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El Niño 1997-1998 in the Midwest

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EL NIÑO 1997-1998 IN THE MIDWEST

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Contents

Abstract

An anomalously warm El Niño event developed in the eastern tropical Pacific Ocean during May-August 1997. El Niño events have become recognized as capable of having major effects on atmospheric circulation patterns over North America and elsewhere, leading to predictable outcomes for future seasonal weather conditions.

The source of the nation's official long-range predictions, the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC), began issuing forecasts in May 1997 about the event's development and growth to near record proportions. The emerging El Niño was expected to match or exceed the El Niño of 1982-1983, the strongest of this century. Predictions of the future weather conditions expected over the nation, as a result of El Niño's influence on the atmosphere, also were issued by CPC beginning in June 1997. Basically, these and subsequent predictions called for a fall, winter, and early spring in the Midwest that would have above normal temperatures and below normal precipitation. The predictions also called for storms and precipitation to increase in other parts of the nation, particularly in the South and West Coast areas.

Media and wide public interest in the evolving record event brought inquiries to the Midwestern Climate Center (MCC) during June 1997. At that time, MCC leadership launched special studies and efforts related to the El Niño event, which included:

1) a climatological reanalysis of past El Niño events and the associated weather conditions in the Midwest,
2) the issuance of outlooks based on these studies, and
3) the collection and analysis of data on the impacts caused by the El Niño-generated weather conditions in the Midwest.

This decision was in keeping with past MCC research policy that has focused on assessing extreme Midwestern weather conditions like the 1988 drought (Changnon, 1991a and b), the 1993 flood (Kunkel, 1996; Changnon, 1996), and the 1995 heat wave (Kunkel et al., 1996; Changnon et al., 1996). These studies also focused on identifying and quantifying the impacts of these extreme events. The findings of such activities help the MCC respond rapidly and accurately to numerous regional inquiries for data and information about such extreme events. They also help the MCC prepare for effectively addressing similar events in the future.

During the El Niño event, beginning in June 1997 and ending in May 1998, the MCC scientists issued several climate outlooks about future Midwestern conditions. These were basically probabilistic-based statements and focused on the winter of 1997-1998, spring 1998, and summer 1998 outcomes. During the El Niño event, the MCC staff collected and recorded all the relevant weather data for the Midwest. Data defining the impacts of El Niño-generated weather events were collected from August 1997 through August 1998.

This report presents information about MCC activities related to El Niño in 1997-1998. It includes three sections: the predictive outlooks issued, a climatic assessment of the monthly and seasonal weather conditions during the event, and a description of the societal and economic impacts caused in the Midwest. Recommendations are offered in the section "Conclusions and Recommendations" for addressing future El Niño events and the handling of long-range predictions.

El Niño Outlooks

Kenneth E. Kunkel

Background

The National Weather Service's (NWS) Climate Prediction Center (CPC) began issuing public alerts about the potential for the development of an El Niño episode in the spring of 1997. They stated that an El Niño was developing in the eastern equatorial Pacific. The June assessments indicated that this El Niño would be of record size and strength. The June and July forecasts included warnings about possible seasonal weather extremes, including heavy rains and storms in California and the Deep South during the winter of 1997-1998.

These forecasts created widespread media interest. The Midwestern Climate Center (MCC) began receiving numerous phone calls from the media in June 1997 requesting more specific information about what future weather conditions would occur. The national media focus on possible weather-driven catastrophes associated with this El Niño created a widespread perception in the public that the impacts of El Niño would be negative everywhere. The information provided by the CPC in their forecasts for the Midwest was rather general in nature. The long-range predictions indicated that the northern part of the Midwest would likely see warmer and drier conditions than normal in the 1997-1998 winter, and cooler and wetter conditions than normal in the fall.

Many of the inquiries received by the MCC were specific in nature, such as potential impacts of El Niño weather on the 1998 crop yields or on winter storm activity. Despite the extensive research on El Niño, many of these issues had not been addressed by the research community Thus, there was a clear need for more specific outlook information focused on likely conditions in the Midwest.

Because there was a need for more specific information and because the approximate one-year lifetime of an El Niño event would sustain interest for several months, the MCC undertook a program of research and analysis. This program is described in the next section. The methods used to disseminate this information are described after that. The specific outlook information provided by the MCC then is discussed.

Research and Analysis

A series of research and analysis efforts were undertaken to expand the available information about the effects of El Niño on Midwestern climate conditions. Four analyses were performed.

The first effort was a historical analysis of the general temperature and precipitation conditions that occurred in past El Niño events for each season and for each state in the region. In this analysis, conditions in each year were categorized as below normal, normal, and above normal. The number of times during past El Niño events that conditions were in each of the three categories were identified. This analysis could be performed quickly because extensive data resources were readily available on the Midwestern Climate Information System (MICIS). The period 1895-1996 was used as the basis for this assessment. Following the definitions used by the NWS, the coolest or driest third (34 years) of the 102 years was considered below normal, the middle third was considered normal, and the warmest or wettest third was considered above normal. Tables 1-4 show the results of this analysis for the four seasons, the temperature and precipitation departures from the median value and the rank (1 = coolest or driest, 102 = hottest or wettest) averaged over the entire Midwest. These tables show the rankings and departures from normal as of the summer of 1997.

The analysis for summer (table 1) showed a tendency for cool and wet conditions. Five of the ten El Niño years were cooler than normal, two years were warmer than normal, and three years were normal. For precipitation, five years were wetter than normal, three years were drier than normal, and two years were normal.

The analysis for fall (table 2) also showed a tendency toward cool, wet conditions. Six of the 11 El Niño years were cooler than normal, one year was warmer than normal, and four years were normal. For precipitation, six years were wetter than normal, three years were drier than normal, and two years were normal.

The analysis for winter (table 3) indicated a tendency toward warm, dry conditions. Four of the 11 El Niño years were warmer than normal, two years were cooler than normal, and five years were normal. For precipitation, six years were drier than normal, three years were wetter than normal, and two years were normal.

There were only four events for spring (table 4). One spring was warmer than normal and one spring was cooler than normal. For precipitation, three events were drier than normal and one event was wetter than normal.

The second analysis focused on agricultural yields. This was of immediate interest to many news media because the initial CPC forecasts were issued near the beginning of the 1997 growing season. To assess the possible outcomes for growing conditions during the 1997 summer, a historical analysis of the corn and soybean yield during past El Niño events was performed. This analysis compared the average corn and soybean yields in El Niño summers with those in non-El Niño summers. The results in table 5 indicate that corn yields have generally been above average during El Niño summers. Average positive deviations of 5 percent or more were found in Illinois, Indiana, Missouri, and Wisconsin. Soybean yields also were generally above normal during El Niño summers, with deviations in excess of 5 percent or more in Michigan, Missouri, and Wisconsin. Soybean yields average slightly below average (-3 percent) in Ohio

Table 1. Summer (June-July-August) during El Niño Events*
Rank values are for 102 years and based on position from highest or lowest values

	Temperature (°F)		*Precipitation (%)*	
Year	*Rank*	*Departure from median*	*Rank*	*Departure from median*
1951	16	-1.9 (B)**	96	+21 (A)
1957	61	+0.2 (N)	79	+7 (A)
1963	51	-0.2 (N)	23	-10 (B)
1965	17	-1.7 (B)	53	-1 (N)
1969	29	-1.1 (B)	84	+9 (A)
1972	20	-1.7 (B)	67	+4 (N)
1976	45	-0.5 (N)	5	-24 (B)
1982	10	-2.4 (B)	77	+6 (A)
1987	85	+1.4 (A)	80	+7 (A)
1991	83	+1.4 (A)	10	-21 (B)

Notes: *Only years when a strong signal was present were used. Values are averages for Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.
**B = below normal, N = normal, and A = above normal.

Table 2. Fall (September-October-November) during El Niño Events was present*
Rank values are for 102 years and based on position from highest or lowest values

	Temperature (°F)		*Precipitation (%)*	
Year	*Rank*	*Departure from median*	*Rank*	*Departure from median*
1951	5	-3.2 (B)**	75	+14 (A)
1957	25	-1.6 (B)	64	+5 (N)
1963	101	+4.1 (A)	4	-45 (B)
1965	48	-0.4 (N)	83	+23 (A)
1969	30	-1.4 (B)	54	-1 (N)
1972	18	-2.0 (B)	90	+27 (A)
1976	1	-5.0 (B)	6	-43 (B)
1982	46	-0.5 (N)	74	+13 (A)
1986	39	-0.7 (N)	99	+45 (A)
1987	44	-0.6 (N)	6	-37 (B)
1991	16	-2.2 (B)	88	+25 (A)

**Notes: ***Only years when strong signal was present were used. Values are average for Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin
**B = below normal, N = normal, and A = above normal.

Table 3. Winter (December-January-February) during El Niño Events*
Rank values are for 102 years and based on position from highest or lowest values

	Temperature (°F)		*Precipitation (%)*	
Year	*Rank*	*Departure from median*	*Rank*	*Departure from median*
1951-52	86	+1.9 (A)**	76	+13 (A)
1957-58	61	+0.4 (N)	27	-15 (B)
1963-64	38	-1.2 (N)	4	-44 (B)
1965-66	48	-0.4 (N)	56	0 (N)
1969-70	18	-3.5 (B)	7	-34 (B)
1972-73	56	+0.0 (N)	64	+5 (N)
1976-77	6	-6.8 (B)	3	-47 (B)
1982-83	100	+5.1 (A)	77	+14 (A)
1986-87	96	+4.2 (A)	6	-37 (B)
1987-88	42	-1.0 (N)	80	+16 (A)
1991-92	101	+5.2 (A)	31	-12 (B)

Note: *Only years when a strong signal was present were used. Values are averages for Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.
**B = below normal, N = normal, and A = above normal.

Table 4. Spring (March-April-May) during El Niño Events*
Rank values are for 102 years and based on position from highest or lowest values

	Temperature (°F)		*Precipitation (%)*	
Year	*Rank*	*Departure from median*	*Rank*	*Departure from media*
1958	54	+0.0 (N)**	12	-28 (B)
1983	21	-1.8 (B)	98	+23 (A)
1987	101	+4.5 (A)	16	-26 (B)
1992	59	+0.3 (N)	18	-23 (B)

Notes: *Only years when a strong signal was present were used. Values are averages for Illinois, Indiana, Iowa, Kentucky Michigan, Minnesota, Missouri, Ohio, and Wisconsin. This is the spring after El Niño starts.
**B = below normal, N = normal, and A = above normal.

Table 5. Historical Corn and Soybean Yield Deviations for El Niño Summers

State	*Corn yield deviation (%)*	*Soybean yield deviation (%)*
Indiana	+6	+1
Iowa	+1	+4
Michigan	+4	+5
Minnesota	+1	+2
Missouri	+5	+7
Ohio	+4	-3
Wisconsin	+5	+7

The third analysis was of Midwestern snowfall conditions during El Niño years. Previous analyses of the relationship of El Niño to snowfall had focused only on the western United States. The forecasts from the CPC indicated a high probability of a dry 1997-1998 winter in the Ohio River basin. Thus, it seemed likely that the snowfall also would be below average. However, because the Midwest typically experiences a mix of frozen and liquid precipitation in the winter, it is possible for total precipitation to be deficient while snowfall is average or above.

The snowfall analysis was performed for the entire nation to assess how any snowfall anomalies in the Midwest during El Niño years were related to snowfall in other regions. More than 3,000 U.S. cooperative observer stations, each with nearly complete data for the past 45 years, were selected for analysis. The average snowfall in El Niño years was compared with average snowfall in non-El Niño years and in La Niña years. In one phase of the analysis, this comparison was done using only strong El Niño years. Both strong and weak El Niño years were used in the comparison for the second phase. The snowfall data were subjected to statistical tests to determine whether differences were statistically significant. This analysis found highly significant differences in portions of the Midwest. As shown in table 6, snowfall during strong El Niño years averaged about half of normal in Illinois, Indiana, and Kentucky and about 60 percent of normal in Missouri and Ohio. Snowfall in Iowa, Michigan, Minnesota, and Wisconsin also was somewhat less than normal during El Niño years, but the decrease was not as great as for the other five states.

Figure 1 shows the distribution of snowfall anomalies for strong El Niño years. This figure shows the difference (in inches) between the average of the strong El Niño years and the average of non-El Niño years. Snowfall decreases of 10 inches or more were found in parts of Illinois, Indiana, Ohio, Michigan, and extreme southern Wisconsin. The deficiencies are most predictable in these areas from one El Niño year to another.

During the fall of 1997, a research group at the University of Michigan issued a press release (University of Michigan, 1997) claiming that El Niño years are associated with more winter storm damage on the Great Lakes. This helped motivate the fourth analysis related to El

Niño. Because MCC staff members had done an extensive study of Great Lakes storms and had compiled a comprehensive database on these storms an analysis was pursued comparing the number and intensity of Great Lakes storms during El Niño winters with average conditions in non-El Niño years.

Table 6. Ratio of State Averaged Snowfall in Strong El Niño Years Versus non-El Niño Years

State	*El Niño/non-El Niño snowfall (%)*
Illinois	51
Indiana	51
Iowa	89
Kentucky	40
Michigan	81
Minnesota	98
Missouri	62
Ohio	60
Wisconsin	92

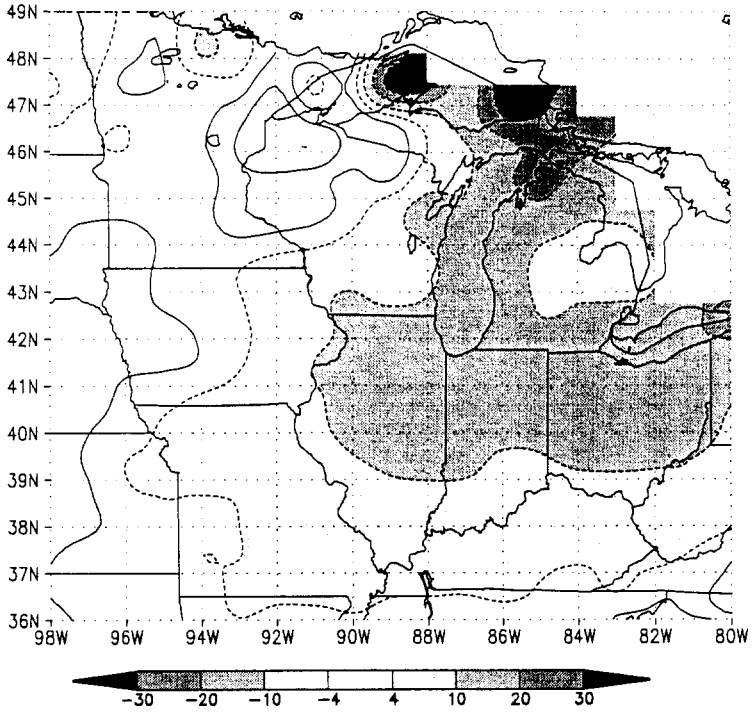

Figure 1. Winter snowfall anomalies associated with strong El Niño events in the Midwest. Values are in inches. Dashed contours denote below average values; solid contours denote above average values; and shading denotes anomalies less than or greater than 4 inches.

Table 7. Great Lakes Cyclone Frequency by Month for El Niño Years Compared to non-El Niño Years

Month	*El Niño*	*Non-El Niño*
September	3.7	4.4
October	4.7	5.6
November	5.1	5.8
December	7.3	6.8
January	4.6*	6.9
February	4.3*	5.9
March	4.5	6.6

Note: *The difference from the neutral case is statistically significant at $p = 0.05$ using a one-tailed t-test.

Table 7 shows the number of strong winter storms affecting the Great Lakes region during El Niño years compared to non-El Niño years. During El Niño years, the number of cyclones on the Great Lakes was less than that expected during non-El Niño years in January, February, and March.

Figure 2 shows the spatial distribution of cyclones in December, January, February, and March during El Niño years, expressed as a difference from what is expected in average years. The Great Lakes is a region of near to slightly below average cyclone frequency. The area of significantly below average cyclone frequency is north of the lakes, over the extreme northern United States and southern Canada. An area of significantly above average cyclone frequency is over the extreme southern United States.

Dissemination of Information

Three approaches were used by the MCC to disseminate the information from the analyses to potential users and decision makers in the Midwest.

News Releases

Three news releases were issued during the summer and fall of 1997. The first, issued in June 1997, described the general temperature and precipitation conditions during past El Niño events by season. The second, issued in September 1997, described the results of the snowfall analysis. The third, issued in November 1997, described the results of the analysis of Great Lakes storms and the potential impact of El Niño on the risk of storms in the Great Lakes region.

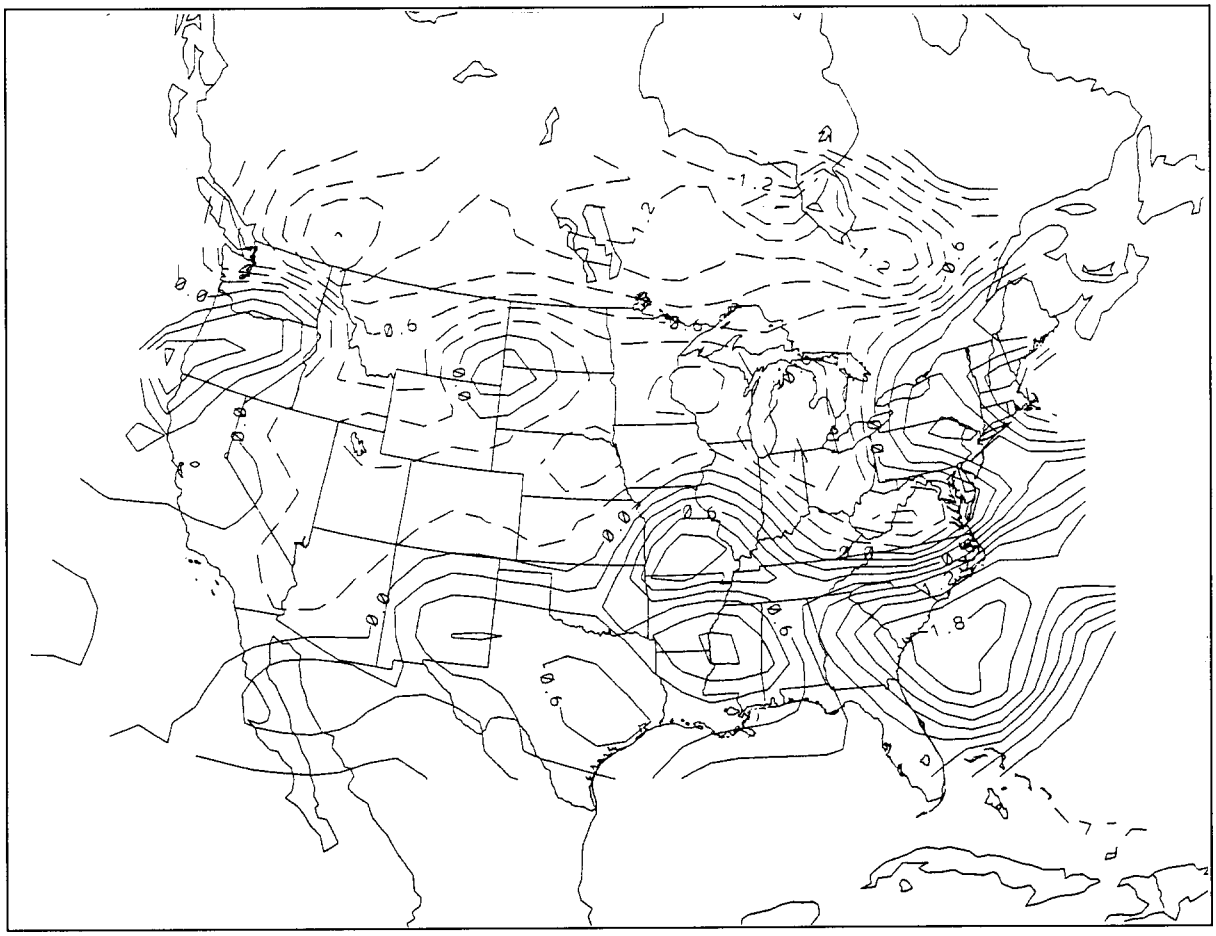

Figure 2. Distribution of cyclones during December-March in strong El Niño years with values expressed as the difference from average frequencies. Dashed contours denote below average frequencies and solid contours denote above average frequencies.

Web Page

A special El Niño Web page was created in June 1997 to present the results of the analyses. This Web page was periodically updated as new information became available. In addition to presenting the results of the MCC analyses, it included links to other government Web pages on El Niño. This Web page received thousands of hits during the El Niño event.

Media Interviews

Many interviews were given to the print and broadcast media. Some were in response to the news releases and others were with reporters who regularly use the MCC as a source of information.

General Outlook Information

The MCC disseminates four types of outlook information:

1. *Seasonal Temperature and Precipitation*. As described previously, the seasonal analyses of general temperature and precipitation trends showed certain tendencies for some seasons. Summers during a developing El Niño are more frequently cooler and wetter than normal. There is a tendency for fall to be cooler and wetter than normal. For both seasons, there were instances in which the opposite conditions occurred; but the wetter and cooler conditions occurred more frequently. For El Niño winters, the northern portions of the region are more frequently warmer than normal. Winters also tend to be drier than normal in the eastern portions of the regions. El Niño springs frequently are drier than normal. This information generally was consistent with that of the CPC. However, the information was more specific and highlighted areas that have weak tendencies for certain conditions but are too weak to be highlighted in the national outlooks of the CPC.

2. *Corn and Soybean Yields*. This analysis showed that past El Niño summers have had a higher frequency of above normal yields. This is consistent with the observation that El Niño summers tend to be cooler and wetter than normal, which are ideal growing conditions for corn and soybeans.

3. *Snowfall*. The historical analysis of snowfall showed that strong El Niño winters typically have much below normal snowfall in the eastern part of the Midwest, particularly Illinois, Indiana, Ohio, and the southern Great Lakes region. In many of these areas, snowfall during past strong El Niño events averaged less than half of normal. In these Midwestern areas, the observed differences are highly statistically significant, and thus predictive skill is quite high. This analysis

showed that much of the northern half of the United States experienced snowfall deficits during strong El Niño winters, and the southwestern United States experienced above normal snowfall (Kunkel and Angel, 1999). The results are consistent with the CPC's outlook that most El Niño winters have below normal precipitation in this eastern Midwest region. Interestingly, this analysis found that snowfall was not deficient in weak El Niño years. Thus the predictive value appears to be limited to strong El Niño events.

4. *Great Lakes Storms.* This analysis found that El Niño events tend to be associated with a below average frequency of strong damaging cyclones in the Great Lakes region. This was particularly true during the latter part of the winter. These results contradicted findings of the University of Michigan research group (University of Michigan, 1997) but are consistent with the observed decrease of snow cover in this region. Strong cyclones also are responsible for much of the snowfall. Furthermore, communication with scientists at the Great Lakes Environmental Research Laboratory indicated that their data on storm damage also did not indicate any increase during El Niño winters.

The next section ("The 1997-1998 Weather Conditions and Their Climatological Relevance") describes the conditions that occurred during the 1997-1998 El Niño event. Comparison of the conditions with the material issued indicates that the actual outcomes were generally what was indicated from the analysis of past events. In particular, much below average snowfall was observed in much of the region, particularly in the eastern portions. The winter also was very warm and set records in many locations. Storm activity decreased, and there were no instances of widespread severe damage on the shoreline of the Great Lakes. Growing conditions during the 1997 summer were generally benign, and corn and soybean yields were above average in most areas.

The 1997-1998 Weather Conditions and Their Climatological Relevance

Steven D. Hilberg

Introduction

This section provides a climatological assessment of the weather conditions in the Midwest prior to and during the strongest portion of the El Niño event that extended from the fall of 1997 through March 1998. The 1997-1998 El Niño event began to develop during March 1997. It strengthened through the spring and waned somewhat during the summer and fall. Beginning in December 1997, the Southern Oscillation Index (SOI) dropped sharply, indicating a remarkable strengthening of the El Niño conditions (Figure 3). The El Niño conditions remained strong into March 1998. By May 1998 the conditions weakened considerably as the transition began to a La Niña phase.

The 1997-1998 El Niño affected the entire 48 contiguous states. The winter season (December 1997-February 1998) was the second warmest and seventh wettest since 1895 (Ross et al., 1998). There were a few extremes during December in parts of the country (very warm in the northern United States, cold in the southwest, and heavy rains in Florida). December was not particularly extreme in the Midwest as a whole, except in the northern states, where it was much warmer than normal.

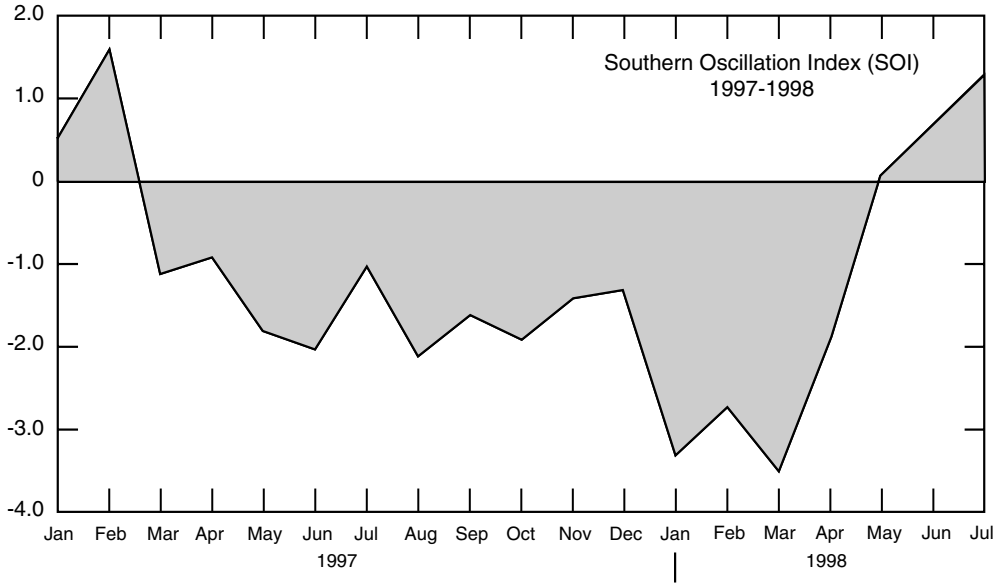

Figure 3. The Southern Oscillation Index (SOI) calculated by computing the differences in sea level pressure between Tahiti and Darwin, Australia. Negative values indicate warming of the sea surface temperatures in the eastern Pacific, or the El Niño phase.

Nationally, January and February were the warmest on record. There were a number of extreme weather events across the country attributed to the El Niño-influenced weather patterns, including numerous heavy rainstorms, flooding, and landslides in California; a crippling ice storm in the northeastern United States and adjacent Canadian provinces; flooding in the southeast; and severe thunderstorms and tornadoes in Florida.

Fall 1997

Fall (September-November) of 1997 across the Midwest was cooler than normal. State average temperatures ranged between 0.2 and 1.7°F below average (table 8). The fall of 1997 ranked as the 15th coldest of the past 104 years in Kentucky, and the 17th coldest in Indiana and Ohio. The variation in the departure of the mean average temperature from normal was not large across the Midwest, but there was a distinct regional difference in the ranks of the average fall temperatures (table 8). It is evident that the fall was unusually cool in the eastern portions of the Midwest, and ranked in the top 30 percent of coldest falls in Indiana, Kentucky, Ohio, Michigan, and Illinois. Figure 4 depicts the departure from normal of the mean fall temperature across the Midwest. The warmest areas were the far western portions of Missouri and Iowa and most of Minnesota and Wisconsin.

The percent of normal precipitation during fall 1997 is depicted in Figure 5. Northwestern Minnesota, as well as small portions of both southwestern Iowa and northwestern Missouri, received 100 percent or more of the normal precipitation. The driest area was the southern half of Wisconsin, which received only 60 percent of the normal precipitation for the three-month period.

Table 8. Fall 1997 Mean Temperatures and Their Rank in Midwestern States
Rank values are for 102 years and based on the position from the lowest value

State	*Mean temperature (°F)*	*Departure from Normal*	*Rank (coldest)*
Kentucky	55.3	-1.7	15
Ohio	51.4	-1.6	17
Indiana	52.2	-1.7	17
Michigan	46.6	-1.0	28
Illinois	53.0	-1.2	30
Missouri	55.4	-0.8	35
Iowa	49.6	-0.7	37
Wisconsin	45.7	-0.4	48
Minnesota	44.0	0.2	58
Midwest	49.9		32

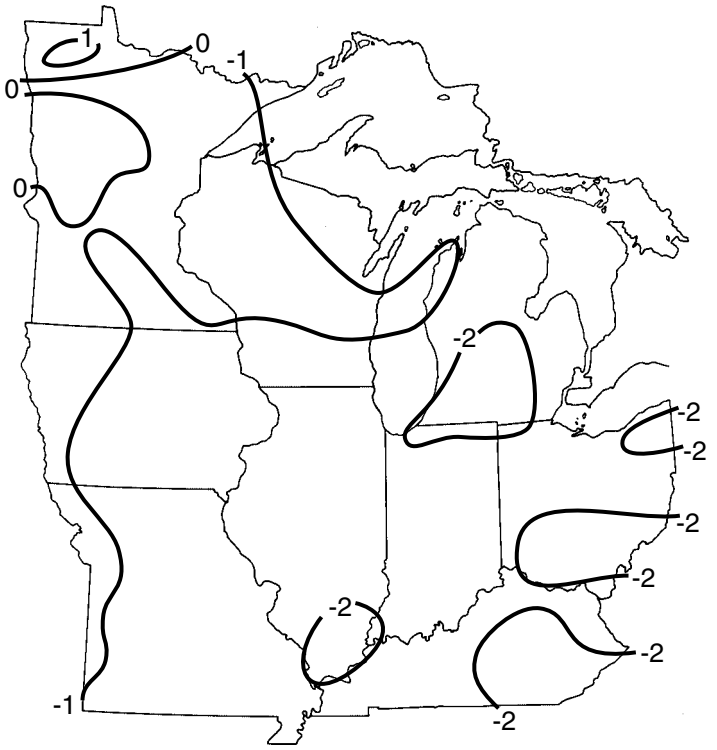

Figure 4. Fall 1997 mean temperature, departure from normal (°F).

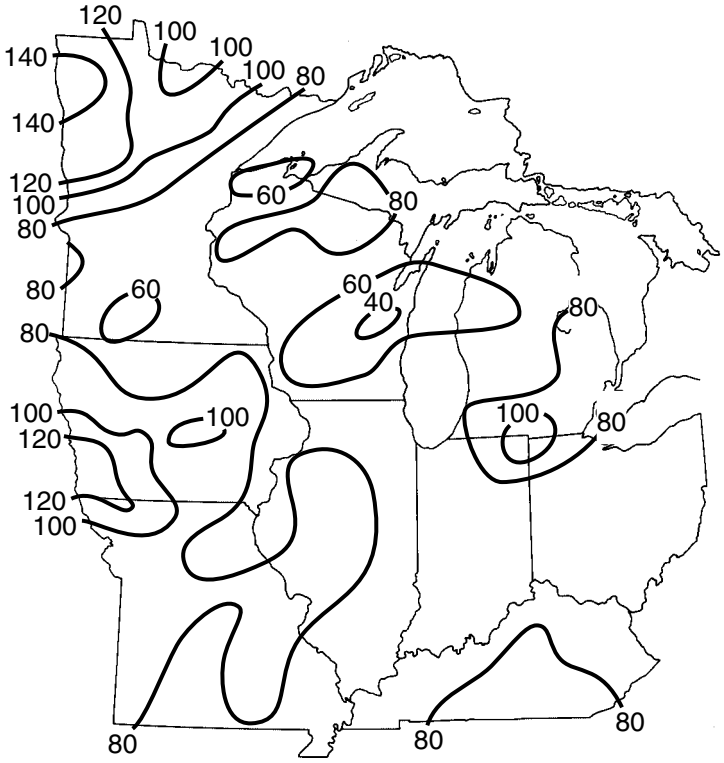

Figure 5. Fall 1997 precipitation, percent of normal.

September 1997

The axis of the mean 500-millibar ridge in September lay just east of the Rockies, and the mean trough axis extended through the eastern third of the Midwest. This pattern was reflected in the temperature pattern for the Midwest. For the Midwest as a whole, temperatures were near normal during September. However, there was a distinct gradient in the temperature departure pattern from northwest to southeast across the Midwest (figure 6). It was much warmer than normal over northwestern Minnesota (+4°F), and cooler than normal over southeastern Ohio (-2°F), with most of the Midwest average temperatures near normal, between 2°F below normal and 2°F above normal.

Precipitation during September averaged 75 percent of normal for the Midwest (figure 7). The driest areas extended from southern Indiana into southwestern Ohio where precipitation was less than 50 percent of normal. Precipitation exceeded 75 percent of normal across the south-eastern half of lower Michigan, northeastern Indiana, and extreme northern Ohio.

October 1997

A general upper level zonal flow across the nation during October resulted in near normal temperatures across almost the entire Midwest. Mean monthly temperatures across a portion of western Minnesota and northwestern Iowa were 1.0 to 1.5°F above average. Small areas with below normal departures of 1.0 to 1.5°F occurred over southern Iowa, southern Missouri, eastern Kentucky, and central Michigan (figure 8).

The western half of the region was much wetter than the eastern half during October (figure 9). Precipitation in most of Minnesota, Iowa, Missouri, the northwestern half of Wisconsin, and a portion of Illinois was generally 75 percent to more than 100 percent of normal. Precipitation exceeded 200 percent of normal in extreme northwestern Minnesota, and 150 percent of normal across southern Iowa. In contrast, the eastern half of the region experienced only 50 to 75 percent of normal precipitation. The driest areas included a small portion of east-central Wisconsin and from the extreme eastern portion of Ohio into West Virginia and Pennsylvania. Both areas received less than 50 percent of normal precipitation in October 1997.

November 1997

There was a significant change in the general upper air pattern over the United States during November. The mean ridge shifted west and extended northwest into western Canada. A broad trough was established over the eastern half of the country. The resulting amplified flow brought much colder than normal weather to the Midwest. Temperatures were 4 to 5°F below normal across most of the nine Midwestern states, with a small area of temperatures 6°F below normal in southern Minnesota (figure 10). The northern half of lower Michigan and the Upper Peninsula, with temperatures 2 to 3°F below normal, were slightly warmer than the rest of the region. The extremely cold November was the major reason that the 1997 fall season ranked

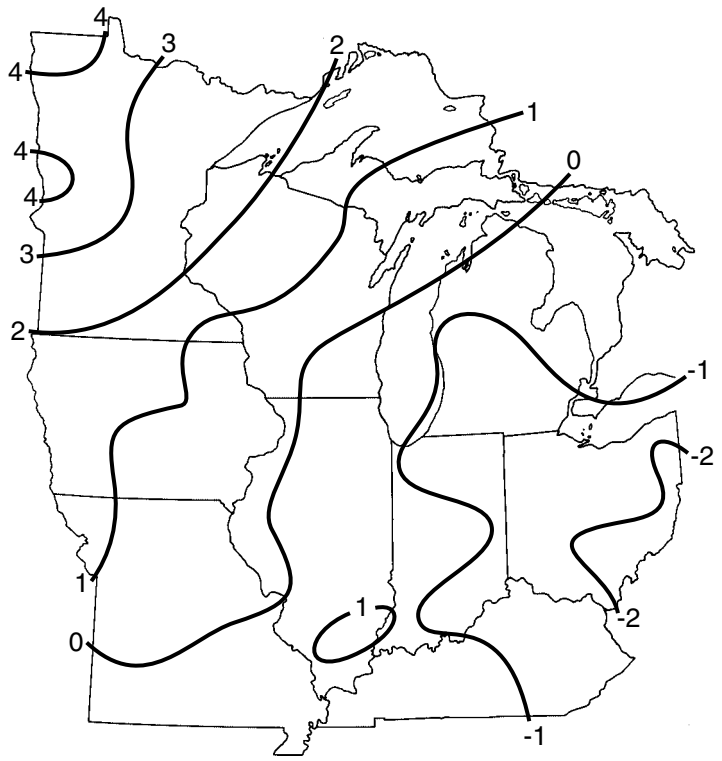

Figure 6. September 1997 mean temperature, departure from normal (°F).

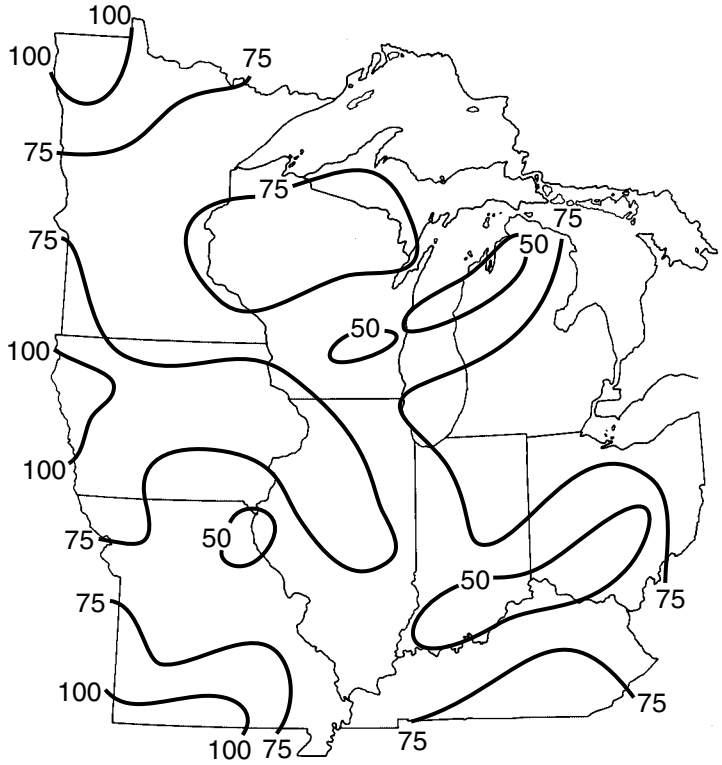

Figure 7. September 1997 precipitation, percent of normal.

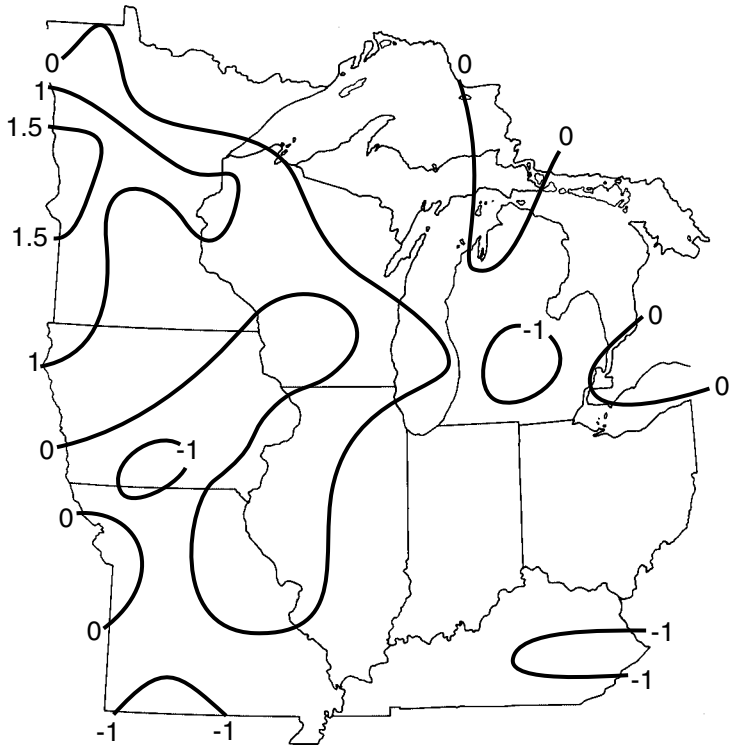

Figure 8. October 1997 mean temperature, departure from normal (°F).

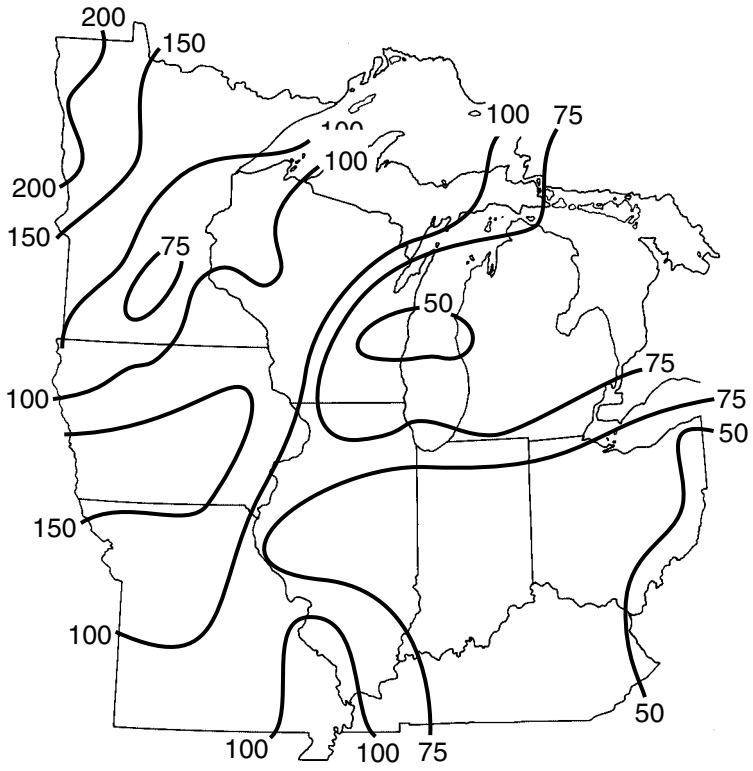

Figure 9. October 1997 precipitation, percent of normal.

among the top 25 coldest Novembers for all the states, and was the 32nd coldest November for the nine-state Midwest area.

Precipitation was quite variable across the Midwest. Southern Indiana, the southern two-thirds of Ohio, central Illinois, the northern half of Missouri, and northwestern Minnesota received 75 to 100 percent of normal precipitation in November (figure 11). In contrast, most of Wisconsin received less than 50 percent of normal precipitation, and a wide band through the central part of the state received less than 25 percent of normal precipitation. The first measurable snow of the season came on November 2 and 3 and extended as far south as central Illinois.

Winter 1997-1998

The winter of 1997-1998 (December-February) ranked as the warmest on record for the Midwest, and ranked in the top six, if not the warmest, for each of the nine Midwestern states (table 9). The upper Midwest experienced the greatest extremes, with seasonal average temperature departures exceeding 12°F above normal in northern Minnesota. In contrast, winter temperature departures across southern Missouri and southern Kentucky were only 5°F above normal (figure 12).

Precipitation ranged from near normal to above normal across most of the Midwest from December through February (figure 13). The wettest portion of the Midwest extended from Missouri and Iowa through the northwestern half of Illinois into Wisconsin. Winter precipitation

Table 9. Winter 1997-1998 Mean Temperatures and Their Rank in Midwestern states
Rank values are for 102 years and are based on position from the highest value

State	*Mean temperature (°F)*	*Departure from normal*	*Rank (warmest)*
Minnesota	22.6	+11.6	1
Wisconsin	26.3	+10.4	1
Michigan	28.9	+8.2	1
Ohio	36.0	+7.7	2
Indiana	35.8	+7.5	2
Illinois	34.5	+7.3	2
Iowa	28.6	+7.9	3
Missouri	36.9	+5.6	3
Kentucky	40.1	+5.4	6
Midwest	31.3		1

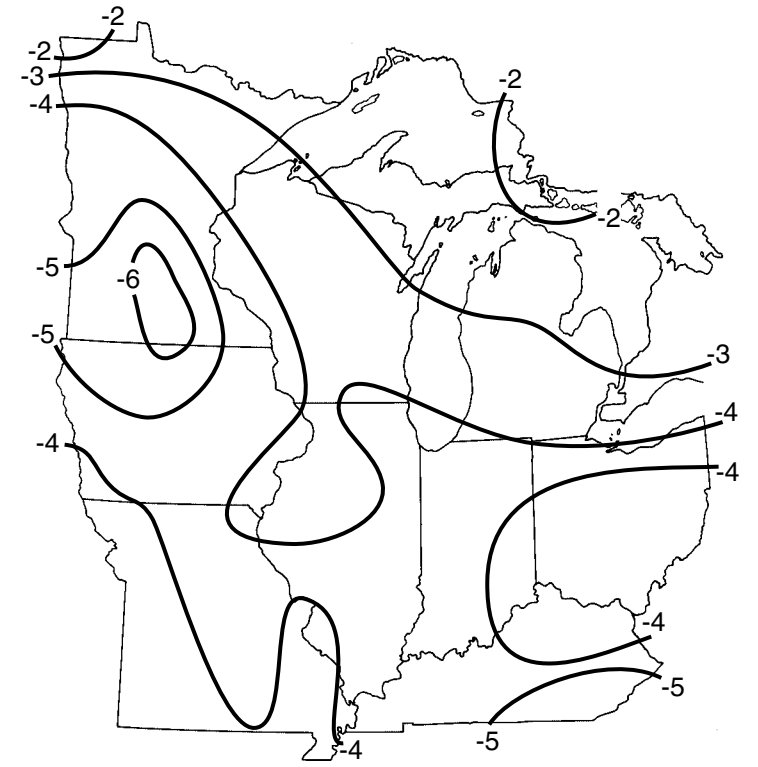

Figure 10. November 1997 mean temperature, departure from normal (°F).

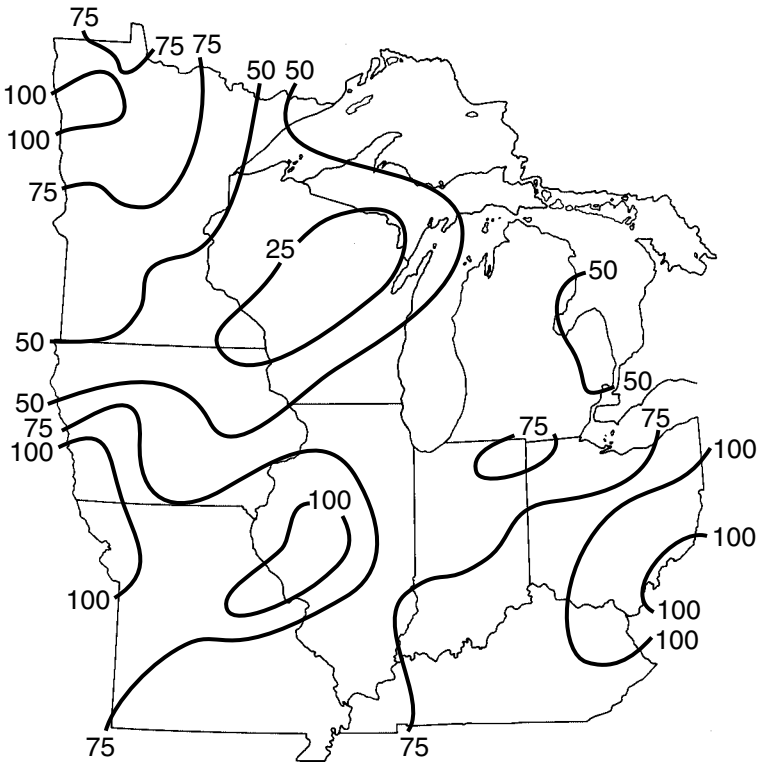

Figure 11. November 1997 precipitation, percent of normal.

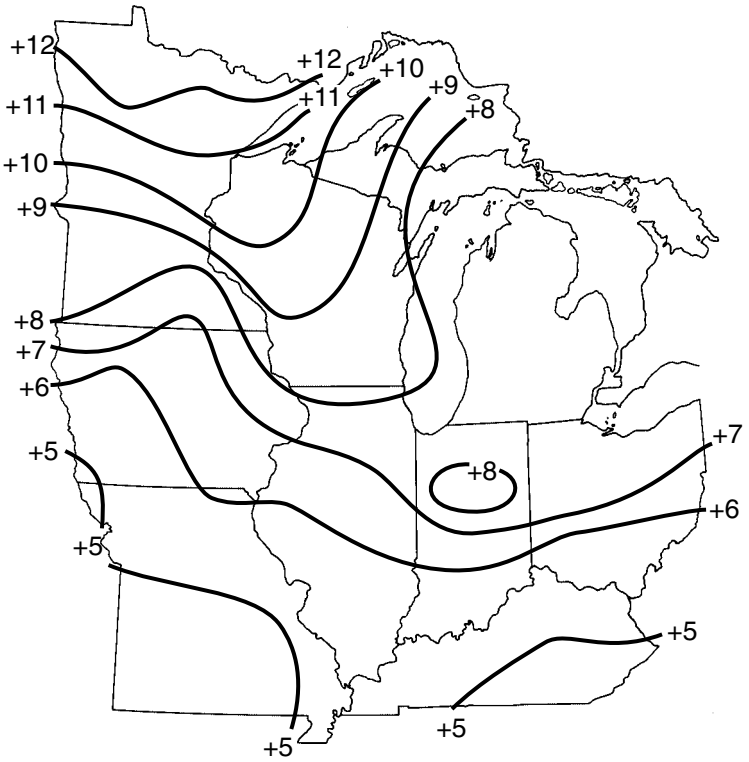

Figure 12. Winter 1997-1998 mean temperature, departure from normal (°F).

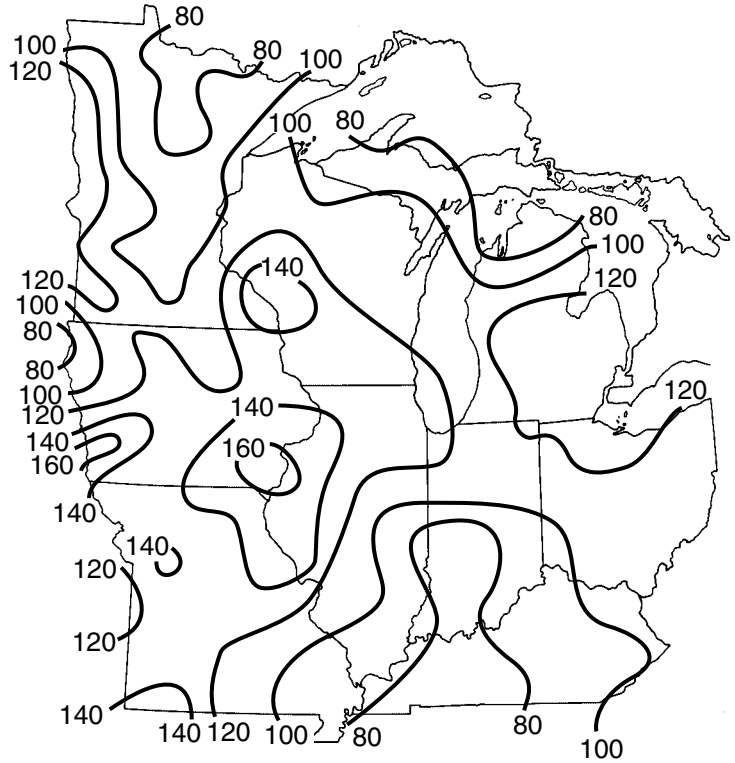

Figure 13. Winter 1997-1998 precipitation, percent of normal.

ranged from 120 to 160 percent of normal in this area. Precipitation was below normal in northern Minnesota, northern lower Michigan, the Upper Peninsula, and Kentucky.

December 1997

The transition from the cold fall, particularly November, into the warm winter was not done quickly. Both the temperature and precipitation monthly patterns show distinct regional differences across the Midwest during December (figure 14). The upper Midwest, particularly Minnesota and Wisconsin, was very warm during December, with average mean temperature departures of +11.6 and +8.4°F, respectively. Record high daily temperatures were set on a few days in Minnesota, Wisconsin, and Michigan. In the southern half of the Midwest, the average departure from the mean temperature ranged from +2 to -2°F.

Precipitation was near to above normal in the western two-thirds of Missouri, southern Iowa, and far western Illinois (figure 15). The very warm weather in the upper Midwest was coupled with a lack of precipitation over most of the region. Monthly totals were less than 50 percent of normal in Minnesota, Wisconsin, and much of northern lower Michigan, and less than 25 percent of normal in far northern Minnesota.

January 1998

January saw a shift in the anomalous warmth from the upper Midwest to the eastern Midwest. The month began with very warm temperatures as record high values occurred throughout the Midwest during the first week. Chicago reached a maximum of at least 50°F on four consecutive days beginning on January 2, only the seventh such occurrence in 125 years of record keeping. Figure 16 depicts the number of daily temperature records set in January 1998 for three locations in each state. Among these 27 stations, 26 record high temperatures were set during January, and 39 record high minimum temperatures also were set. Figure 17a shows the average maximum temperature departure from normal for January 1998, and figure 17b shows the average minimum temperature departure from normal. Higher than normal, maximum temperature departures ranged from +1 to +5°F across the western half of the region, and +6 to +9°F across the east. Average minimum temperature departures, on the other hand, were almost twice the magnitude of the maximum temperature departures across most of the region, ranging from +5 to +7°F in the west to +10 to +12°F in the east and across northern Minnesota. The abnormally warm minimum temperatures were the major contributor to the record warmth in January 1998.

The largest mean temperature departures from normal (>+10°F) were centered over eastern Indiana and western Ohio, with most of Indiana, Ohio, and Kentucky experiencing mean temperature departures from an average of at least +8.0°F (figure 18). Except for north-eastern Minnesota, where temperature departures averaged +8 to +9°F, the strength of the positive temperature anomaly in the western third of the Midwest was only +3 to +6°F. January 1998 ranked from 5th to 22nd warmest among the nine Midwestern states (table 10) and was the 10th warmest for the entire Midwest

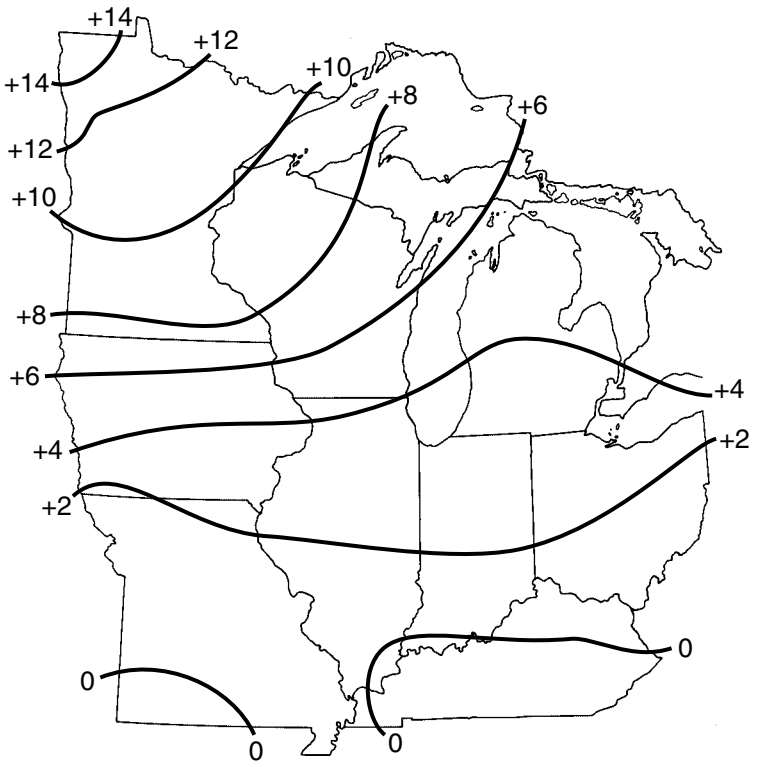

Figure 14. December 1997 mean temperature, departure from normal (°F).

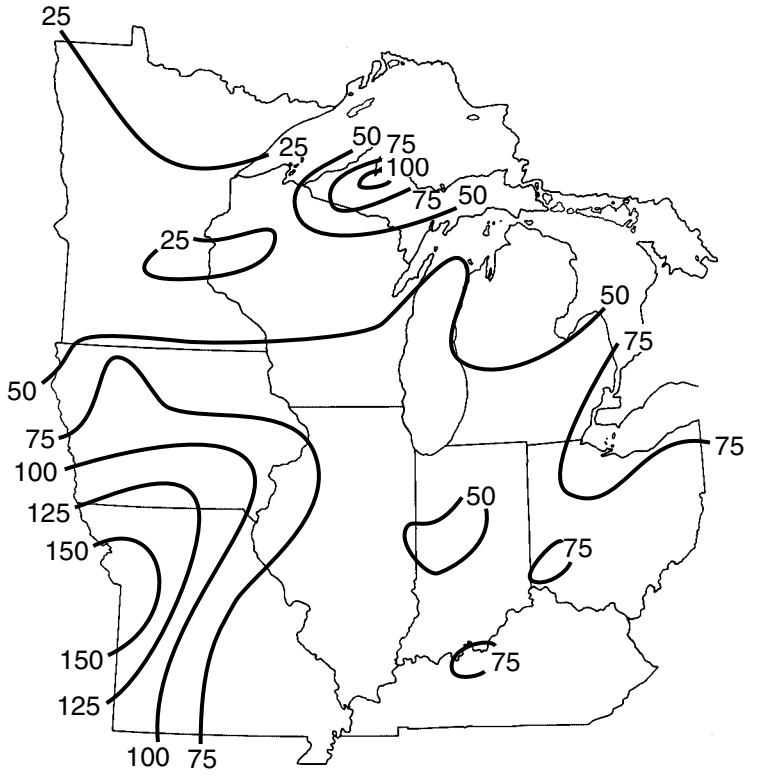

Figure 15. December 1997 precipitation, percent of normal.

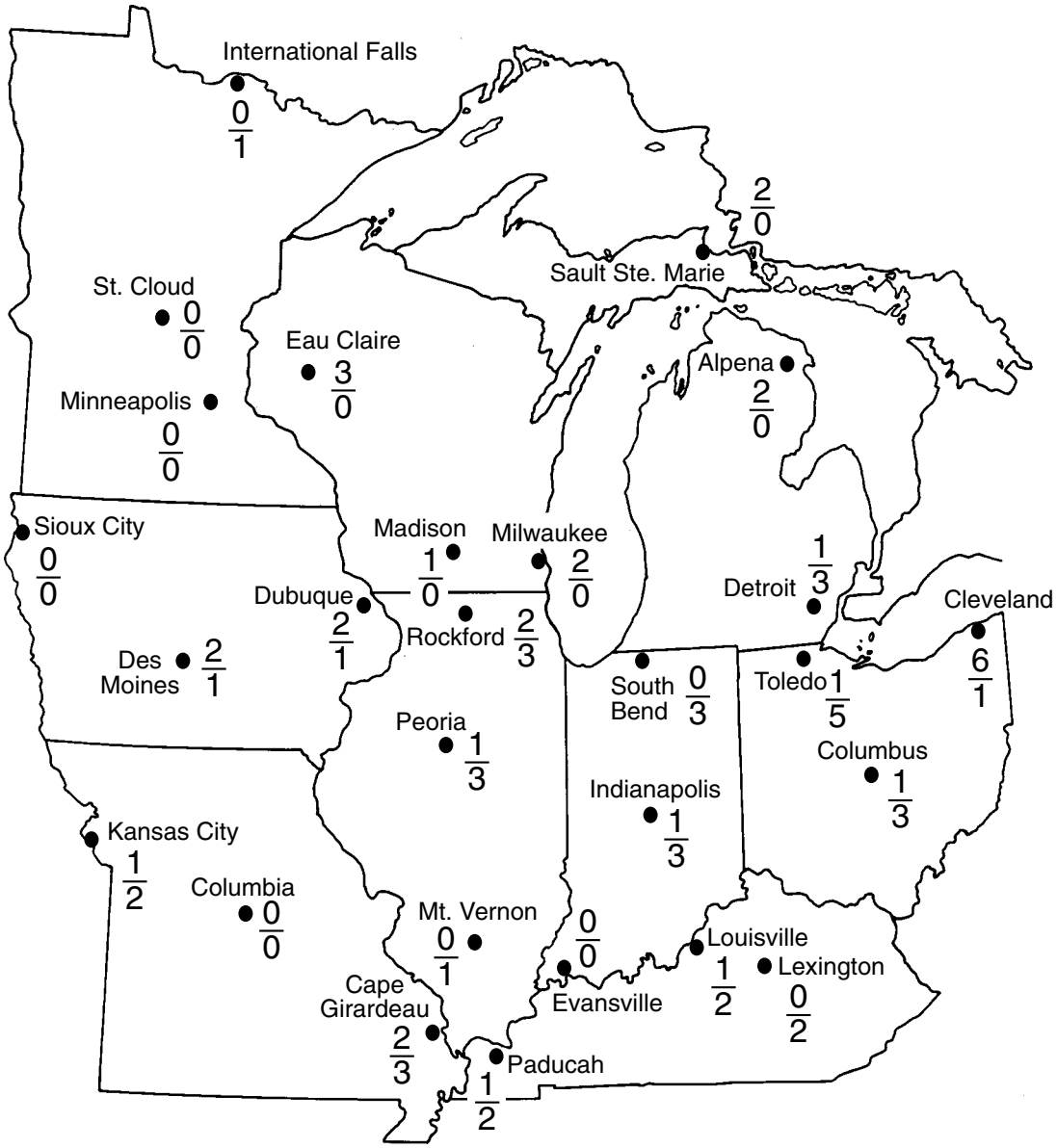

Figure 16. Number of daily temperature records set in January 1998 for selected Midwest stations.

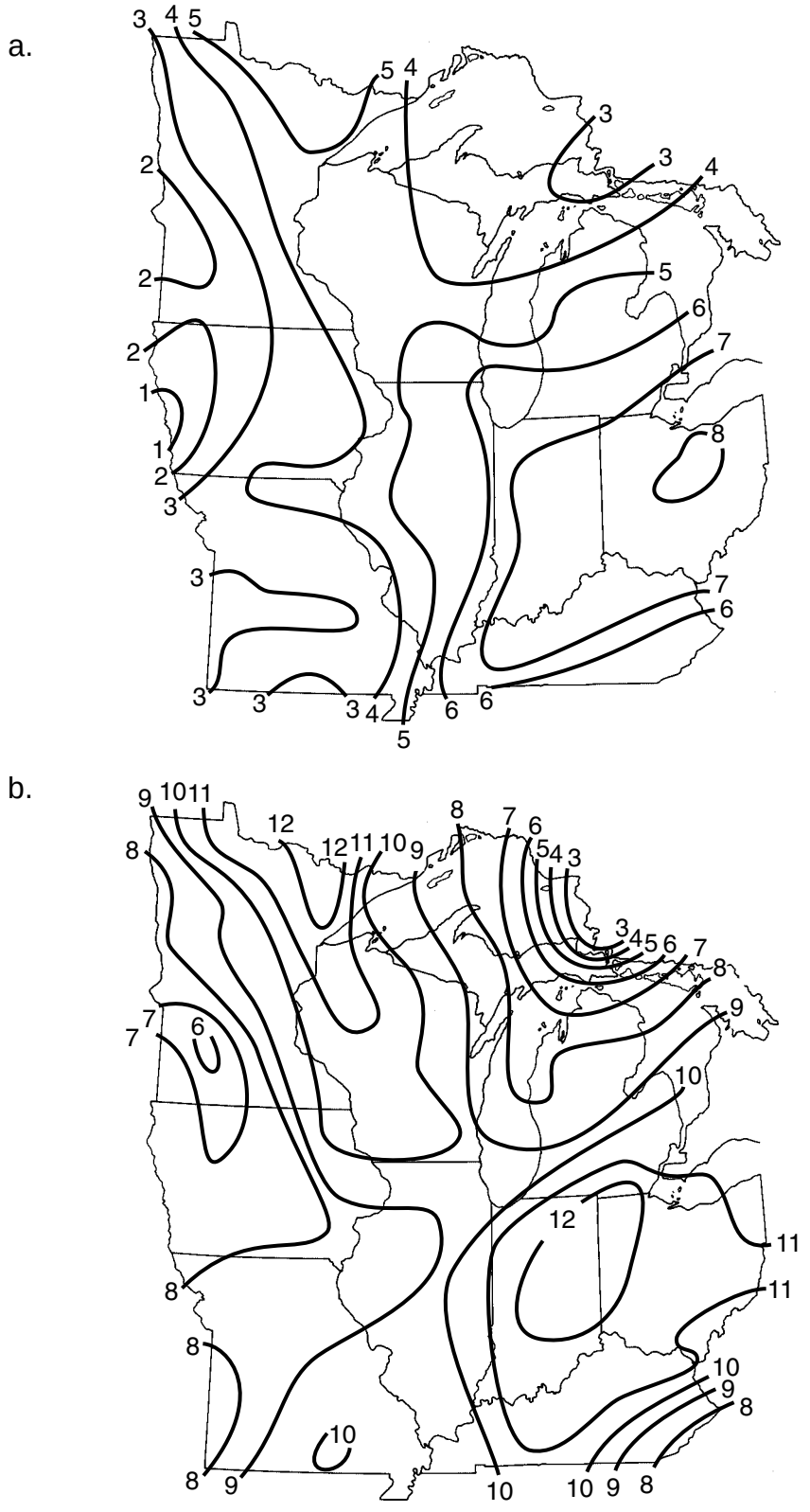

Figure 17. (a) January 1998 average maximum temperature, departure from normal (°F) and (b) January 1998 average minimum temperature, departure from normal (°F).

Table 10. January 1998 Mean Temperatures and Their Rank in the Midwestern States
Rank values are for 102 years and are based on position from the highest values

State	*Mean temperature (°F)*	*Departure from normal*	*Rank (warmest)*
Ohio	35.8	+10.4	5
Indiana	34.9	+9.7	5
Kentucky	41.0	+9.2	9
Michigan	25.1	+6.8	9
Missouri	35.3	+7.0	12
Wisconsin	20.6	+8.2	13
Illinois	31.6	+7.7	14
Iowa	23.6	+6.4	20
Minnesota	14.4	+7.4	22
Midwest	27.7		10

January was a wet month across the Midwest, with precipitation 100 to 150 percent of normal across most of the region (figure 19). Only northern Minnesota received less than 75 percent of normal precipitation. Precipitation in excess of 200 percent of normal fell in a band across central Wisconsin, and in another area from northeastern Illinois across extreme northern Indiana and into lower Michigan.

February 1998

The temperature anomaly pattern for February 1998 (figure 20) exhibited a north-to-south orientation similar to that of December 1997. However, the magnitude of the February anomaly was almost double that of January. The February temperature departures from mean ranged from +18°F in northern Minnesota to +4 to +6°F across southern Missouri and southern Kentucky. The departure of the average maximum temperatures from normal ranged from +10 to +13°F in northern Minnesota to only +1 to +3°F in southern Missouri and southern Kentucky (figure 21a). As was true in January, mean minimum temperature departures from normal far exceeded the maximum temperature departures from normal. Minimum temperature departures ranged from +8°F across southern Missouri, extreme southern Illinois, Indiana, Ohio, and much of Kentucky, to +24°F in northern Minnesota (figure 21b).

Figure 22 depicts the record high daily temperatures for 27 locations in the Midwest during February. Only seven total maximum temperature records were set, but 48 record high minimum temperatures were set. Most of these records were set in Minnesota, Iowa, Wisconsin, and Michigan. February 1998 was the warmest February on record in 105 years in five Midwestern states, tied with the warmest in one state (Iowa); and it was the warmest ever for the Midwest as a whole (table 11).

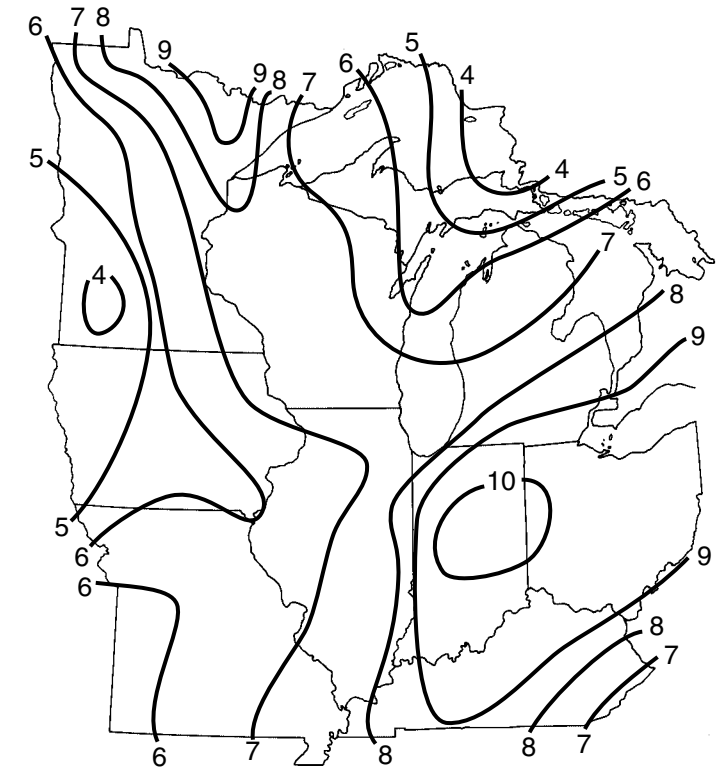

Figure 18. January 1998 mean temperature, departure from normal (°F).

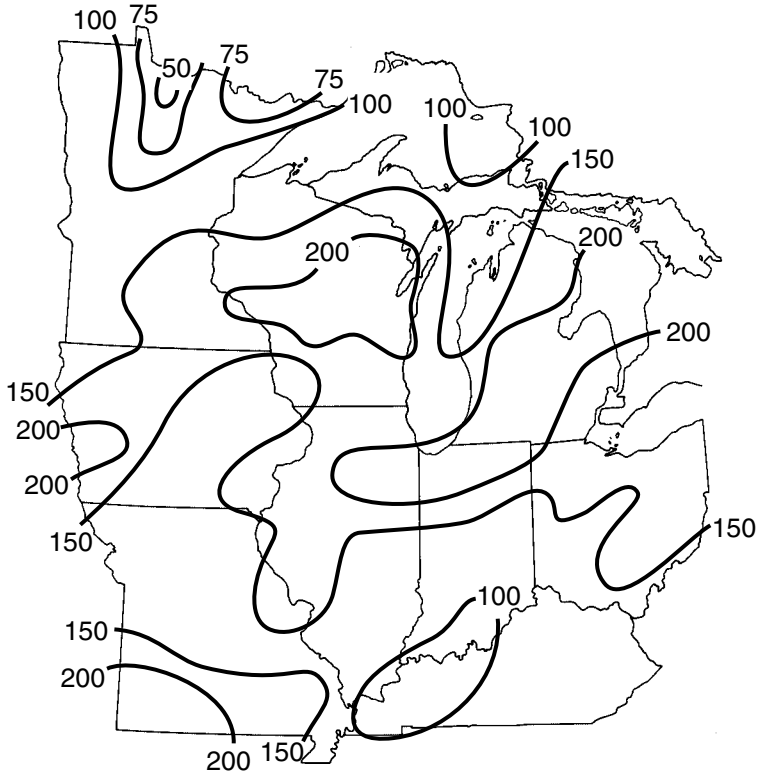

Figure 19. January 1998 precipitation, percent of normal.

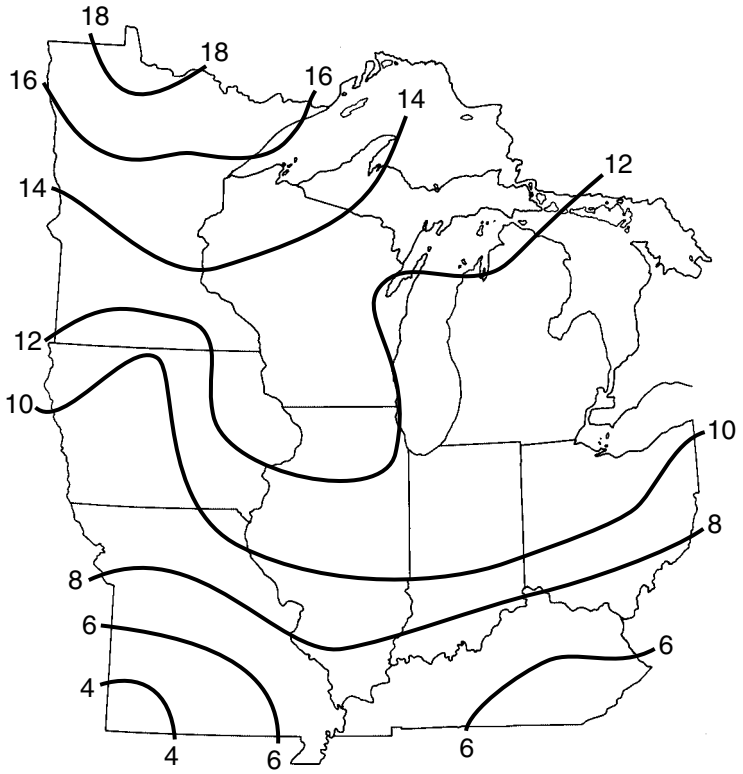

Figure 20. February 1998 mean temperature, departure from normal (°F).

Table 11. February 1998 Mean Temperatures and Their Ran in Midwestern States
Rank values are for 102 years and are based on position from the high value

State	*Mean temperature (°F)*	*Departure from Normal*	*Rank (warmest)*
Minnesota	29.0	+15.9	1
Wisconsin	31.8	+14.6	1
Michigan	32.3	+12.4	1
Illinois	39.9	+11.5	1
Indiana	39.5	+10.5	1
Ohio	38.6	+10.2	1
Iowa	34.7	+12.1	2
Missouri	41.2	+8.1	6
Kentucky	42.4	+6.7	11
Midwest	35.9		1

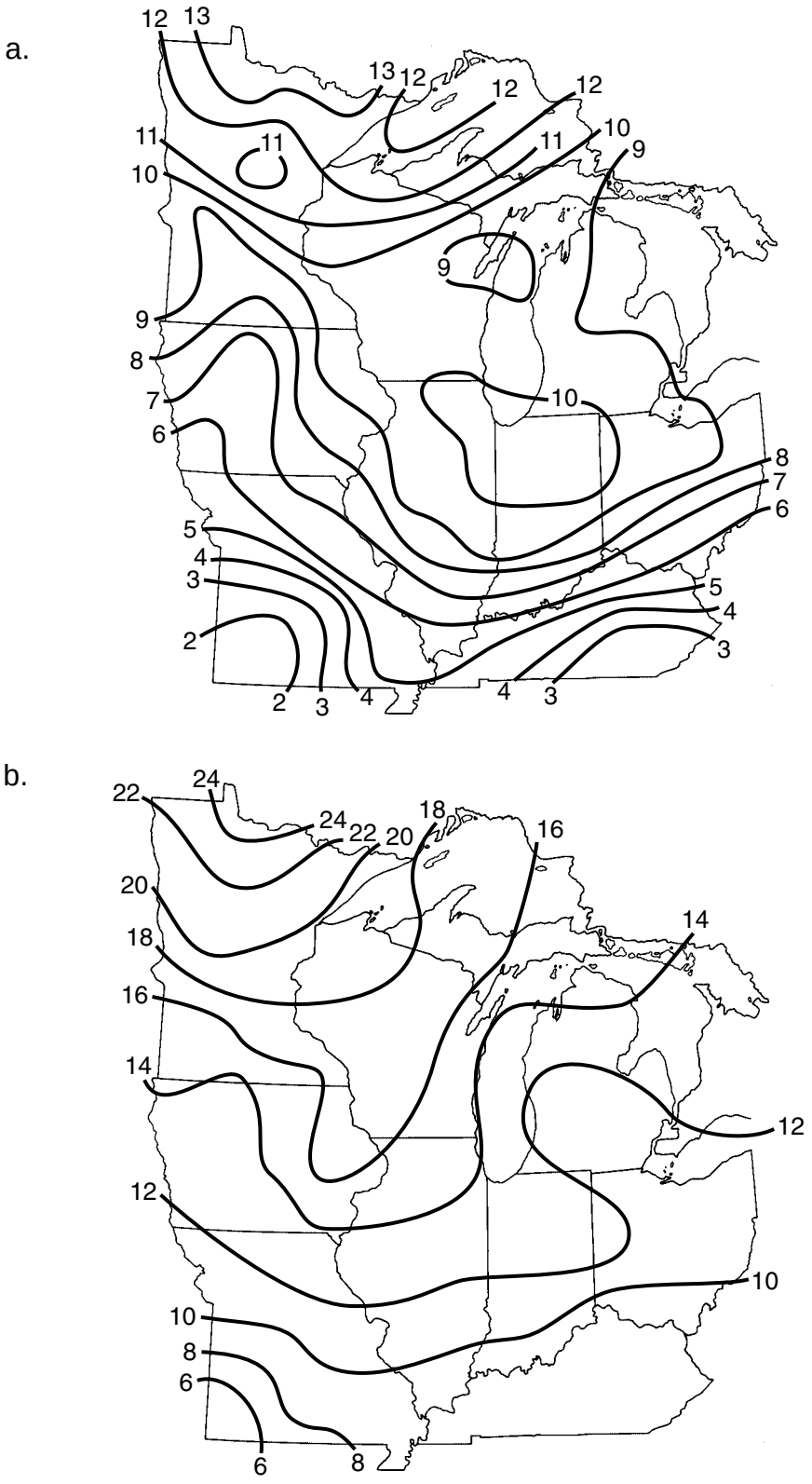

Figure 21. (a) February 1998 average maximum temperature, departure from normal (°F) and (b) February 1998 average minimum temperature, departure from normal (°F).

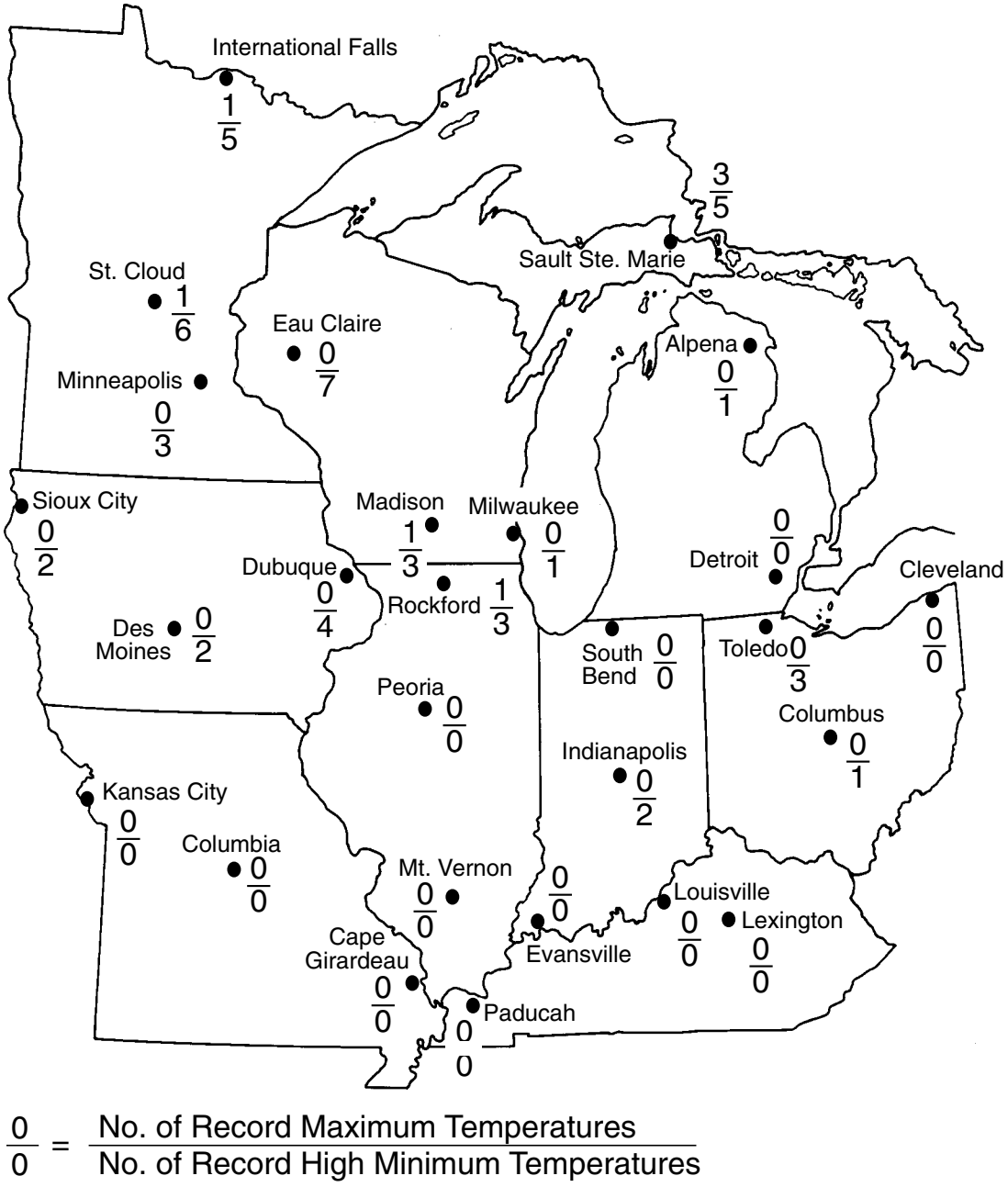

Figure 22. Number of daily temperature records set in February 1998 for selected Midwest stations.

To put the abnormally warm February temperatures into further context, in all nine Midwestern states the mean February temperature exceeded the mean November, December, and January temperatures. In Iowa, Minnesota, and Wisconsin, the mean February temperature was the highest of any month from November through March. Climatologically, February is normally the second coldest month of the year after January.

February was also a wet month, with precipitation exceeding 100 percent of normal throughout most of the Midwest (figure 23). A wide band extending from southern Missouri with an axis along the Mississippi River north to western Lake Superior received from 150 percent to more than 200 percent of normal precipitation. Much of the Upper Peninsula and the northern portion of lower Michigan were drier than normal, receiving less than 50 percent of the usual February precipitation. Indiana was mostly dryer than normal.

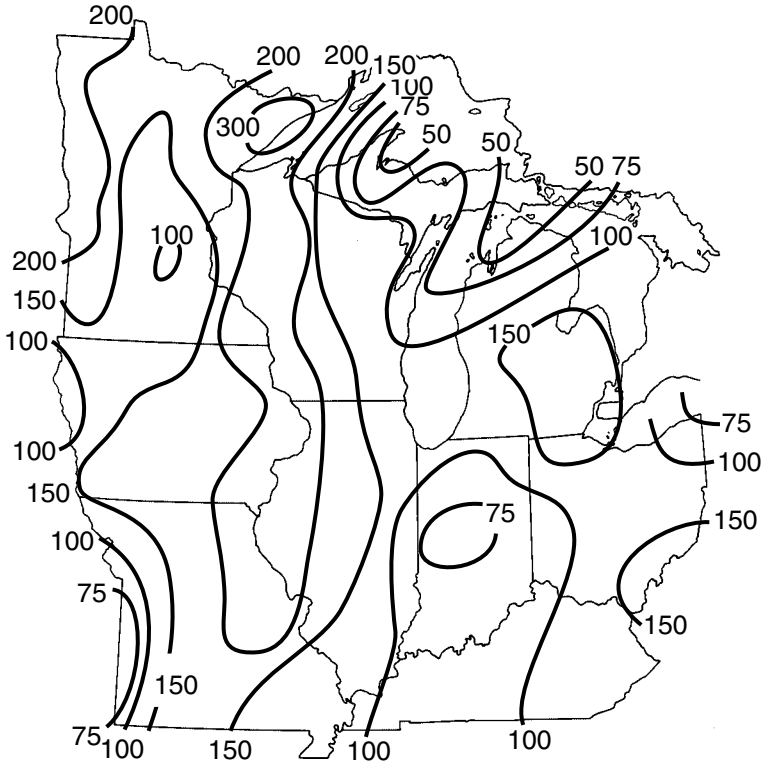

Figure 23. February 1998 precipitation, percent of normal.

Spring 1998

The intensity of the El Niño event peaked in early March 1998, then weakened through April and May. Temperatures across the Midwest during the spring averaged from near normal to above normal. March and April temperature anomalies exhibited distinct regional patterns as the SOI transitioned from the strong El Niño to La Niña condition. May was much warmer than normal throughout the Midwest. The wet weather of the winter continued through March, but by April distinct areas of dry weather began to appear in the upper Midwest. May was a wet month throughout the heart of the Midwest, with small, dry pockets in eastern Missouri and the eastern Great Lakes.

March 1998

There was a distinct southwest-to-northeast gradient in the temperature anomaly pattern during March (figure 24). The average temperature departure from normal ranged from -5 to -7°F in western Iowa and Missouri, to +3 to +4°F in extreme eastern Michigan and northern Ohio. State average temperature departures ranged from -3°F in Missouri to +2.8°F in Michigan.

Precipitation continued to be heavy over a large part of the Midwest in March (figure 25), and all states averaged in excess of 100 percent of normal precipitation. Precipitation was heaviest in an area from eastern Iowa and southern Minnesota, through Wisconsin, and into the northern half of lower Michigan. The driest area was in northwestern Minnesota, where less than 50 percent of normal precipitation was received. The Ohio valley was also relatively dry during March, with only 60 to 75 percent of normal precipitation.

April 1998

The temperature anomaly pattern in April was well defined, but not as strong as those of the previous three months (figure 26). There was a general north-to-south gradient, with a pocket of much higher than average temperatures (+5 to +8°F) in northwestern Minnesota. The southern third of the Midwest remained rather cool, with average temperature departures from the mean from –1.5 to -3°F. The upper Midwest experienced a warm month, with average temperatures +2 to +5°F from normal. State average temperature departures ranged from -1.3°F in Missouri to +4.8°F in Minnesota.

Rainfall was well above normal over most of the region, except Minnesota and the northern half of Wisconsin, where precipitation was less than 50 percent of normal. Rainfall was 150 to 200 percent of normal in the Ohio valley, making up for the drier than normal March (figure 27).

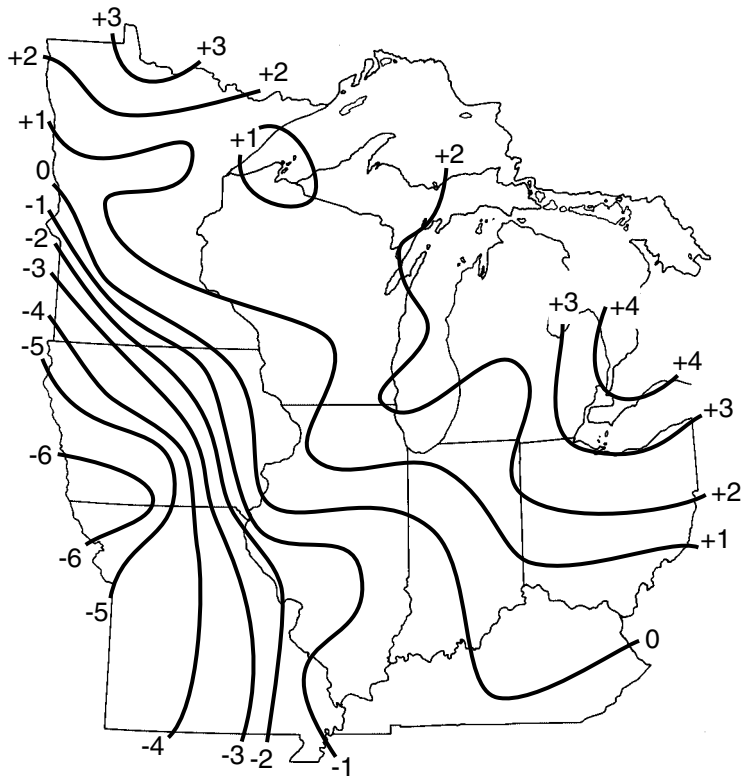

Figure 24. March 1998 mean temperature, departure from normal (°F).

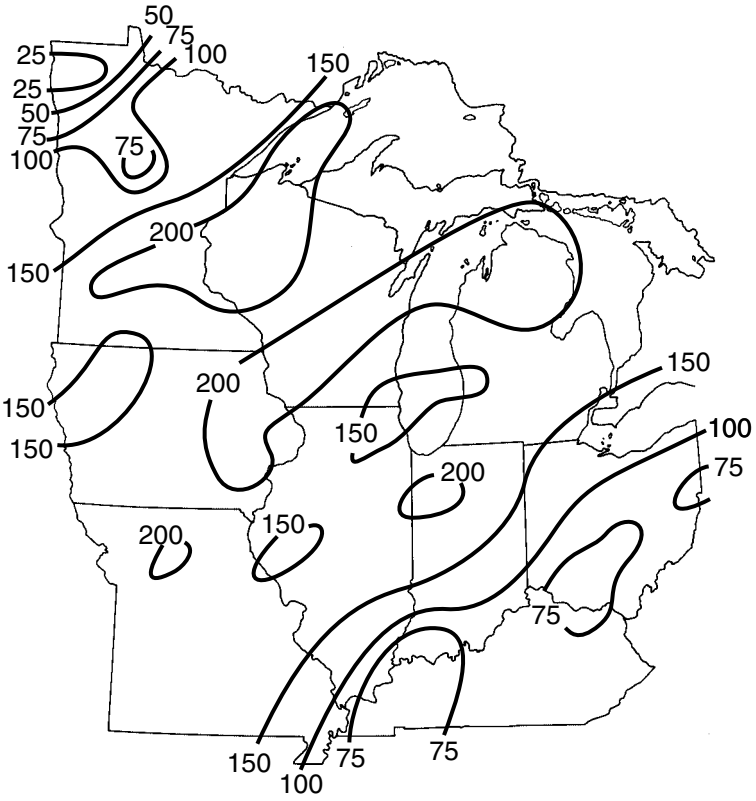

Figure 25. March 1998 precipitation, percent of normal.

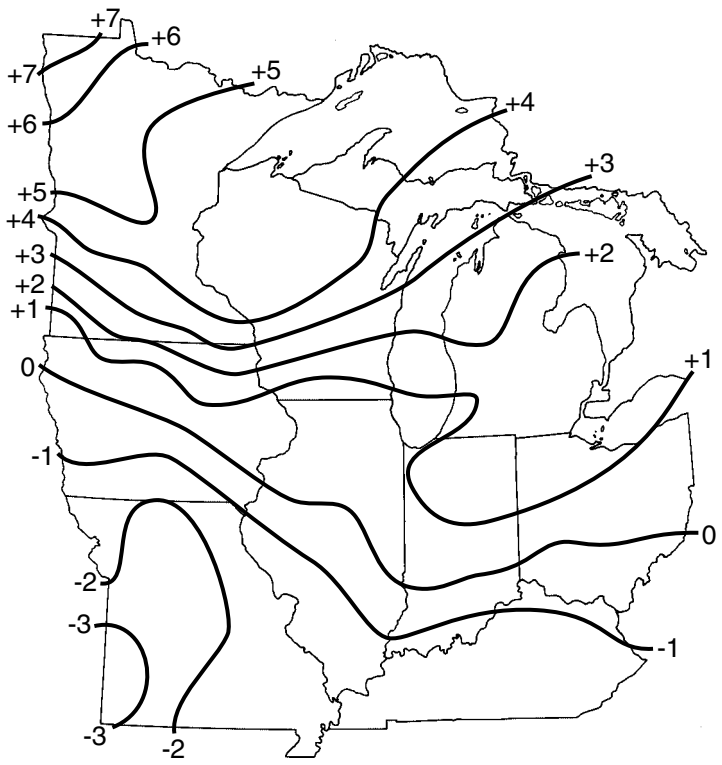

Figure 26. April 1998 mean temperature, departure from normal (°F).

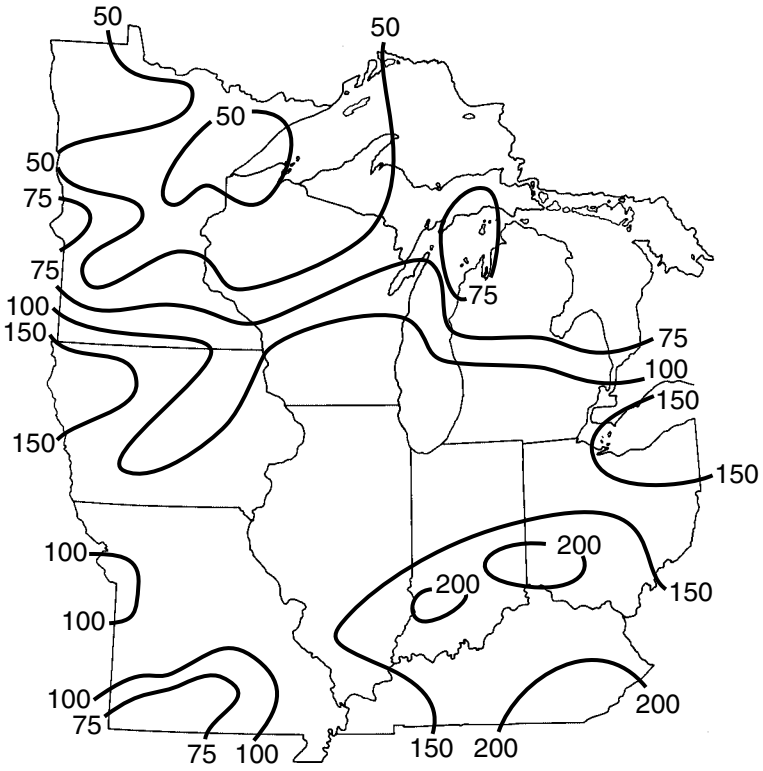

Figure 27. April 1998 precipitation, percent of normal.

May 1998

Temperatures during May were much above normal, with departures ranging from +3.5 to +6.5°F (figure 28). State average temperature departures from normal were fairly uniform, ranging from +3.9°F in Kentucky to +6.1°F in Michigan. The upper Midwest had the warmest weather, with departures from normal as high as +7°F in northern Michigan. Rainfall was plentiful during the month in most of the region, exceeding 100 percent of normal (figure 29). Drier conditions occurred in western Missouri, southern lower Michigan, northern Indiana, and northern Ohio. Northwestern Minnesota, which had experienced very dry conditions during March and April, received 150 to 200 percent of normal rainfall.

Snowfall 1997-1998

Seasonal snowfall (October through April) across the Midwest (figure 30a) was below normal across almost the entire region (figure 30b). The only exception was a portion of southwestern Iowa, which received 5 to 10 inches more than normal. The snowfall analysis was based on the record of 416 stations in the Midwest with long-term snowfall records.

As might be expected, the unusually cold weather in November was conducive to early snowfall across the Midwest. Snowfall was greater than normal across most of Minnesota, northern Illinois, and much of Indiana (figure 31). The first measurable snowfall came on November 2-3, as much as two to three weeks earlier than normal in Illinois and Indiana. On November 13-15, 1 to 7 inches of snow fell across Illinois and Indiana, with a few reports of up to 12 inches. For many locations in Illinois and Indiana, this November storm created more snow than any other storm of the entire snow season. November snowfall was well below normal across much of Wisconsin, and below normal in the northern half of lower Michigan.

Most of the Midwest experienced below normal snowfall in December (figure 32). The only exceptions were in the southern three-quarters of Iowa and the northern third of Missouri, where locations received up to twice the normal December snowfall. Most of Minnesota, Wisconsin, Michigan, Indiana, and Ohio received less than 50 percent of the normal December snowfall; areas in each of these states received less than 25 percent of normal.

The January 1998 snowfall pattern (figure 33) had a distinct demarcation. The northern tier of Midwestern states—Minnesota, Wisconsin, and Michigan—received from 150 to 200 percent of the normal January snowfall (typically 40 to 60 inches in nonlake-effect areas). Most of Ohio, Indiana, Kentucky, and Missouri received less than 25 percent of normal snowfall. Near normal snowfall occurred in most of Iowa and the northern third of Illinois, but most of this was due to one storm that occurred on January 9-10.

The abnormally warm weather in February 1998 was reflected in the snowfall totals across the Midwest (figure 34). The upper Midwest received less than 50 percent of normal

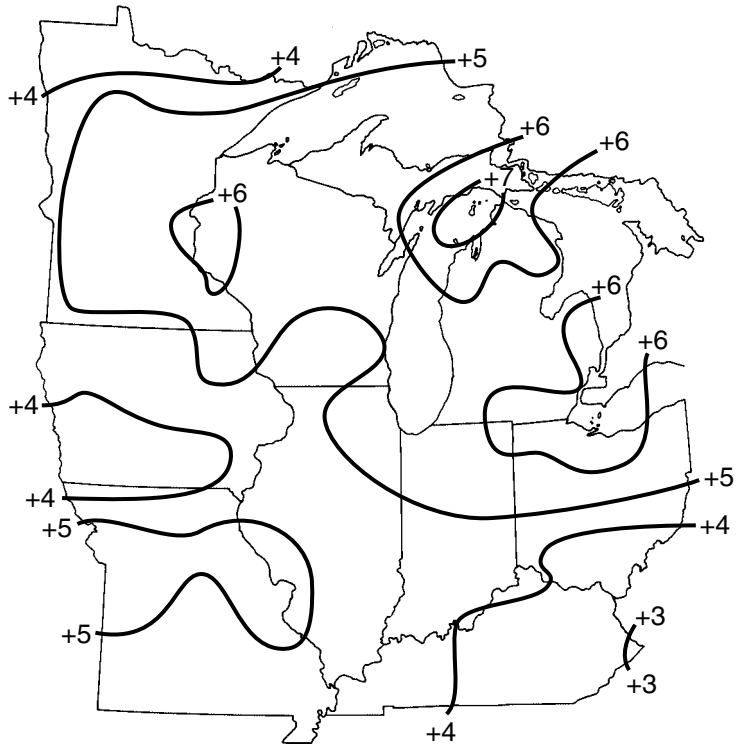

Figure 28. May 1998 mean temperature, departure from normal (°F).

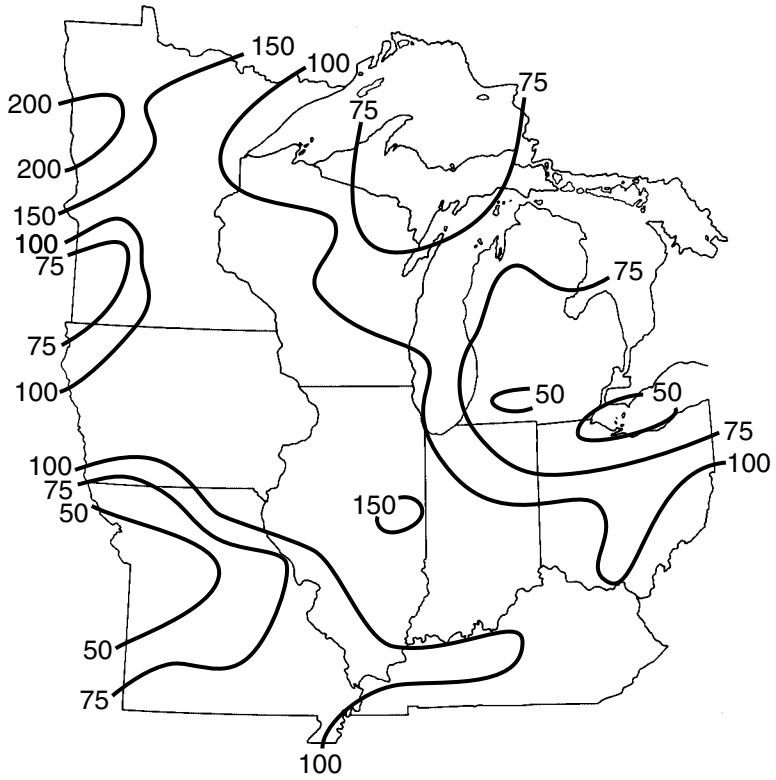

Figure 29. May 1998 precipitation, percent of normal.

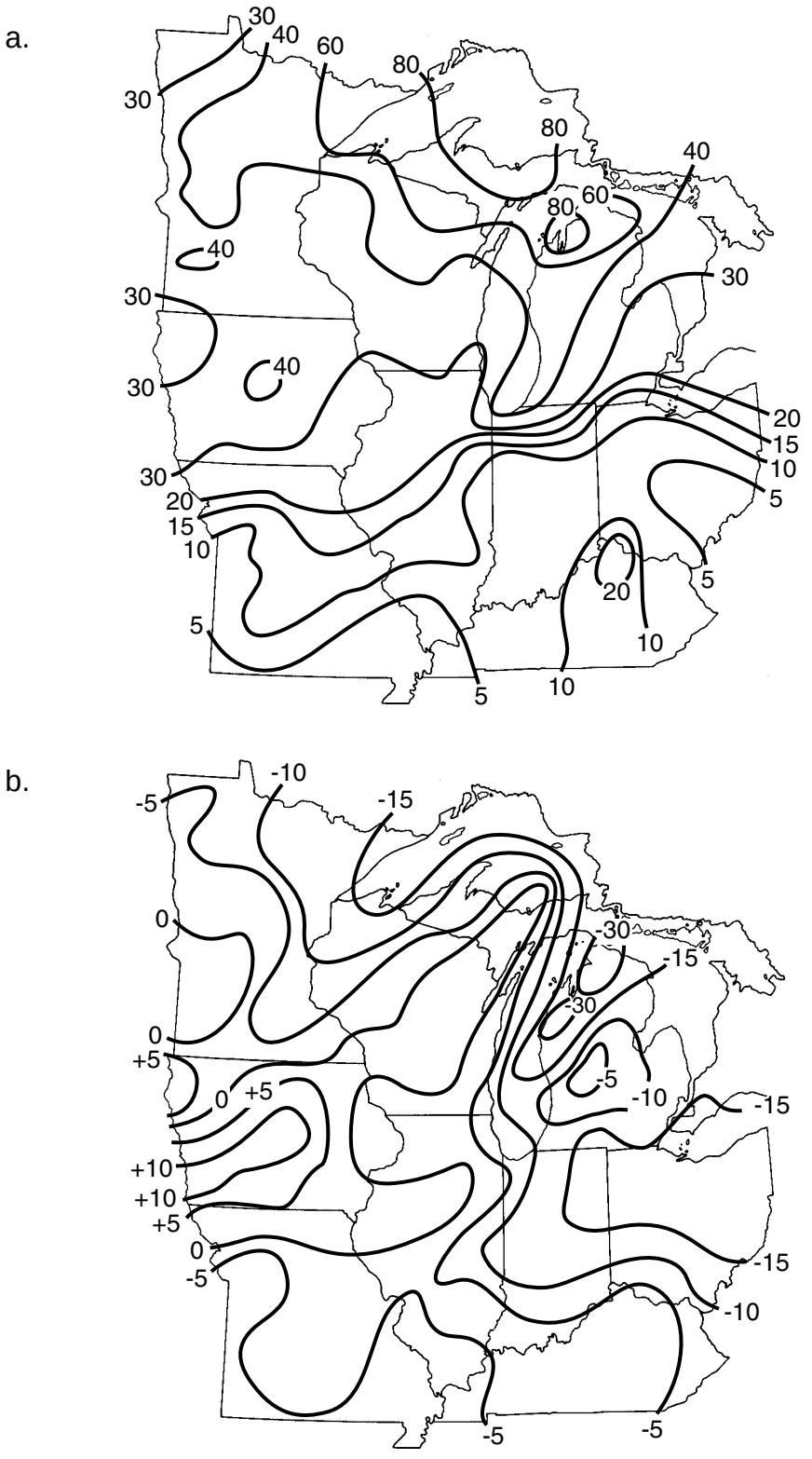

Figure 30. (a) October 1998-April 1998 snowfall for the Midwest and (b) departure from normal (inches).

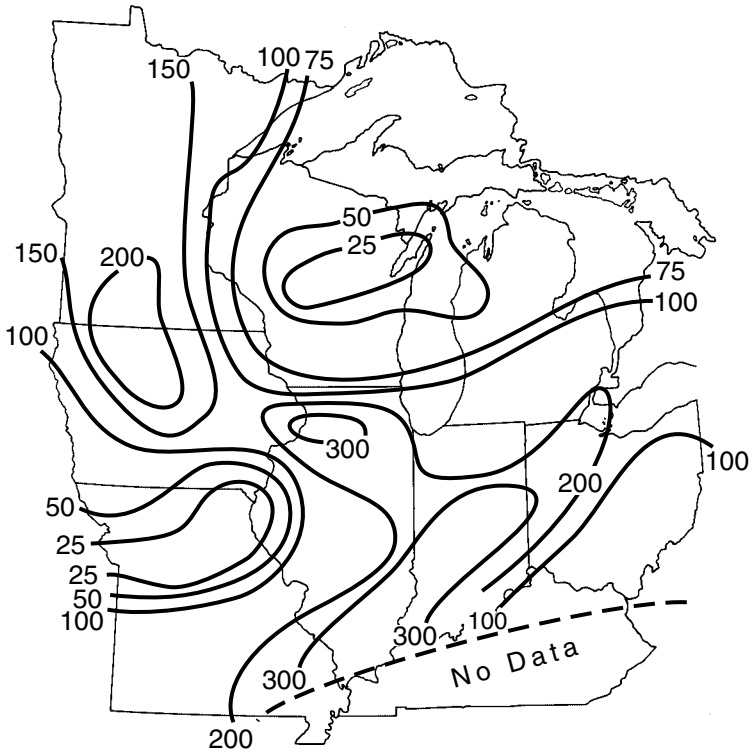

Figure 31. November 1997 snowfall, percent of normal.

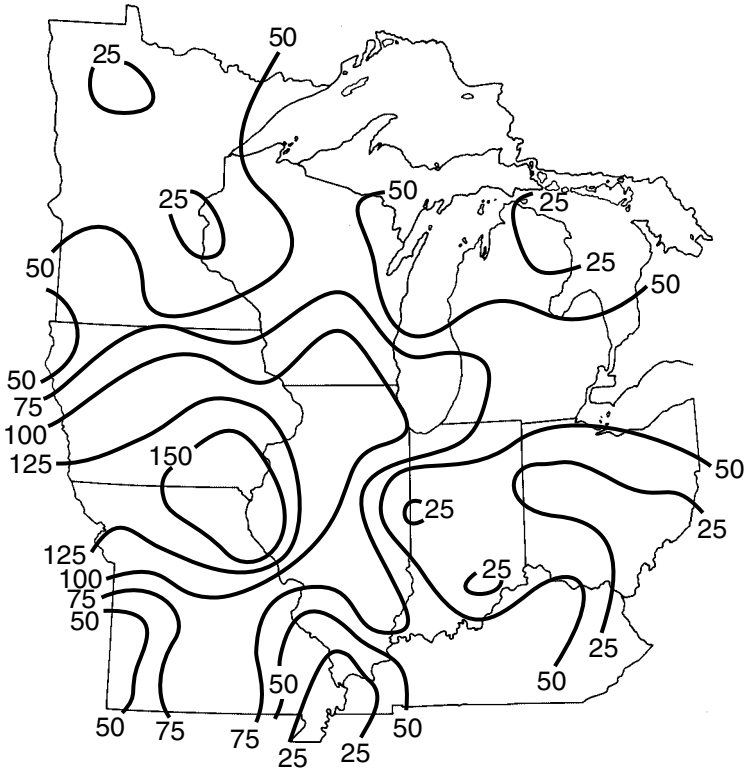

Figure 32. December 1997 snowfall, percent of normal.

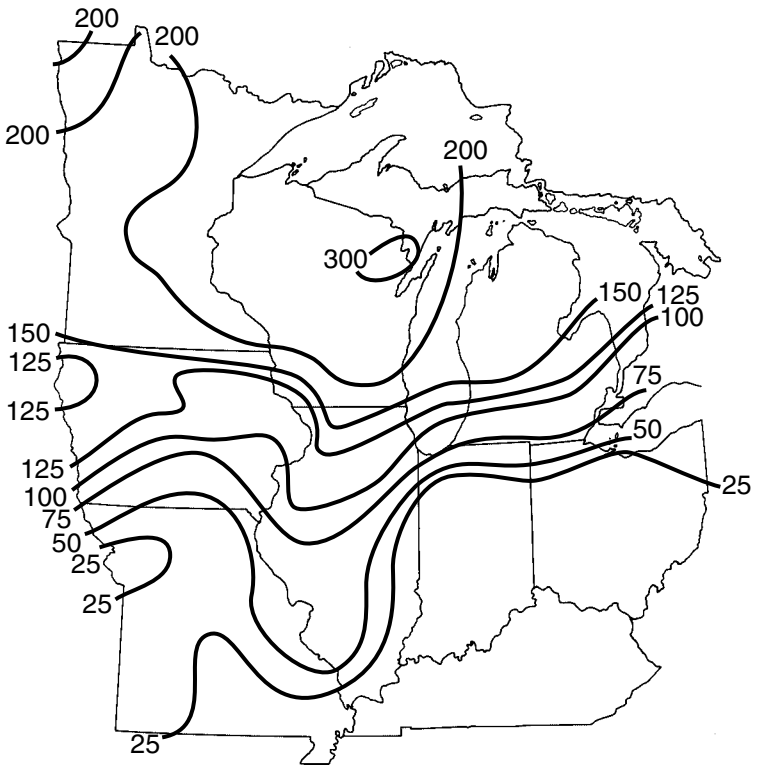

Figure 33. January 1998 snowfall, percent of normal.

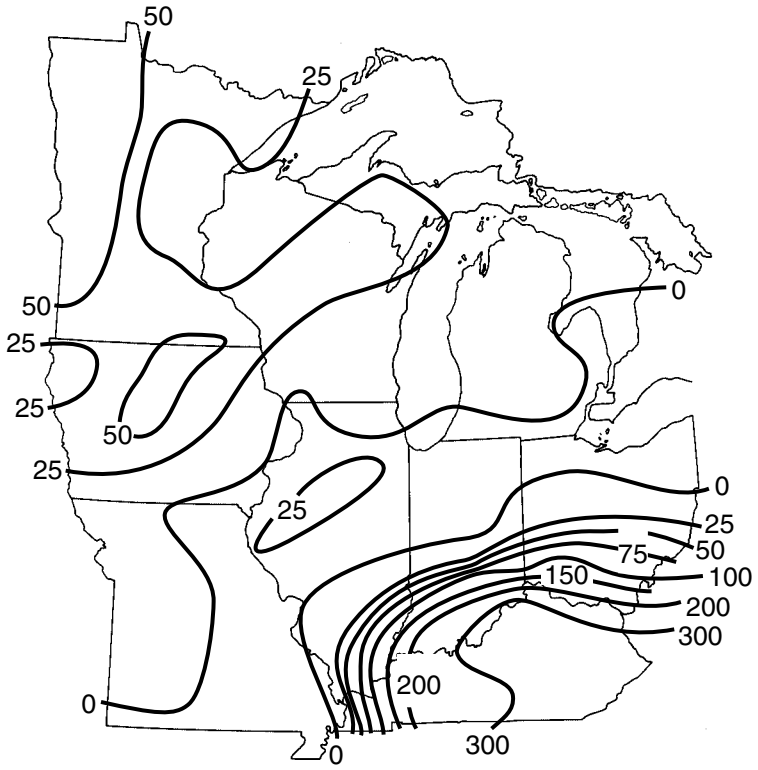

Figure 34. February 1998 snowfall, percent of normal.

snowfall, and most of the area north of Kentucky and southeast of a line from the Straits of Mackinac to the southwest corner of Iowa received less than one-quarter of the normal snowfall. Large portions of Missouri, Illinois, and Indiana received no snow during February. The only part of the Midwest to receive normal-to-above normal snowfall during February was Kentucky. All of this snow came during a storm on February 4-6, which produced 12 to 18 inches of snow over large portions of the state; some locations reported more than 2 feet of snow.

The March snowfall pattern (figure 35) was notable for the continued lack of snow in parts of the upper Midwest, particularly Minnesota, where the northern half received less than 50 percent of normal snowfall. Normal-to-above-normal snowfall occurred in a wide southwest-to-northeast band extending from Missouri through lower Michigan. Most of this snow came during a storm that moved through the Midwest March 7-9 and was accompanied by strong winds and blizzardlike conditions.

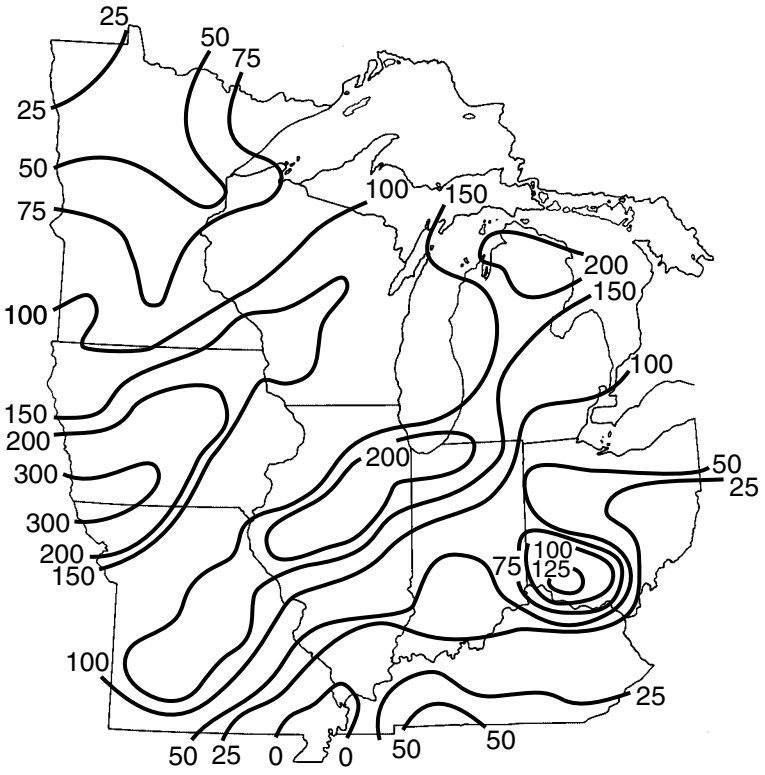

Figure 35. March 1998 snowfall, percent of normal.

Summary

Snowfall during 1997-1998 was below normal across most of the Midwest. The lack of snowfall is not surprising given the much above normal temperatures across the Midwest during the winter. The largest snowfall deficits were in locations that normally receive large amounts of snow—northern Minnesota, northwestern Wisconsin, and northern lower Michigan. The snowfall deficit was in excess of 30 inches in northwestern Michigan, and 10 to 20 inches in the remainder of the these areas.

Larger snowfall deficits might be expected across the Midwest with the record warmth during January and February. However, a few storms brought heavy amounts of snow to different parts of the Midwest at different times. What was different during the 1997-1998 season was the distribution of snow throughout the season. Normally, the southern half of the Midwest receives 80 percent or more of its seasonal snowfall during the climatological winter months of December, January, and February (figure 36). The remainder of the Midwest receives about 75 percent of its seasonal snowfall during the winter, with northwestern Minnesota receiving 50 to 60 percent. During the 1997-1998 snow season, a smaller than normal proportion of the seasonal snowfall fell in all areas except western Minnesota (figure 37). From eastern Illinois across central Indiana, 60 percent of the seasonal snowfall, which was only from 8 to 15 inches, occurred during November and March. The snowfall, which was near normal across Iowa, was less than 60 percent of the seasonal total compared to a normal of approximately 75 percent. Not only was there less snow during the 1997-1998 season, but in most areas it also was more widely distributed throughout the season. For the southern Midwest, the most significant snows fell during November and early March.

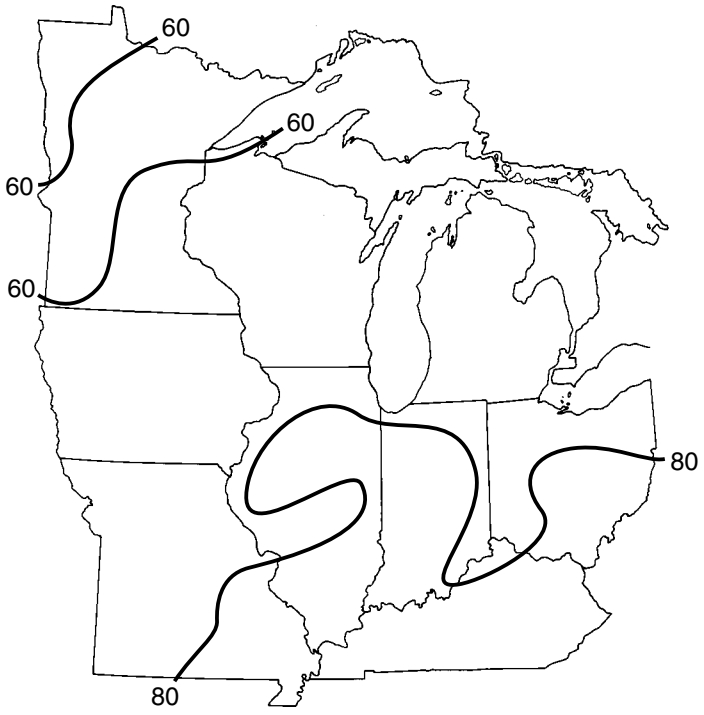

Figure 36. Average snowfall during the winter (December-February) compared to average season total, percent of normal.

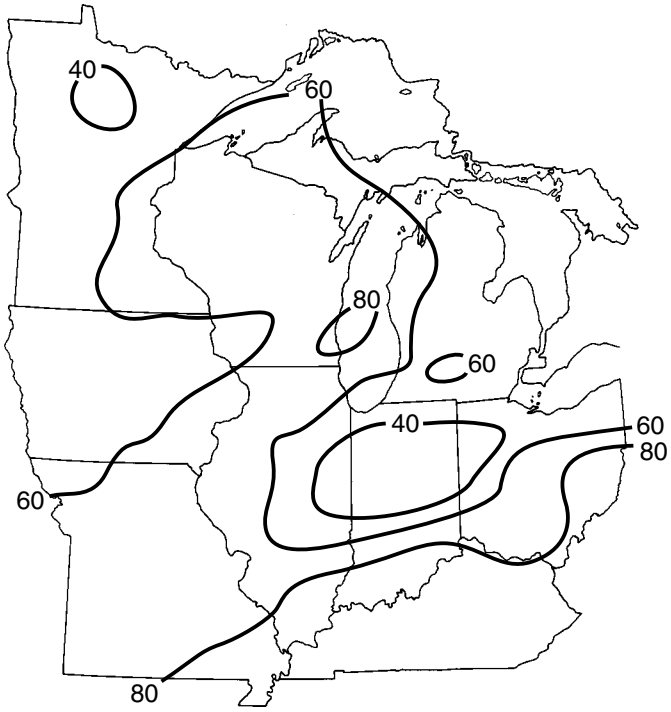

Figure 37. Percent of snowfall during the 1997-1998 winter (December-February) compared to average season total.

Impacts of El Niño-generated Weather Conditions in the Midwest

Stanley A. Changnon

Introduction

This study assessed for the Midwest the myriad of impacts resulting from the use of the long-range weather predictions based on atmospheric influences from El Niño 1997-1998 and then from the actual El Niño-driven weather conditions. The Midwest experienced a near record warmth during the cold season (November 1997-April 1998), with near normal precipitation and minimal snowfall (see the section "The 1997-1998 Weather Conditions and Their Climatological Relevance").

Without a major costly study, it is impossible to derive a precise measure of the human health, economic, and environmental impacts of a major, nationwide event such as those created by El Niño-generated weather conditions (NRC, 1999). However, by using data in news accounts, business reports, and government reports, coupled with data on insurance losses on catastrophes, one can gain useful estimates of the impacts. Many values were available from the business world about percentage changes, up or down, by month in various sectors, and these were used with past values in normal winter conditions to derive estimates of losses or benefits.

This section begins with an overview of the national impacts on human lives and the economy resulting from weather events attributed to El Niño 1997-1998. The net national economic effect was surprisingly positive. This section is followed by an analysis of the impacts in the Midwest that illustrates in detail the types of negative and positive effects created by the El Niño-generated weather conditions.

National Overview

The economic and environmental impacts of weather events and climate conditions in the United States normally vary spatially across the nation; and for any given period, such as a season, the impacts reveal a mix of winners and losers. This was certainly true with the impacts resulting from El Niño 1997-1998. The long-range predictions issued in June-August 1997 called for more storms in parts of the nation and heavy precipitation for the South and Far West. These outlooks created widespread fears about damages; and with the help of considerable media attention, the situation created a sense across the nation that all "El Niño weather" was going to be damaging. This led to considerable concern and major mitigation endeavors in California where storm and rain predictions were ominous. The resulting mitigative activities that reduced losses were a major beneficial impact of the predictions. The potential impacts resulting from the predictions of a fall-winter-early spring period of above normal temperatures and below normal

precipitation and snowfall for the Midwest and other northern sections of the United States were largely ignored because these predictions were not seen by most as creating negative impacts.

El Niño-influenced atmospheric conditions created a considerable amount of damaging weather in parts of the nation. A series of weather disasters was attributed to the record largest El Niño of 1997-1998, which led to numerous intense storms across parts of the United States. As predicted when El Niño developed during June-August 1997, California was assaulted by a series of coastal storms and heavy rains that caused floods, numerous landslides, and damage to the state's valuable agriculture, with losses totaling $1 billion statewide. Florida, Texas, and several other southern states were struck by several severe rainstorms and numerous tornadoes, events uncommon in winter. Tornadoes caused more than 50 deaths, and El Niño-caused losses in Florida reached $500 million. A record early snowstorm swept across the High Plains and upper Midwest in October. Extremely severe ice storms struck the Northeast in January, creating losses in excess of $300 million and 28 deaths (Ross et al., 1998). By the end of May 1998, the national death toll caused by El Niño's weather conditions was 189 (Changnon, 1999).

The major effects of El Niño on storm activity in the United States occurred from September through April. The property insurance industry identified 15 catastrophes, events each causing more than $25 million in insured losses, during the eight-month period ending in May 1998, when El Niño's influence on the weather largely dwindled. The total insured losses caused by these 15 catastrophes was $1.7 billion (Property Claim Service, 1998). States with insured losses from three or more catastrophes were Alabama, California, Florida, Georgia, Louisiana, Mississippi, and North Carolina. These events showed how the forecasted outcomes calling for storms on the West Coast and the Deep South were correct. Florida experienced losses in 5 of the 15 catastrophes, and 3 of these caused more than $100 million in losses nationally. The single greatest insured storm loss was $305 million caused by heavy rains (flooding), hail, and tornadoes in a storm system on April 15-17 that swept across Arkansas, Missouri, Kentucky, Tennessee, and Illinois.

Federal Emergency Management Agency relief payments for El Niño-caused storm losses reached $289 million by the end of March, but this was lower than relief payments in the prior two winters that were not El Niño related (*Champaign-Urbana News Gazette*, April 5, 1998). There were 18 Presidentially declared disasters from the fall of 1997 through April 1998, and all were partly attributed to El Niño's influence on the atmosphere (Leetma, 1998). El Niño events have become stronger and more frequent since 1980; this is one reason for the increased losses from weather-related natural disasters over the past 15 years (Changnon et al., 1997).

In summary, the national economic losses attributed to El Niño-generated weather were about $4.2 to $4.5 billion, with 189 lives lost.

The mild, almost snow-free winter produced by El Niño's influence on the atmospheric circulation over North America resulted in major beneficial impacts. Michaels (1998) made an early estimate that accounted for national benefits of $15 billion versus losses of $2 billion.

Fewer lives were lost due to bad winter conditions (bad roads, low temperatures, etc.) than normally occur. Estimates from various parts of the northern United States indicated a national drop from an average of 950 winter deaths to less than 100 lives lost to winter conditions during 1997-1998 (*Detroit News*, March 20, 1998). El Niño's influence led to a virtual elimination of Atlantic hurricanes during 1997 (Gray, 1997). Annual hurricane damages in the United States averaged $5 billion per year in the 1990s (Pielke and Landsea, 1998). The lack of hurricanes in 1997 meant an enormous savings to home and business owners, the government, and insurers. It further meant no lives lost to hurricanes, which have averaged 20 deaths per year since 1986.

A fall-winter-early spring that was abnormally warm, dry-to-near normal precipitation, and almost snow free across the northern two-thirds of the nation created an interesting array of beneficial impacts and a few losses. The abnormal warmth led to major reductions in heating costs with less use of natural gas and heating oil. Nationally, the energy savings were 10 percent (Ross et al., 1998), which represents a savings of $6.7 billion. This reduction in energy use was large enough to have an effect on global oil prices, as El Niño's influence brought abnormally warm seasons to North America and Europe.

The generally good weather with little snowfall and temperatures averaging 10°F above normal also had a major influence on construction, retail shopping, and home sales. Many retail chains reported record high sales for January-March, and record high sales of homes occurred during December-March. Income and employment in the construction industry increased 25 percent from December through February, a value estimated at $350 million over normal winters. The record sales of goods, products, and homes created $5.6 billion in added income.

The Federal Reserve Board announced in February 1998 that the warm January caused a 4 percent drop in production at the nation's electric and gas utilities, ending a run of months with production increases that economists had expected to be +0.3 percent in January (*Minnesota Star Tribune*, February 18, 1998). El Niño's net influence coupled with the Asian financial crisis combined in February to eliminate inflation in the prices paid by wholesalers, as food processors and manufacturers charged wholesalers 0.1 percent less than in January for finished goods (*Minneapolis Star Tribune*, March 14, 1998; *Champaign-Urbana News Gazette*, March 19, 1998). Inflation was held to zero during January-March, the first time in 10 years, and the Consumer Price Index went unchanged due to falling energy prices (*Detroit News*, April 15, 1998).

Some outcomes partially attributed to El Niño-created conditions are difficult to quantify. For example, gasoline prices in the United States reached record lows in early March 1998, and oil experts indicated that part of the cause was attributed to the warmer-than-usual winter in the United States, which greatly reduced the demand for oil. Another part of the cause was the result of the Asian financial crisis and the bickering over sale quotas by the world's oil producers (*USA Today*, March 10, 1998). This gas price reduction, averaging $0.25 per gallon below pre-El Niño costs, continued through 1998 and represented an enormous saving to drivers. With 250 million autos and trucks operating and using an estimated 10 gallons of gasoline per

week, the savings for just March-May 1998 amounted to $7.5 billion. But how much of this can be attributed to an El Niño-caused warm winter? Even if only a small amount of this saving was attributable to El Niño, very large benefits accrued across the nation with gasoline prices remaining low throughout 1998.

The national economic gains due to El Niño-generated weather conditions were estimated to be $19.6 billion, a value about four times greater than the losses. In addition, 850 lives were saved due to the mild, largely storm-free winter (Changnon, 1999).

Impacts in the Midwest

The Evolution of Major Events Creating Impacts

Assessment of the Midwestern impacts from the El Niño-generated weather conditions is based on the temporal history of El Niño 1997-1998 and events related to these weather conditions. The CPC began issuing official predictions about the development of a major warm phase (El Niño) of the Southern Oscillation in the tropical Pacific in late June 1997. By August the official CPC predictions were calling for mild fall and winter seasons, with below normal precipitation in the Midwest. All experimental forecasts by other scientists and institutions agreed. The MCC issued a climate-based outlook that called for much below normal snowfall in the winter of 1997-1998 for the Midwest in September (see the section "El Niño Outlooks"). An MCC outlook for decreased cold season storminess on the Great Lakes was issued in October. These predictions received wide coverage in the national and Midwestern news media.

By late September most Midwestern residents and decision-makers in weather-sensitive industries were aware of the fall-winter predictions and were in a position to make decisions relating to the forecasted conditions. Thus, the first series of impacts occurring largely during the fall of 1997 related to decisions to use, to ignore, or to be confused by the El Niño-based forecasts for a mild, low snowfall winter across the Midwest.

The ensuing mild, relatively dry, and almost snowless winter (December 1997-February 1998) revealed that the official forecasts were accurate. During this season the major impacts from the El Niño-driven weather conditions occurred across the Midwest. These impacts transcended most human and economic activities in the Midwest and were realized in numerous sectors, e.g., human health and safety, financial outcomes, energy production and use, societal activities, agriculture, a myriad of businesses, recreational activities, and the environment.

The third series of Midwestern impacts and responses was related to the long-range predictions issued during January-April that forecast the spring and the 1998 growing season (May-September) weather conditions. These forecasts were of great interest to Midwestern agricultural interests and the commodity-investment markets. The various predictions for summer 1998, unlike those for the winter, were not in agreement. Some called for a mild and wet

summer; others called for high temperatures and drought. The spring season predictions issued in February called for a continuation of the winterlike conditions with predictions for warmer and drier than normal conditions for the Midwest. The spring weather in the Midwest had above normal temperatures but above normal precipitation instead of drier than normal conditions. March had a two-week period of cold and snowy weather with two major winter storms, temporarily interrupting the mild winter conditions.

Considerable information on impacts was extracted from articles containing any El Niño references published by eight Midwestern newspapers: the *Chicago Tribune*, *Cincinnati Inquirer*, *Cleveland Plain Dealer*, *Des Moines Register*, *Detroit News*, *Indianapolis Star, Minneapolis Star Tribune*, and *St. Louis Post-Dispatch*. El Niño information from 502 newspaper articles and more than 200 Internet issuances pertaining to the Midwest, (found during July 1997-May 1998) were assessed.

Impacts and Responses to the Weather Predictions for Fall and Winter

Predictions of cold season conditions as being wet and stormy from California eastward through the Gulf states to Florida quickly got the attention of various persons interested in agriculture. By mid-September 1997, a commodities group in Chicago predicted food prices would rise (*Cleveland Plain Dealer*, September 18, 1997), a prediction echoed by a leading economist a few days later (*Detroit News*, September 22, 1997). A private sector meteorologist in the Midwest predicted the types of crops (produce and fruit) that would be hurt by El Niño weather, and added that Midwestern prices would soon rise (*Cincinnati Inquirer*, October 3, 1997). In a more cautious vein and after El Niño's effects of fall weather had been demonstrated, the U.S. Department of Agriculture (USDA) predicted, in mid-December, that higher fruit and vegetable prices would exist in the first six months of 1998 because of bad weather expected in California, Arizona, Texas, and Mexico (*Chicago Tribune*, December 17, 1997). Interestingly, events in January and succeeding months proved that these agricultural impact projections were essentially correct.

Several companies began enhancing stocks and supplies in October in anticipation of buyers' reactions to the El Niño-based predictions of an increased frequency of damaging storms (*Minneapolis Star Tribune*, October 27, 1997). Big hardware and lumber chains began increasing stocks, the insurance industry reported increased sales and enlargement of existing policies, and commodity traders, who were betting on the forecasts of dry conditions in the Corn Belt and elsewhere, had increased purchases from investors. Some homeowners, fearing the worst, sought home repairs, and this benefitted the construction industry.

Conflicting responses to the El Niño predictions were issued by Midwestern energy experts. One expert predicted little effect of the projected warm winter on the Midwestern use of natural gas (*Des Moines Register*, October 26, 1997). Another predicted a major drop in the prices for natural gas (*Chicago Tribune*, December 5, 1997), a correct outlook. More conflicting predictions were issued concerning the incidence of damaging winter storms on the Great Lakes.

One Midwestern Climate Center climatologist predicted fewer storms than normal as a result of El Niño's effect on storm tracks (University of Illinois, 1997); other scientists predicted bad storms and much shore erosion (University of Michigan, 1997). The ensuing winter had below normal lake storms and minimal erosion.

Experts in the travel and tourist industry reacted to the predictions with outlooks of bad business for winter sports and skiing in the Midwest (*Des Moines Register*, November 16; *Detroit News*, December 10, 1997), generally correct predictions. Financial specialists foresaw instability developing in Midwestern commodity markets (*Chicago Tribune*, September 25, 1997), a condition that did not develop. Economists predicted that the expected winter weather would have mixed effects on Midwestern businesses, a cautious and correct outlook (*Chicago Tribune*, January 7, 1998).

The reactions of various groups and the public to the El Niño-based predictions for the mild winter weather were interesting. A group of 100 Iowans were polled in late October, and the majority doubted the winter forecast (*Des Moines Register*, November 3, 1997). A mid-November assessment of public attitudes in the Midwest indicated that the general public was confused by the El Niño forecasts. Experts interviewed in three Midwestern natural gas supply companies questioned the accuracy of the predictions; they indicated they were going to ignore the mild winter predictions, and it would be business as usual *(Cleveland Plain Dealer*, November 9, 1997). Managers responsible for clearing highways and streets in several Midwestern cities also indicated doubt in the predictions, and all sampled had decided to "play it safe" and plan for the worst, as to road crews and salt supplies (*Chicago Tribune*, January 18, 1998). Thus, there was a widespread disbelief in the predictions and few responded to them. This was unfortunate because those who did respond to the predictions realized handsome profits.

Impacts from the Fall-Winter-Spring Weather Conditions

The various impacts associated with the El Niño-caused weather conditions in the Midwest from October through May 1998 were classified by sector beginning with the societal impacts that include effects on behavior and health. This is followed by seven assessments, including the effects to business and industry, energy use and production, the recreation industry, the construction industry, agriculture, the environment, and government agencies.

Societal Impacts

These impacts include behavioral aspects as well as human health. Midwesterners quickly adopted, as did the entire nation, the concept that El Niño was a good excuse for everything bad, including personal failures (*Minneapolis Star Tribune*, October 22, 1997; *Detroit News*, October 30, 1997). It was noted that street and highway workers, because of less road clearance activities, were getting less work, had more rest, and experienced less stress than in normal winters (*Chicago Tribune*, January 7, 1998).

Public sampling done in Ohio during late January, in Michigan in early February (*Detroit News*, February 6, 1998), and in Chicago during mid-February (*Chicago Tribune*, February 16, 1998) revealed most people were quite happy with the nice winter. It had allowed them to be outdoors more and had lowered heating costs. Only a few complained about the lack of snow-related sports.

The nice conditions led to fewer winter highway accidents, with a reduction in the average number of deaths of 230 (*Detroit News*, March 20, 1998). There were notably fewer winter injuries, such as falling on a slippery surface, and the reductions in injuries were most notable among the elderly (*Detroit News*, March 20, 1998). Doctors in several hospitals reported 22 percent fewer heart attacks. The homeless were seen as beneficiaries of the mild winter (*Cleveland Plain Dealer*, March 1, 1998), and emergency highway-related calls were down by 11 percent in Michigan during December-February (*Detroit News*, March 20, 1998). The estimated reduction in deaths due to the milder weather was between 125 and 150 in the Midwest.

In general, it was healthier and safer to be outdoors and to travel during the winter of 1997-1998. However, deaths related to El Niño's weather did occur. Three persons riding on snowmobiles over northern Michigan lakes, which are normally covered by thick ice, fell through the thinner ice in February 1998 and drowned (*Detroit News*, February 15, 1998). A huge storm system that developed over the South, and was attributed to El Niño, produced up to 18 inches of snow in parts of Kentucky and Ohio, and floods elsewhere along the East Coast, leading to four Midwestern deaths. A tornado in Minnesota in March killed two people, and a NWS spokesman attributed the storm to El Niño (*Cleveland Plain Dealer*, March 31, 1998). There were no spring floods in the Midwest, events that normally cause considerable regional damage and a few deaths. The huge flood in April 1997 on the Red River of the north had devastated parts of Minnesota and North Dakota, and the nice winter weather of 1997-1998 was considered a huge blessing to morale in that area as people were able to rebuild their homes faster than expected (*Chicago Tribune*, March 23, 1998).

Impacts on Business and Industry

The unexpected and persistent good winter weather led the buying public to circulate and behave in many interesting and different ways. The region experienced a major increase in housing starts in December and January (*Chicago Tribune*, January 7, 1998). Realtors reported that the December-March sales of homes in the Midwest were up by 25.5 percent, the highest level in four years (*Chicago Tribune*, March 30, 1998), representing added income to realtors and homeowners of $0.6 billion. National sales of homes in January alone reached a record high at 4.4 million units (*Chicago Tribune*, April 5, 1998), and these record sales were attributed to the mild and snowless weather created by El Niño.

Restaurants reported record crowds as people went out more than in normal cold and snowy winters (*Detroit News*, January 8, 1998), and retail sales skyrocketed for the same reason. In early January, major Midwestern department store chains such as Dayton-Hudson,

Nordstroms, and Neiman Marcus, as well as major shopping centers, reported winter season retail sales were up by 5 to 15 percent (*Chicago Tribune*, January 7, 1998). Retail sales continued to boom during February, including sales of clothing and products for yard work. Wal-Mart reported a 9.6 percent increase in sales over the previous winter, Sears' sales were up 4.7 percent, and Kmart's increase was 5.6 percent (*Chicago Tribune*, March 5, 1998). Such increases represent additional incomes of over $1.5 billion to these firms. The nation's retail index was up by 5.4 percent in February after a gain of 5.1 percent in January, and a group of major Midwestern department stores reported winter sales were up by 7 percent (*Chicago Tribune*, March 6, 1998). These outcomes across the Midwest produced a total benefit due to increased merchandise and home sales estimated at $2.9 billion.

Transportation and shipping systems in the Midwest benefitted considerably from the unusual winter conditions. With less bad weather, trucks, express parcel shippers, and the railroads experienced fewer delays and fewer accidents. Airlines operating at Midwestern hub airports also had many fewer delays and canceled flights, and experienced increased ridership. The warm conditions reduced ice cover on the Great Lakes and allowed lake carriers to haul more tonnage than any year since 1982. The resulting savings and increased profits from the winter conditions are estimated at $100 million.

Not all Midwestern businesses benefitted from the winter weather conditions. Firms manufacturing or selling snow equipment (snowmobiles, snow plows, shovels, etc.) were hurt by low sales. Snowmobile sales were down 35 percent (*Detroit News*, March 20, 1998), a major snowplow manufacturing firm in Ohio laid off half its staff (*Cleveland Plain Dealer*, March 1, 1998), and another Ohio-based manufacturer went broke. Sales of salt were down 50 percent and sales of winter clothes and fur coats went down 15 percent (*Detroit News*, March 20, 1998). Midwestern salt providers reported losses of $68 million in sales. Urban taxis reported fewer riders (*Chicago Tribune*, January 7, 1998), and manufacturers and outlets for furnaces reported sales down by 20 percent. Towing companies reported business down by 40 percent. Natural gas utilities had reduced sales due to the above normal temperatures, with winter sales down by 15 percent. Firms that had planned, based on the predicted winter conditions, benefitted by buying gas supplies during the winter. Other firms that had contracted for gas early when the price was still high, were able to pass on the higher price paid to the consumer by not lowering rates as much in the winter.

Energy Use and Production

The higher temperatures, many at near record levels for winter (see the section "The 1997-98 Weather Conditions and Their Climatological Relevance"), greatly decreased the use of natural gas and heating oil in the Midwest. Use was down by 15 to 20 percent, depending on the area. By early December, gas futures were falling after a high in October, and were down by 36 percent (*Chicago Tribune*, December 5, 1998). This was reflected by the amount of natural gas in storage. Regional storage in early December was 88 percent of capacity as compared to 77 percent a year before. In the Chicago area, the December gas prices fell, on average, by 3.3

percent. Gas prices to consumers fluctuated, some remaining relatively high and others cascading down, based on whether their suppliers had contracted early when prices were up or whether the supplier waited and was able to buy gas at the ever lowering prices. Some of the gas utilities that used the predictions and waited to buy on the spot market during the winter, gambled further and used the gas they had in storage in the early winter; this allowed them to wait to buy as the price fell ever lower (*Des Moines Register,* February 23, 1998).

By late February, energy bills for the winter in Ohio, Iowa, and Illinois had decreased 16 percent, and the average person had saved $50 (*Des Moines Register*, February 23, 1998; *Cleveland Plain Dealer*, March 1, 1998). In portions of Iowa and Illinois, one utility reported its 610,000 customers had realized savings of $39 million. By late February, savings from lower heating costs in the nine-state Midwest had reached $4 billion, and more savings lay ahead with the continuing above normal temperatures of March and April. Utilities in lower Michigan announced that gas usage in March was down 18 percent, the average savings per person was $21, and the region's one-month savings was $125 million (*Detroit News*, March 12, 1998).

As the demand for heating fuels fell, global energy prices also declined, falling 2.4 percent in January and by 2.2 percent in February; this helped bring the price of gasoline down to $1.10 per gallon, the Midwestern average price in early March (*Chicago Tribune*, March 20, 1998). This was down 25 cents per gallon from the average in prior months. The only energy-related problem reported was a major power outage in southern Ohio and northern Kentucky resulting from a major snowstorm in early February (*Des Moines Register*, February 7, 1998). By April 30, the savings in energy costs in the Midwest were estimated at $4.7 billion.

Recreation

The effects of the mild winter on recreation in the Midwest were mixed, with some winners and some losers. The major problems came to the ski industry in Michigan, Ohio, and Wisconsin. Overall, sales at Michigan's ski resorts were down 50 percent, a loss of $25 million; but the resorts that had or added snow-making equipment (some based on the mild winter forecasts), reported a good financial season (*Detroit News*, December 10, 1997). A major ski resort in northern Ohio spent $2.5 million on snow-making equipment and reported its seasonal income exceeded its cost (*Cleveland Plain Dealer*, March 1, 1998). Several ski resorts had to close two to four weeks earlier because they could not make enough artificial snow, given the warmth and rainfall (*Detroit News*, March 20, 1998). Cross-country skiing was also hindered as was ice skating (*Des Moines Register*, January 14, 1998). The thin ice problem of the warm winter also curtailed ice fishing across the Midwest. However, fishing on Lake Erie in mid-winter was possible because there was no lake ice to contend with, which was a big boon to fishermen and to the local boating industry (*Cleveland Plain Dealer*, February 13, 1998).

Many other positive impacts came in the recreation sector. Golf courses reported golfers were out in record numbers all through the winter. A Chicago course reported that 75 groups had played on January 5, a record for any day in a previous winter (*Chicago Tribune*, January 7,

1998). Chicagoans in February were reportedly enjoying their parks, walking along the lake, roller skating, and sailing on Lake Michigan, all activities not common in winter (*Chicago Tribune*, February 16, 1998). Attendance at city zoos set records (*Cleveland Plain Dealer*, March 1, 1998). Many skiers went to the West to ski, leading to increased skiing income in California and Colorado (*Cincinnati Inquirer*, March 22, 1998). Among the oddities reported was the fact that owners of classic cars were able to operate their vehicles in winter because of the lack of salted roads, and the mild temperatures allowed track athletes to begin practice earlier than usual and to improve their racing times (*Detroit News*, April 2, 1998). In sum, many people found other outlets for their recreational needs, but those most unhappy with the winter of 1997-1998 were skiers, ice skaters, and ice fishermen.

Construction Industry

The mild temperatures and low precipitation allowed construction to proceed at a fast pace in the Midwest. Winter construction projects in Ohio and Michigan were up 30 percent (*Cleveland Plain Dealer*, March 1, 1998; *Detroit News*, March 20, 1998). People not only started building houses, but many also added on to existing structures (*Detroit News*, March 20, 1998). Cincinnati construction firms reported losing only one day to bad weather between December 1 and February 28, as compared to 14 bad weather days in a normal winter (*Cincinnati Inquirer*, March 20, 1998). The good weather also increased construction employment by 4.7 percent, another benefit (*Cincinnati Inquirer*, April 4, 1998). The economic benefits were estimated and between $250 million and $300 million in the Midwest.

Impacts on Agriculture

Because the cold season is not the growing season, Midwestern agriculture did not experience major impacts from the winter weather of 1997-1998, but most effects that occurred were positive. Farming impacts included lower costs for heating farm buildings. Larger herds of cattle and sheep could be kept because feed was less expensive, and animals could be outside a greater percent of the time consuming grasses. Gardens got an early start (*Des Moines Register*, March 8, 1998a). Although many orchardists feared then witnessed early budding of fruit trees, no freezes came late to damage trees (*Farm Week*, April 6, 1998), and apple and peach crops in the Midwest had above normal yields in 1998, bringing added profits of $85 million (*Champaign-Urbana News-Gazette*, August 1, 1998). The sale of crop insurance in the spring rose 21 percent above average levels, representing farmers' fears for the 1998 growing season. However, no drought developed, and corn and soybean yields across most of the Midwest were above average.

Environmental Effects

The warm and dry winter had predictable environmental outcomes. Trees and bushes began budding earlier than normal in 1998 (*Cleveland Plain Dealer*, March 1, 1998). Wisconsin authorities reported an increase in the deer population (*Chicago Tribune*, March 2, 1998).

Because wild birds could access natural feeds during the winter, they consumed less human-supplied bird feed, leading to reduced sales of commercial feeds (*Cincinnati Inquirer*, March 4, 1998). The number of bald eagles in the Midwest, which normally winter in Missouri, was reduced because the eagles spent the winter at habitats farther north (*St. Louis Post-Dispatch*, March 9, 1998). The early budding of some tree varieties led to damages caused by an early March snowstorm, the only significant winter storm of the year, across the Midwest (*Chicago Tribune*, March 10, 1998). Stream measurements taken throughout the region also revealed less water pollution in most streams and rivers than normal (*Detroit News*, March 20, 1998). Streamflows were at or below average as a result of the drier winter. But they did not approach serious shortage levels in streams or reservoirs, and shallow ground-water levels remained near normal in Illinois. The levels of the Great Lakes declined by 0.5 to 1 foot as a result of the dry, warm season, but this was a benefit as lake levels were much above normal. Furthermore, the much below normal number of lake storms reduced damage to the shorelines.

Impacts on Government

The principal impact on city and state governments of the mild and snow-free winter of 1997-1998 was reduced costs. This occurred because of the lack of snowstorms and ice storms, which greatly (1) reduced the amount of salt needed and purchased, and (2) reduced normal pay for overtime to road crews. For example, the Ohio Department of Transportation used only one-third the amount of salt normally applied, saved 10,000 hours of overtime pay, and reported a total savings of $930,000 (*Cleveland Plain Dealer*, March 1, 1998). Counties across Michigan realized 40 percent cuts in overtime pay and reported an average winter cost reduction of $1 million per county, representing a statewide savings of $100 million. For example, Wayne County, Michigan, saved $200,000 in overtime pay and $2.4 million in salt purchases (*Detroit News*, March 20, 1998). Illinois collar counties around Chicago reported winter savings ranging from $100,000 to $250,000 each, and Chicago spent $8 million for snow removal, which was $4 million less than normal (*Chicago Tribune*, April 1, 1998). The Illinois Department of Transportation used only 50 percent of the normal amount of salt in the Chicago metropolitan area, a savings of $2 million. The metropolitan region's total savings amounted to $21 million. Use of such values to estimate the Midwestern benefits results in a regional savings of approximately $250 million. The increased retail sales and home sales also added taxable income to the state and local coffers, and the lower use of energy cut heating costs for government buildings. The impacts on government bodies were beneficial.

Impacts and Responses to Predictions for Spring and Summer 1998 Weather

Analyses of the official and nonofficial experimental predictions issued by various groups from mid-winter onward about the spring and summer weather conditions revealed a wide variety of predicted outcomes, particularly for the late spring and summer–the growing season of 1998. Some called for a continuation of the El Niño-type conditions into June; others foresaw a rapid development of La Niña conditions that would result in droughtlike conditions in the

Midwest. The point is that the various scientific models used to generate the seasonal predictions did not agree and provided a wide range of forecast outcomes.

These uncertainties were translated into various predictions of the effects on agriculture, a major concern in the Midwest. In early February, an Iowa climatologist forecasted normal corn and soybean yields for Iowa (a correct forecast), but other weather experts in Iowa disagreed (*Des Moines Register*, February 19, 1998). Five days later a USDA economist in Washington predicted "bumper" corn and soybean yields for the United States in 1998 (*Chicago Tribune*, February 23, 1998), a forecast that was correct for the Midwest. Five days later, a private sector meteorologist in Chicago stated there was a 57 percent chance for bad growing season weather (due to high temperatures) in the Midwest and used that prediction to further project that future corn and soybean prices would soar (*Chicago Tribune*, March 1, 1998). Future events proved that both of these predictions were incorrect. The USDA regional crop insurance office in the Midwest recommended buying coverage for a likely bad weather season in 1998 (*Des Moines Register*, March 8, 1998b).

A sampling of various crop-weather experts in early March revealed a wide range of predicted Midwestern crop outcomes, from poor to great; and one expert wisely observed that they should all be ignored as there was no skill involved (*Farm Week*, March 6, 1998). An official forecaster of the NWS predicted a normal summer in the Midwest, a correct prediction *(Minneapolis Star Tribune*, March 18, 1998). An Iowa climatologist predicted a cold spring with above average snowfall (later shown to be incorrect), and predicted that July and August would be hot and dry (*Des Moines Register*, March 20, 1998), an outcome that did not occur. The media noted that the fluctuating forecasts raised serious questions about the ability of atmospheric scientists to correctly predict either the end or the beginning of El Niño events (*Cincinnati Inquirer*, March 26, 1998). However, there were positive media responses to the NWS's spring flood predictions, which correctly called for low flood probabilities as a result of the dry, snow-free winter (*St. Louis Post-Dispatch,* March 25, 1998).

Medical experts predicted a bad warm season for allergies because of the prediction for a warm spring, earlier budding, and a lengthened growing season *(Detroit News*, February 23, 1998; *Minneapolis Star Tribune*, March 29, 1998). Other medical experts predicted more asthma problems for 1998 (*Detroit News*, March 20, 1998). Statistics are not available to verify or refute these predictions.

Predictions also were issued about the effect of the warm winter and the probable warm spring on insect pests, which would result in more mosquitos and other pests in the spring and summer *(Cincinnati Inquirer*, January 7, 1998). Others concluded that the weather predictions would improve Midwestern fishing (*St. Louis Post-Dispatch*, February 22, 1998).

Conclusions and Recommendations

Conclusions

The MCC received an enormous number of requests for data and information related to El Niño 1997-1998. These included requests for outlooks, explanations of the El Niño phenomenon, possible impacts of expected weather, and information about the climatic values experienced and their departures from normal.

The climate-based outlooks developed by the MCC and widely released using the news media, media interviews, and the Internet proved highly accurate and found wide use among climate-sensitive groups in the region. First, a detailed analysis of the seasonal temperature and precipitation conditions accompanying El Niño events was performed, and a summary of the results was disseminated in the region. This product complemented the outlooks produced by the NWS by adding more detail at the regional level. Second, the potential impacts of El Niño weather on agriculture were investigated by analyzing yields that occurred in past El Niño summers. The results suggested that regional crop yields were likely to be near or above average. Third, an MCC analysis focused on past snowfall conditions. The results suggested a high likelihood of below average snowfall in the central and eastern portions of the Midwest. A fourth study area concerned cold season storms on the Great Lakes basin. Results of this study indicated that the number of damaging storms would likely be below normal. In summary, the snowfall outlook called for below normal snowfall, and this occurred. The winter storm outlook for the Great Lakes basin also was correct. Agricultural yields were above average, which agreed with the MCC findings.

Following a colder than normal fall season, the winter weather pattern over the Midwest induced by the strong El Niño of 1997-1998 produced a record warm winter, including a much warmer than normal January and a record warm February. Snowfall was generally much below normal across most of the Midwest. On the whole, precipitation was near to or above normal in the Midwest from December through May, although there were some significant differences across the Midwest month to month. The seasonal long-lead outlooks issued by the CPC for the fall (September, October, November), winter (December, January, February), and spring (March, April, May) were fairly accurate in their identification of the areas of likely above normal, normal, or below normal temperatures in the Midwest. However, the extent of the climatological effects of El Niño 1997-1998 was larger than indicated by the statistically based outlooks.

The long-lead outlook issued by the CPC on August 14, 1997, indicated that, during the fall season, temperatures likely would be below normal over the entire Midwest, with an equal probability of above, normal, or below (climatology) in Ohio and Kentucky. Fall mean temperatures were, in fact, below normal in all nine Midwestern states, and it was the 22nd coldest fall for the Midwest as a whole. The precipitation outlook for the fall was for a higher probability for above normal precipitation in Michigan, eastern Illinois, Indiana, western Ohio,

southern Missouri, and western Kentucky, and "climatology" elsewhere with likelihood of above normal, near normal, and below normal values. Actual precipitation in the forecast "above normal" area was 60 to 80 percent of normal. Precipitation was 60 to 120 percent of normal in the remainder of the Midwest.

The long-lead outlook for the winter season was issued on November 13, 1997. The outlook indicated a probability for higher than normal temperatures for an area of the Midwest north of a Kansas City, Missouri - Evansville, Indiana - Columbus, Ohio line, with the highest probability for above normal temperatures across Minnesota and Wisconsin. South of this line, there was an equal probability of above normal, normal, or below normal temperatures. Minnesota, Wisconsin, and Michigan experienced their warmest winter on record. Illinois, Indiana, and Ohio experienced their second warmest winter, Iowa and Missouri experienced their third warmest, and Kentucky experienced its sixth warmest. It was the warmest winter on record for the Midwest. The precipitation outlook indicated a higher than average probability of wet weather in the western half of the Midwest, and an equal probability of above normal, normal, or below normal precipitation across northern Minnesota and the eastern half of the Midwest, with the exception of Ohio. The outlook for Ohio was for a slightly higher probability for below normal precipitation. Actual precipitation during the winter was 80 to 100 percent of normal across northern Minnesota and the Great Lakes, and from 80 to 120 percent of normal in the eastern Midwest.

Seasonal outlooks for the Midwest as issued by the CPC for the fall, winter, and spring were quite accurate in their identification of the areas of likely above, near, and below normal temperatures. However, the magnitude of the anomalies experienced was often larger than indicated by the statistically based outlooks.

The outlook for spring 1998 called for an equal probability of above normal, normal, or below normal temperatures across most of the Midwest, with a slightly higher probability for warmer than normal temperatures across Minnesota and northern Wisconsin. Average spring temperatures varied from 2 degrees below normal in western Missouri to 2-3 degrees above normal from Minnesota southeast through northern Illinois, Indiana, and Ohio. Small portions of Minnesota and Wisconsin experienced temperatures 4-6 degrees above normal. The precipitation outlook for the spring indicated a higher probability for below normal precipitation in all the states except Minnesota, Iowa, and Missouri. Spring precipitation was near to above normal over the entire Midwest, except for a portion of far northern Wisconsin and northeastern lower Michigan, where precipitation was 80 to 90 percent of normal.

Requests for data and information steadily increased each month beginning in September 1977 as people sought more information on the developing El Niño. Figure 38 shows the number of contacts (phone calls, e-mail, or fax requests), accesses to the MICIS, and hits on the MCC Web site. The MICIS accesses decreased during the fall, a typical pattern as the growing season ends. Accesses increased steadily again beginning in January as the full effects of the El Niño winter were being experienced.

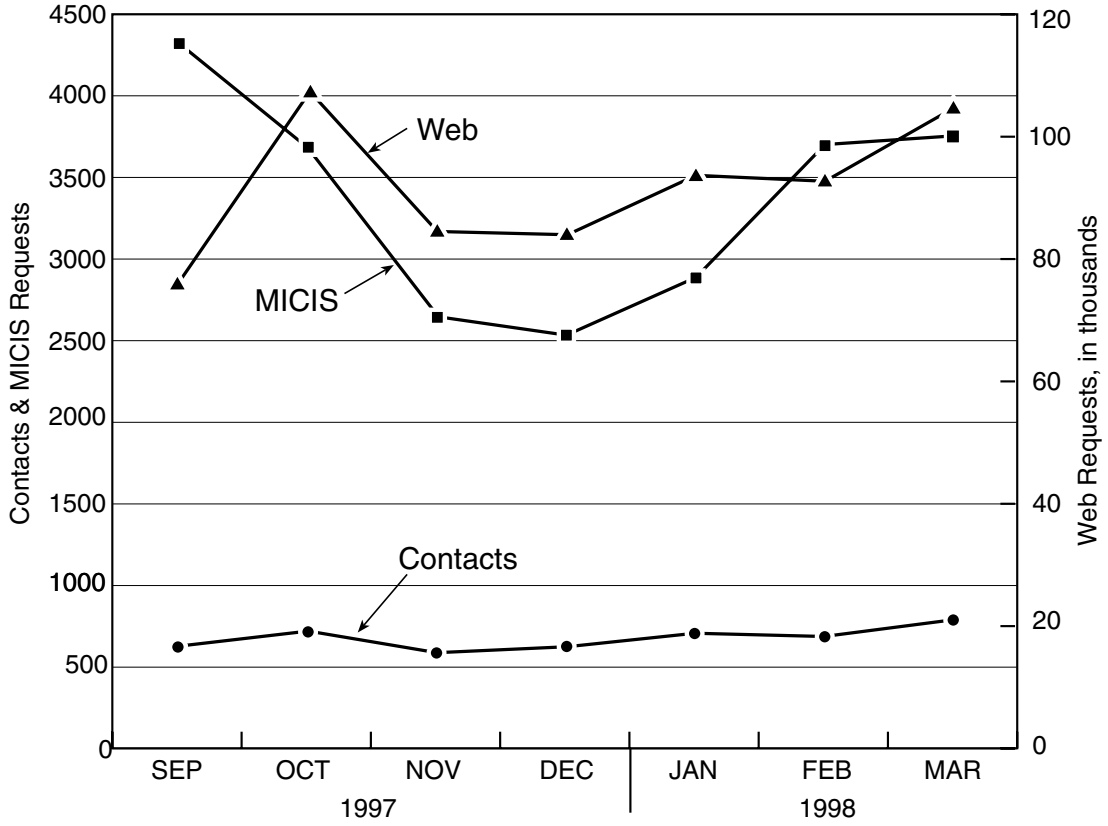

Figure 38. Data and information requests received by the Midwestern Climate Center via the Web, the Midwestern Climate Information System (MICIS), and contacts via telephone, fax, or e-mail between September 1997 and March 1998.

Review of the official outlooks for the three seasons in the Midwest and their outcomes shows that the temperature outlooks were largely correct in all three seasons. However, the precipitation outlooks were correct for certain areas only in winter and spring.

The mild, relatively dry, and largely snow-free winter across the Midwest created an interesting array of impacts, and most were beneficial. The recreation industry had winners and losers; but in general, the public, many businesses, and federal, state, and local government agencies were major winners. Some benefitted from using the seasonal weather predictions to alter their normal operational plans, and most Midwesterners benefitted healthwise and financially from the mild winter and spring weather conditions.

The population of the nine-state Midwest is 60 million, and it is reasonable to conclude from numerous samples of public attitudes that most residents were pleased with the mild, almost snow-free winter. It was safer and healthier than a normal winter. There was much less illness and many fewer deaths than occur in a normal winter as a result of cold temperatures and

accidents caused by dangerous travel conditions. Medical and travel experts concluded that the winter conditions led to saving of between 350 and 380 lives. Many residents of the Midwest altered their recreation plans, and many used the mild weather to fish, play golf, and hike.

Those benefitting in business included commodity brokers who realized increased investments resulting from buyers who feared El Niño-related damages to foods grown in the United States and elsewhere. Insurers sold more policies and realized fewer than normal claims and losses. The construction industry enjoyed more favorable work conditions, and the region's income from construction was up $300 million over normal winters. Employment in retail firms and construction was up 4 percent to 5 percent. Home sales soared to 25 percent higher for December 1997-March 1998 than in normal conditions, and this additional income represented a gain of $0.6 billion in the Midwest. All forms of transportation and shippers benefitted from better weather than usual, resulting in savings and added profits of $100 million.

The mild weather with below normal rainfall and snow made it nice to be outdoors, and this led to major increases in retail sales of clothing, furniture, and other goods. The added sales reached $2.9 billion over the average December-March sales period. Restaurants reported increased business, but no estimates of the increased income are available. The near record warmth in the Midwest reduced heating costs, creating consumer savings of $4.7 billion. Local and state government agencies saved $250 million due to reduced costs related to less winter care of roadways. Airlines reported more travelers than normal and fewer delays due to improved weather; but no measure of the benefits is available.

In summary, the known financial benefits from the winter-early spring weather in the Midwest amount to an estimated $8.85 billion. This does not include additional but unknown income in several sectors. Little is known about the environmental impacts, but nothing significant for or against environmental conditions was reported.

Those who lost as a result of the El Niño conditions in the Midwest included those who failed to use the predictions of a mild winter and those who were hurt by the atypical weather conditions. Several natural gas providers failed to heed the long-range weather predictions and bought gas early in the fall at high prices. These higher costs were largely transferred to their customers, who failed to realize all the benefits that later, lower cost purchases would have produced. From a health standpoint, the unusual winter weather conditions resulted in nine deaths in the Midwest. Certain businesses suffered, including manufactures and sellers of snow-mobiles ($10 million in lost sales) and manufacturers of snow removal equipment (lost $22 million). Private snow removal firms lost $26 million in expected income, towing firms lost $16 million, and sellers of salt reported diminished sales and losses of $68 million. Business at Midwestern ski resorts was down 50 percent, and losses were $120 million. Furnace manufac-turers and sales firms reported losses of $300 million. Retail sales of winter clothing, including fur coats, were down 15 percent, which represented losses of $180 million. The total estimated losses in the Midwest amounted to $750 million. Thus, losses were approximately 10 percent of the total benefits. Figure 39 illustrates the distribution of winner and losers within the Midwest.

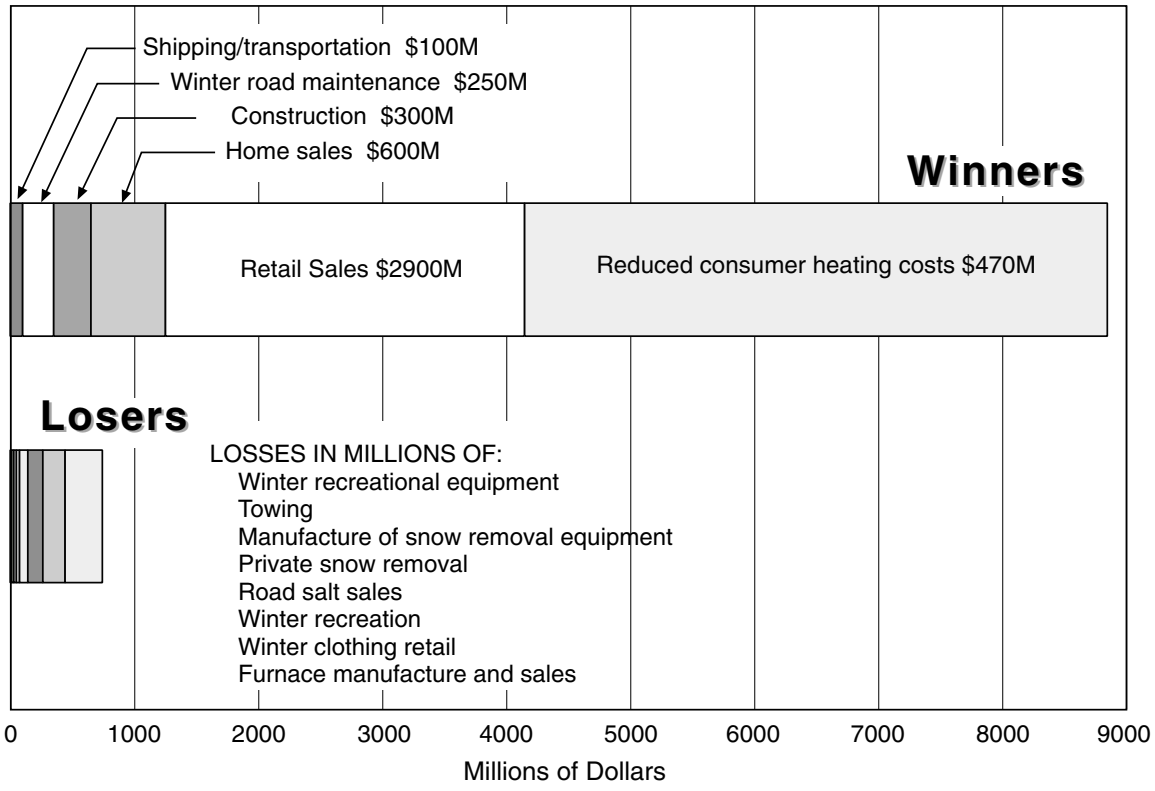

Figure 39. Estimated economic impacts of the 1997-1998 El Niño in the Midwest.

In general, the varying predictions of summer and the growing season weather conditions left decision makers with no guidance and often confused. Hence, responses to the predictions were negligible.

Recommendations

The number and types of requests for information received by the MCC as this El Niño event developed and occurred indicated gaps in our knowledge of the relationship of El Niño to those weather/climate conditions that affect our society and environment. A key recommendation is to continue to pursue studies of these relationships for atmospheric conditions that have major impacts in order to have better information available in the future.

Climate outlooks usually are associated with a high level of uncertainty. During El Niño events, the forecast probabilities for Midwestern weather conditions became more certain, but some uncertainty remains. There needs to be research to assess the optimal ways to apply probabilistic outlook information in the decision-making process. Demonstration projects with decision makers are needed to advance this process.

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