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MEAN 1951-1980 TEMPERATURE AND PRECIPITATION FOR THE NORTH CENTRAL REGION

by

Wayne M. Wend/and, John L. Vogel, & Stanley A. Changnon, Jr.

North Central Regional Climate Center
Illinois State Water Survey
Champaign, Illinois 61820

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Introduction

This atlas presents patterns of 1951-80 mean precipitation, temperature, and heating- and cooling degree days data for the Upper Midwest and High Plains states of the North Central region. These analyses are prepared from observations of National Weather Service Cooperative and First Order Station stations to obtain maximum data density, and summarized by the National Climatic Data Center, Asheville NC.

All mean temperatures were corrected for the bias incurred as a function of the time of observation, if other than midnight-to-midnight. The correction for time of observation biases are important because First Order Stations calculate daily mean temperatures between the hours of midnight to midnight, whereas most cooperative observers take their observation at an hour convenient to their schedule, but maintaining the same hour of observation for several years. When maximum and minimum thermometers (read once per day) are read near the time of the occurrance of maximum daily temperature, mean temperatures for a week, month or longer, are positively biased (from a midnight reading) by up to about 3.6F (2C), depending on location, altitude of the station, and time of year (see, e.g., Mitchell, 1958; Baker, 1975; Nelson et al., 1979; Dale et al., 1983; Blackburn, n.d.; Head, 1985; Karl et al., 1985). When the maximum and minimum thermometers are read near the time of minimum daily temperature, mean values are negatively biased by up to about 1.8F (1C), again depending on location, altitude of station, and time of the year. These biases can therefore introduce errors of several degrees which can impact studies of temporal temperature change, or spatial studies which compare mean temperatures across a region. Hence, the isotherms presented herein are based on mean temperatures corrected for the time of observation, i.e., corrected to a midnight observation.

The Data

The mean temperatures, heating- and cooling-degree, and precipitation data used for this study were obtained fom the National Climatic Data Center, Asheville NC, and represent normal (mean) data for all available stations from 1951-1980. A total of 562 useable data sets were obtained for the 12 states, 23% of the observations were taken between the hours of 2300 and 0200 local time, none between 0300 and 0600, 12% between 0700 and 1100, 57% between 1200 and 1800, and 8% between 1900 and 2200 local time. Data were available for another 322 sites, however, they consisted of observations taken at least at 3 different hours of the day during the 30 years, and therefore no constant correction could be applied and they were unuseable for the temperature study. However, all 884 stations were used for the analysis of precipitation. Station histories provided information as to when observations were made at each station for the 30 years of record.

Analysis Technique

The basic goal of this atlas is to show the large scale features of regional temperature and precipitation, the former corrected to represent midnight-to-midnight observations. There are smaller scale features which are real but difficult to show on a chart of this scale: e. g., anomalies due to (1) topographic features of only a few kilometers extent, (2) small water bodies, or (3) the effect of moderate and large size cities. The present data base is insufficient to allow this detail in most circumstances. Therefore the following criteria were established to define the minimum scale of analysis, and to give uniformity to the analysis. Temperature or precipitation anomalies (identified either by closed or open contours) were not retained if the initial complete analysis was not supported by more than at least 5 adjacent stations, and unless the anomaly was clearly related to a topographic feature or near a large body of water. In addition, urban heat islands were apparent from data in or near large metropolitan sites of the region. The data density was too sparse, however, to permit either a clear definition of the shape, intensity, or the horizontal extent of the urban centers. Therefore, the effect of urban heat islands was not retained in the final analysis pattern, but the text below provides guidelines for estimating in-city temperatures.

Temperature Analyses and Discussion

The observations from large cities permitted a comparison of urban temperatures to the regional values inferred from the isotherm analysis, to evaluate the magnitude of the urban effect. Differences were determined for the following cities for January, April, July and October: Fargo ND; Pierre SD; Omaha NE; Topeka KS; Minneapolis MN; Des Moines 1A; Kansas City MO; St. Louis MO; Milwaukee WI; Chicago IL; Detroit MI; Indianapolis IN; Cincinnati and Cleveland OH. Differences between monthly mean temperatures of urban areas with populations greater than 200,000 are presented relative to the urban population (1960 census) in Fig. 1. Excluding Chicago and Detroit, a linear trend is apparent, where an increase of 100,000 population is related to a mean temperature increase of 0.122C (0.219F). The equation is:

Urban temp anomaly (C) = 0.012 popl'n - 0.114

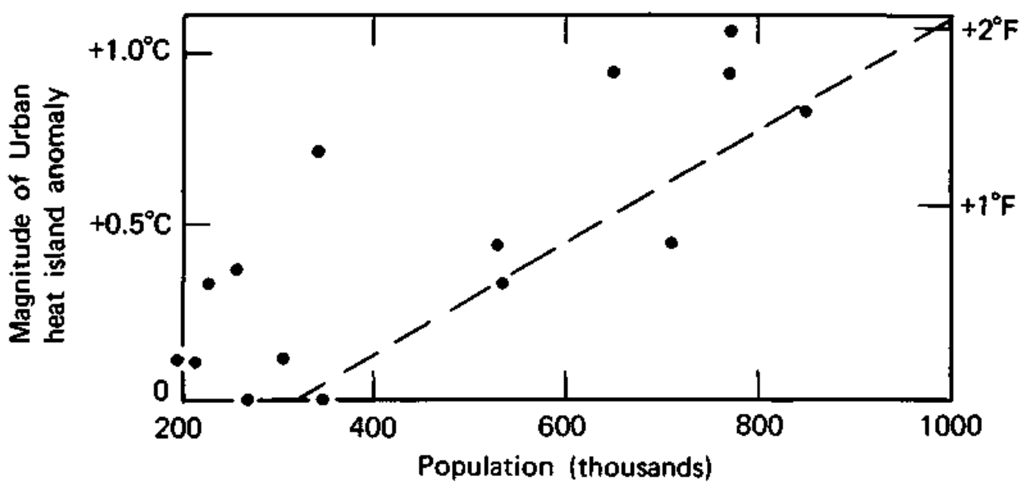

Fig. 1. Relationship of urban temperature anomaly and urban population.

where the population is given in thousands. The correlation coefficent for this relationship is 0.786. The resulting increase to the mean maximum and mean minimum temperatures is 0.078C (0.143F), and 0.106C (0.190F) per 100,000 population increase, respectively. These data suggest that the urban minima are elevated to a greater degree than the maxima, resulting in a decreased diurnal range. When Chicago and Detroit are added to the data population, the slopes of the linear relationship are decreased markedly, i.e., a given population yields an urban temperature anomaly substantially less than that derived from the cities other than Chicago and Detroit. This is due to the fact that the populations used in the present study represented that of the city alone, whereas the urban temperature anomaly responds to the impact of the population of the metropolitan area, i.e., urban plus suburban. A similar relationship was found between population and mean minimum and mean maximum temperatures, however, the correlation between population and temperature anomaly declined from about 0.79 (between mean temperature and population) to 0.60 and 0.53 (for minimum and maximum temperatures, respectively, and population).

The temperature analyses proceeded by first noting the midnight observations, and complementing these values as possible with observations from other times of the day, first correcting them for the time of observation bias referenced above. This method provided an average of 47 useable stations per state (range: 34 to 64).

The large scale <u>patterns</u> of isotherms (Figs. 2-14, with units in Fahrenheit in block numbers and Celsius in italics) are similar to others published for earlier 30-years periods (Environmental Data Service, 1968), however some cooling was noted relative to temperatures from those published ear-

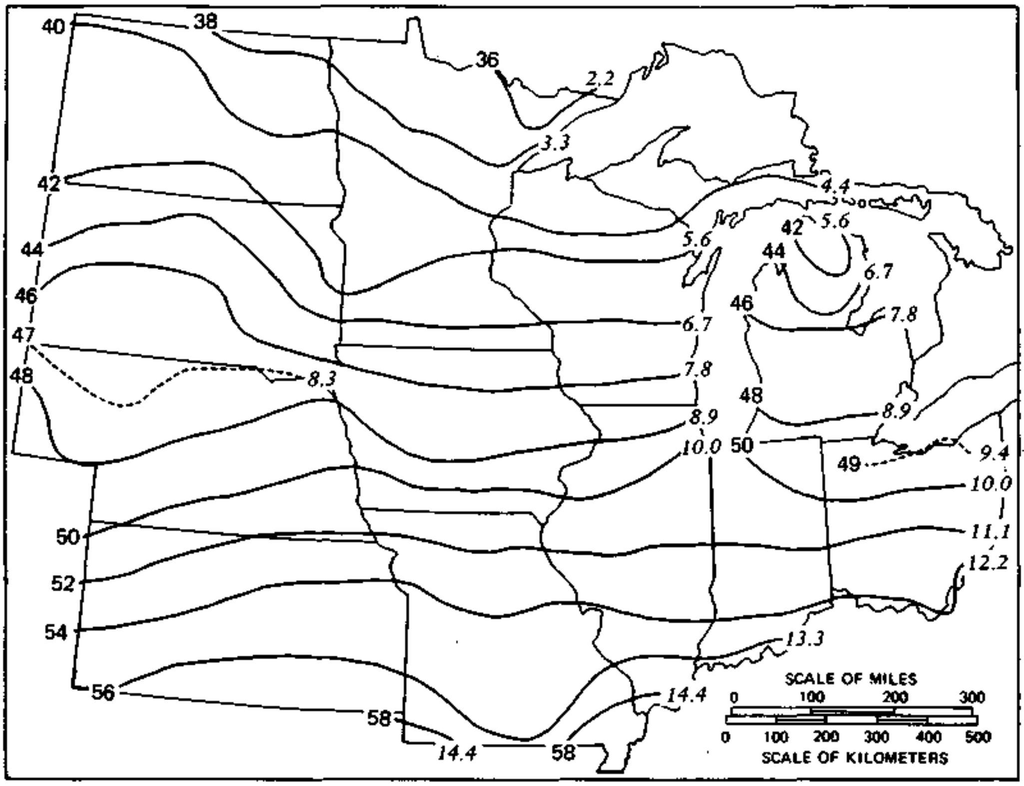

Fig. 2. Mean temperature - Annual

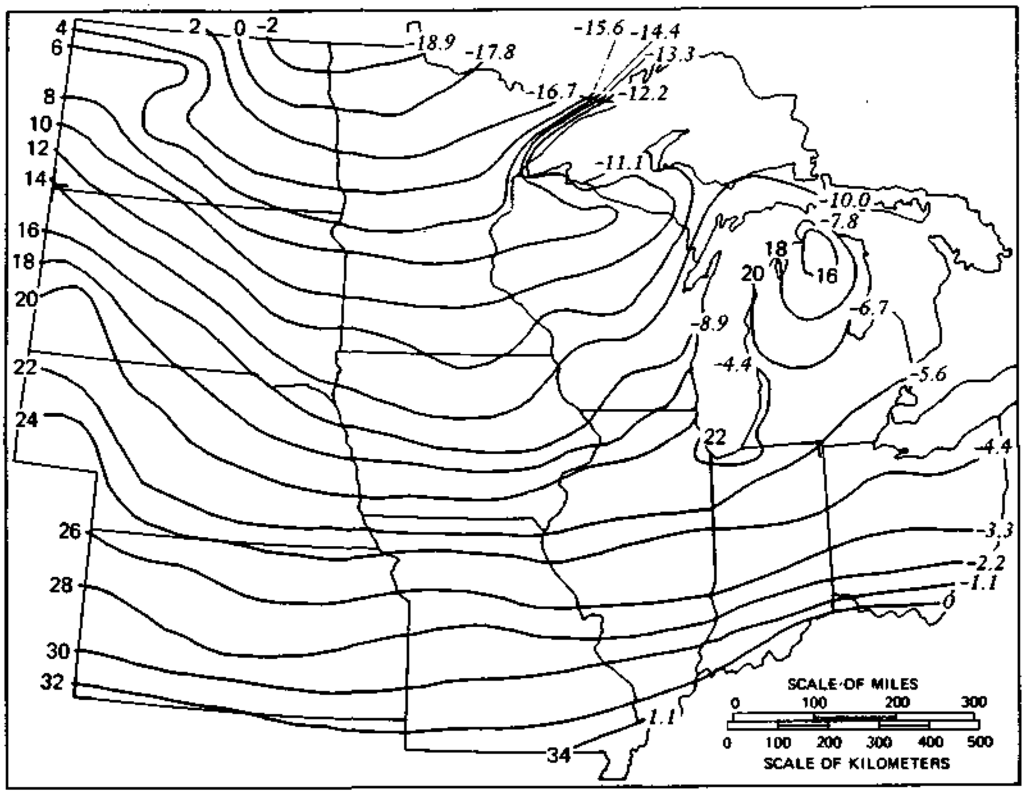

Fig. 3. Mean temperature - January

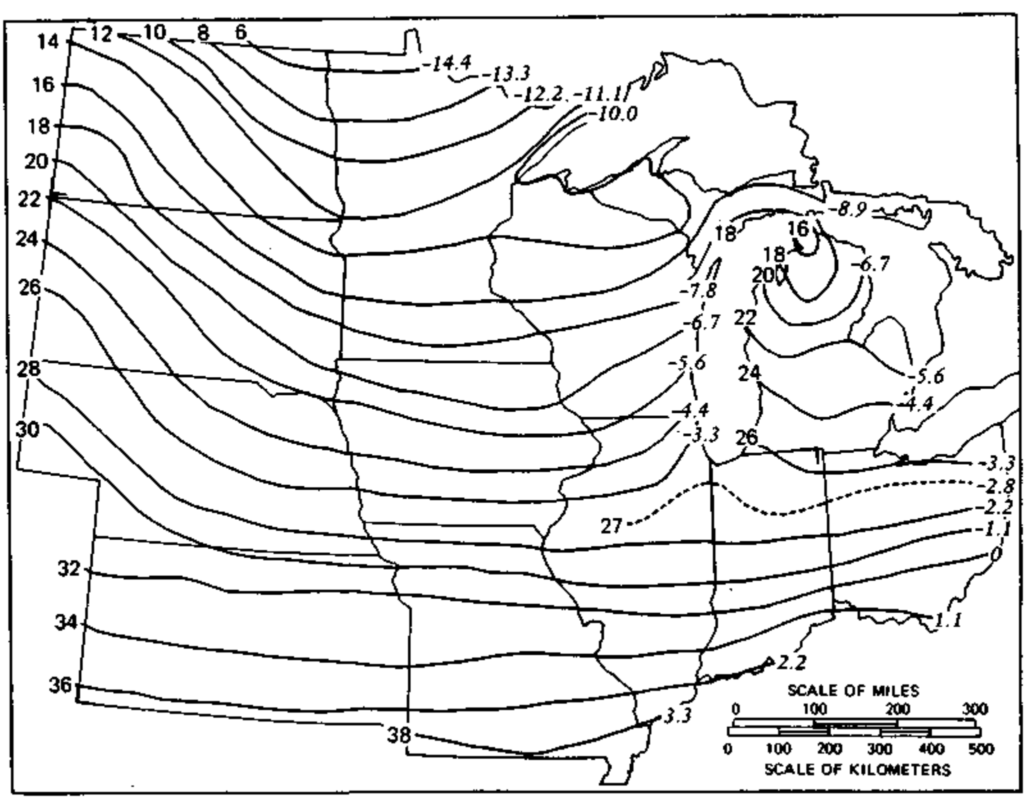

Fig. 4. Mean temperature - February

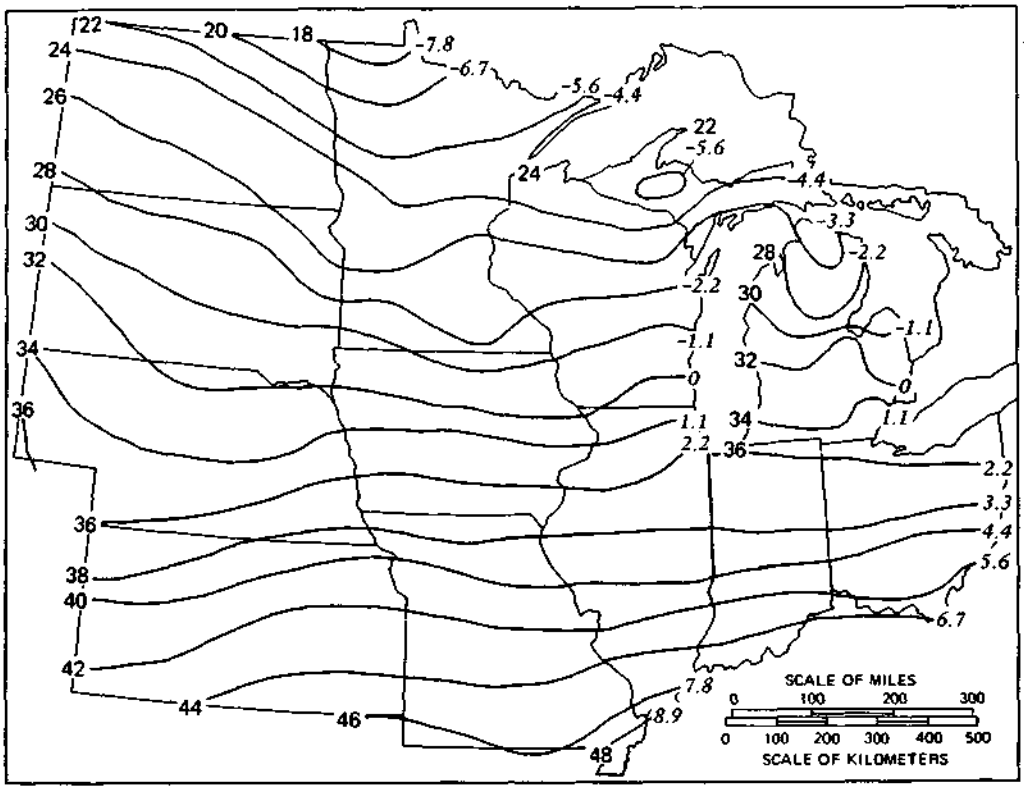

Fig. 5. Mean temperature - March

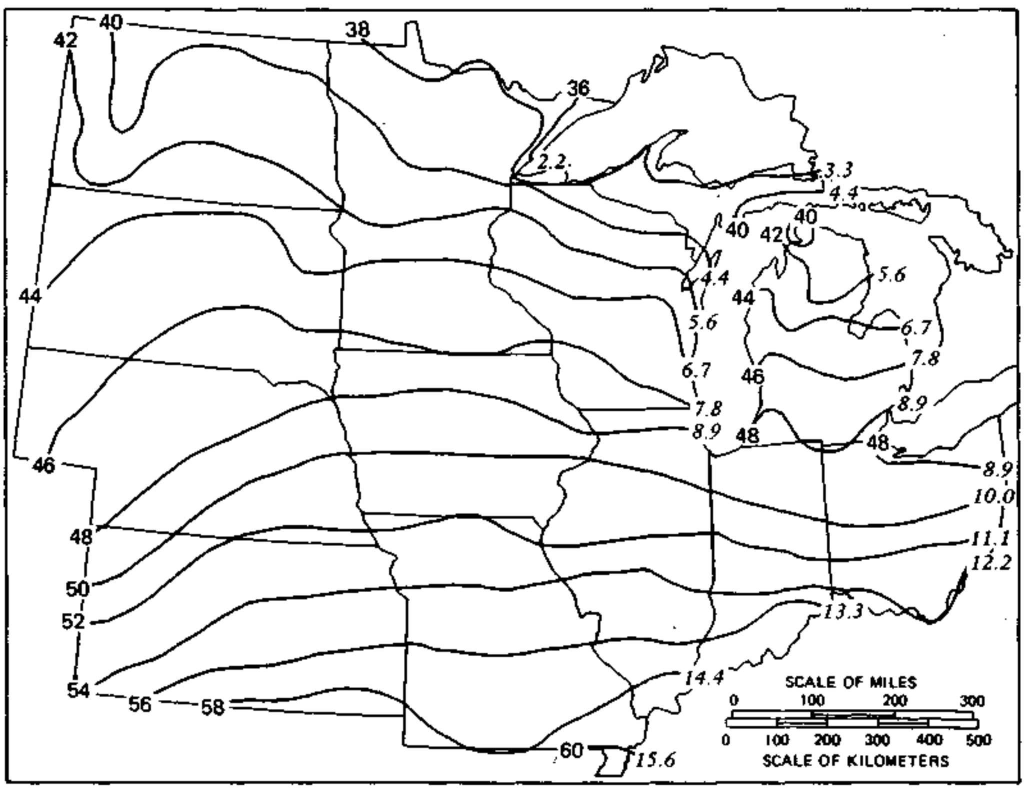

Fig. 6. Mean temperature - April

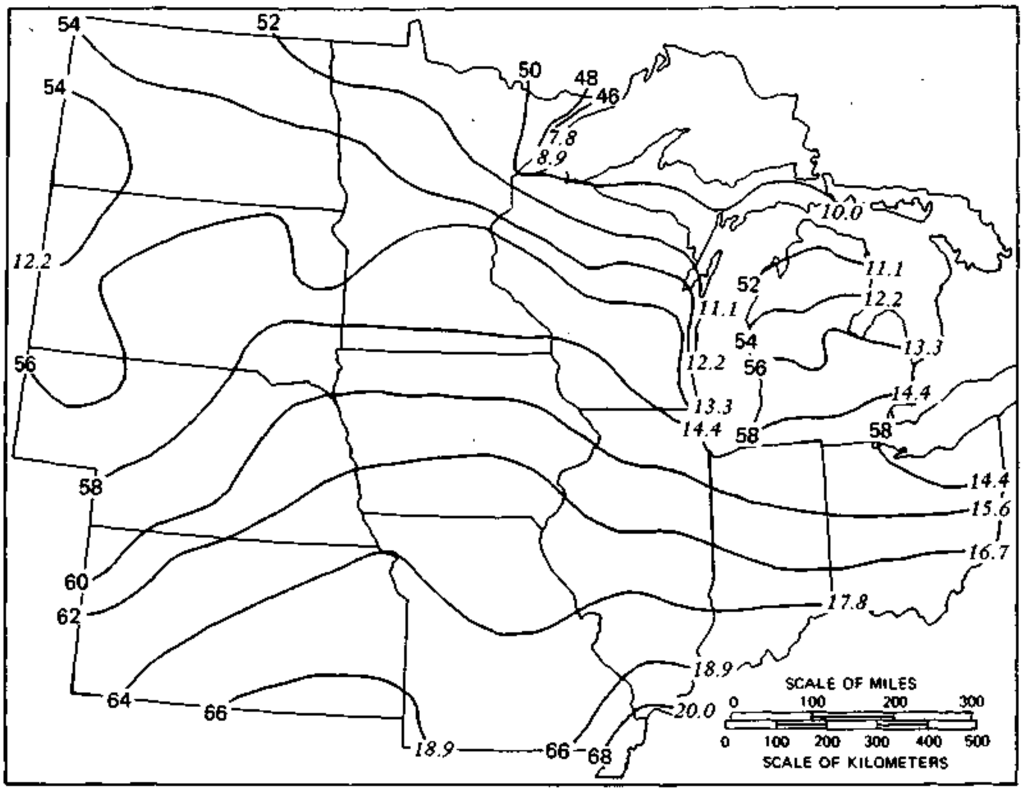

Fig. 7. Mean temperature - May

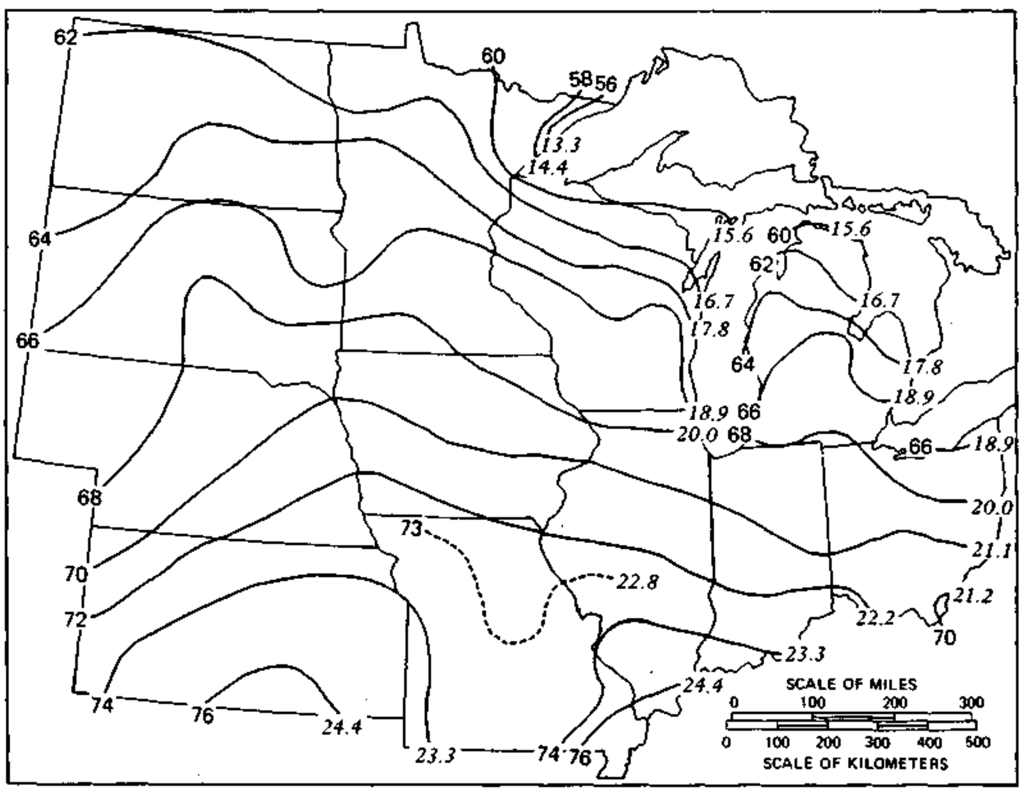

Fig. 8. Mean temperature - June

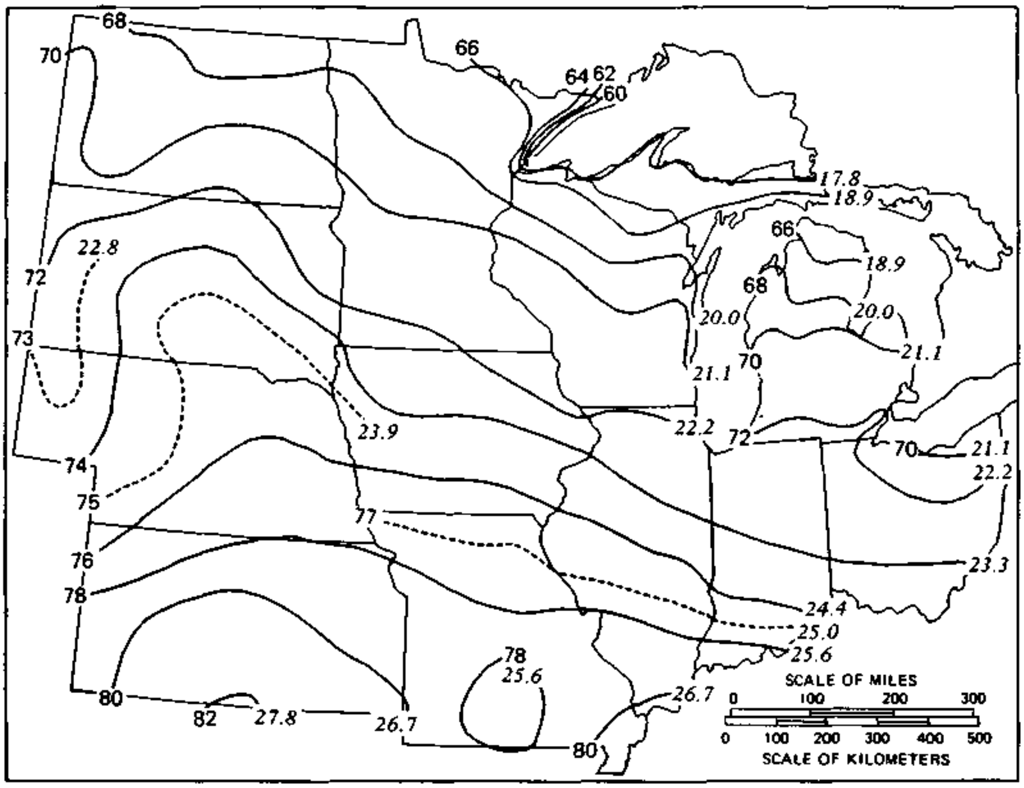

Fig. 9. Mean temperature - July

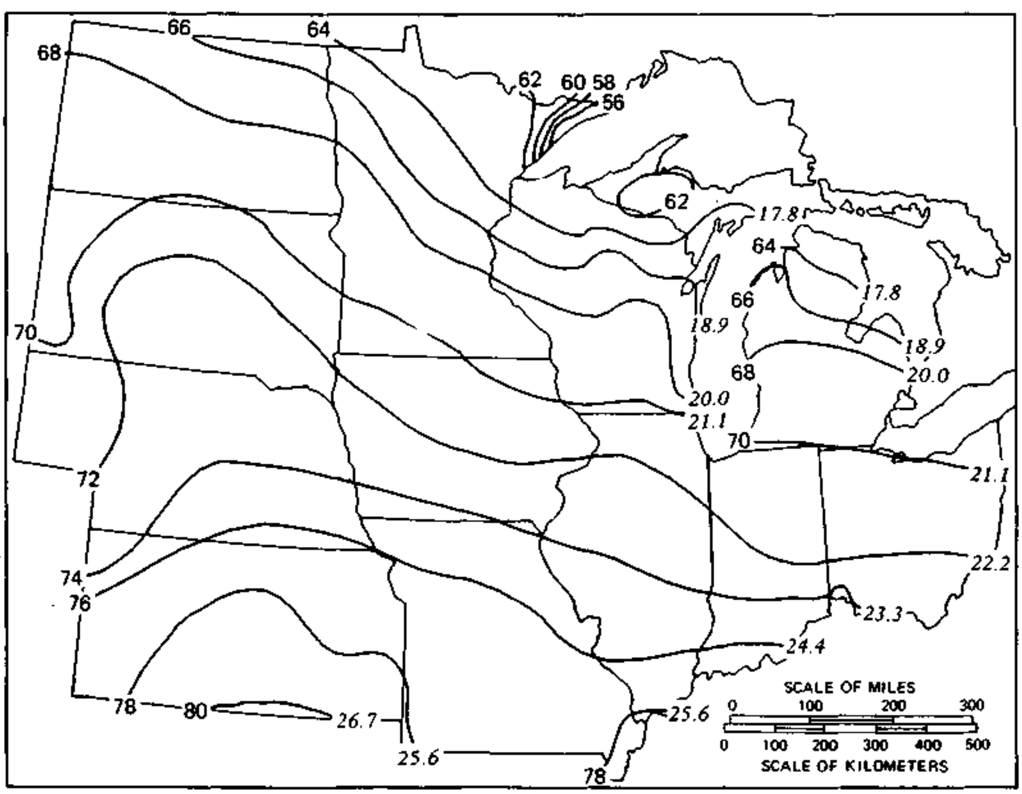

Fig. 10. Mean temperature - August

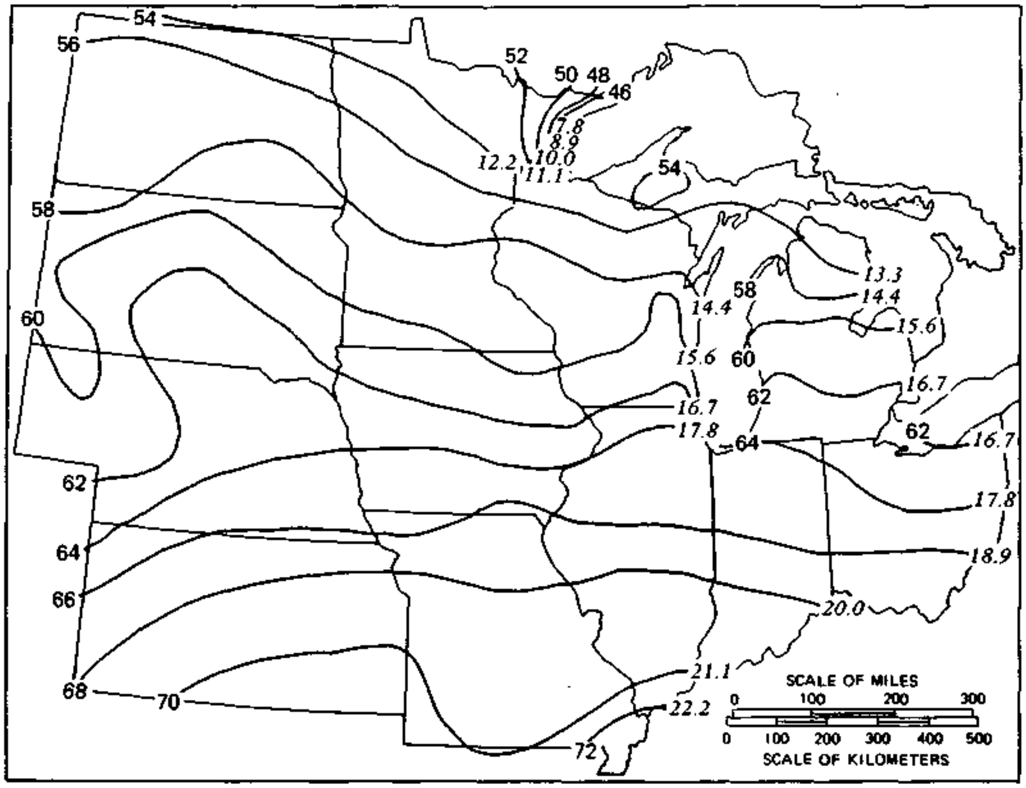

Fig. 11. Mean temperature - September

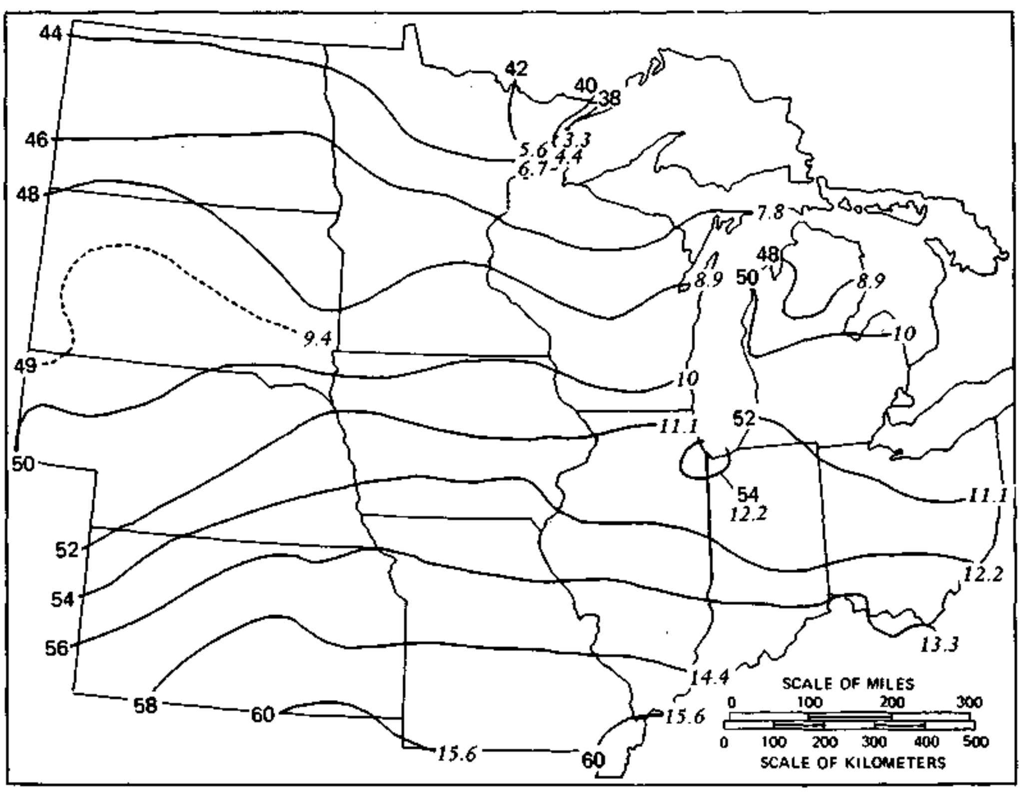

Fig. 12. Mean temperature - October

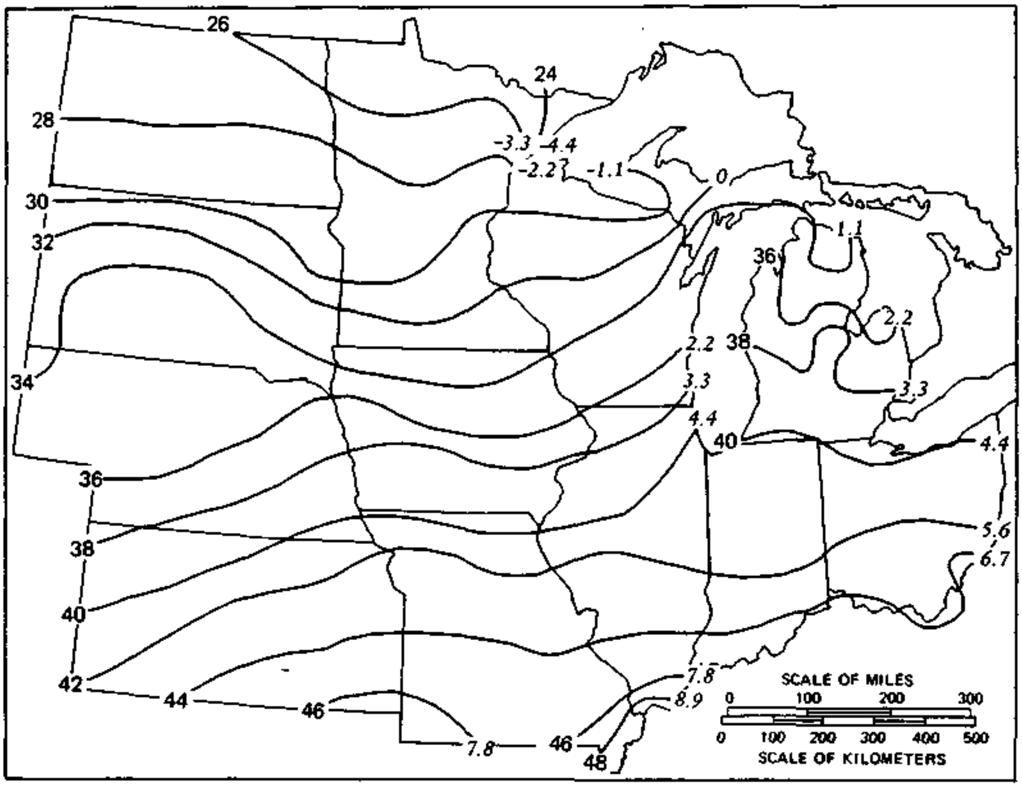

Fig. 13. Mean temperature - November

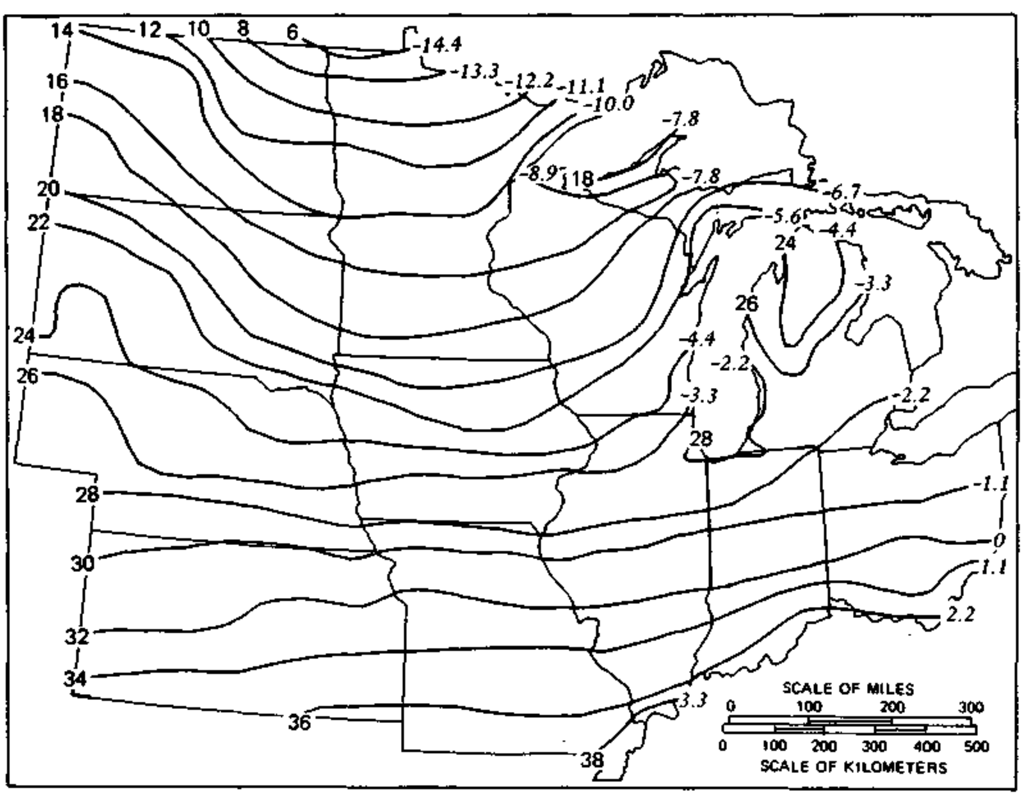

Fig. 14. Mean temperature - December

lier, assuming that the earlier analyses were based on data observed at midnight. Meaningful small scale features are present on the present charts, some of which have not been noted previously. The mean annual isotherms (Fig. 2) lie essentially east-west, except for cooler state-scale pools located over southwestern and northeastern Minnesota, western Nebraska, Missouri and northern Michigan. The maximum north-south gradient is about 20F (11.1C).

From November (Fig. 13) through February (Fig. 4) the coldest temperatures are noted over the eastern Dakotas and western Minnesota, exhibiting the cooling due to arctic intrusions from Canada. The warming impact over Lakes Michigan and Huron on mean annual temperatures of lower Michigan is apparent. The mean temperature difference from north to south over the region in winter is about 35F (19.4C).

That colder temperatures are observed in the central part of the region in winter (as opposed to the west or east), is noted from the patterns of isotherms from December (Fig. 14) through February (Fig. 4). The warming influence of the Great Lakes is also apparent during these months. The degree of warming appears to be on the order of 2 to 4F (1.1 to 2.2C) over distances of about 40 miles (64 km) near the shorelines. The temperature difference from the eastern extremity of the mapped region to the central part along any line of latitude is about 2 to 3F (1.1 to 1.7C).

From March (Fig. 5) through November (Fig. 13), on the other hand, the isotherms exhibit a northward extension in the central part of the region, and the north to south temperature gradient is reduced to only 12 to 14F (6.7 to 7.8C) over the region. The magnitude of the temperature difference from the eastern part of the region to the center is 6 to 8F (3.3 to 4.4C) at latitudes greater than about 42N, and and about 2 to 4F (1.1 to 2.2C) at latitudes less than about 42N. A cool pool of air is noted over Missouri from April (Fig. 6) through October (Fig. 12). Apparently, this is a function of altitude , i.e., the Ozarks in southern Missouri. A clear northward expension of isotherms is noted over Nebraska and the Dakotas during these months as well, reaching its greatest prominance in August. The cooling influence of the Great Lakes is apparent, being greatest along the Minnesota shoreline of Lake Superior, the Great Lake with the coldest mean surface temperatures.

January, April, July and October distributions of mean maximum and mean minimum temperature are presented in Figs. 15-18, respectively. The patterns are very similar to those shown in the mean monthly temperature charts, and show that the mean diurnal temperature variation is about 20 to 22F (11.1 to 12.2C) in winter and about 24F (13.3C) in summer.

Heating- and Cooling-Degree Day Analyses

The mean distribution of annual heating degree days is presented in Fig. 19 (in units of Fahrenheit degree days on the left and Celsius degree days on the right). The total impact, of course, is due to the Mean heating degree-days vary from about 4,000 (F) in the southern part of the region to more than 10,000 (F) in the north. The effect of Lake Michigan on lower Michigan is apparent, and results in a 3 to 5% reduction in the annual total. Mean annual cooling degree days are presented in Fig. 20 (again in both Fahrenheit and Celsius degree day units). Within the 12 state region, cooling degree days (in excess of 50 per month) are only accummulated from May through September in the mean. The pattern of mean annual cooling degree-days is similar to the mean isotherm patterns of summer monthers. Annual accummulations vary from about 150 (F) in Upper Michigan to more than 1,600 (F) in southern Kansas. The moderation of Lake Michigan on lower Michigan is again apparent, with the

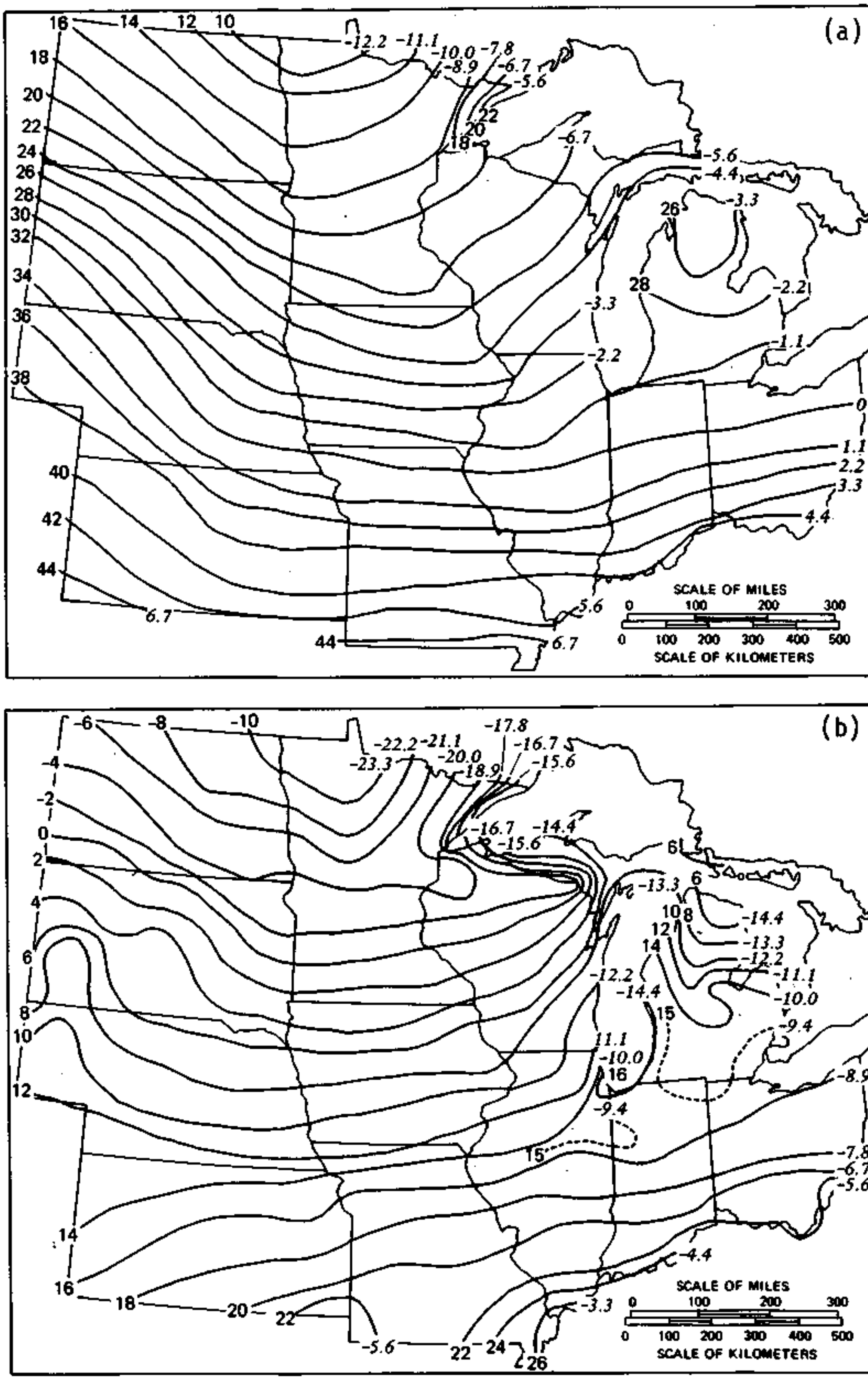

Fig. 15. Mean maximum temperature (a) and mean minimum temperature (b) for January

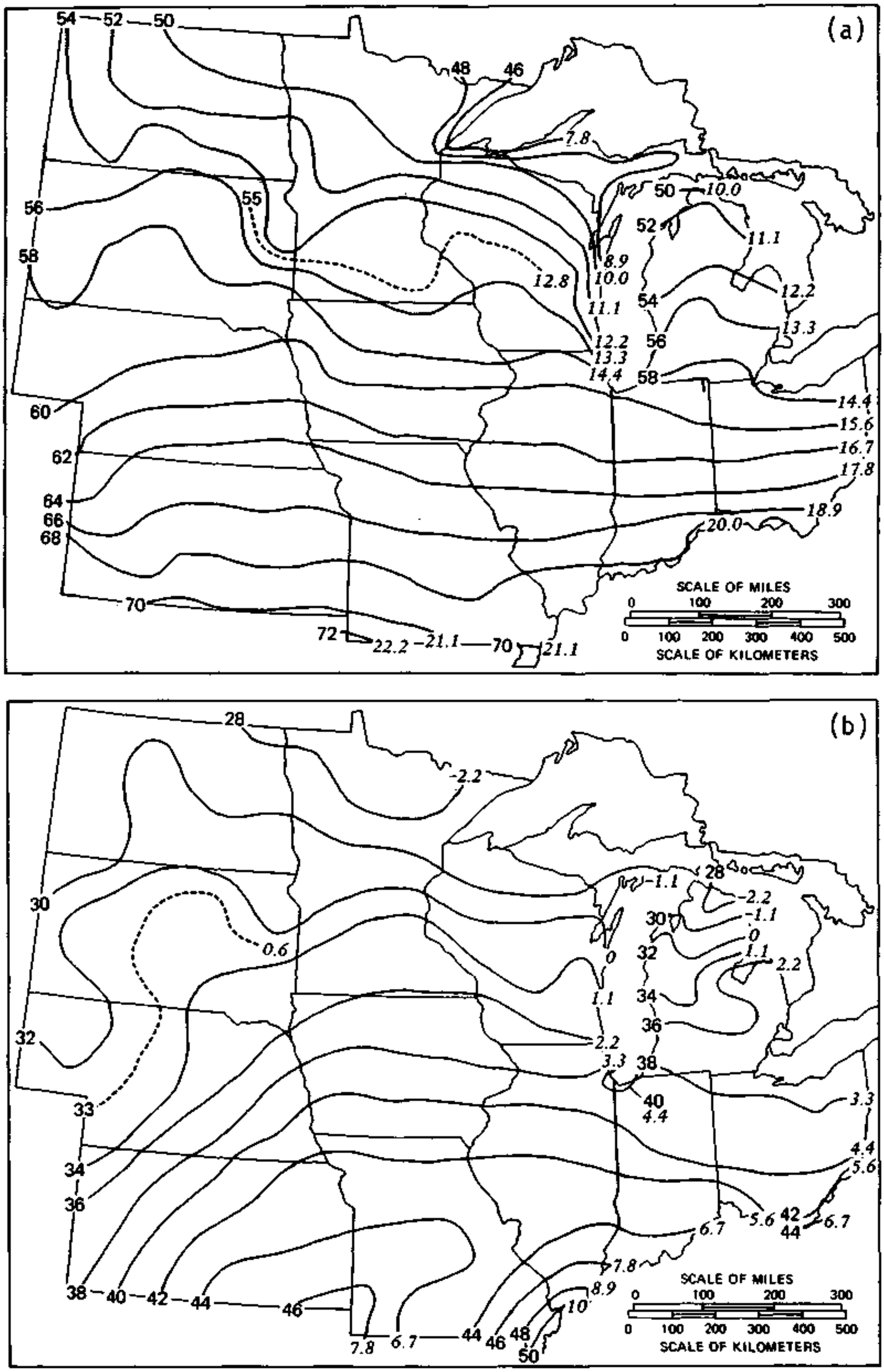

Fig. 16. Mean maximum temperature (a) and mean minimum temperature (b) for April

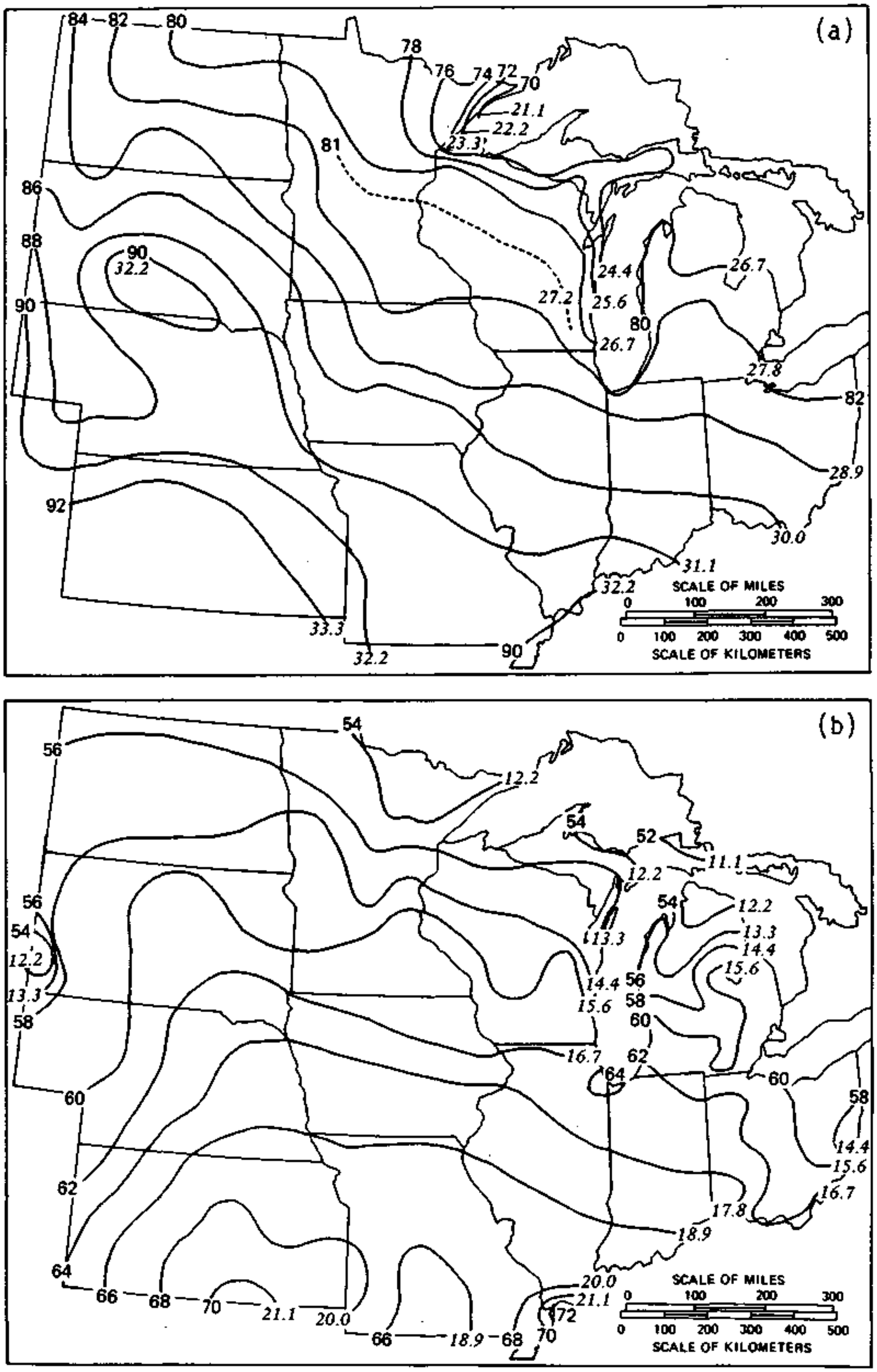

Fig. 17. Mean maximum temperature (a) and mean minimum temperature (b) for July

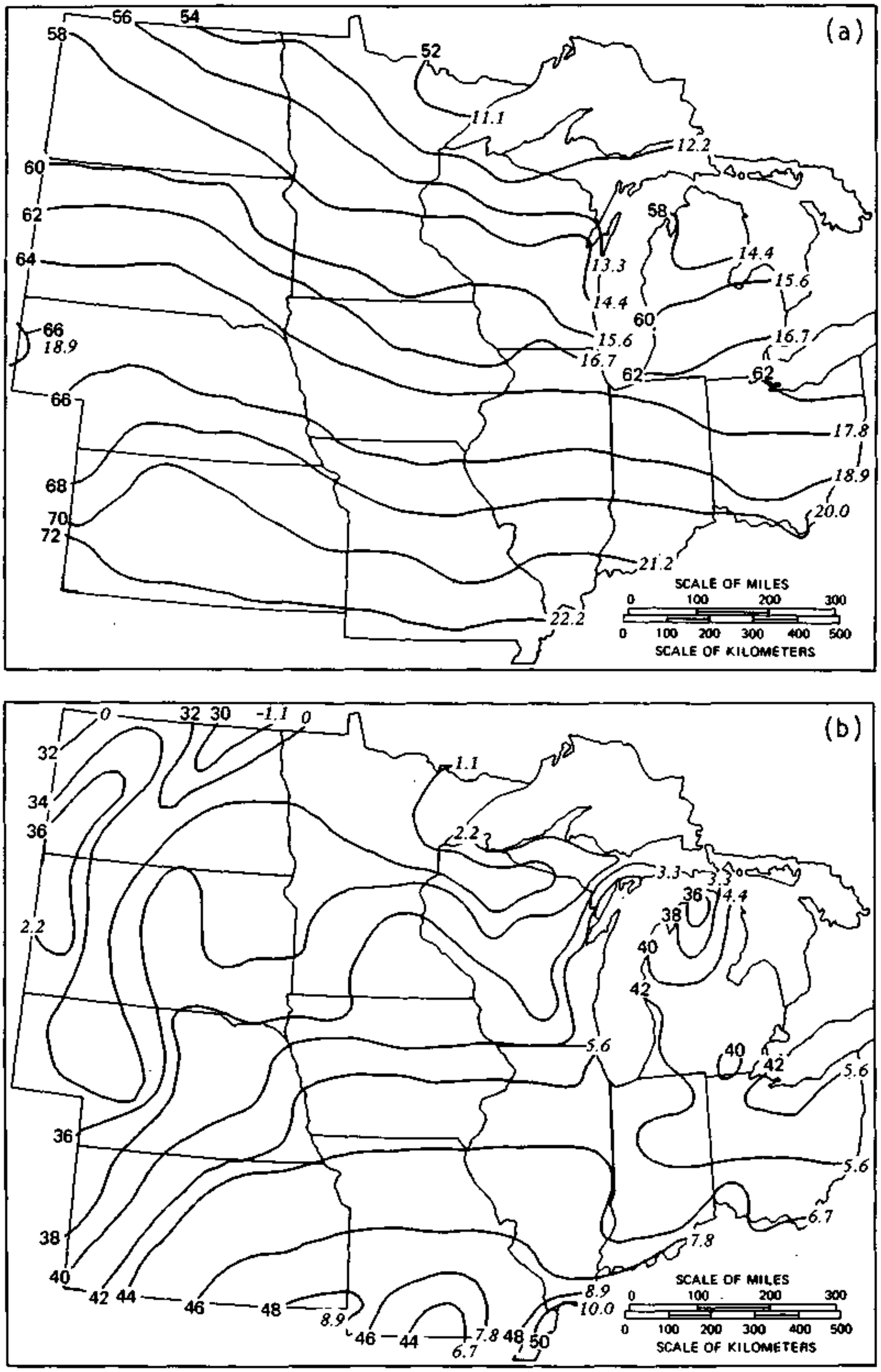

Fig. 18. Mean maximum temperature (a) and mean minimun temperature (b) for October

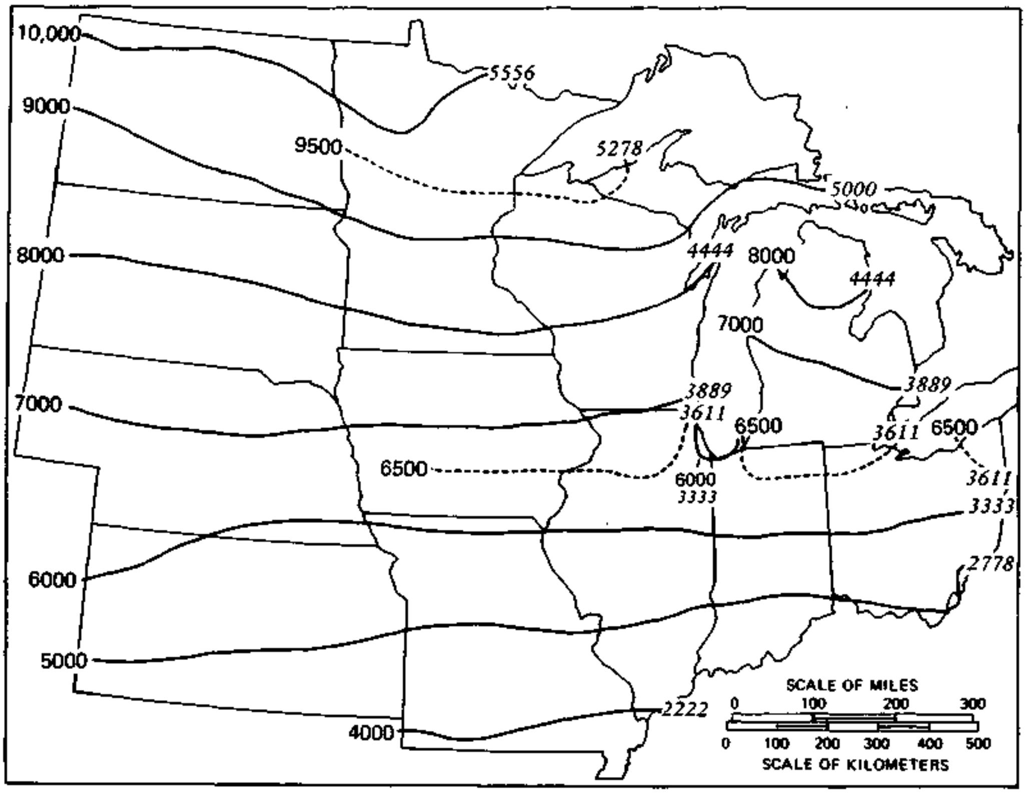

Fig. 19. Mean heating degree days - Annual

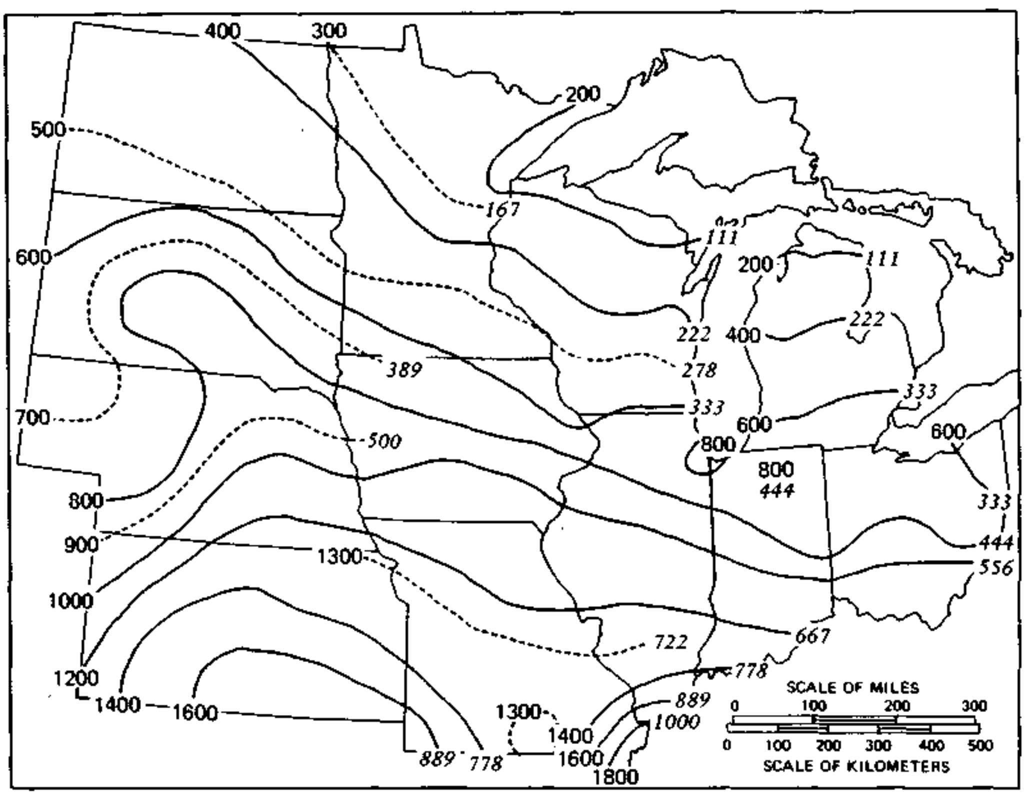

Fig. 20. Mean cooling degree days - Annual

magnitude of the impact being about the same in absolute terms (200 to 300 degree-days), but the percentage change now being about 25%.

Precipitation Analyses and Discussion

The charts showing mean monthly precipitation (liquid equivalent) are not systematically corrected for the time of observation. A potential error, believed to be minor, is introduced for monthly totals (depending upon the hour of observation) because the recorded observation of the first and last days, respectively, of each month potentially could include precipitation which actually fell during the last day of the previous month or during the first day of the month after the day in question. We suggest that this error self-cancels in the long term. The error to observations made at times other than midnight will most likely be greatest during spring and fall months, when the monthly precipitation is increasing and decreasing most rapidly, respectively. However, a systematic mean correction cannot be calculated since precipitation is a temporally (and incidently, spatially) discontinuous function. The mean values presented herein represent an analysis of mean monthly totals based on 1951-80 data from all 884 reporting stations.

The mean annual and monthly patterns of precipitation are presented in Figs. 21-33 (units of inches in block numbers and millimeters in italics). During the cooler months of the year (November through March) precipitation within the region generally decreases from about 4 inches per month (100 mm) in southeastern Missouri to 0.5 inch (13 mm) or less per month over the Great Plains. The precipitation enhancement downstream of the Great Lakes is most apparent in October through January, being primarily noted along the northern near-shore of upper Michigan, the western near-shore of lower Michigan, and northern Ohio. These areas receive as much as 50% (about 1 inch or 25 mm) or

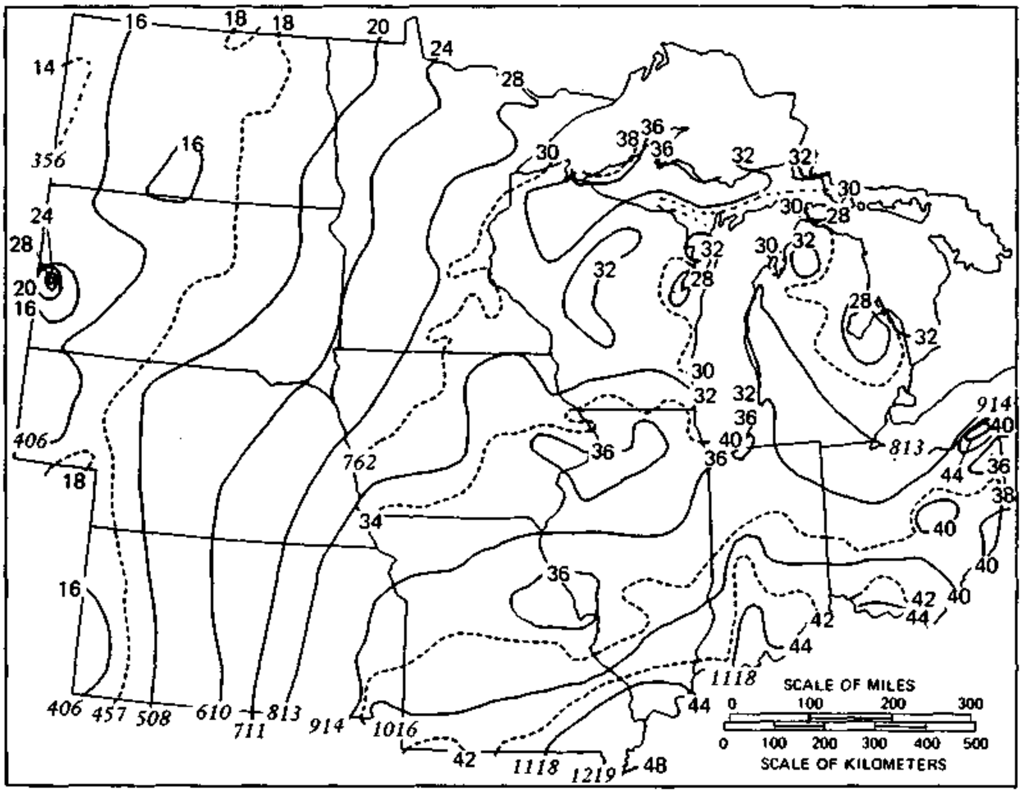

Fig. 21. Mean precipitation - Annual

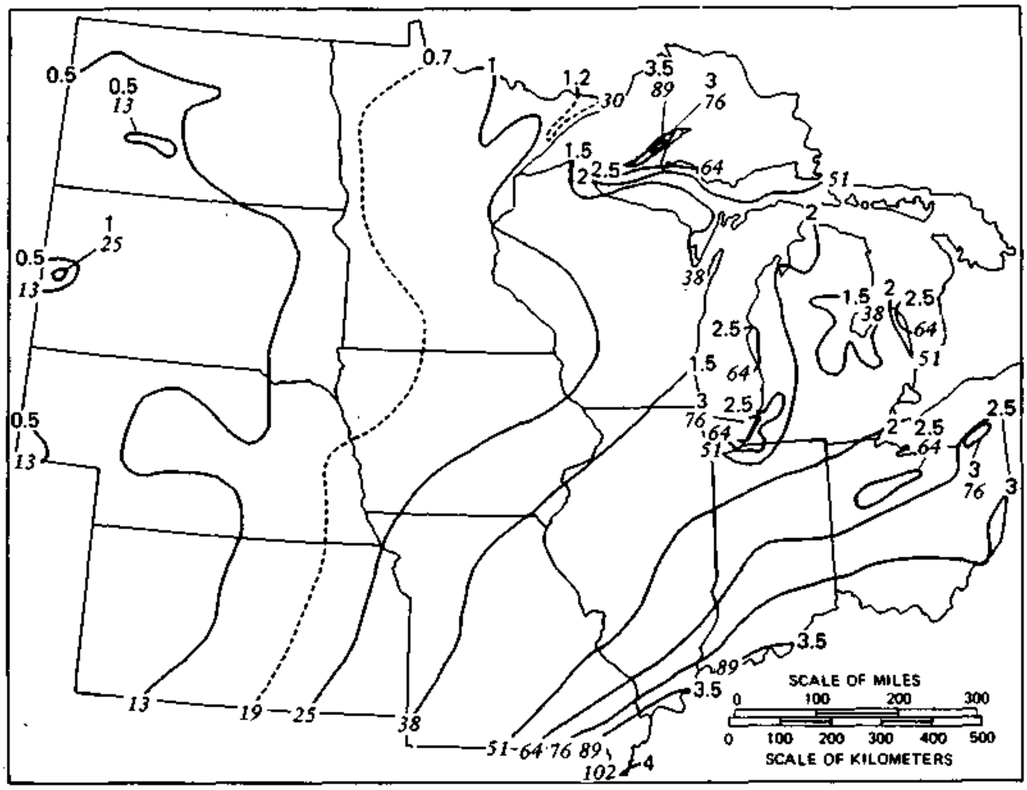

Fig. 22. Mean precipitation - January

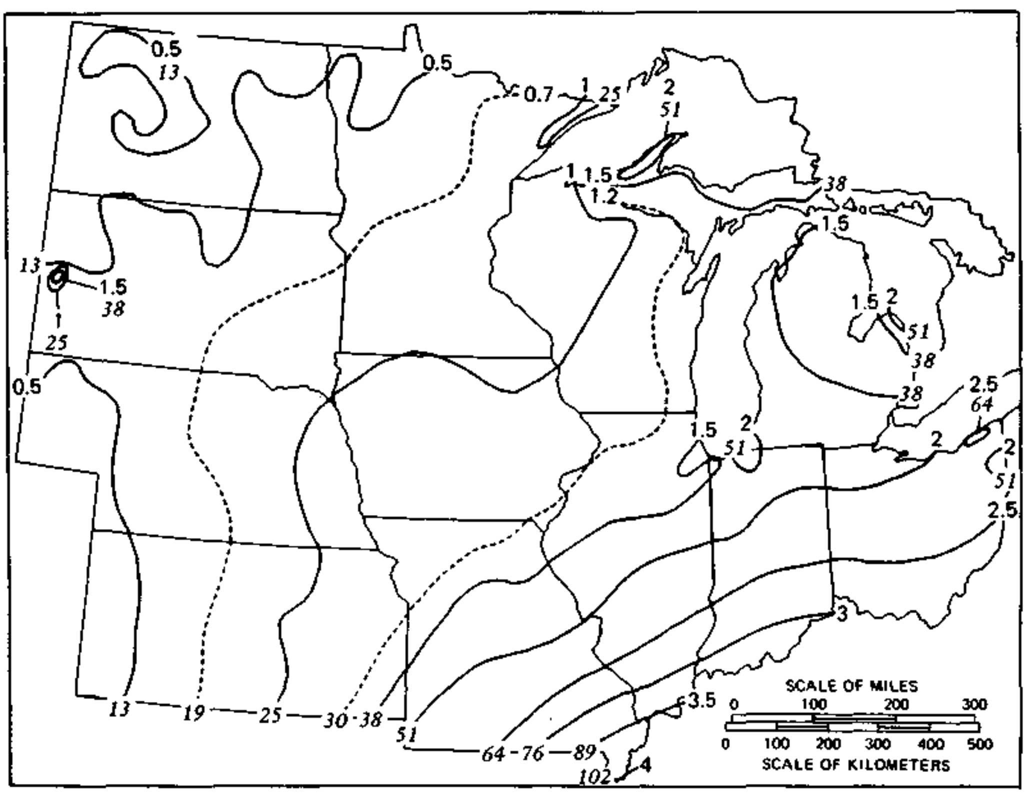

Fig. 23. Mean precipitation - February

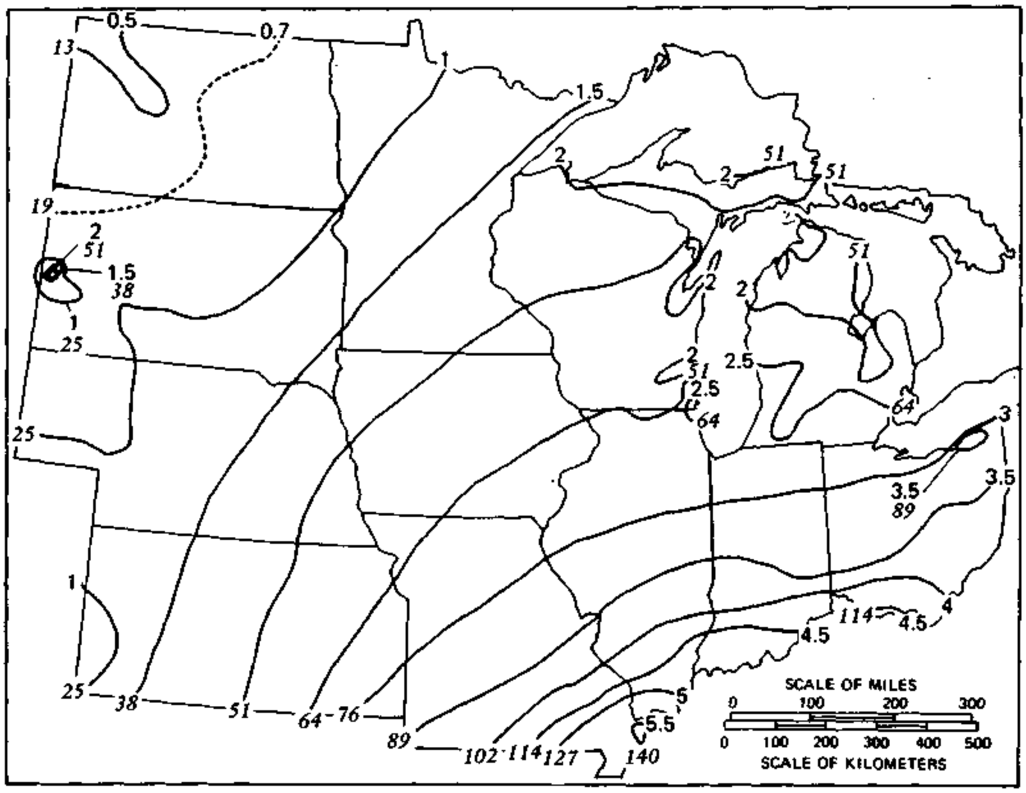

Fig. 24. Mean precipitation - March

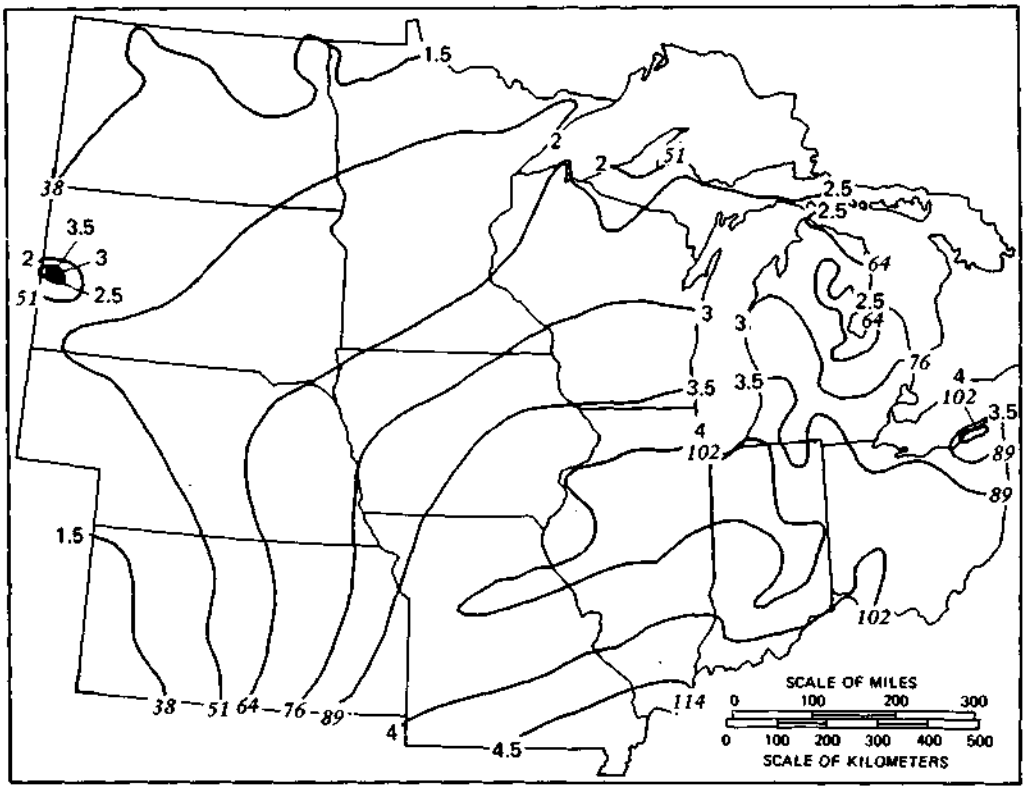

Fig. 25. Mean precipitation - April

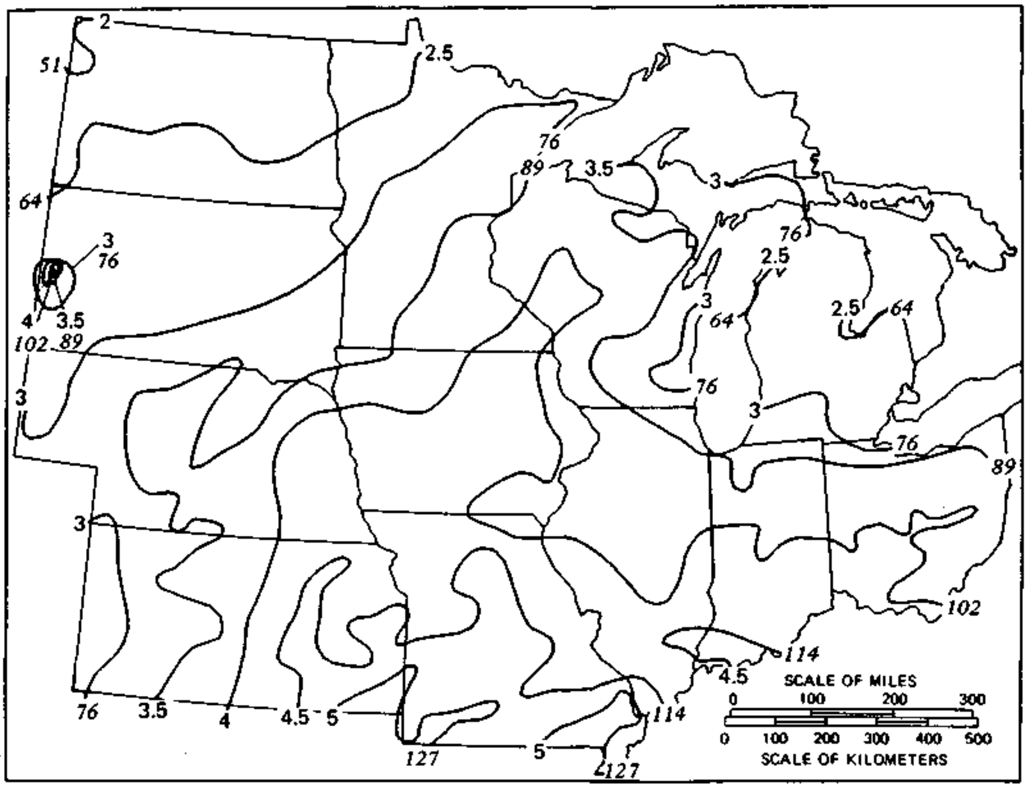

Fig. 26. Mean precipitation - May

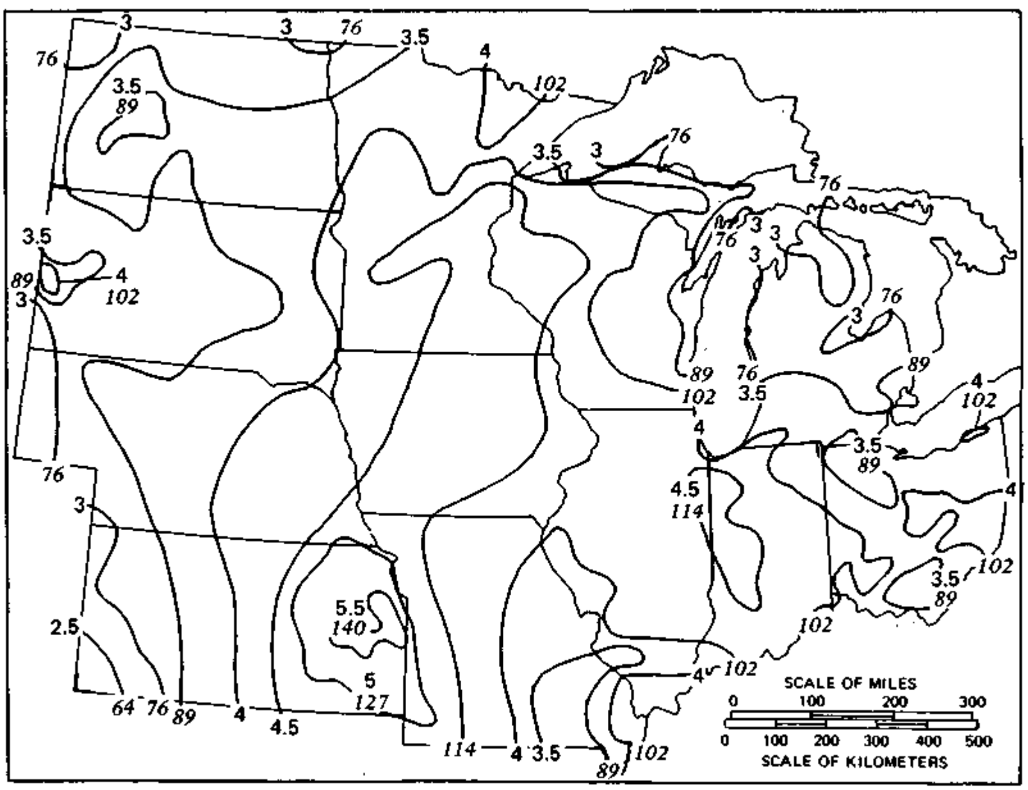

Fig. 27. Mean precipitation - June

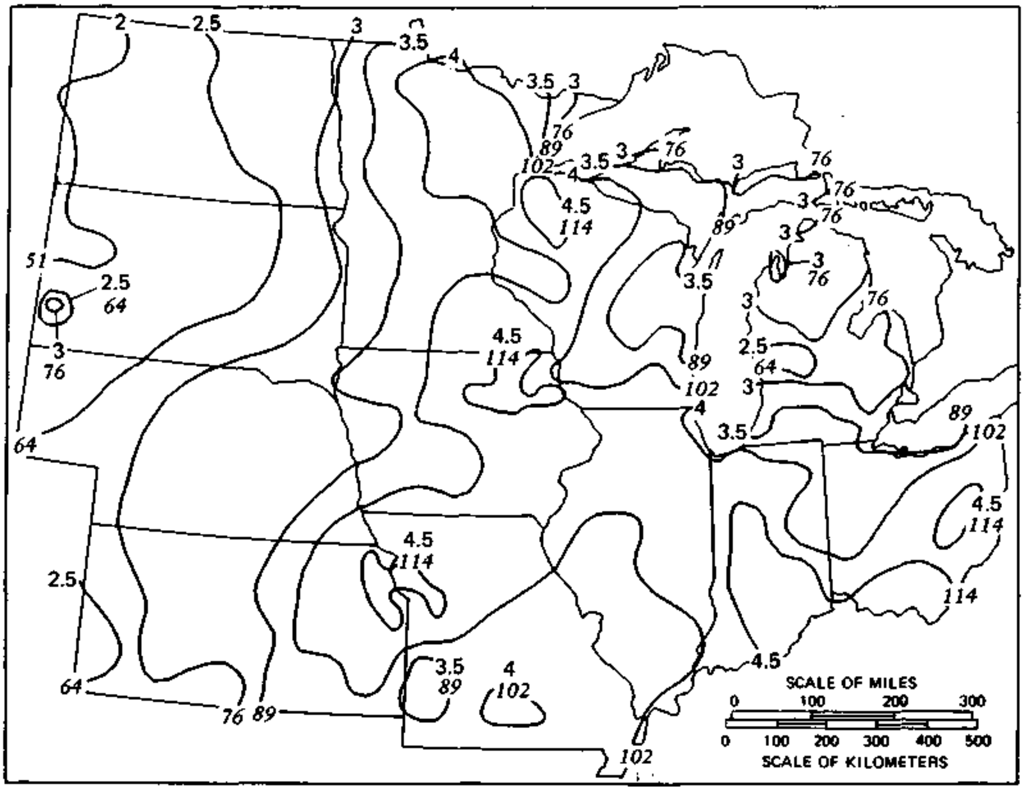

Fig. 28. Mean precipitation - July

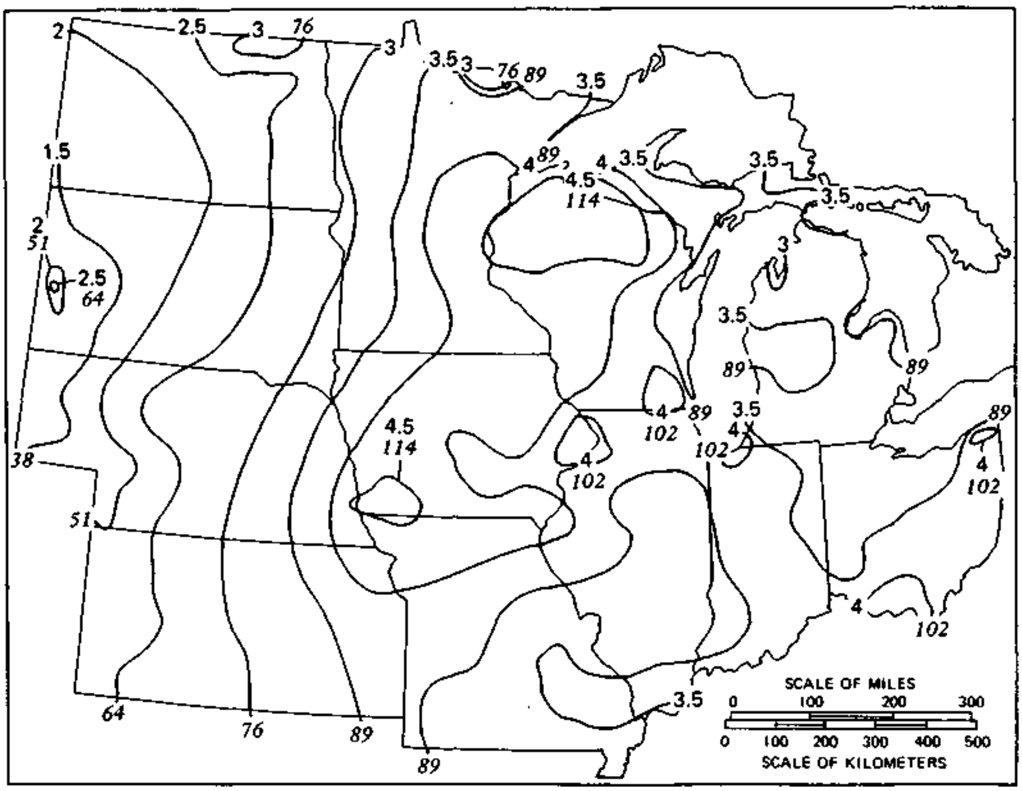

Fig. 29. Mean precipitation - August

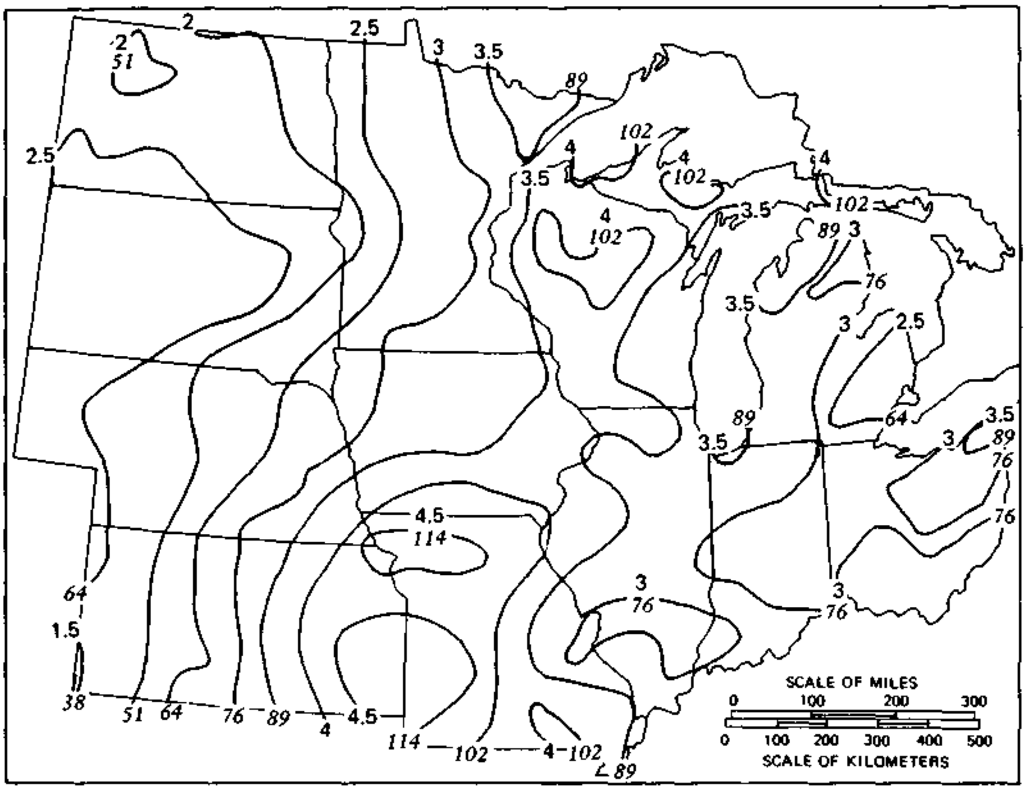

Fig. 30. Mean precipitation - September

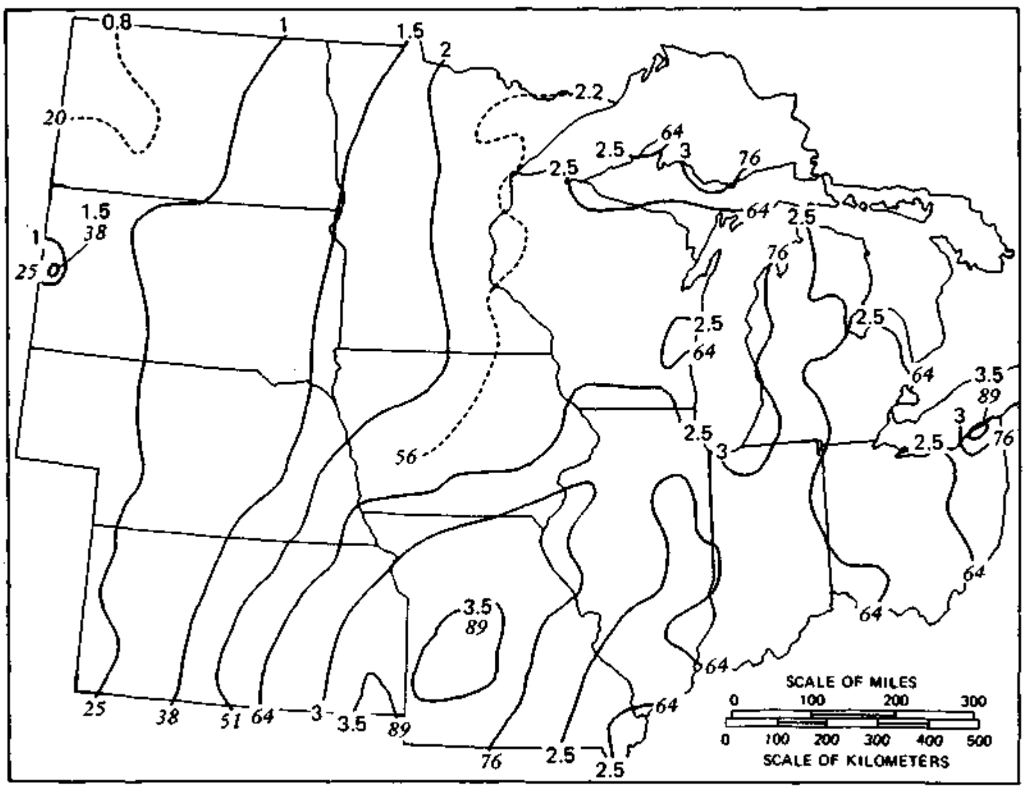

Fig. 31. Mean precipitation - October

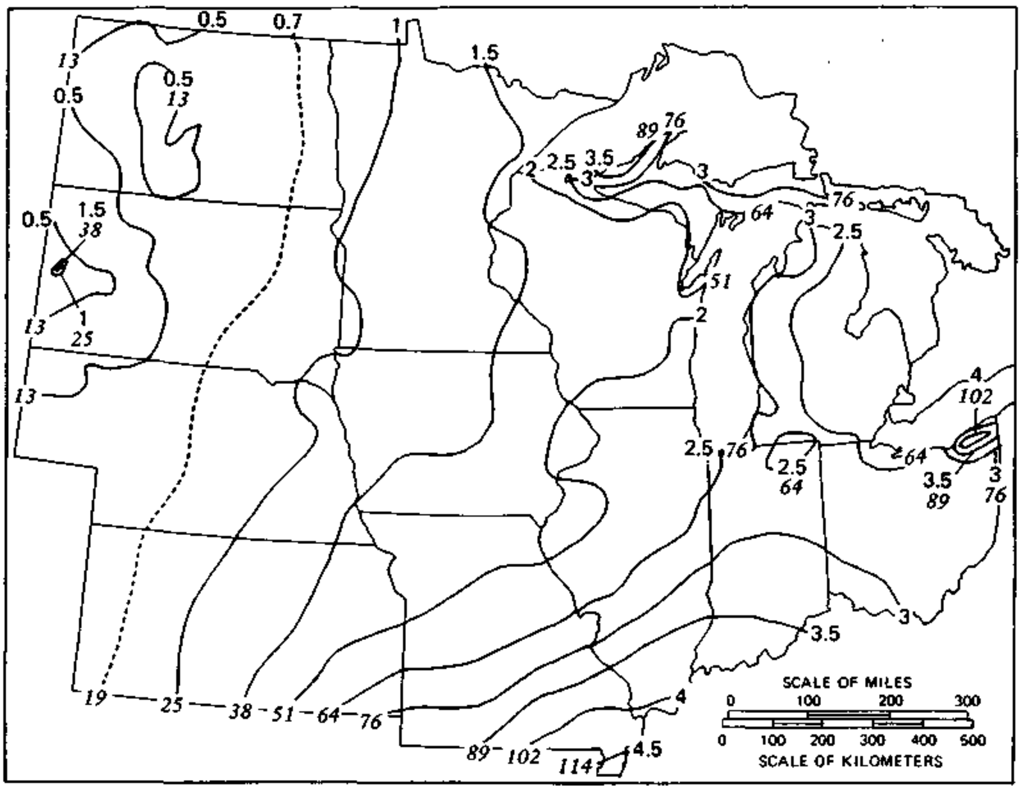

Fig. 32. Mean precipitation - November

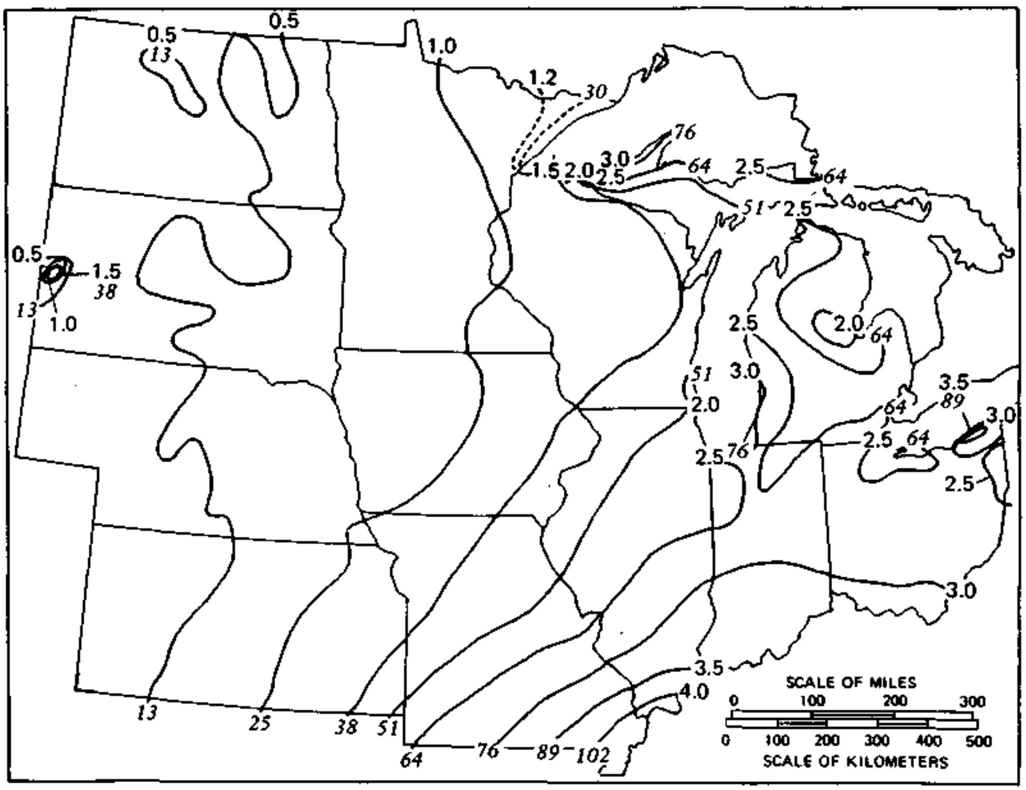

Fig. 33. Mean precipitation - December

more monthly precipitation than a location 50 miles (90 km) further inland.

During summer (June, July and August), the mean monthly patterns become much less spatially continuous, with an area of relatively high precipitation developing from Missouri northeastward. It persists through October although it begins to decrease its latitudinal extent after August, reaching the winter pattern in November. As with the isotherms over Missouri and northward, precipitation in this area is related to the increase of the surface elevation above sea level, a feature which enhances precipitation. Because summer precipitation results from convective (showers and thunderstorms) precipitation, the amount of precipitation received at any one location does not typically correlate well with the amount received at a nearby station (perhaps only a few miles away). Because of this phenomenon, the isohyets in summer are rather more spatially discontinuous than those of winter. Precipitation decreases from 3 to 4.5 inches (76 to 114 mm) in the southeast to about 1.5 inches (38 mm) in the west. Precipitation is diminished near and especially downstream of the Great Lakes in summer, although the magnitude of the effect is reduced from that noted during winter.

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