land surface has reached its maximum period of heating (summer solstice) and the lake being slower to react to heat and to temperature changes is still below the average temperature of the surrounding land area. Thus the lake continues to rise to higher

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[1]See Plate IV

temperatures more rapidly than does the land hence the temperatures in the immediate vicinity of the lake also rise in a correspondingly higher rate than those of stations farther away. From mid-summer on the inland stations continue to record lower temperatures than those nearer the lake. This can be explained by the fact that the lake has begun to yield heat as a stabilizer of temperatures. The lake water is now in the period of its maximum temperature and thus it heats the surrounding air masses. On clear calm nights of autumn when the cooling of land is very rapid due to a high rate of radiation the lake holds an even temperature because of its higher specific heat. The higher temperatures at night bring up the daily averages a decided degree since daily averages are a computation derived from taking the average of temperature readings of 7 a.m., 2 p.m., and 8 p.m. Thus it can be seen that night temperatures enter into two of the three components and will influence the result greatly.

The same reasons used in the preceding paragraph will help to explain why lake stations during this month should have a higher maximum temperature than inland stations. The observation stations are located on land surfaces. Hence during the daytime they are subjected to a high rate of heating due to the absorption power of the dark soil surface. Local lows are set up over land areas developing stagnant conditions in general and thus little chance is given for the lake to cool the atmosphere over land. At night, however, radiation takes place over land and water. Over the land away from the lake the rate is very high, but near the lake the water maintains a fairly even temperature throughout the night so that the radiation is not so rapid. Of course since the rate of transfer of heat is directly proportional to the differences in temperature between the emitting body and the receiving body, the rate of decline in temperature for land masses near the lake is lower than for those away from the lake.

The temperature of near-lake stations remains higher than those away from the lake throughout the late summer and fall. This condition exists until late November or December. In early December the lake freezes. It then acts as a land mass because the ice has reached a minimum temperature and acts as a blanket for the underlying water. In severe winters Lake Erie will freeze entirely across the shallow parts. Thus it is seen that the temperature readings near the lake begin to drop very rapidly until they again cross with those of the more southerly stations. The result is the expected vertical distribution controlled purely by latitudinal displacement.[1]

The crossing of lines on Plate IV does not occur until late in January. This condition is a result of the prevailing northwest winds in the winter time in northern Ohio. Thus Ashtabula, Warren and Canfield stations located on the north turn of the southern shore of the lake, experience a longer period in which to receive the stabilizing benefits of the higher temperatures of Lake Erie. As a result of the above conditions there is only a short period in the eastern section of the lake shore where the temperature distribution is consistent.

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[1]See Plates V and VI

AVERAGE DAILY TEMPERATURES

Since northern Ohio is located in the belt of the prevailing westerly winds and in the path of cyclonic storms the daily average temperatures are very irregular from day to day. The irregularities, however, are rather consistent in their occurrences, as might be expected from the rather consistent period of passage of highs and lows. These irregularities in weather conditions help to emphasize the influence of Lake Erie on the regions within fifty miles of the lake

The months chosen to illustrate the effect of a large body of water were again those of June and November when the effect of solar insolation is of decidedly different intensities on land and on water. The ability of water to impart a more even temperature to the air above is most noticeable during these months because of its higher specific heat, and hence, its slower heating in spring and its slower cooling in fall.

The condition of the sky in these transition months is a very important factor. Radiation may take place more rapidly if the skies are clear in the evening resulting in abnormally low temperatures, but on the other hand, exceptionally high temperatures may result by day. Highs or lows with very steep gradients may cause indrafts or outdrapfts of warm or cold air and also produce conditions out of the ordinary, but usually two as compared are located near enough to each other to eliminate any great error due to these causes.

From the accompanying graphs the slowness of stations near the lake to react to sudden changes in weather is readily discernible. The temperature curves of near-lake stations are much more stable than for those stations farther from the lake. Moreover, the curves of the latter have more frequent variations as well as more pronounced changes. In general, the temperatures of inland stations rise considerably above those for lake stations during warm periods and drop considerably lower during cold spells. These again are effects of the higher specific heat of water as compared to that of land. The minor fluctuations as occur over land areas are wiped out by the stabilizing influence of the presence of the lake.

The range of temperature as shown in the accompanying table illustrates the effect of the lake on temperatures. These figures are taken for the months of June and November, 1936. The maximum temperatures of all the stations do not vary to any great extent, but the minimum temperatures of stations at the lake are from 10° to 15° higher than for those away from the lake.

Except for the points of excessively high temperatures, the retardation of temperature along the lake is not as noticeable on the daily temperature graphs as it is on the graphs for the monthly mean temperatures. However, the November curves all show the retardation of decline in temperature of near-lake stations as compared with those farther inland. Upper Sandusky, Bangorville, and Canfield all average about two degrees lower than their corresponding lake stations Put-In-Bay and Jefferson.

The march of temperature is well illustrated by these curves. The gradually increasing daily means of all the curves for June represent the increasing amount of insolation received as the month progresses. In November the decrease in the daily average temperatures as winter sets in is still more clearly marked. A very accurate march of temperature curve could be gotten by drawing a graph illustrating the daily average temperatures over a period of a year and thus some otherwise unnoticed irregularities might come to view.

The rate of heating of a land mass as compared to a water body is clearly shown on the June daily average curve for Put-In-Bay and Bangorville. On the fourth of the month, both stations indicate a rising temperature although Bangorville starts at a temperature 5^{o} below Put-In-Bay, it soon surpasses the latter in temperature rise and then begins to take a sharp turn downward while the recording for Put-In-Bay holds to a maximum.

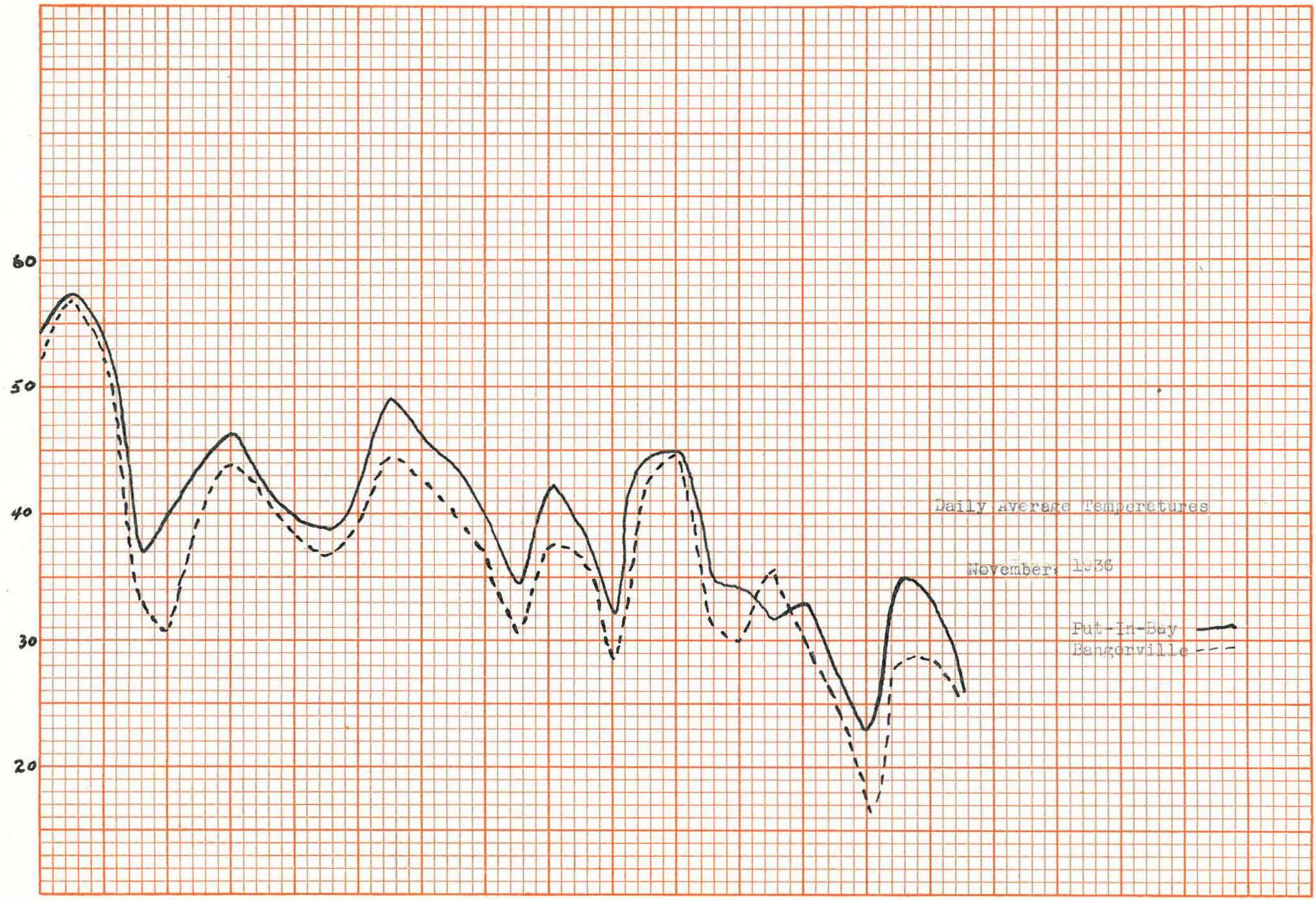
The rapid cooling of land in late autumn is clearly shown on the curves for November. Especially noticeable is this condition during the last week when a rapid decline in temperatures occurs for the near-lake stations as well as for those farther from the lake. However, the temperature for the stations away from the lake (Upper Sandusky, Bangorville, and Canfield) drop 8^{o}, 4^{o}, and 7^{o}respectively, below their corresponding lake station temperatures.

TABLE I

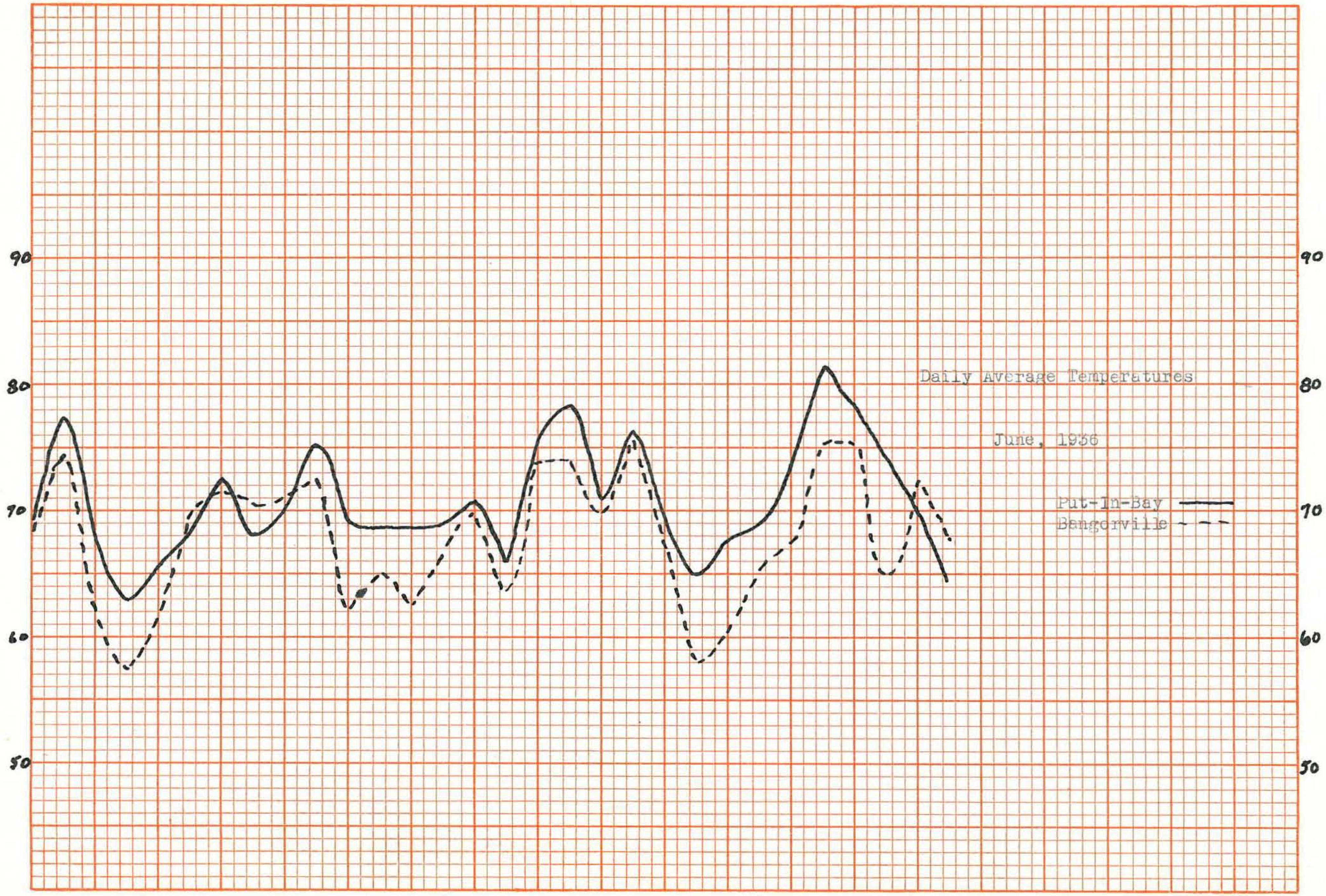
JUNE

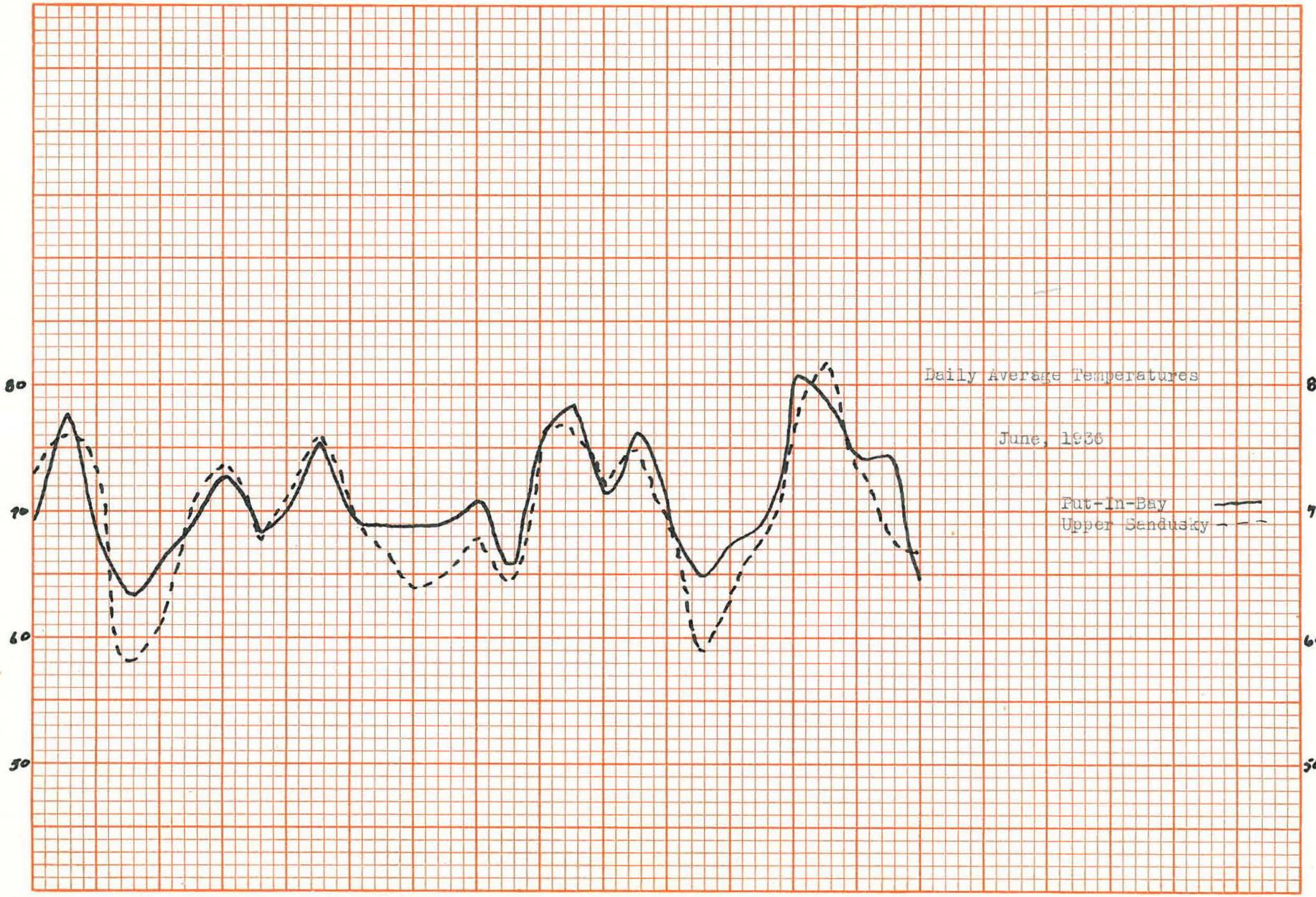
Station	Maximum	Minimum	Range
Upper Sandusky	82	58	24
Put-In-Bay	81½	64½	17
Bangorville	75	53	18
Jefferson	79	13	66
Canfield	80	14	68

NOVEMBER Station	Maximum	Minimum	Range
Upper Sandusky	59	14	45
Put-In-Bay	57	32	35
Bangorville	56	15	41
Jefferson	56	27	29
Canfield	57½	27½	30

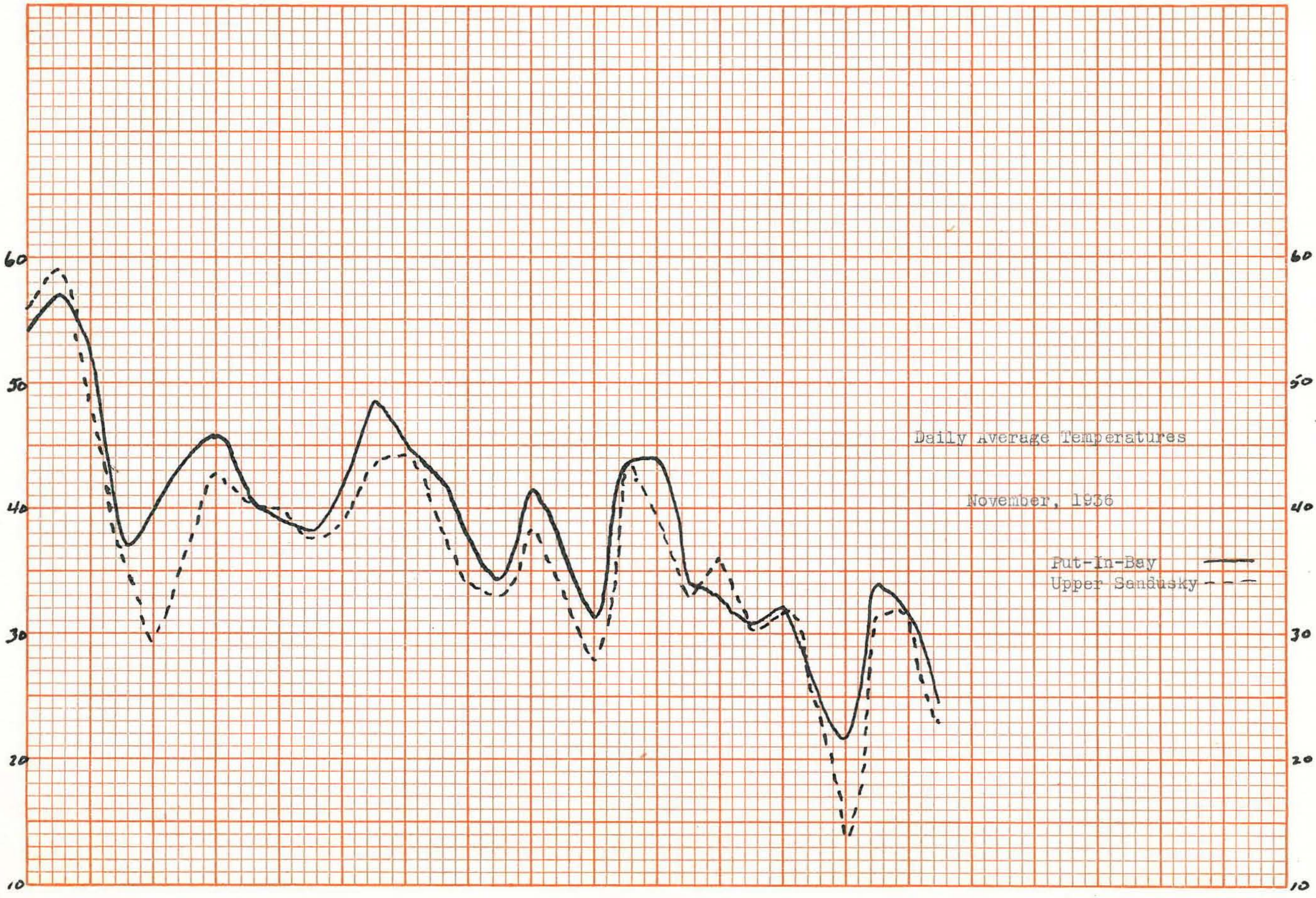

60
50
40
30
20
Daily Average Temperatures
November, 1936
Put-In-Bay
Bangorville

2

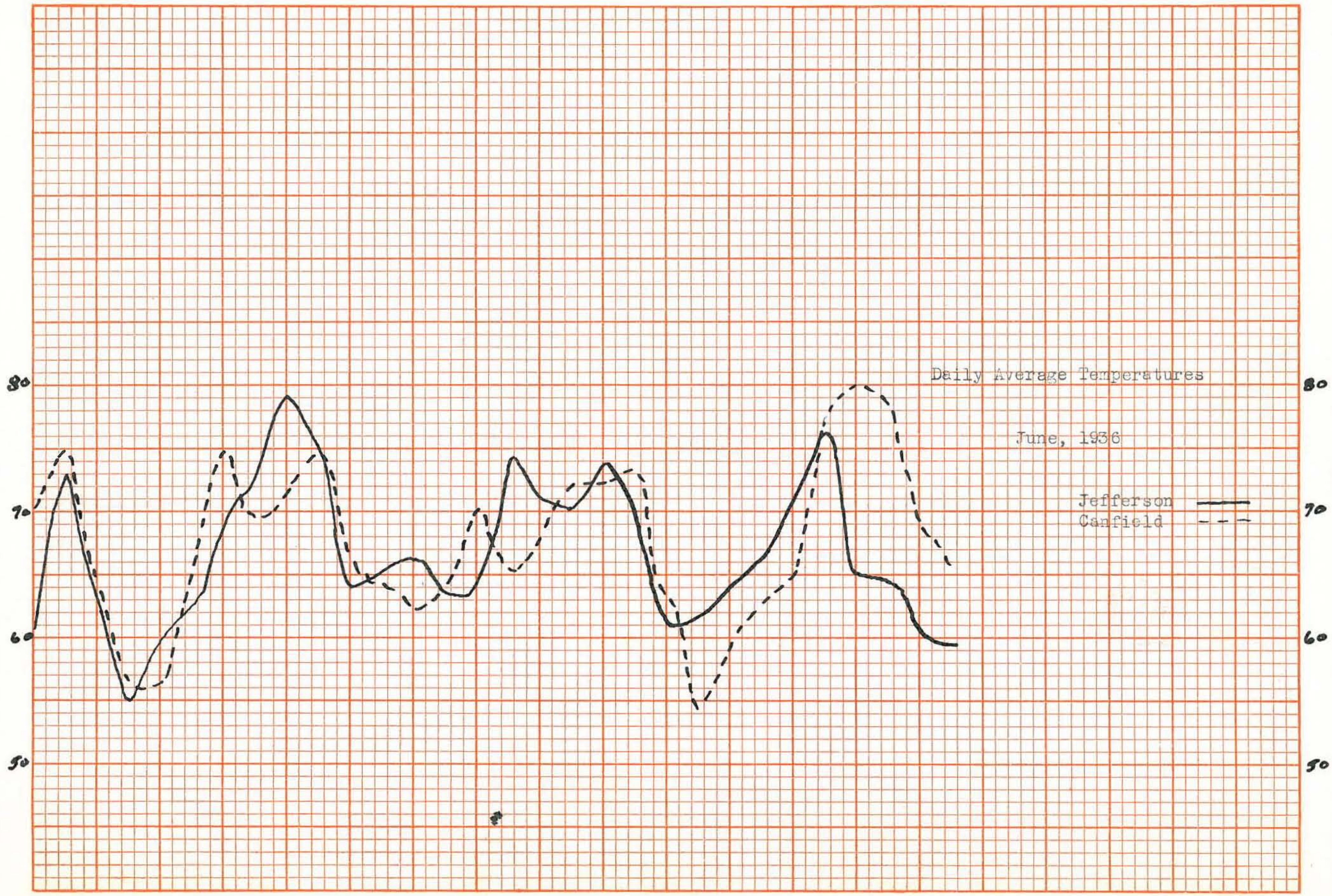

Daily Average Temperatures
June, 1956
Put-In-Bay
Bangorville
90
80
70
60
50


Daily Average Temperatures
June, 1936
Put-In-Bay
Upper Sandusky
80
70
60
50

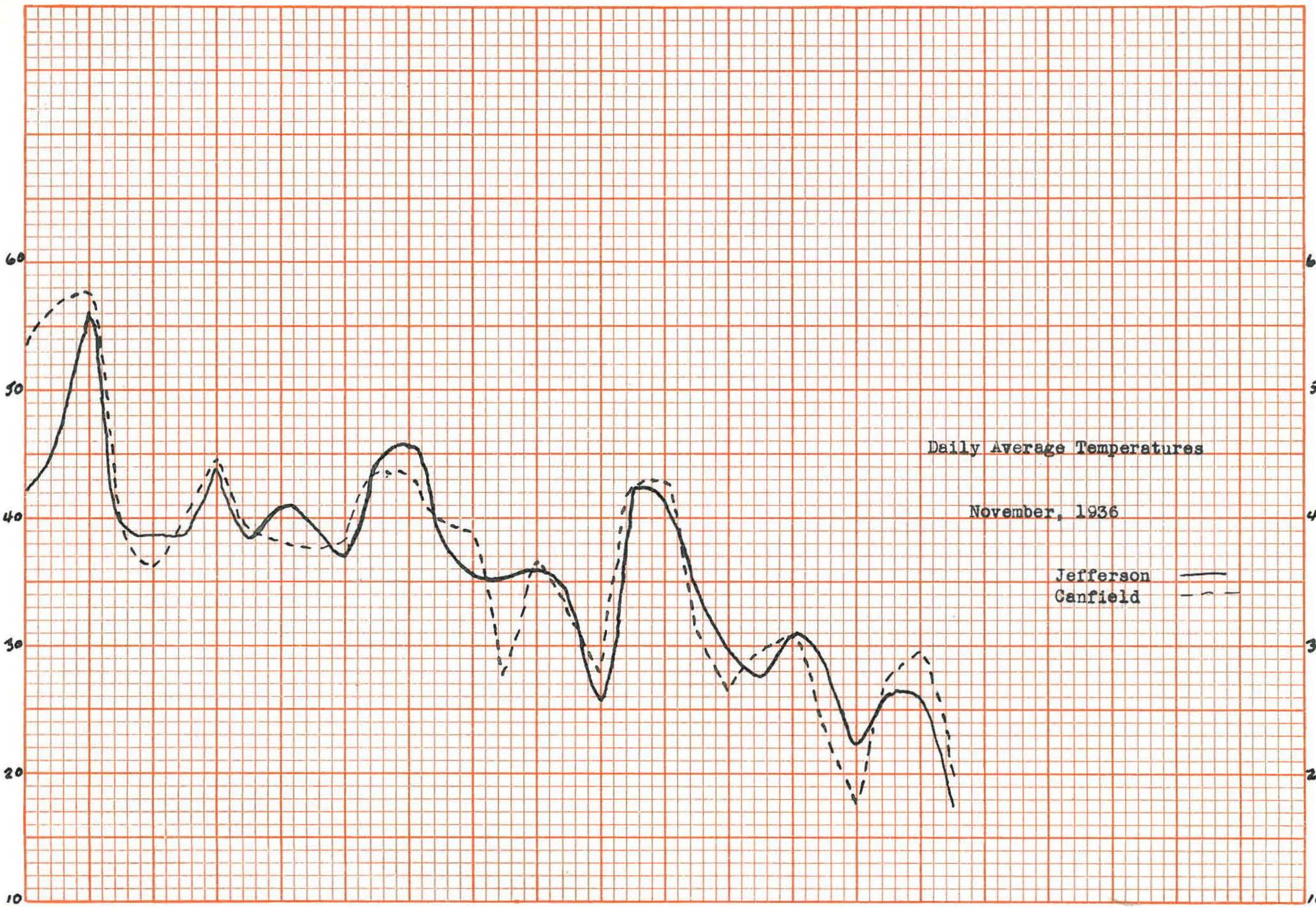
4


Daily Average Temperatures
November, 1936
Put-In-Bay
Upper Sandusky
60
50
40
30
20
10

5


Daily Average Temperatures
June, 1936
Jefferson
Canfield
80
70
60
50

6


60
50
40
30
20
10
Daily Average Temperatures
November, 1936
Jefferson
Canfield

WIND DIRECTIONS

The following tables represent a compilation of wind directions for the months when the lake would exert the greatest influence on the surrounding land area, and would be at a maximum variation from it as regards temperature.

According to the march of temperature curves previously discussed, May and June are the months when the land temperatures are just beginning to exceed the lake temperatures. Thus it might be expected that the effect of local high pressure area on wind direction would not be noticeable until after the land temperatures are appreciably higher than the lake temperatures. Throughout the winter, the lake acts as if it were a body of land since it is frozen or near freezing temperature. However, in the spring the land warms very rapidly with increase in elevation of the sun and, with cold lake water, a local high pressure area may be expected to form over the lake. Since northern Ohio is in the belt of prevailing southwesterlies one would expect the winds of winter to be prevailing in that direction, but when the high is formed over the lake a change in wind direction might be expected since the movement of air is in a clockwise direction from a high pressure area in the northern hemisphere. The tables indicate a decided shift in prevailing wind from the southwest to the northeast in the late spring and summer months. Enough investigation has not been carried on to state definitely whether the occurrences of wind variation are due to local conditions in entirety or if the presence of a local high acts as a line of least resistance and induces other highs of the cyclonic storm belt to follow a route over the lakes region. It is suspected that the latter is true since no coordination is apparent in the wind directions and distance from the lake as would be the case if a local high were the control at that season.

In the fall and early winter the reverse conditions exist. The wind directions again swing back to the southwest, and so decidedly as to indicate other conditions existing besides the influence of the prevailing southwesterlies. Apparently, parallel but reverse conditions exist in the fall as compared to the spring. The lake retains its heat longer than the land and hence either a local low might be casting its influence entirely or it may be acting in such a way as to attract the passing lows of the cyclonic storms. Again it seems that the latter condition is most influential since there is no correlation between distance from the lake and wind directions.

In order to draw any absolute conclusions, the daily weather maps and pressure distributions would have to be studied very carefully, and a careful investigation made of existing topographic conditions which might influence recordings of wind directions. The latter condition is quite obvious in the recordings for Warren, Jefferson and Canfield, where the valley trends and fairly high relief are such as to maintain a fairly constant wind direction.

TABLE II

WIND DIRECTIONS

May, 1936

	N	NE	E	SE	S	SW	W	NW	Var.
Put-In-Bay	1	2	5	1	3	7	2	3	7
Fremont	5	5	-	-	4	11	3	3	-
Upper Sandusky	4	3	-	2	-	13	4	6	-
Norwalk	6	5	1	-	1	14	3	1	-
Mansfield	3	6	1	3	6	9	-	4	-
Bangorville	1	4	-	1	6	9	-	4	-
Jefferson	-	-	-	-	-	3	24	4	-
Warren	5	-	-	3	1	12	1	9	-
Canfield	5	-	1	-	2	5	11	7	-
Cleveland	5	4	-	-	-	9	3	10	
Medina	3	-	-	7	4	9	1	7	-
Wooster	1	4	1	2	-	10	4	9	-

TABLE III

WIND DIRECTIONS

June, 1936

	N	NE	E	SE	S	SW	W	NW	Var.
Put-In-Bay	4	8	4	-	-	9	1	-	4
Fremont	3	14	-	-	3	8	-	2	-
Upper Sandusky	2	11	3	-	-	6	6	2	-
Norwalk	7	9	1	-	2	7	1	2	1
Mansfield	2	18	-	5	4	1	-	-	-
Bangorville	3	13	-	-	-	8	2	4	-
Jefferson	-	-	-	1	-	3	25	1	-
Warren	5	1	1	2	-	5	3	12	-
Canfield	11	4	3	1	4	-	3	4	-
Cleveland	11	5	-	1	2	6	-	5	-
Medina	7	3	-	9	2	2	-	7	-
Wooster	5	10	-	4	3	5	2	1	-

TABLE IV

WIND DIRECTIONS

July, 1936

	N	NE	E	SE	S	SW	W	NW	Var.
Put-In-Bay	3	7	4	-	3	2	3	2	7
Fremont	5	17	-	-	2	3	3	1	-
Upper Sandusky	7	8	1	-	-	8	3	4	-
Norwalk	11	9	2	-	-	7	-	2	-
Mansfield	1	15	-	3	6	3	1	1	-
Bangorville	10	9	1	-	-	4	2	5	-
Jefferson	-	-	-	-	-	2	27	2	-
Warren	7	-	-	-	-	10	1	13	-
Canfield	8	-	-	-	1	3	5	12	-
Cleveland	5	0	-	-	2	5	4	6	-
Medina	5	-	-	6	1	4	-	15	-
Wooster	3	8	2	3	-	8	1	6	-

TABLE V

WIND DIRECTIONS

October, 1936

	N	NE	E	SE	S	SW	W	NW	Var.
Put-In-Bay	3	1	2	-	9	7	3	5	-
Fremont	4	1	-	-	7	10	4	5	-
Upper Sandusky	-	1	-	-	5	10	6	9	-
Norwalk	5	2	-	3	4	11	5	2	-
Mansfield	1	3	-	8	1	8	2	7	1
Bangorville	4	4	1	2	-	10	2	7	1
Jefferson	-	-	-	3	-	4	22	2	-
Warren	-	1	-	2	-	17	2	9	9
Canfield	4	-	-	1	7	10	5	4	-
Cleveland	5	3	-	-	-	19	3	6	-
Medina	-	-	1	13	1	4	2	10	-
Wooster	1	4	1	-	4	13	1	7	-

TABLE VI

WIND DIRECTIONS

November, 1936

	N	NE	E	SE	S	SW	W	NW	Var.
Put-In-Bay	1	3	1	-	4	8	8	4	1
Fremont	-	4	-	-	8	11	3	5	-
Upper Sandusky	-	2	1	-	3	8	7	9	-
Norwalk	1	1	1	1	2	13	6	6	-
Mansfield	3	2	1	2	4	7	4	7	-
Bangorville	3	4	1	2	1	7	5	7	-
Jefferson	2	-	-	-	-	8	20	-	-
Warren	3	1	-	3	2	11	4	6	-
Canfield	3	-	1	2	4	8	8	4	-
Cleveland	-	1	1	2	1	10	5	9	-
Medina	-	3	-	4	6	3	7	1	-
Wooster	1	-	1	2	15	5	6	-	-

TABLE VII

WIND DIRECTIONS

December, 1936

	N	NE	E	SE	S	SW	W	NW	Var.
Put-In-Bay	1	2	4	3	6	3	4	3	6
Fremont	-	4	4	-	8	10	4	1	-
Upper Sandusky	1	1	-	5	13	5	1	3	1
Norwalk	2	2	6	4	2	9	6	-	-
Mansfield	1	3	-	8	7	9	-	3	-
Bangorville	2	2	1	5	1	11	1	7	-
Jefferson									
Warren									
Canfield									
Cleveland	1	2	-	5	6	8	3	6	-
Medina	-	3	-	11	7	2	4	3	1
Wooster	1	1	2	6	2	14	1	4	-

DAILY MINIMUM TEMPERATURES

The average daily temperatures show the progressions of the rises and falls and occurrences of irregularities in the relatively normal curves, but do not show all of the more desirable points to be shown. Since the minimum and maximum temperatures are averaged to give the daily average, it is most desirable that the components be discussed separately and then be compared to each other to illustrate actual effects of the lake.

Similar to the graphs for the daily averages, those for the daily minima take on forms of such irregularity that it is impossible to develop any standard set of equations to represent the curves in a relation to the existing variables. Because of the irregularity in passage of the highs and lows and because of the minor variations in elevations above the lake level it is also impossible to get any set of interpolation curves for points between the regularly located weather observation bureaus. Although these irregularities make it impossible to give a definite number for each of the intermediate points, they do help to show just how the lake does affect the region surrounding and to some degree how much.

Since Lake Erie is frozen from about the fifteenth of December till the early part of May, no discussion need be made of curves for the winter months since the lake, acting as if it were a land area, does not affect the temperatures of the nearby stations to any appreciable amount.

Starting in June the minimum temperatures for stations away from the lake are noticeably lower than are those of stations adjacent to the lake. This is due to the rapid cooling of the land surfaces at night because of the higher radiation constant of earth as compared to that of water. Since the observation boxes are located about five feet from the ground they are decidedly affected by rapid cooling of the earth's surface at night. In the spring of the year, practically all of the heating is daily. By this is meant that the land is heated by the radiation from the sun and hence it may get faily warm while the sun is shining, but at night it may get cool because of the absence of a source of heat and the cooling of the land by radiation. Although the lake has not yet reached temperatures as high as the daytime temperature over land, its temperature at night is above the normal for overland temperatures.

There are several places on the graphs that show a much higher minimum temperature for stations inland from the lake, than for stations near to the lake.

These conditions can be explained by the occurrence of a hot day and a cloudy night following. This would mean that the land would remain very warm during the night because of the limited amount of radiation which can very easily take place. The lake, having a temperature which is fairly stable day and night, would not heat as much during the daytime as the land and hence have a lower temperature than the land at night. This relationship will be explained more fully in the next sedtion dealing with maximum temperatures.

The November minima of Put-In-Bay and Upper Sandusky clearly show the effect of the lake in maintaining a higher temperature throughout the day and night. A significant fact in the comparison of these two stations is noticed in the range of temperature minima. The range for the lake station of Put-In-Bay is 35°F. for the month of November while the range for Upper Sandusky is 51°F. The actual temperature ranges are 17° to 52° for Put-In-Bay and 4° to 55° for Upper Sandusky.

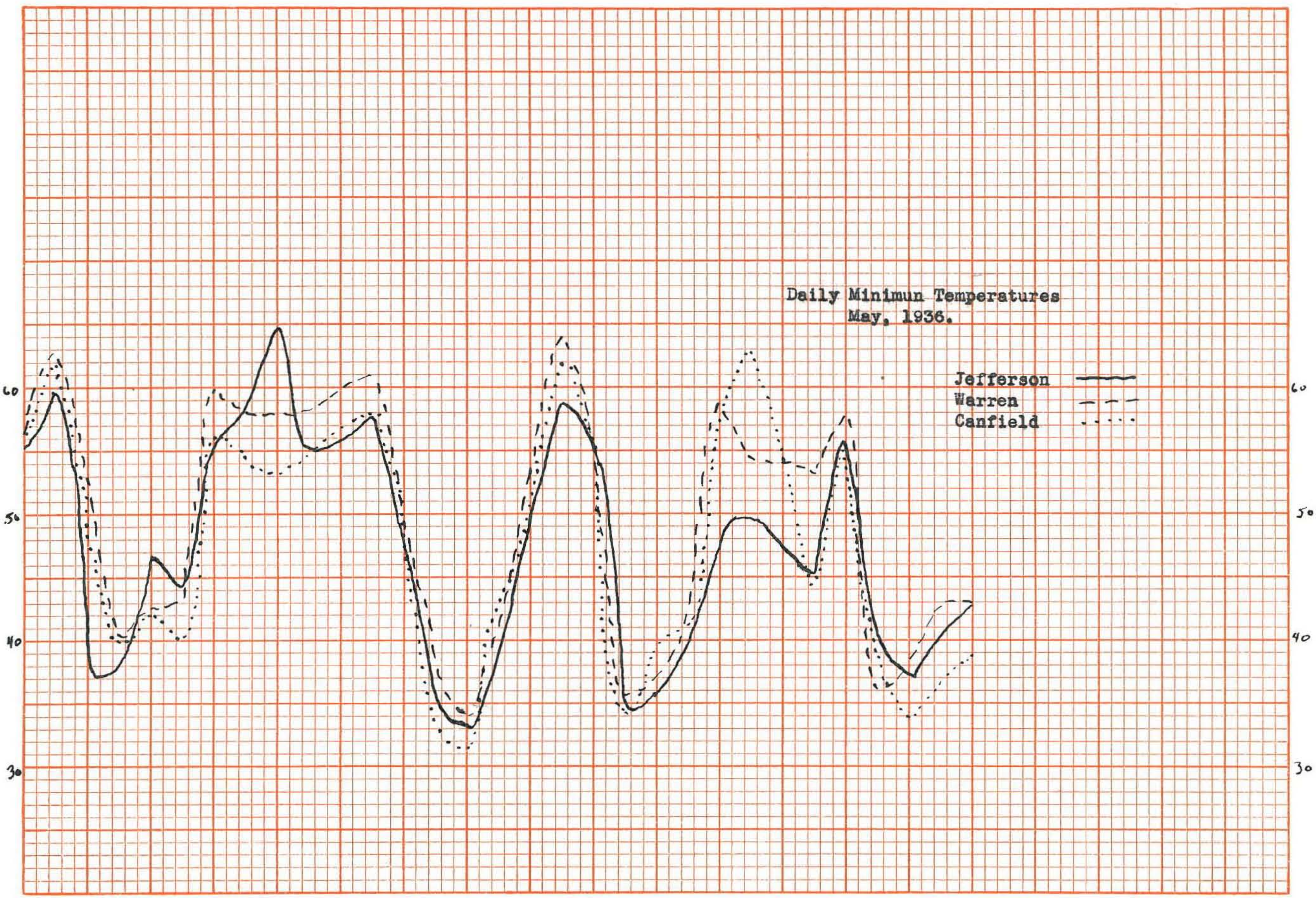
For the year 1936, Put-In-Bay had its first frost on the eleventh of November, whereas the first frost in November for Upper Sandusky occurred on the fifth. At this time Upper Sandusky recorded a temperature of 19° F. as compared to a temperature of 32° for Put-In-Bay. At the same time Bangorville located east of Upper Sandusky and just a little farther from Lake Erie recorded a temperature of 17°F.

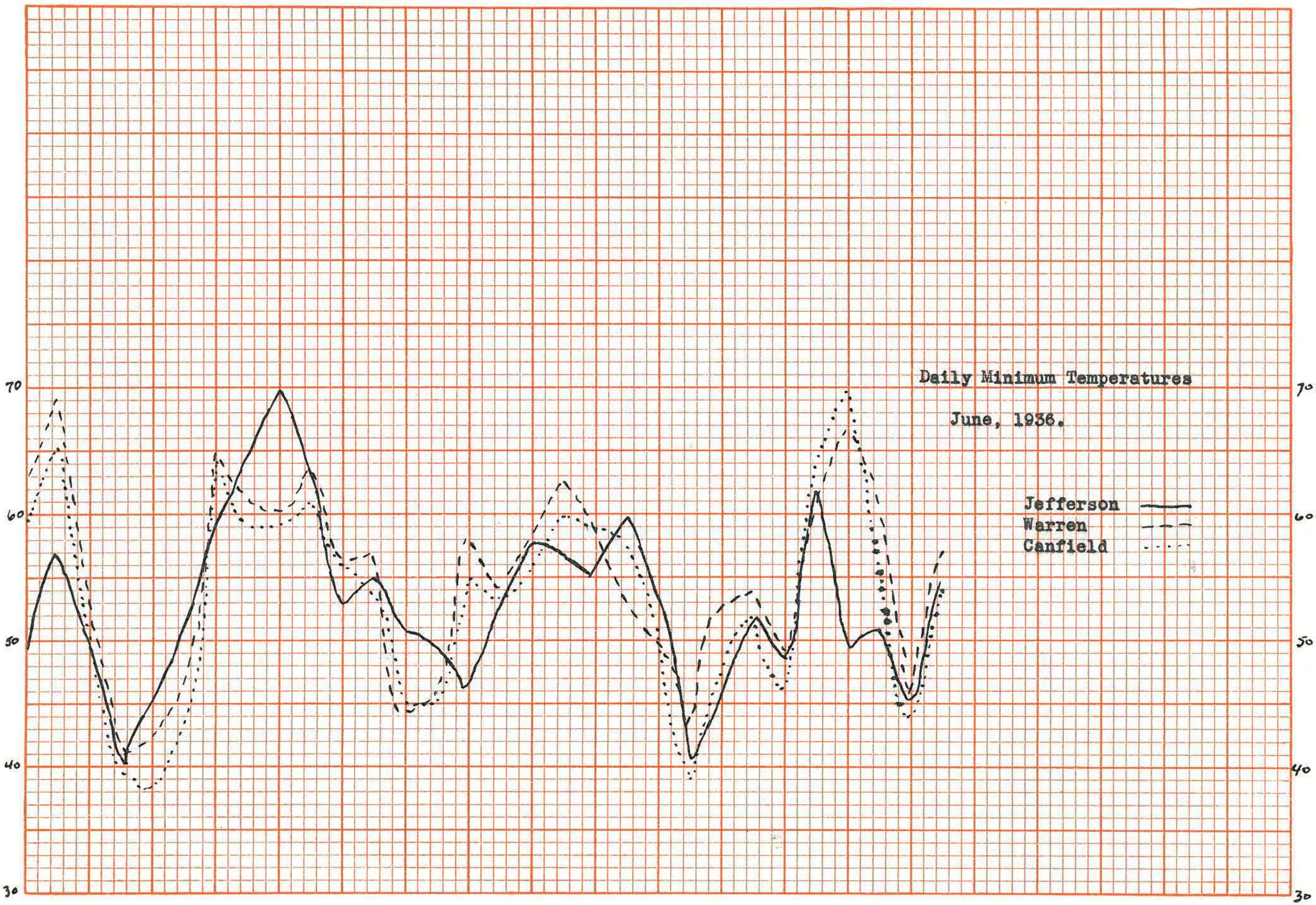
In 1936, Lake Erie froze in part some time during the first week in December. Since a body of water that has been frozen over affects temperature changes just like a land mass it would be expected that there would occur no very great irregularities as in other months. For the first day in December, the temperatures for Upper Sandusky, Fremont and Put-In-Bay are 11°, 10° and 21° respectively. After the first day, the temperature differences in the recordings of the three stations.

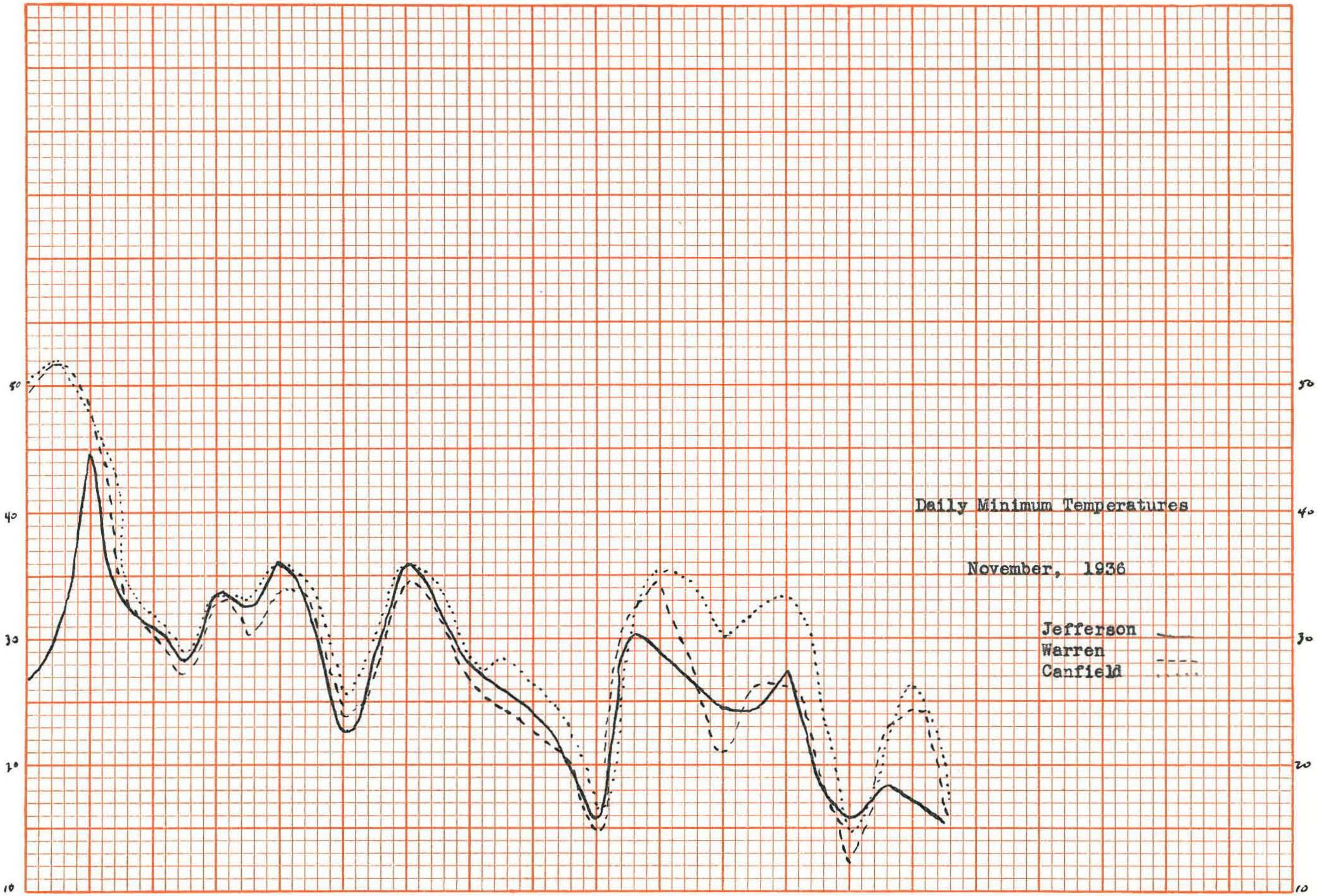
There are a few irregularities to be accounted for. On the twelfth and twenty-second of December, the stations away from the lake show a temperature decidedly lower than that of the near-lake station, Put-In-Bay. On the twelfth, Put-In-Bay shows a temperature of 20°as compared to 19° and 16° for Fremont and Upper Sandusky respectively. Up until the twelfth of the month the ice did not extend very far out into the lake, and since our low temperatures are recorded with a north wind in general, the lake still cast some influence upon the adjacent land area. The same conditions must have existed on the twenty-second of the month, since the temperature distribution is similar. The absence of cloud cover would permit a very high rate of radiation and hence cause lower temperatures over the land.

On December twenty-seventh the stations of Put-In-Bay, Fremont and Upper Sandusky all record temperatures which are within a degree of each other, and in the middle forties. This can be accounted for by the presence of a low pressure area centering over the middle Atlantic coast. The movement of winds, then, is from south to north, eliminating any or most influence that the lake might have upon temperatures along the south shore. As a result the three stations react in about the same way to the inflow of equatorial air.

The temperature distribution for the twenty-ninth of December indicates that the lake has ceased to affect appreciably temperatures in the region. There is no regularity in the distribution of temperature and the actual recording are dependent upon local conditions as well as the conditions caused by the passing of highs and lows.


Daily Minimun Temperatures
May, 1936.
Jefferson
Warren
Canfield
60
50
40
30
60
50
40
30

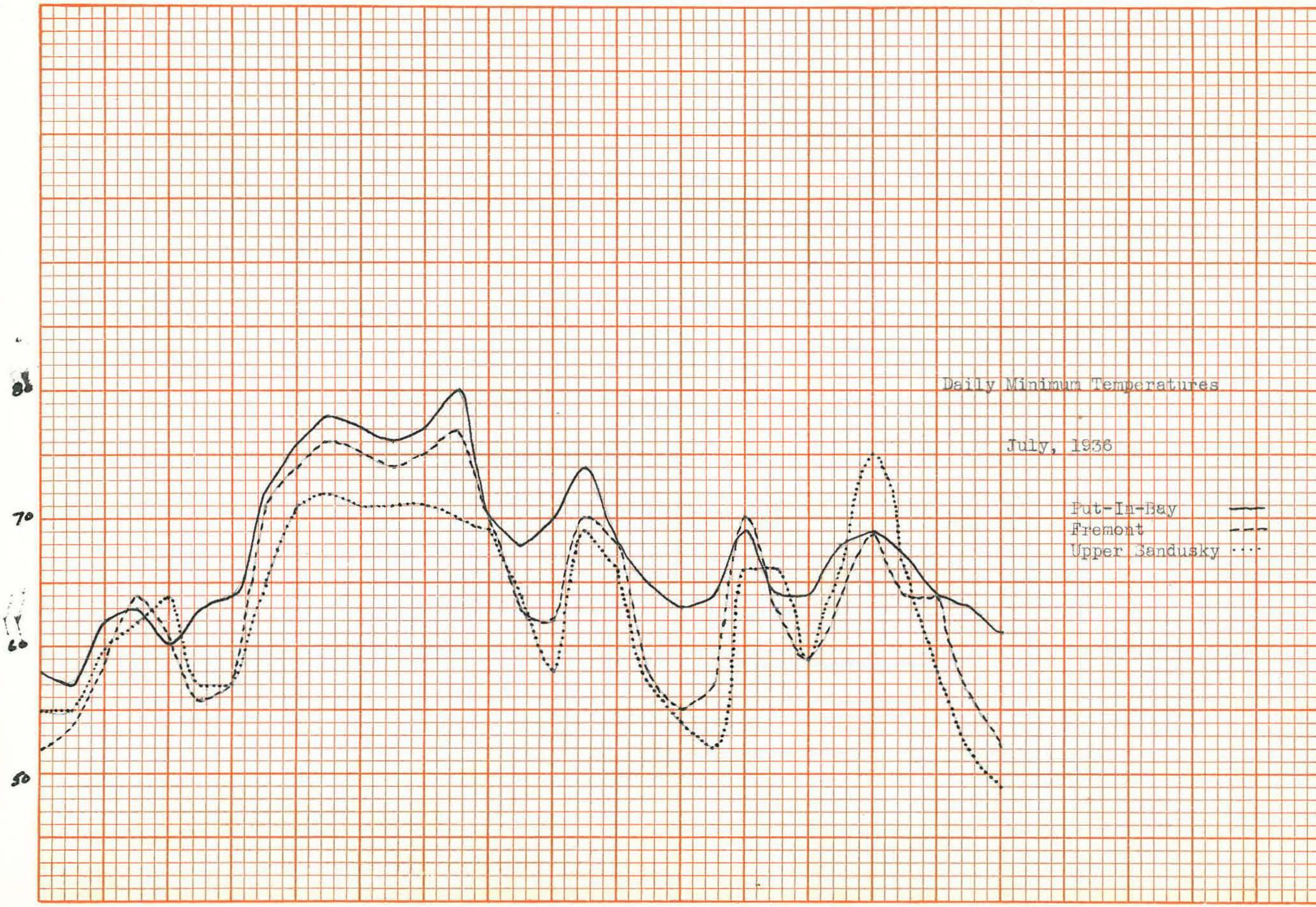

Daily Minimum Temperatures
June, 1936.
Jefferson
Warren
Canfield
70
60
50
40
30


Daily Minimum Temperatures
November, 1936
Jefferson
Warren
Canfield
50
40
30
20
10

7


Daily Minimum Temperatures
June, 1936
Put-In-Bay
Fremont
Upper Sandusky
70
60
50
40

9


Daily Minimum Temperatures
July, 1936
Put-In-Bay
Fremont
Upper Sandusky
80
70
60
50

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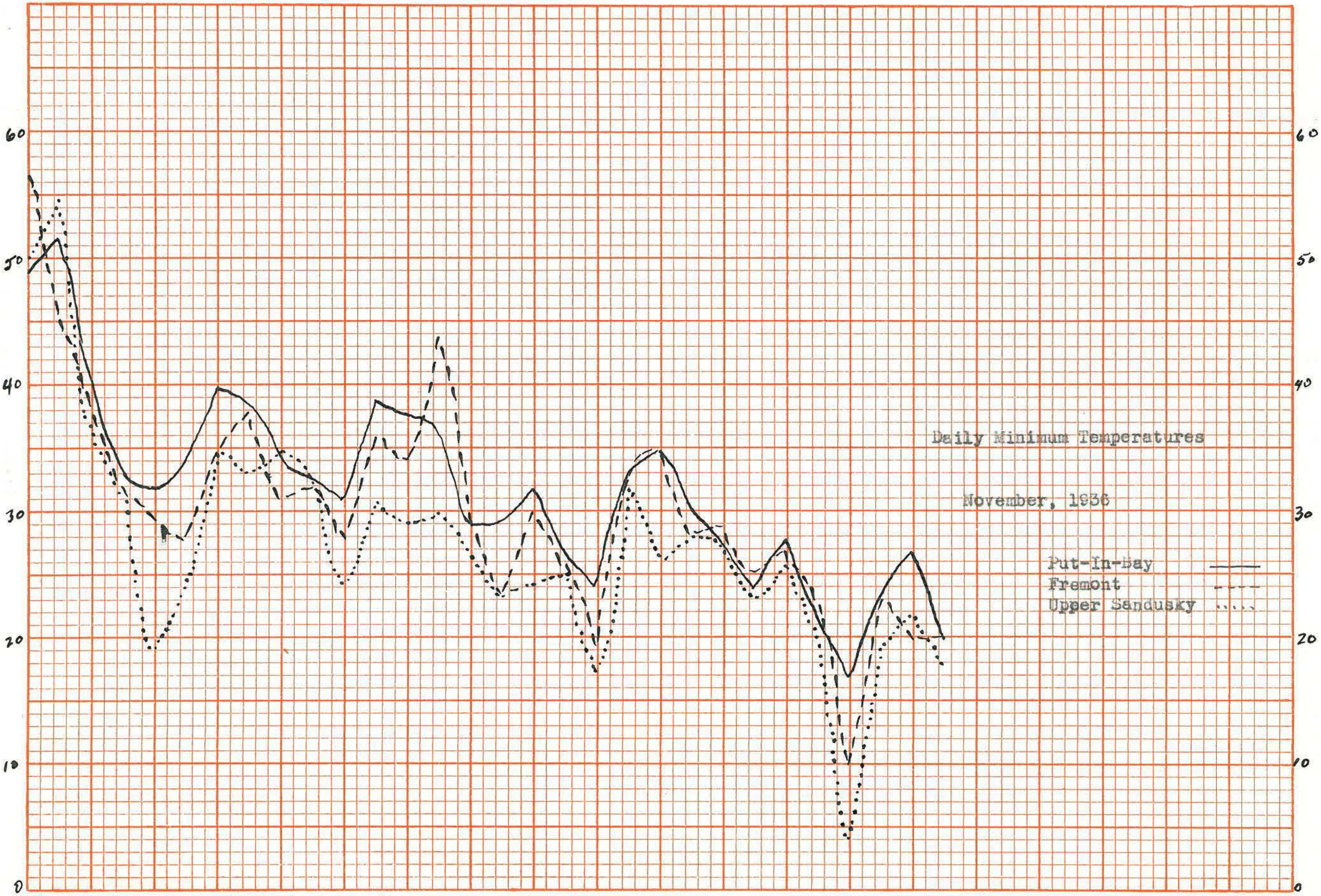
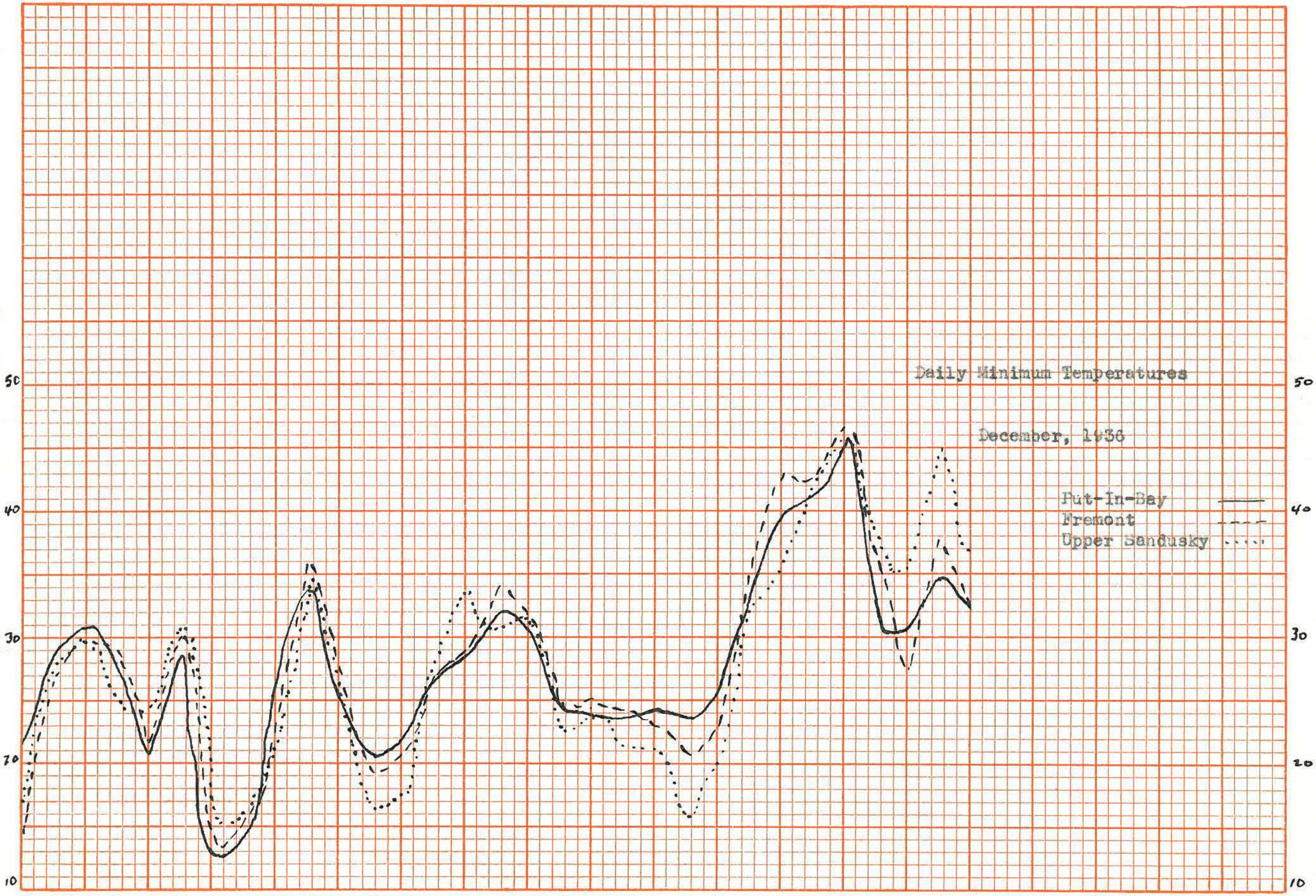
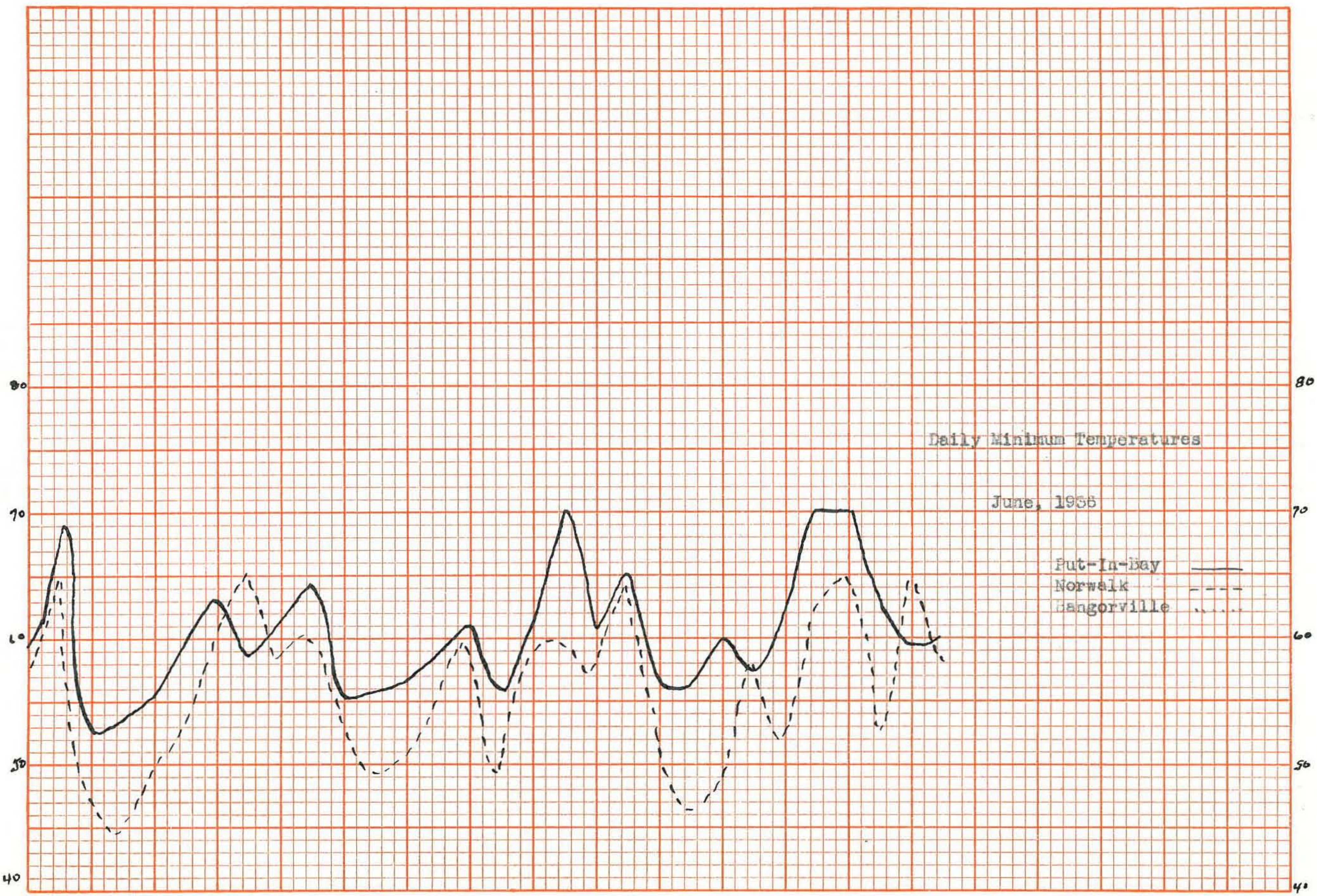
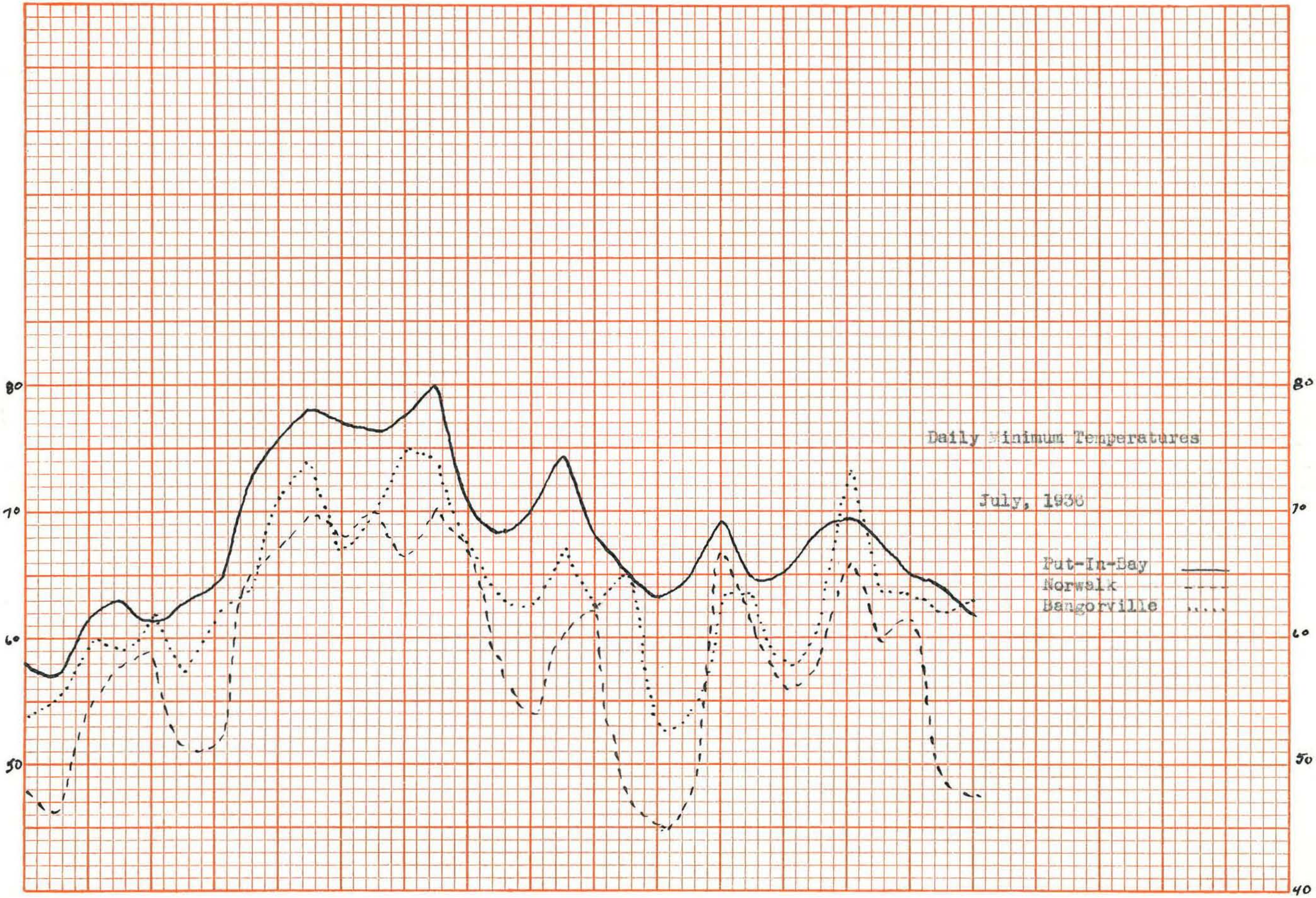
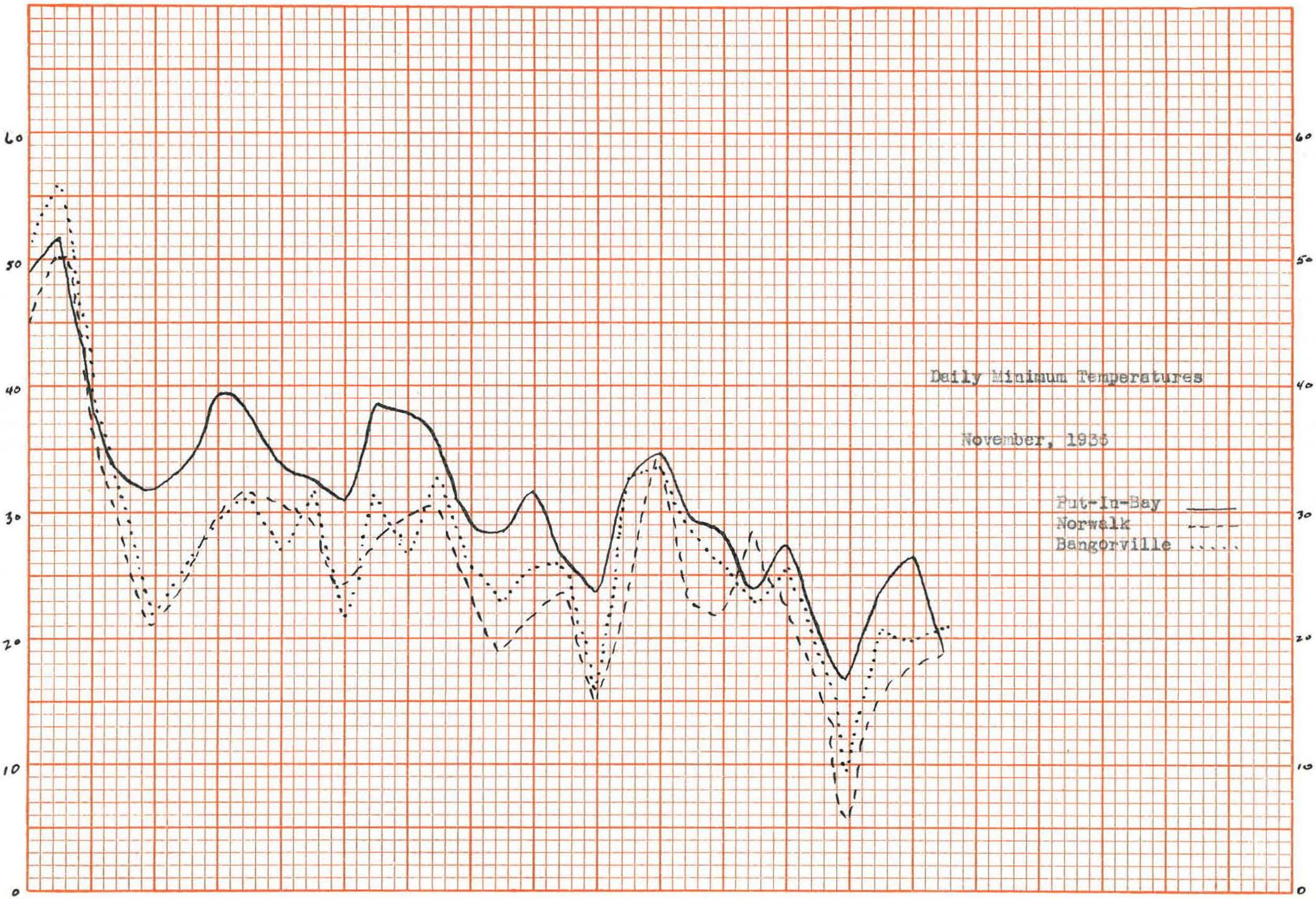

Daily Minimum Temperatures
November, 1936
Put-In-Bay
Fremont
Upper Sandusky
60
50
40
30
20
10
0

14


Daily Minimum Temperatures
December, 1936
Put-In-Bay
Fremont
Upper Sandusky
50
40
30
20
10


Daily Minimum Temperatures
June, 1956
Put-In-Bay
Norwalk
Bangorville
80
70
60
50
40


Daily Minimum Temperatures
July, 1936
Put-In-Bay
Norwalk
Bangorville
80
70
60
50
40


Daily Minimum Temperatures
November, 1935
Put-In-Bay
Norwalk
Bangorville
60
50
40
30
20
10
0

DAILY MAXIMUM TEMPERATURES

The purpose of separating the two components of the average daily temperature is to make it possible to note any irregularities in the curves taken for the average. By breaking up the components, one can see just which factors in determination of temperatures are acting and in some degree to what extent they are exerting their influence. In general, the maxima will show up the rapid heating of land on clear days, and to some extent the influence of the presence of a warm body of water on cool and cloudy days. The first condition is most noticeable during the earlier part of the year while the latter condition is most apparent in the latter months.

The months chosen to represent the differential influences again are the transition months — June, July and November. While it might have been desirable to plot all the months, it was deemed desirable to omit those which likely would have little or no bearing on the present investigation.

The sequence of passing highs and lows again shows the most noticeable influence on the temperature of both the near-lake and the inland stations. There are periods of from one to three days when the temperatures of all stations are rising to a peak and the periods of a similar length when there is a decrease or decline to a minimum temperature. On the average there are from eight to twelve of these passing cycles during a month. The accompanying changes in weather during the passing of one of these storms have been discussed previously and need not be pointed out now. However, it might be worthwhile to recall the conditions occurring during a cyclonic storm which would produce a maximum of temperature.

The two principal factors are the indraft of great quantities of equatorial air as a result of the low pressure locating to the north, and the generally clear skies over a region of high pressure. The latter condition is rather important in summer when the pressure gradients are not very steep, but rather conducive to calms in the wind and absence of any visible air movement. The first of the above factors is particularly noticeable during the early spring months when the land temperatures are usually low. A low passing to the north will sometimes draw in air from as far south as the gulf states provided, of course, that the high is located that far to the south. As a result temperatures will rise as much as 40° or 50° degrees in a period of a few hours, and sometimes less than that. Similarly the reverse condition will produce a sudden drop in temperature. This drop occurs along the wind shift line and often times takes place within a few minutes. It is most always accompanied by driving rains in the winter and thunderstorms in the summer. The wind will blow steadily from the southwest for a few hours with fairly clear skies, and quite suddenly black clouds will appear and the wind increases in velocity. In a few minutes rain starts to fall and very rapidly the wind will shift to the west or northwest.

The above discussion appears to be somewhat off the subject, but in order to get the best interpretation from the accompanying curves these weather changes must be kept in mind. The daily temperature is a result of the foregoing non-periodic controls and if one of these changes should occur in the evening, the maximum or minimum temperature may be recorded either a day in advance or a day behind, thus affecting the normal slope of the curves. The only way this could be overcome would be by use of a constant recorder.

Generally the lake stations are the last to record a maximum of temperature and also the last to reach a minimum. A prolonged period of heating, such as that shown during the first week in July indicates that the stations away from the lake are the first to reach a maximum. When the sudden shift of wind occurs, the stations nearer the lake are much slower to react to the change in temperature; hence they require a longer period to reach a minimum. This condition is clearly shown on the July curves during the period from the fifteenth to the twenty-first.

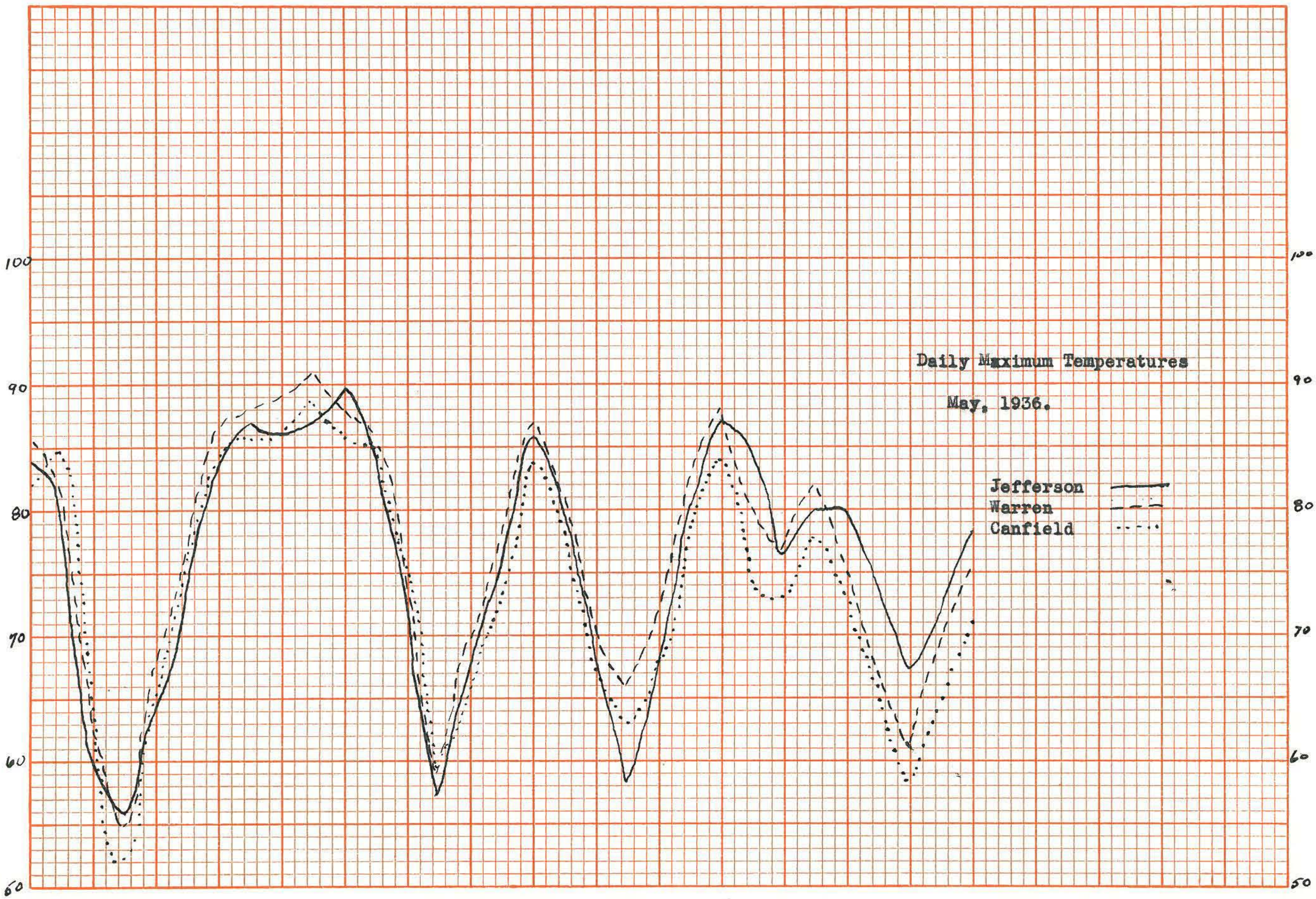
A very interesting feature to note on all of the graphs for daily maxima is that during the warm spells the inland stations have a higher maximum than the near-lake stations, and during the cool or cold spells, the lake stations record the highest maximum.

The march of temperature is pictured very well in the curves for maximum daily temperatures. The steadily rising temperatures are noted for the months of the earlier part of the year, and the steadily decreasing daily maxima are observed for the autumn months.

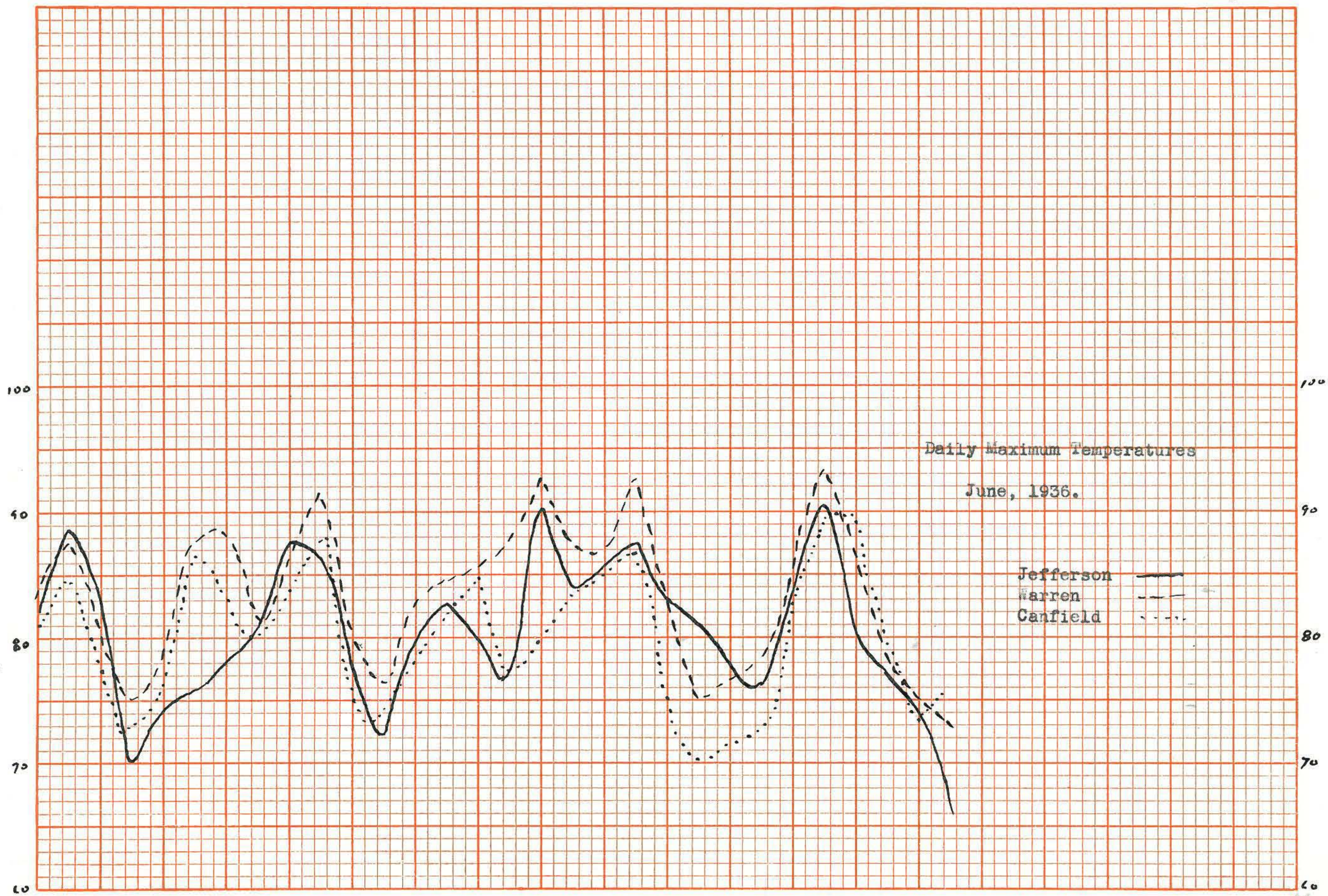
Comparing the curves for the last three sections of this paper, the significant fact to be noted is that the lake stations record their highest temperatures at night in comparison to inland stations, and their minimum temperatures during the daytime. By this is meant that the temperatures increase during the daytime, as one goes away from the lake, and decrease at night. This, of course, does not hold true for the winter time while the lake is frozen, or in the very early spring when the lake water is near maximum density.

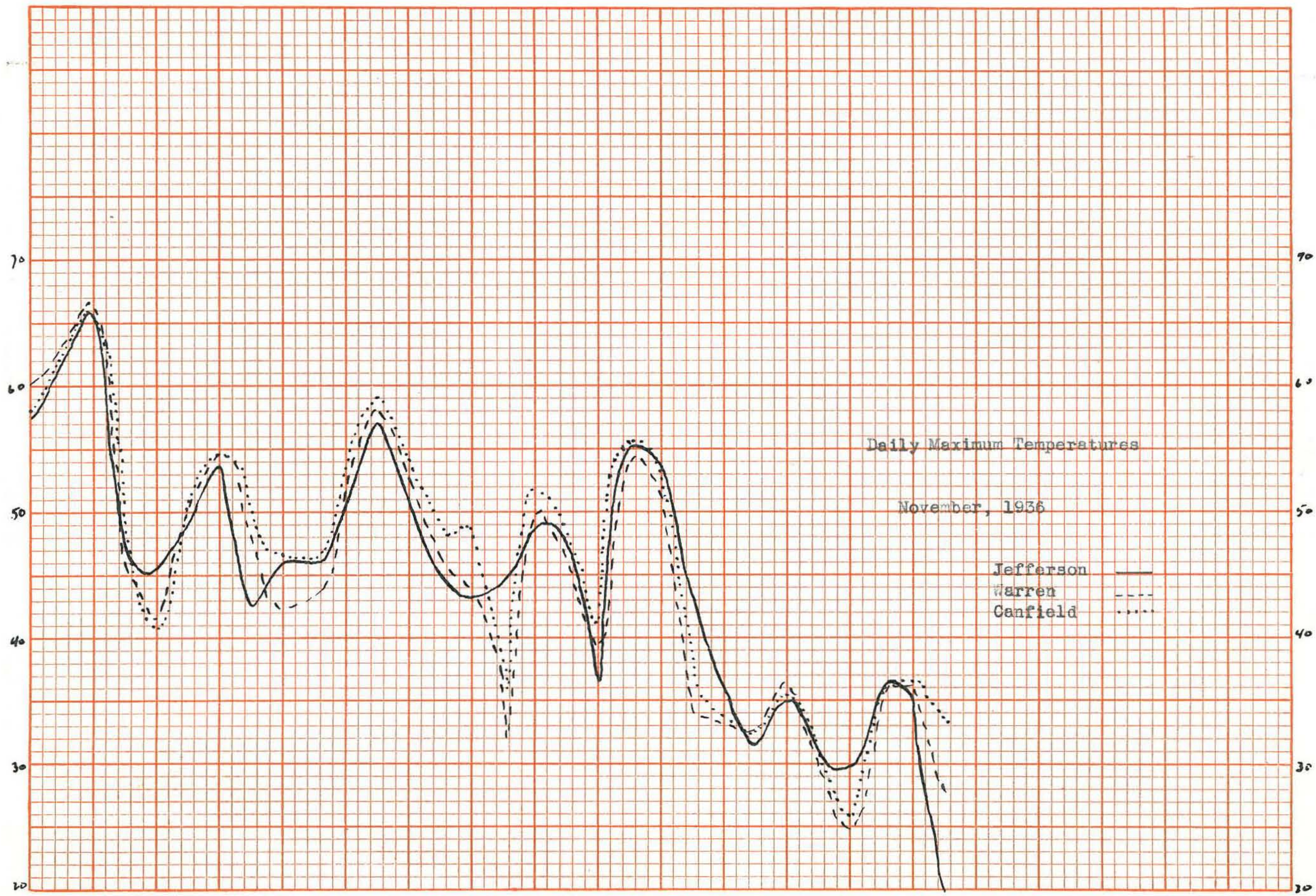
Observing the Put-In-Bay, Bangerville graphs for November, the lake station records a higher maximum temperature than does the station away from the lake. Taking the fourth, ninth, and fourteenth days of the month as typical examples and attempting to give just reasons for these conditions is a very simple matter. On these particular days a high pressure area centers to the north and west of northern Ohio. As a result the cold north winds and northwest winds blow across Lake Erie and into the land section of northern Ohio. The lake partly warms the air near the surface of the water, and as a result, the land immediately adjacent to the lake does not experience such a serious drop in temperature. As the winds continue to blow toward the south, the colder upper air mixes with the surface air and as a result any moderating influence of the lake is almost completely obliterated.

At times when there is a north wind, the velocity has much to do with the distance to which the lake influences will be felt. Because of the wide expanse of Lake Erie, the velocity apparently has little to do with the amount of heating received in passing over the water, but it no doubt appreciably affects the distance to which the moderating influences of the lake will be carried. Just as a stream will set up a more violent but not larger eddy in the current by traveling very swiftly past an obstruction a wind blowing over irregular topography will set up eddies not larger but more violent. Thus since the intermixture of the air will probably not take place any more quickly than in a wind of lower velocity, its ratio of forward movement to intermixture of air directly with the velocity of the wind. Hence the lake will cast its influence farther toward the south if there is a strong wind than if there is a light wind.

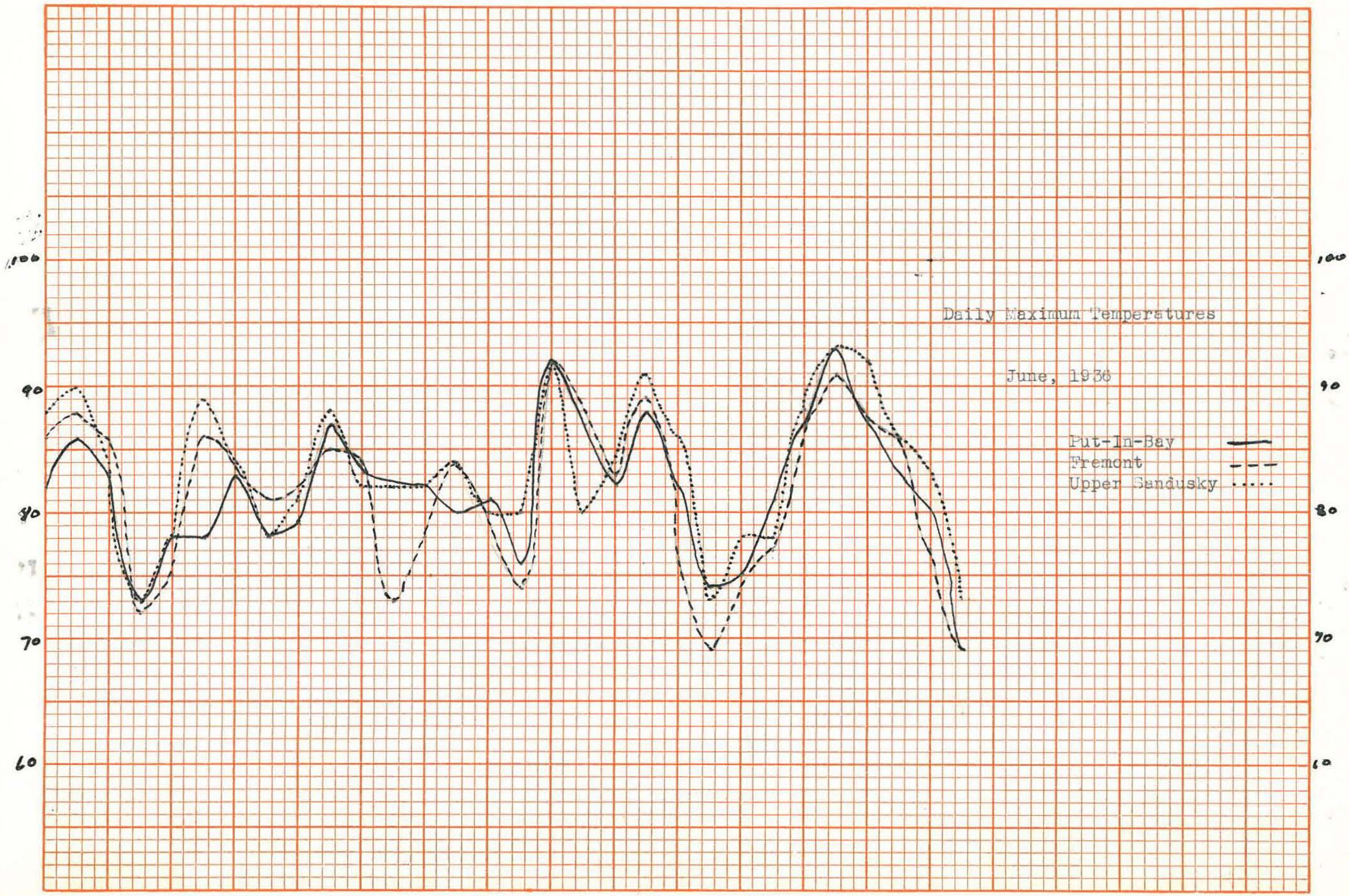

Daily Maximum Temperatures
May, 1936.
Jefferson
Warren
Canfield
100
90
80
70
60
50

KEUFFEL & ESSER CO., N. Y. NO. 359-6
10 × 10 to the inch, 5th lines heavy.
MADE IN U. S. A.




Daily Maximum Temperatures
November, 1936
Jefferson
Warren
Canfield
70
60
50
40
30
20

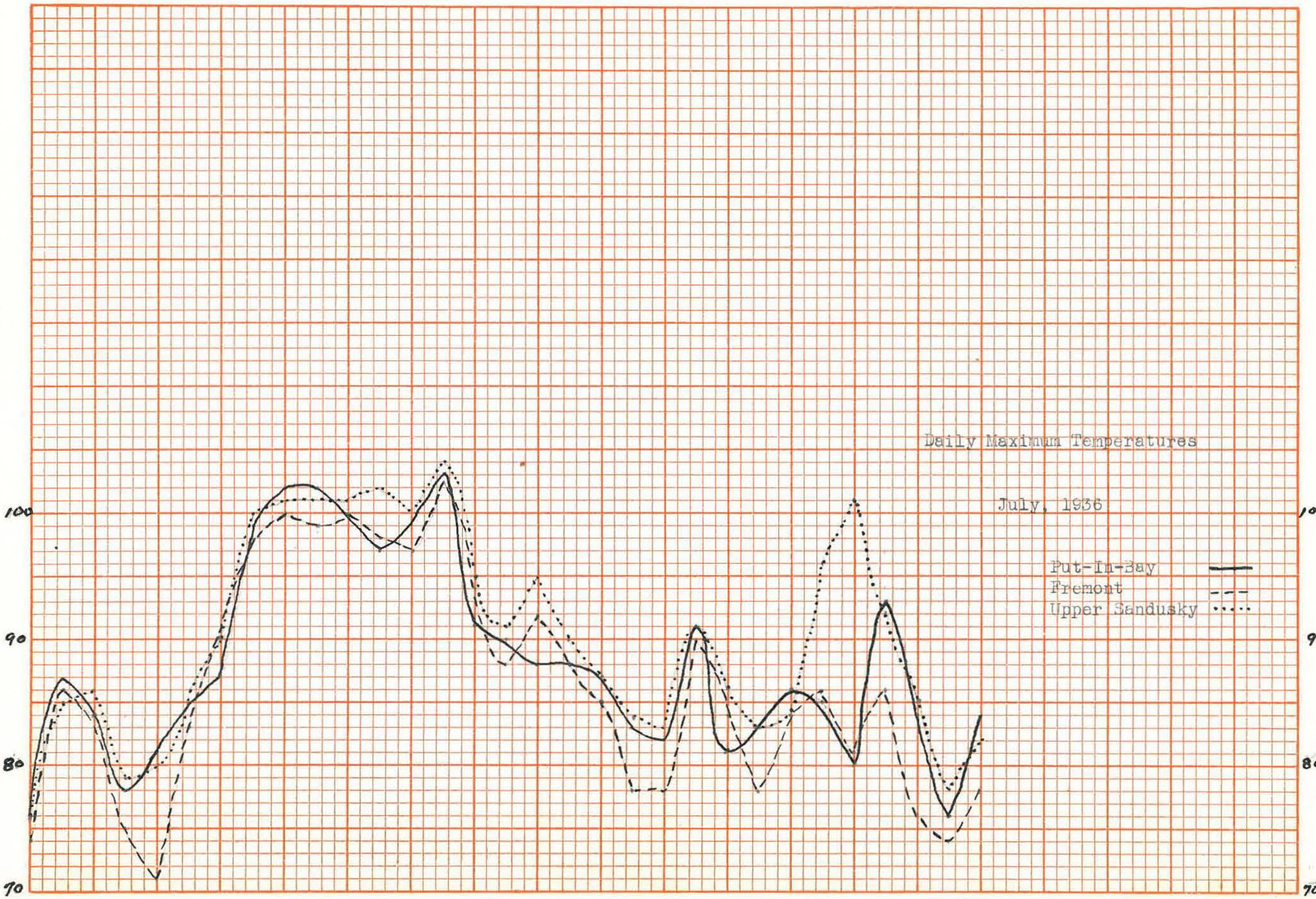
8

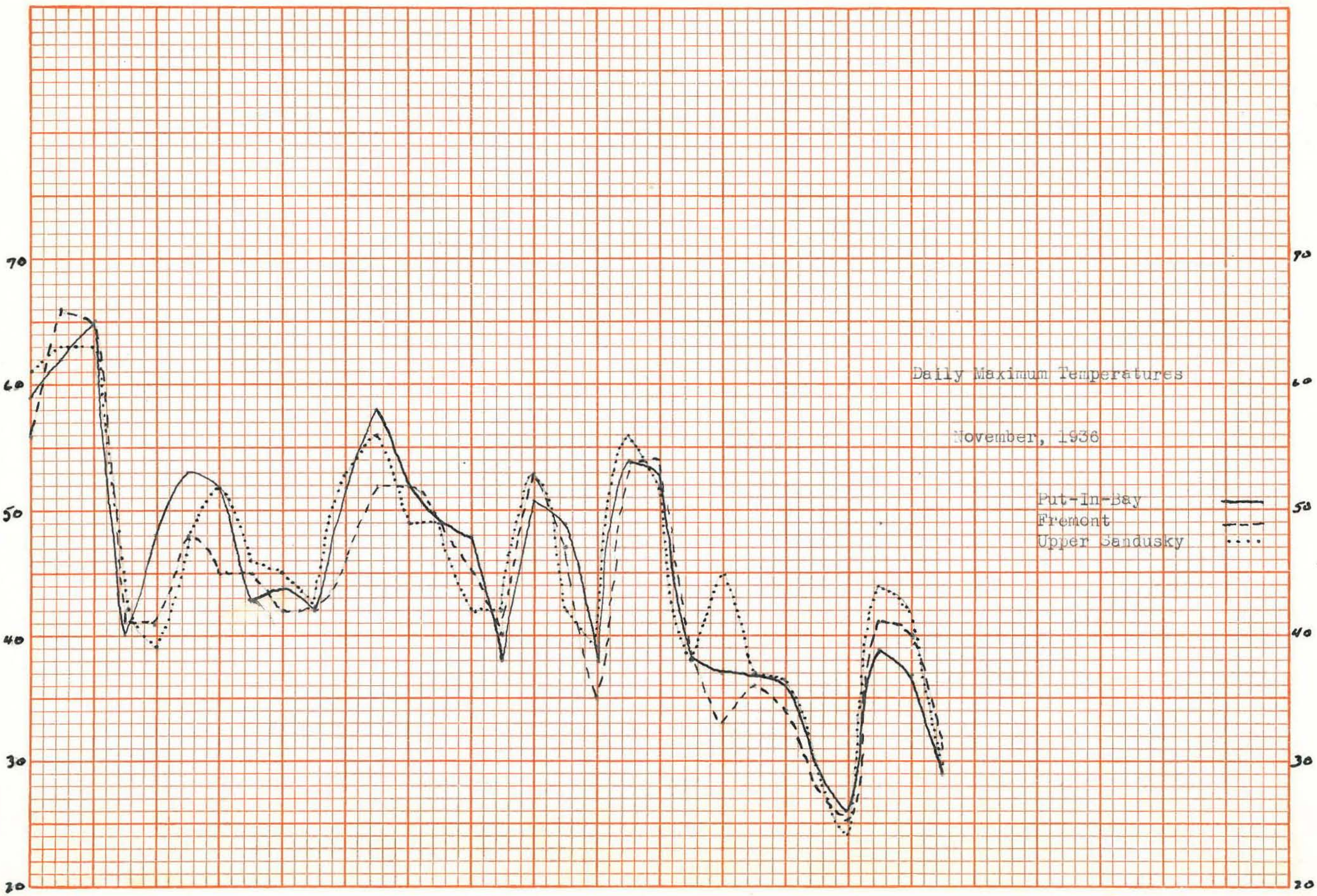

Daily Maximum Temperatures
June, 1936
Put-In-Bay
Fremont
Upper Sandusky
100
90
80
70
60
100
90
80
70
60

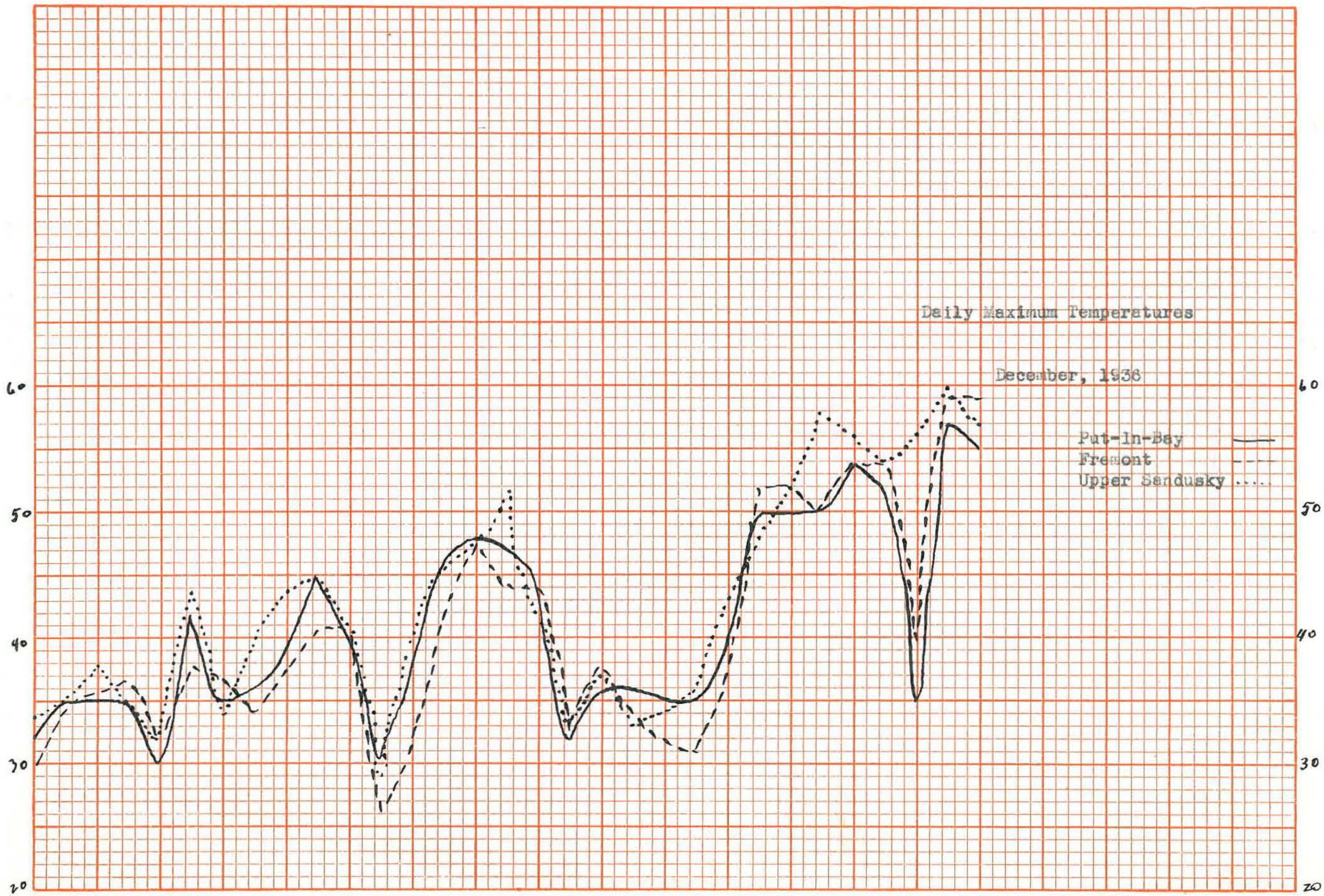
KEUFFEL & ESSER CO., N. Y. NO. 359-6
10 × 10 to the inch. 5th lines heavy.
MADE IN U. S. A.

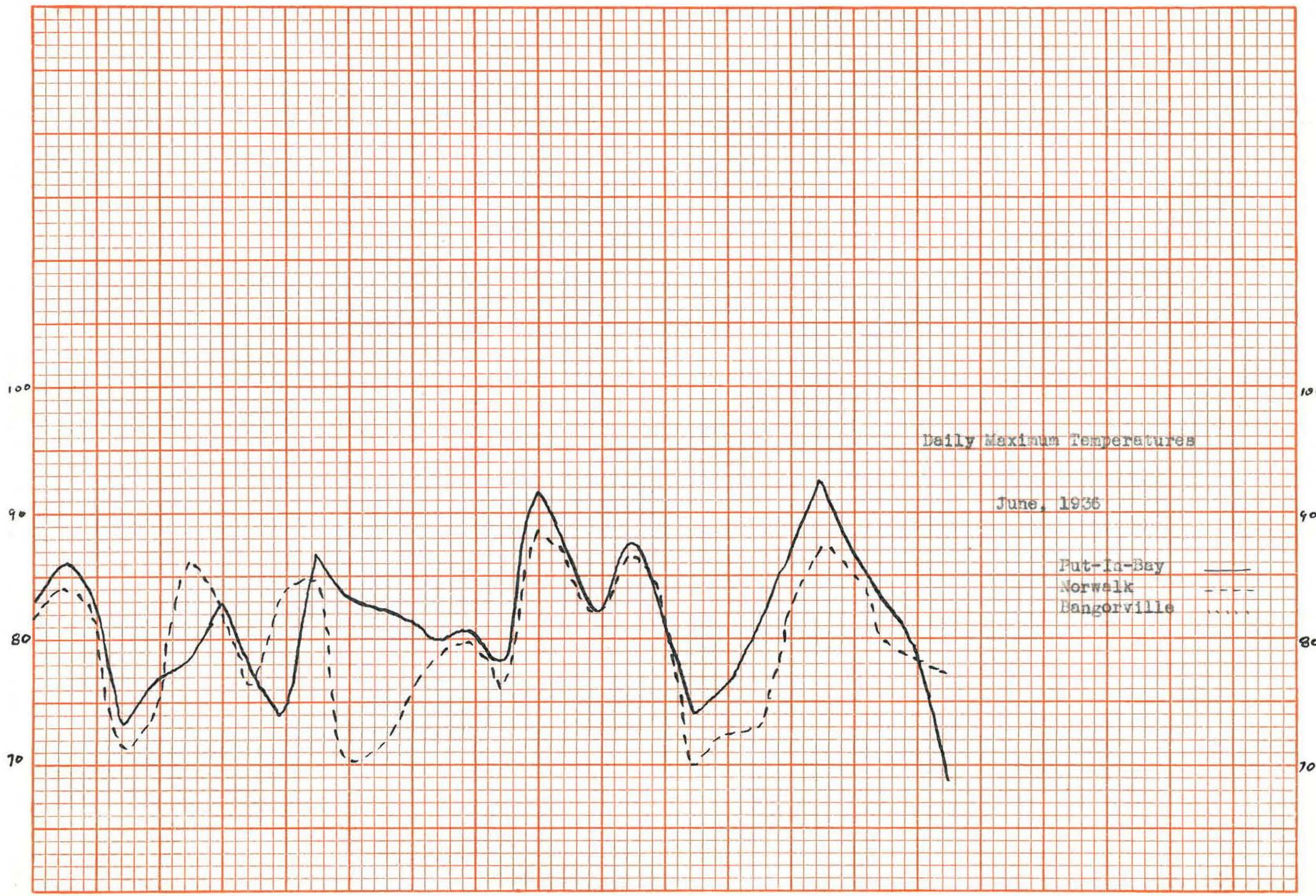
10

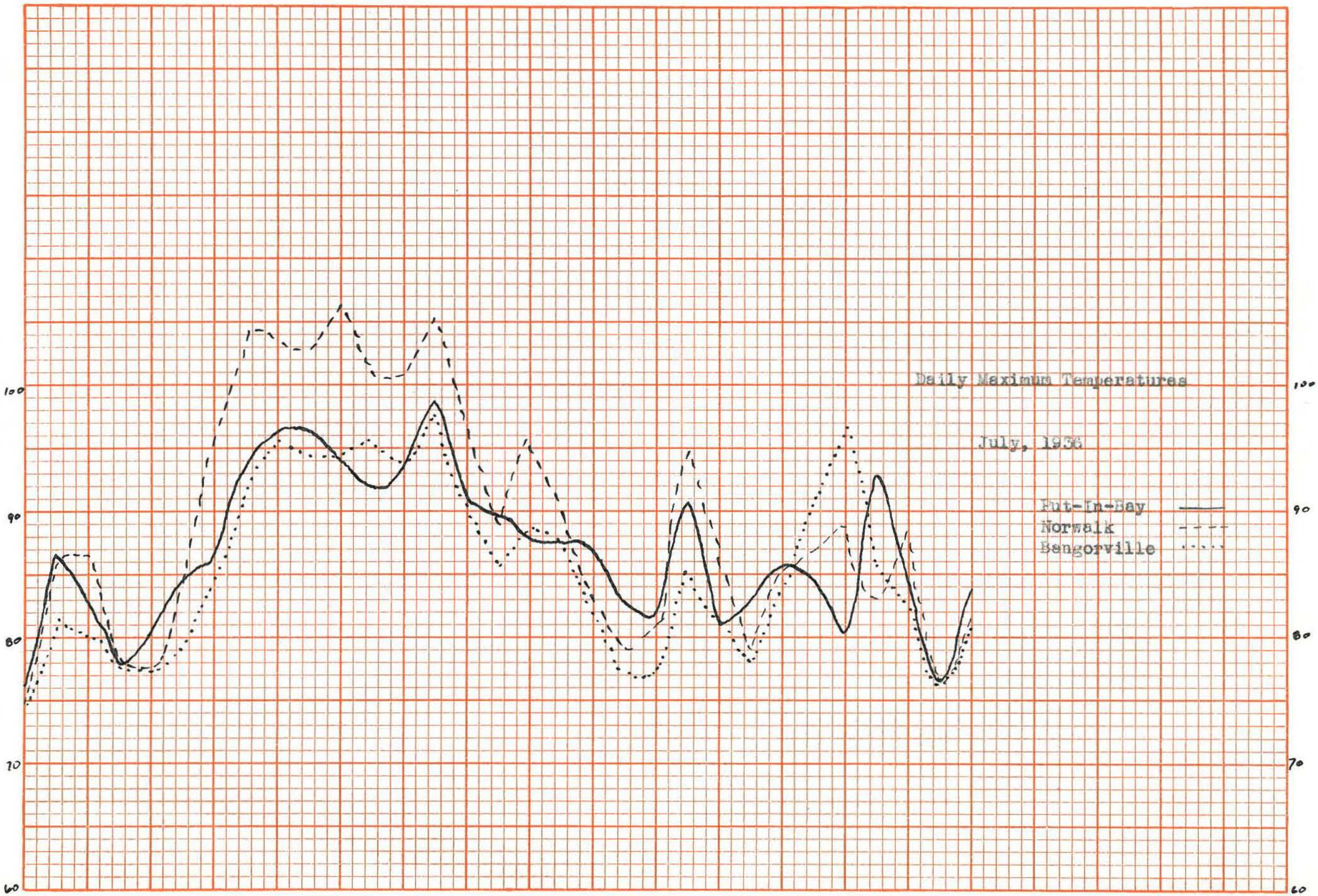
10



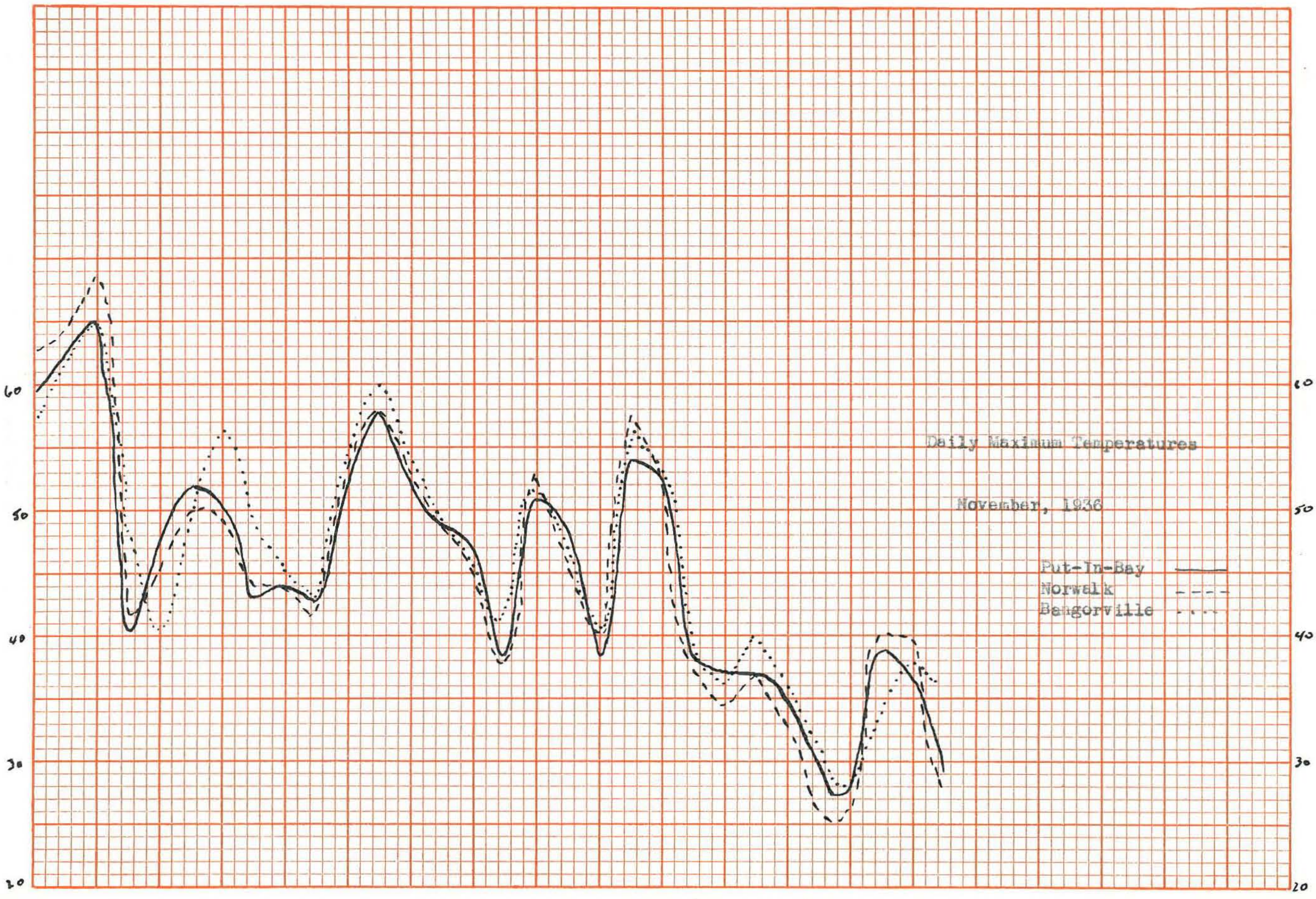

70
60
50
40
30
20
90
60
50
40
30
20
Daily Maximum Temperatures
November, 1936
Put-In-Bay
Fremont
Upper Sandusky


Daily Maximum Temperatures
December, 1936
Put-In-Bay
Fremont
Upper Sandusky
60
50
40
30
20


Daily Maximum Temperatures
June, 1936
Put-In-Bay
Norwalk
Bangorville
100
90
80
70


Daily Maximum Temperatures
July, 1936
Put-In-Bay
Norwalk
Bangorville
100
90
80
70
60

KEUFFEL & ESSER CO., N. Y. NO. 359-8
10 × 10 to the inch, 5th lines heavy.
MADE IN U. S. A.



CONCLUSION

Lake Erie casts its influence on northern Ohio over an area about fifty miles wide and extending from Toledo to the eastern border of the state. Fifty miles is the maximum extent of lake influence, and this is only at rare intervals. Factors determining this maximum distance are the velocity of wind, direction of the wind and comparative temperatures of the water surface and the land surface. A strong north wind will carry the lake's influence farther towards the south. The lake's influence is felt most when the relative temperatures of the land and water approach extreme opposites. The seasons for these conditions are the late spring and fall, just after the thawing and just prior to the freezing of the ice on the lake.

The length of growing season along the lake is about as long as that of any place in the state. This condition, combined with slow rise of temperature in spring and slow cooling in fall permits growth of crops such as peaches, apples, cherries, grapes and other sensitive budding plants.

The average daily temperatures show the retardation of heating of the lake proper which in turn affect in the springtime the temperatures of the land mass adjoining. The rapid cooling of land in autumn as compared to that of water is shown on the graphs of daily average temperatures for stations in November. The December graphs show that the lake after freezing acts the same as if it were a land mass.

The daily maximum and minimum temperatures show the differential rates of heating and cooling of land and water and also show the influence of the slower reaction of the lake upon the adjoining land areas. These curves also show the relationship between near-lake and inland stations at times when their variations are greatest. In general, the lake retards growth in the spring and promotes it for a longer period in the fall.

Wind direction apparently is considerably affected by the presence of the lake. In spring a high pressure area exists over the lake, causing passing highs to follow a path near the lake, and be re-enforced by the local conditions. As a result stronger winds will blow in the springtime, and be predominantly from the north and northeast. These winds, having passed over the cold water surface become very chilling winds when they strike the land which has been heated during the spring daytime.

In the autumn, the lake remains warmer than the rapidly cooling land surrounding and hence a low pressure area forms over the lake which results in an indraft of south winds. These winds often originate in the Gulf coast region and hence appear very warm in a region which is cooling very rapidly due to the declining sun.

Agriculture is greatly influenced by the moderated temperatures produced by the presence of the lake. Orchards are characteristic in many sections of northern Ohio, especially along the Warren, Whittelsey and Maumee beach ridges which are remains of shorelines of old post-glacial lakes. Exact statistics are available as to percentage of crop types grown, but from general observations the distribution of agricultural development has a decided relationship to the lake's influence. Other agricultural phases might be noted, the maple sugar industry of early spring, for which the season is particularly well fitted, vineyards, flower culture, and general natural vegetation characteristics.

The average person may comment that the air is chilly upon visiting the lake shore in the springtime, but beyond that thinks little of the actual significance of the lake in man's adaptation to occupation. This paper, then, has tried to describe some of the unusual influences of Lake Erie upon the climate of northern Ohio as well as the expected effects that occur in the land area adjacent to Lake Erie.

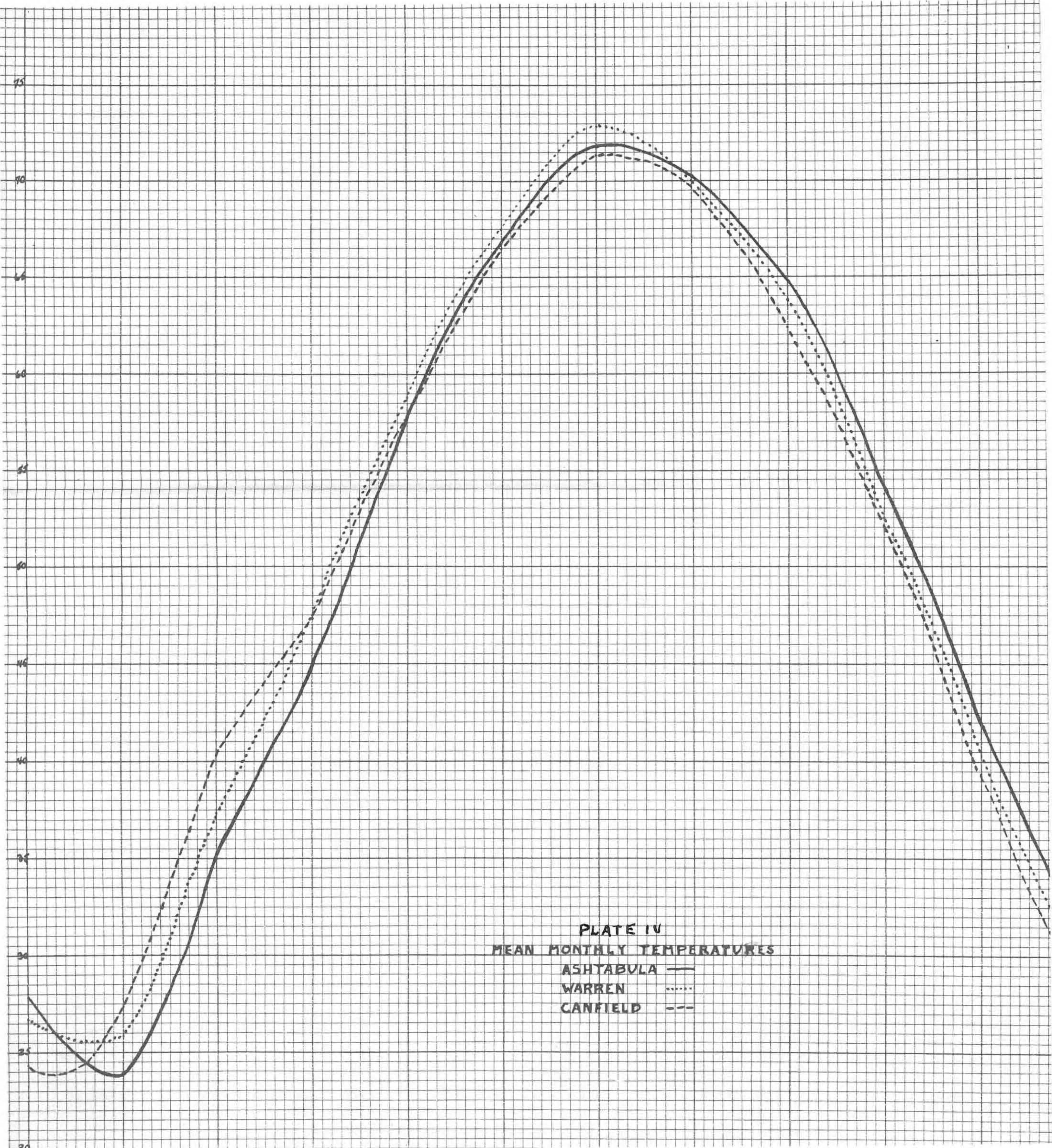


PLATE IV
MEAN MONTHLY TEMPERATURES
ASHTABULA
WARREN
CANFIELD

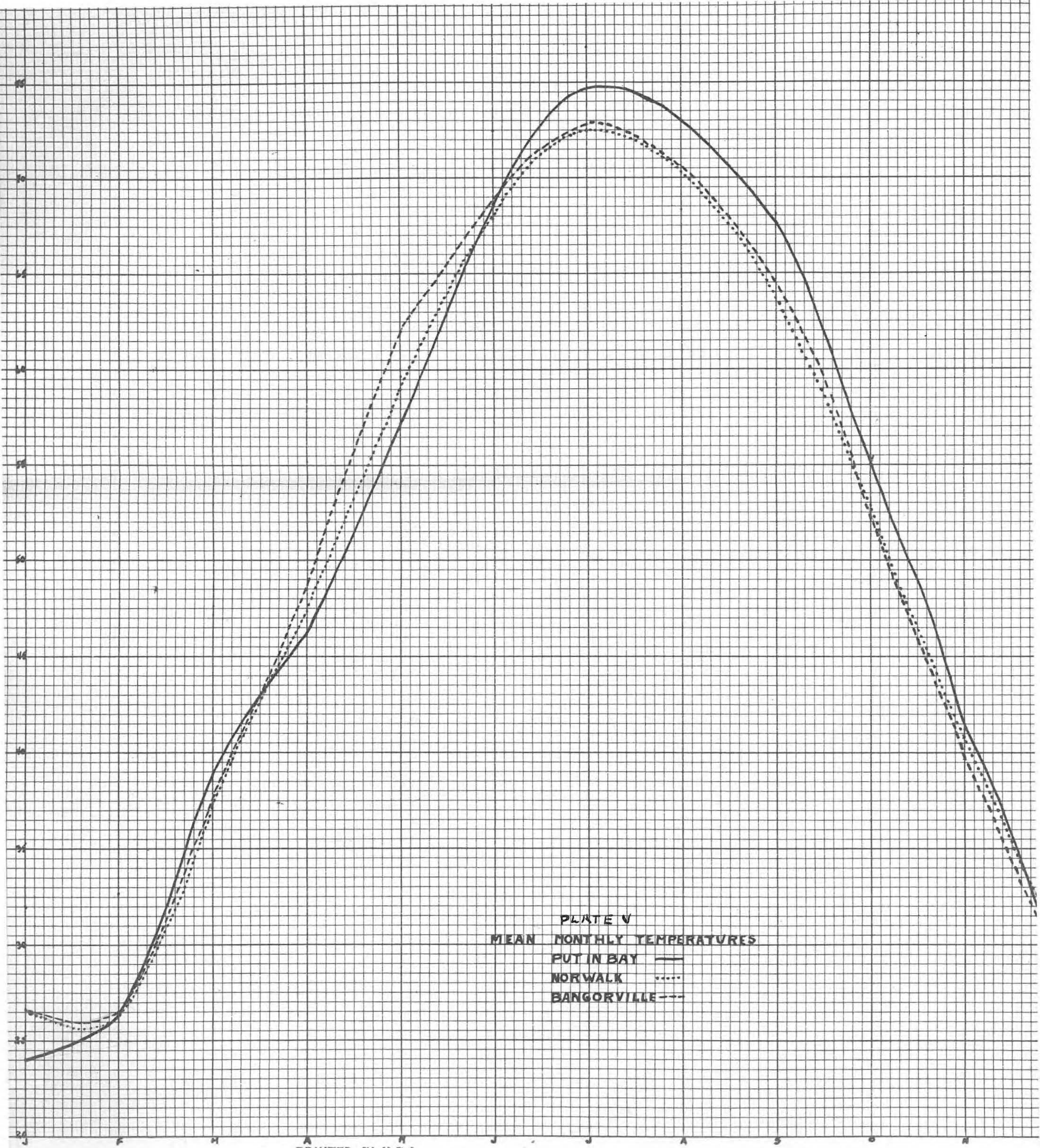


PLATE V
MEAN MONTHLY TEMPERATURES
PUT IN BAY
NORWALK
BANGORVILLE
75
70
65
60
55
50
45
40
35
30
25
20
J
F
M
A
M
J
J
A
S
O
N

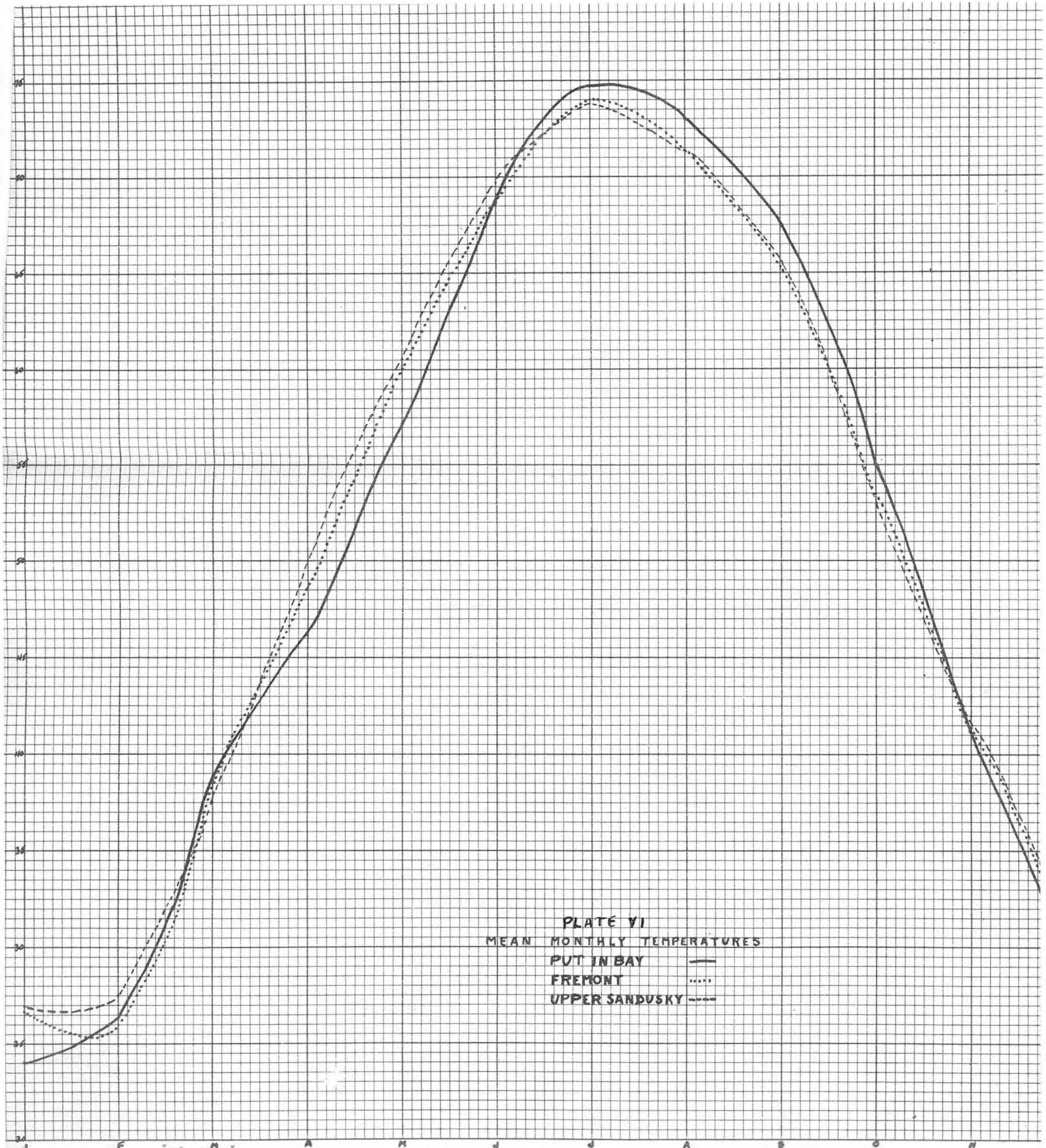


PLATE VI
MEAN MONTHLY TEMPERATURES
PUT IN BAY
FREMONT
UPPER SANDUSKY
J F M A M J J A S O N