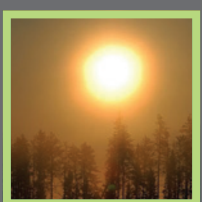
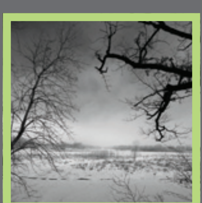
CHAPTER ONE

CLIMATE PAST.

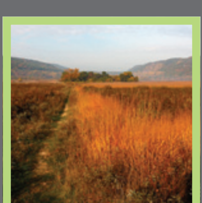
Wisconsin's Recent Historical Temperature Trends



Projected Changes in Temperatures



Wisconsin's Recent Historical Precipitation Trends



Projected Changes in Precipitation

Wisconsin's climate is changing. A wealth of temperature and precipitation data gathered over more than half a century, along with records from a variety of other periods and sources, paint a consistent picture of our state becoming generally warmer and wetter. The decades ahead are likely to bring changes much more profound than those seen so far, according to climate models.

The warming Wisconsin has experienced to date is consistent with the global trend.

The warming Wisconsin has experienced to date is consistent with the global trend. The past three decades have been Earth's warmest since reliable surface temperature records began to be kept in 1850, with a global average increase of about 1.5 degrees Fahrenheit over that period (see figure 1). In fact, temperature trends based on Arctic ice cores and other evidence indicate that the Earth's temperature

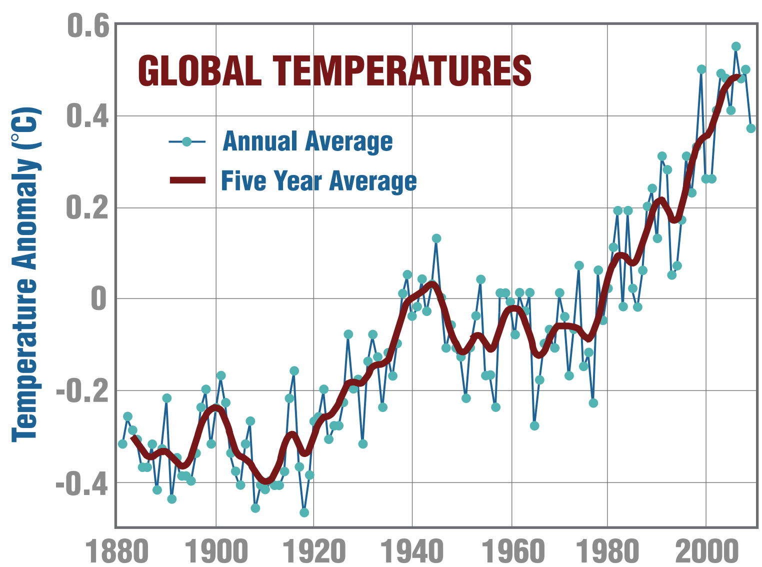


Figure 1. Global average temperatures have been steadily rising since reliable records began being kept in 1850.

Source: Intergovernmental Panel on Climate Change, 2007.

CHANGE IN WISCONSIN: PRESENT AND FUTURE

in the late 20th century may have been the highest in at least the last 1,000 years. Here in Wisconsin, our annual average temperature rose by about 1.1º F from 1950 to 2006, (figure 2), according to an analysis by scientists at the University of Wisconsin-Madison of daily measurements gathered from an extensive statewide network of weather stations.

While that one-degree increase in our statewide average might not seem significant, it coincides with the shorter length of time that our lakes remain frozen, the change in timing of some bird migrations, the emergence and flowering of certain plants, and other effects that indicate milder winters and earlier springs. Annual precipitation has also registered a modest increase, with 3.1 inches more per year, an increase of approximately 10 percent over the 57 years covered by the UW-Madison study.

The real story, however, is in the details. Wide variation is seen across regions of the state, especially when seasonal differences are factored in. Northwestern Wisconsin, for example, has seen a wintertime temperature increase of 4.5º F, while some parts of the state have actually cooled slightly in the fall.

Precipitation has also varied widely, with a localized drying trend in northern and northeastern counties and much wetter conditions in western and south central Wisconsin (figure 3).

What we have experienced so far may be a preview of what is likely to occur in coming decades. According to our state's best climate scientists – using the most recent computer models – Wisconsin's warming trend will not only continue, it will increase considerably by the middle of this century. Although future precipitation patterns are more difficult to discern, Wisconsin climatologists say the state is likely to continue its trend toward more precipitation overall, with the most probable increases in winter, spring and fall.

CHANGE IN ANNUAL AVERAGE TEMPERATURE (°F) FROM 1950 TO 2006

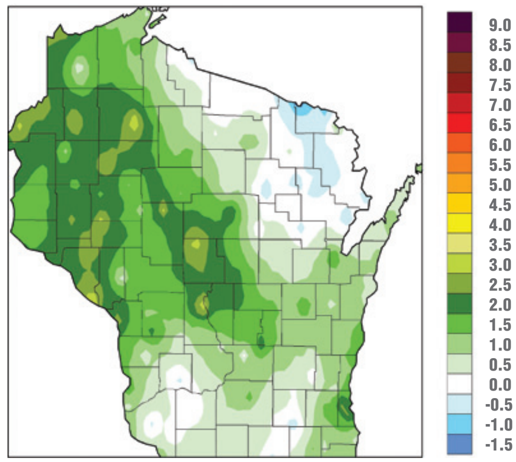


Figure 2. Wisconsin's annual average temperature has increased on average just over one degree statewide, with most of the increase experienced in the northwestern part of the state.

CHANGE IN ANNUAL AVERAGE PRECIPITATION (INCHES) FROM 1950 TO 2006

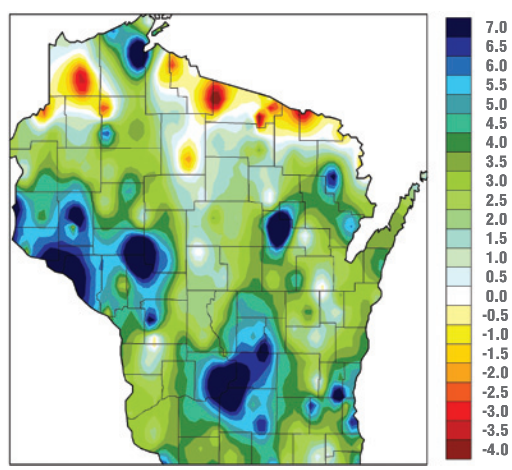


Figure 3. Overall, our state became somewhat wetter in the latter half of the 20th century, with much of the change concentrated in western and south central Wisconsin. Most northern counties became generally drier.

Wisconsin's Recent Historical Temperature Trends

Funded by a grant from Wisconsin Focus on Energy, scientists in the Nelson Institute Center for Sustainability and the Global Environment at the University of Wisconsin-Madison compiled daily temperature and precipitation readings gathered between 1950 and 2006 by a statewide network of 176 weather stations, part of the NOAA National Weather Service Cooperative Observer Program (figure 4).

While older data sets exist in some locations – Madison, for example, has weather information beginning in the 1870s – the starting point for the WICCI analysis is 1950 due to the reliability and consistency of weather station data from that point forward, allowing for the most robust scientific analysis.

Using this extensive body of weather data, the scientists found that, except for northeastern Wisconsin, most of the state has warmed since 1950. On a statewide annual average, the temperature has increased by 1.1° F, with the highest average warming of 2.5° F across northwestern Wisconsin. The greatest warming is occurring during winter and spring (figure 5), with

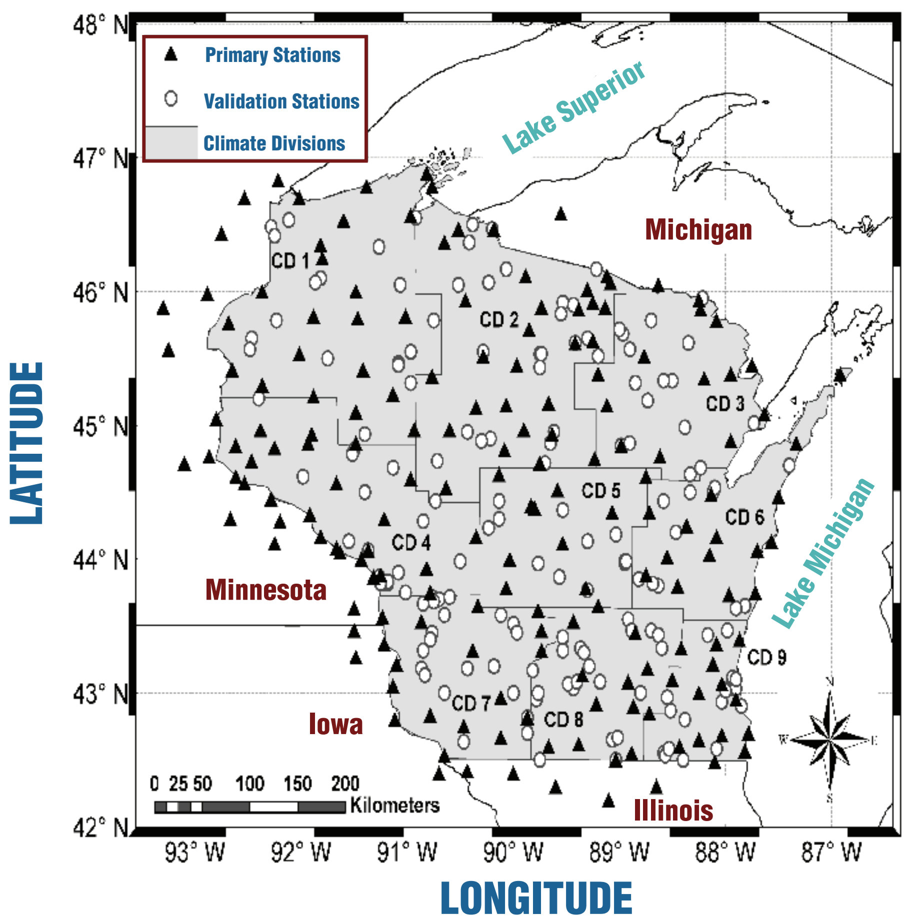
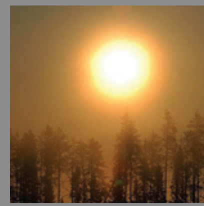


Figure 4. Daily temperature and precipitation data collected over more than five decades at scores of weather stations across Wisconsin were used to analyze the state's climatic trends since 1950. Stations in the neighboring states of Illinois, Iowa, Michigan, and Minnesota were included to help validate the Wisconsin data and identify errors and anomalies.

Source: Serbin, S.P. and C.J. Kucharik, 2009: Spatiotemporal mapping of temperature and precipitation for the development of a multidecadal climatic dataset for Wisconsin. J. Appl. Meteor. Climatol., 48, 742-757. ©American Meteorological Society. Reprinted with permission.



> The greatest warming is occurring during winter and spring, with nighttime temperatures increasing more than daytime temperatures.

nighttime temperatures increasing more than daytime temperatures.

Winter: The observed warming since 1950 has been greatest in winter, with an average increase of 2.5° F across Wisconsin. The largest increase has occurred in northwestern Wisconsin, with an average increase of 4.5° F in some locations. In addition, the state is seeing fewer extended subzero stretches, and the nights have gotten milder.

Spring: Springtime average temperatures across Wisconsin have increased by 1.7° F since 1950, with increases of up to 3.5° F in the northwestern part of the state. In addition, most of the state has experienced a trend toward an earlier occurrence of the last spring freeze from two to 10 days, with the statewide average being 5.6 days earlier. In northwestern Wisconsin, the date of the last spring freeze has retreated by two weeks during just 57 years. Another significant change is seen in the official onset of spring (defined as the date at which daily temperatures have reached 50º F for 10 days running). The majority of the state – southwest of a line from Manitowoc to Ashland – has experienced an earlier onset of spring by this measure. The most significant changes have been found in the southern half of the state, where spring has been coming from three to 10 days earlier since 1950.

Summer: Since 1950, summer temperatures have increased by only 0.5° F when averaged statewide. The largest summertime warming has been 1.5-2° F over central and northwestern Wisconsin, while the remainder of the state has shown little change.

Autumn: Fall temperatures throughout much of the state have changed little since 1950 except for northeastern and southern Wisconsin, which have cooled by about 1.5° F. In spite of this small overall cooling pattern, the first fall freeze has trended toward a later date of occurrence in central, northeastern and northwestern Wisconsin, shifting from three to 12 days. Statewide, the first fall freeze averages 6.5 days later than it did in 1950.

WEATHER VS. CLIMATE

People often confuse *weather* with *climate*. These two words mean very different things. Knowing the difference can help us understand changes in climate that have already occurred and those that lie ahead.

Simply put, weather is the set of conditions happening at any time, or over relatively short periods such as days or weeks. We typically measure weather with instruments that record temperatures, humidity, rainfall, wind and other specific factors.

Climate is measured over much longer periods, most often on a scale of decades or more. Climate is the long-term average of weather conditions in a specific location. It is determined through statistical analyses of weather data collected over a long period of record.

An unusually heavy thunderstorm, a three-day snow event, three weeks of drought, an unusually hot summer or an unusually short winter are all examples of *weather*, which by themselves tell us little about *climate*. However, if those unusual conditions persist for long periods and cannot be explained by normal variability, it might indicate that a change in climate is taking place.

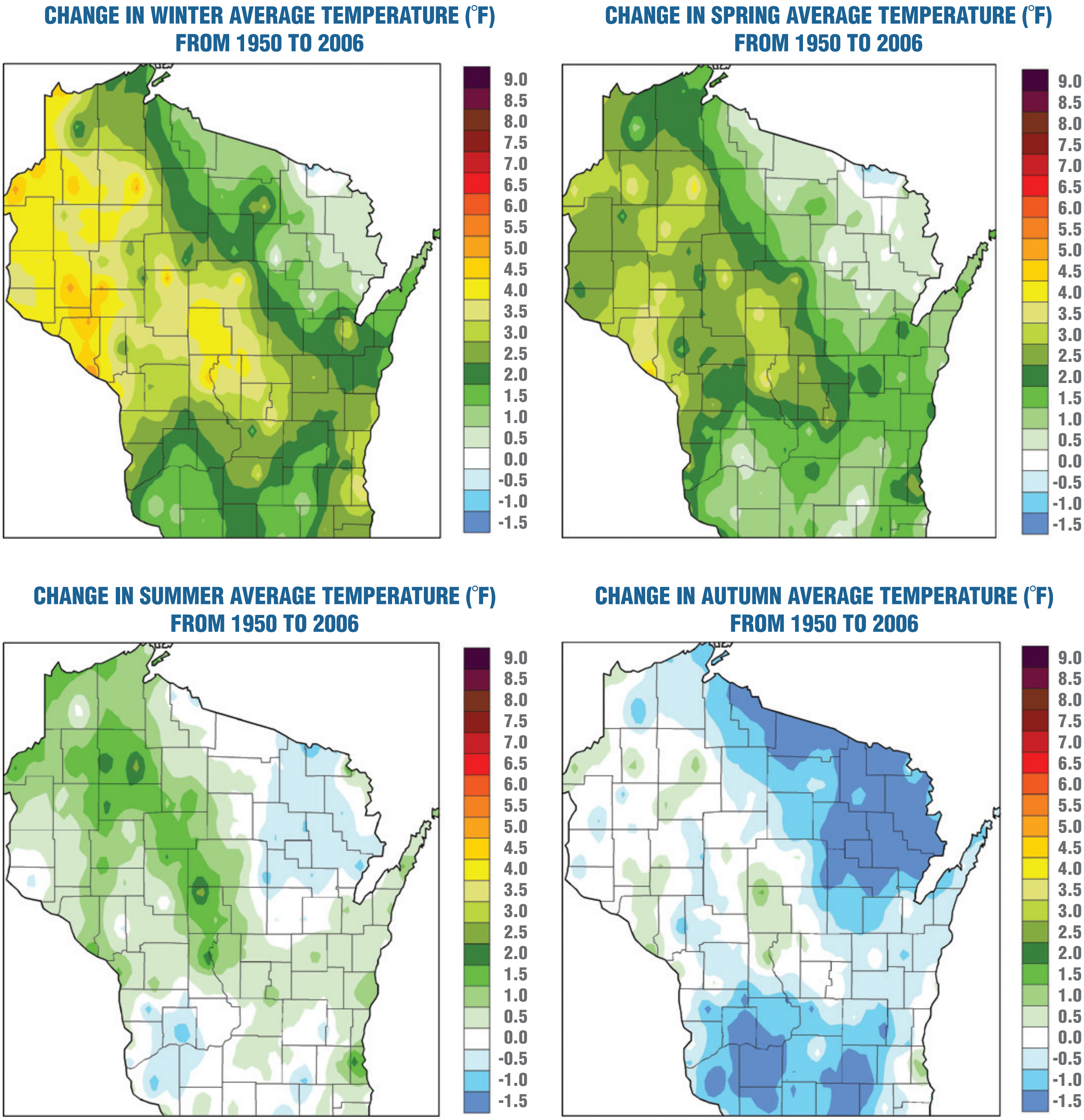
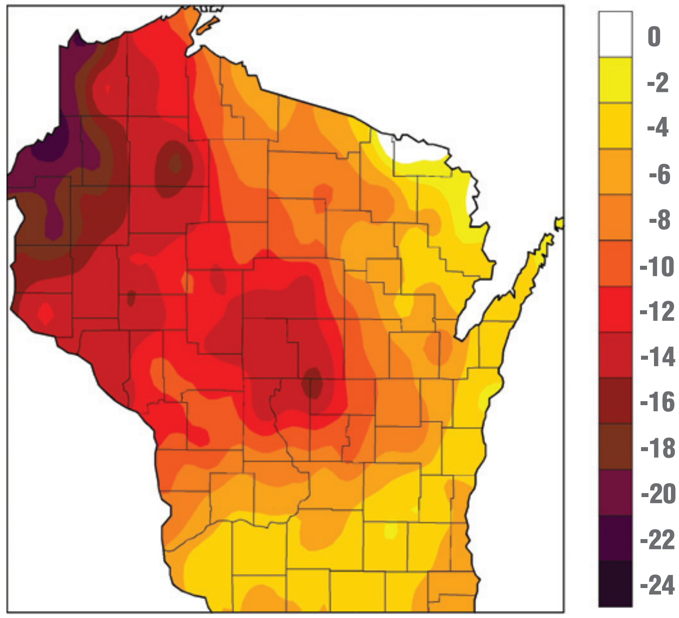


Figure 5. Wisconsin winters have warmed more than any other season in recent decades, especially in the north-western part of the state, where average temperatures have increased by as much as 4.5º F. Fall has seen a slight cooling trend.

Source: Kucharik, C.J., S.P. Serbin, S. Vavrus, E.J. Hopkins, and M.M. Motew. Patterns of climate change across Wisconsin from 1950 to 2006. Physical Geography 31, 1-28.

Extreme temperatures: From 1950 to 2006, the annual frequency at which daily low temperatures fell below 0° F diminished by about five days across southern Wisconsin and by 14 to 20 days across northwest-central Wisconsin, a 10-30 percent reduction in the number of extremely cold days each year. However, a consistent trend toward more frequent hot days was not seen in the record over that same period. The observed frequency of days over 90° F increased by two days per year across the northwestern portion of the state and decreased by two to four days per year over central and southwestern Wisconsin (figure 6).

CHANGE IN THE FREQUENCY OF NIGHTS BELOW 0°F PER YEAR FROM 1950 TO 2006



CHANGE IN THE FREQUENCY OF 90°F DAYS PER YEAR FROM 1950 TO 2006

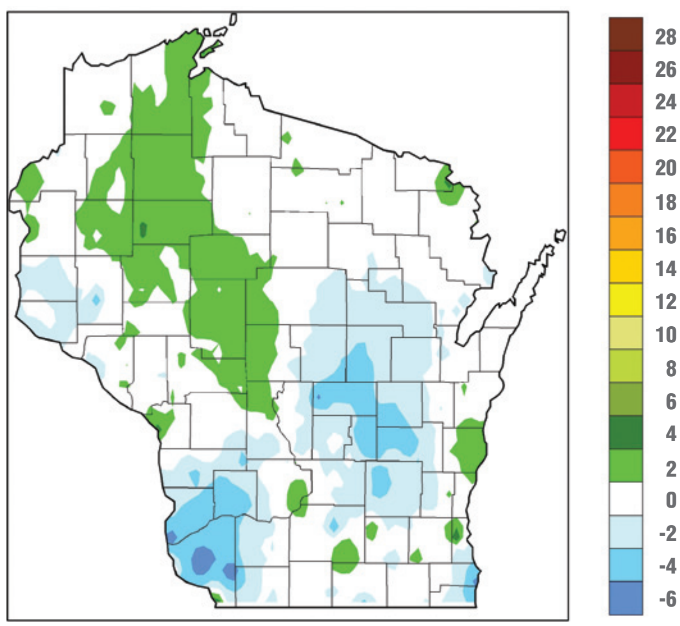


Figure 6. Consistent with the winter warming trend, Wisconsin experienced far fewer extremely cold nights between 1950 and 2006, especially in the northwest and central parts of the state. At the same time, extremely hot days did not significantly increase in number during summer.

Source: Kucharik et al., 2006.

WHY 1950 THROUGH 2006?

The historical analysis of Wisconsin's climate that forms the basis for this chapter includes the years 1950 through 2006. While researchers acknowledge that this 57-year span limits some of the conclusions that can be drawn, data from these years are the most complete for all the weather stations analyzed. By 1950, Wisconsin had established its dense network of cooperative observing stations (figure 4), allowing for the high-resolution spatial analysis by WICCI climate scientists.

While a handful of weather stations go back much further - for example, some observations from Madison date to 1869, and reliable Milwaukee data begin in 1929 - older data from these few stations, while suggesting variability in long-term climate, are too few to accurately show any of the long-term natural climate cycles that can affect our climate for decades at a time. The data period ends with 2006, the most recent year available to the climate scientists when the data were compiled. Future updates will extend the analysis to present.

CHANGE IN THE LENGTH OF THE GROWING SEASON IN DAYS FROM 1950 TO 2006

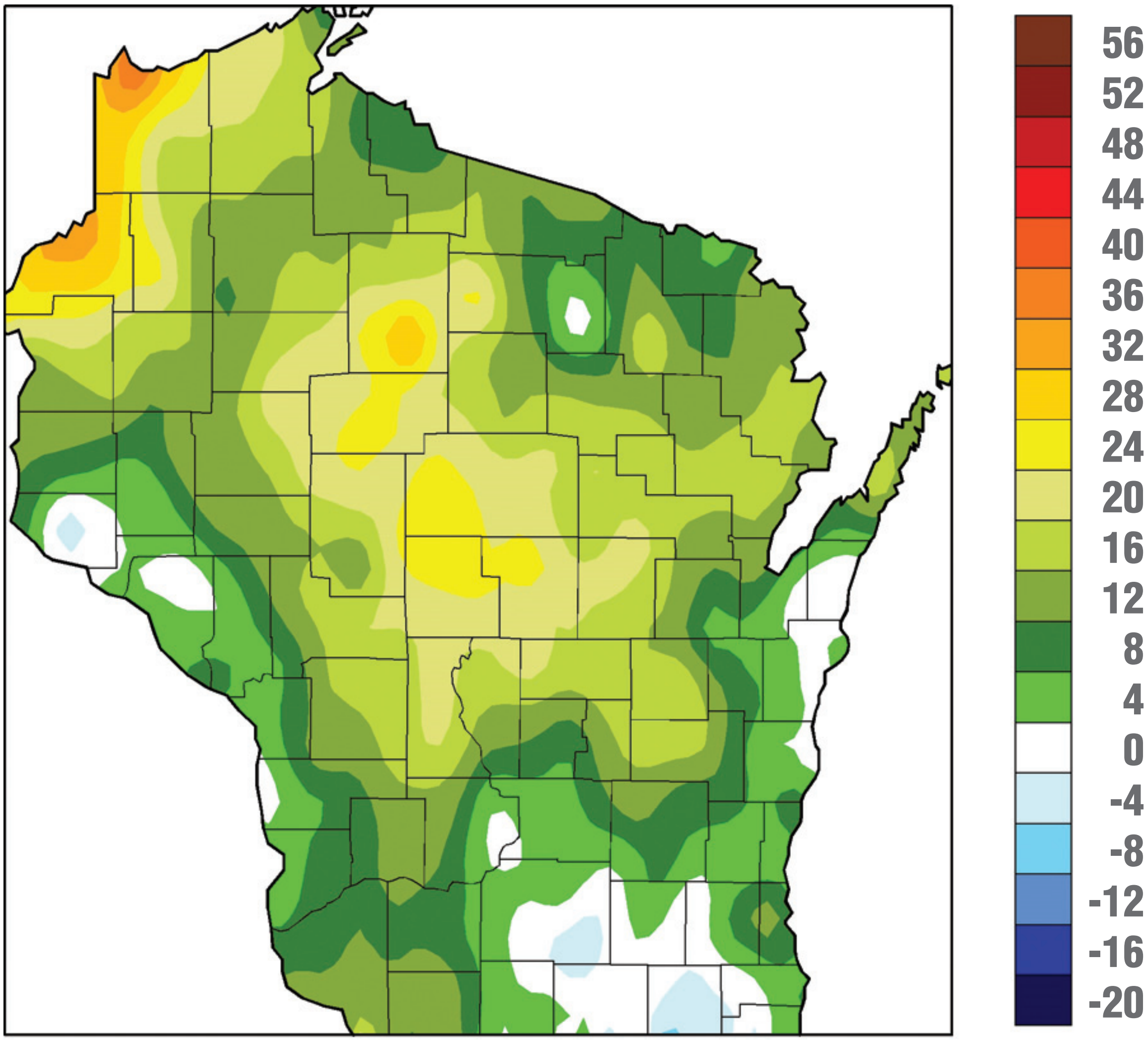


Figure 7. The length of the growing season has increased by as much as four weeks in parts of the state. (For this report, the growing season is defined as the number of days between the last spring freeze and the first autumn freeze, that is, when the daily low temperature falls below 32˚F.)

Source: Kucharik et al., 2006.

Growing season: The earlier spring and later fall freeze date trends have led to a significant increase in the length of the growing season in many locations (figure 7). The largest gains are located in the northwest and central regions, where the growing season has been extended by two to three weeks, with some counties in the extreme northwest seeing the growing season lengthen by about four weeks since 1950. The western counties near the Mississippi River, along with the south central, southeast, and east central counties, have not seen significant changes in the growing season length. While some counties along Lake Michigan, the Mississippi River and in southern Wisconsin have not seen a significant change in growing season, Milwaukee County's increased by approximately 10 days from 1950 to 2006. The statewide average increase in growing season length was 12 days.

Photo: Elizabeth Katt-Reinders

Projected Changes in Temperatures

Scientists in the Nelson Institute Center for Climatic Research at UW-Madison have developed detailed climate projections for our state over the 21st century. These projections use both large-scale information from climate models and local data drawn from the NOAA cooperative weather stations used for the historical analysis.

The researchers (funded by Wisconsin Focus on Energy) "downscaled" the global models to a localized grid of five-by-five-mile sections. This level of resolution improved the representation of water bodies, urban areas and other landscape features and enabled detailed analysis of locally projected changes and their potential impacts. The researchers used 14 different climate models and three different projections of future greenhouse gas emissions to quantify the range of possible future warming and precipitation for Wisconsin. The projections used in this report assume our continued reliance on fossil fuels, with carbon emissions remaining on a steady upward trajectory over the next few decades and carbon dioxide levels in the atmosphere rising from 390 parts per million today to 550 parts per million by the mid-2050s (figure 8).

The WICCI climate projection shows that Wisconsin's annual average temperature is likely to warm by 4-9° F by the middle of the century

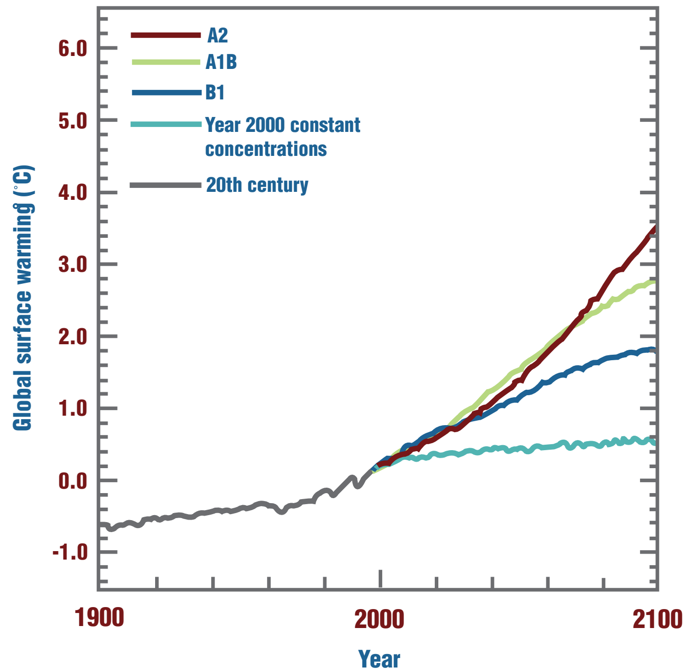


Figure 8. WICCI climate projections have been made using the A2 (high end), B1 (low end) and A1B (middle) carbon emissions scenarios developed by the Intergovernmental Panel on Climate Change. Projections shown in this report represent only the A1B scenario, which assumes continued reliance on fossil fuels.

Source: Adapted from Intergovernmental Panel on Climate Change, 2007.

Photo: Avery Dorland

The WICCI climate projections show that Wisconsin's annual average temperature is likely to warm by 4-9° F by the middle of the century (figure 9). Northern Wisconsin is projected to warm the most, with the least warming expected along Lake Michigan. Overall, the expected rate of warming is about four times greater than what we have experienced since 1950, and in keeping with the observed trend of the past half century, Wisconsin winter temperatures will continue to increase more than those of the other seasons.

Wisconsin winter temperatures will continue to increase more than those of the other seasons.

Winter: Wisconsin's future warming is projected to be greatest during winter, with increases of 5-11° F by the mid-21st century (figure 10). The largest increase is expected in northwestern Wisconsin. Overall, Wisconsin winters will be milder and shorter by an average of four weeks, with annual snowfall likely to decline by about 14 inches per year. The greatest snowfall reductions are projected for the flanks of the snowfall season in November and March-April as rainfall replaces snow; likewise, the largest projected decreases in Wisconsin snow depth and cover occur in February-March. The duration of a snow pack of at least one inch is projected to decline from the current average of 140 days per year to 116 days per year by the mid-21st century.

PROJECTED CHANGE IN ANNUAL AVERAGE TEMPERATURE (°F) FROM 1980 TO 2055

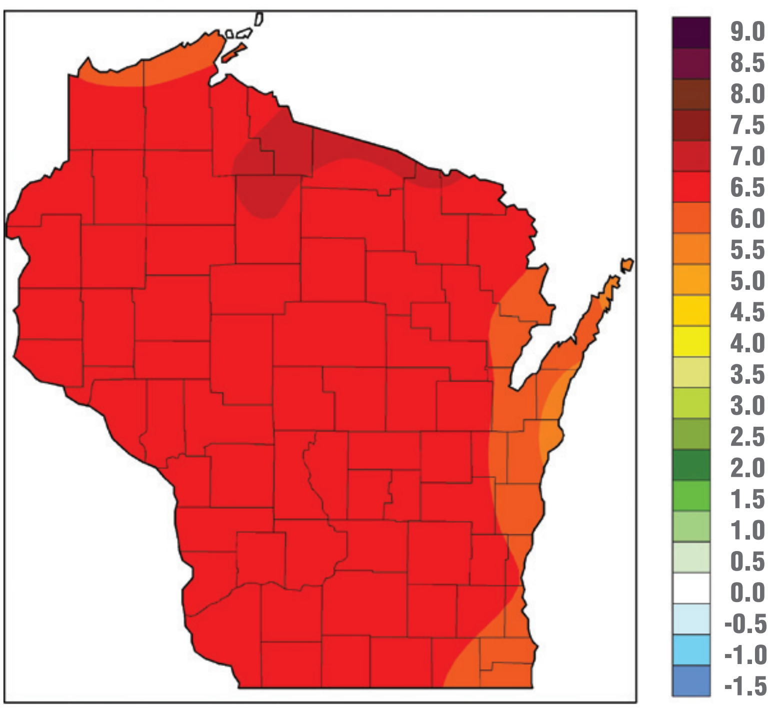


Figure 9. Climate models project significant warming across Wisconsin over the next few decades.

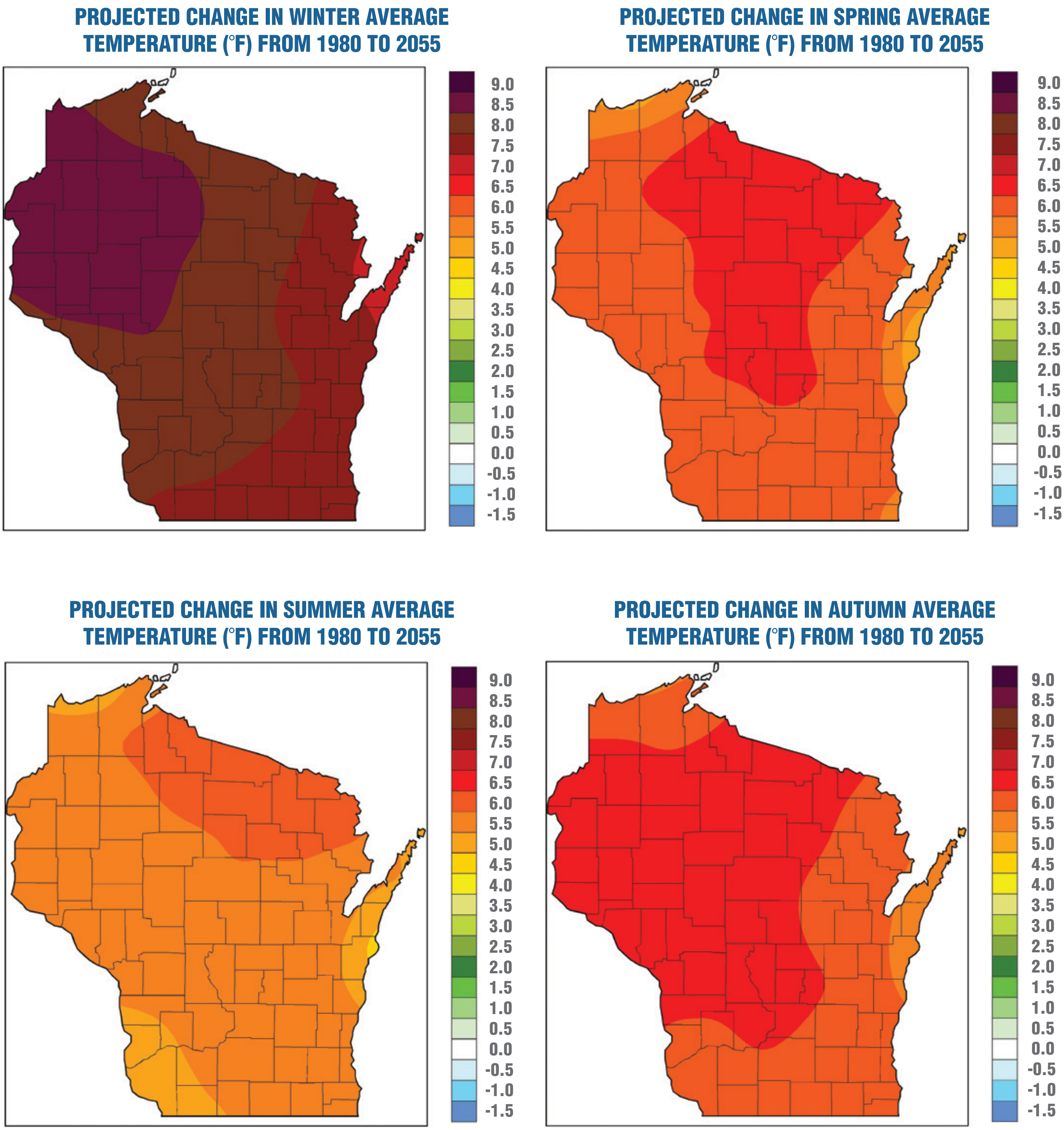


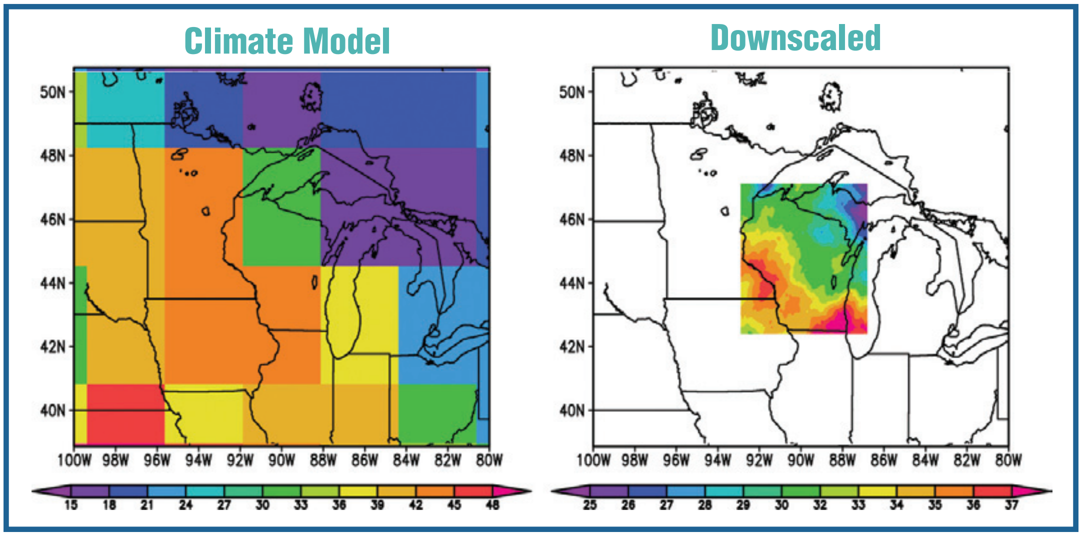
Figure 10. While all four seasons are expected to see large increases in temperature, the greatest warming is projected to occur during Wisconsin winters.

WHAT IS A CLIMATE MODEL?

A climate model is a complex set of equations representing the global climate system, including its physical, chemical and biological components. Referred to as General Circulation Models (GCMs), these models typically use supercomputers to simulate the interactions of the atmosphere, oceans, land and ice. They adhere to the basic laws of physics, fluid motion and chemistry to create a three-dimensional grid that depicts the major components and actions of the climate system.

The equations used to represent these basic laws of physics cannot solve the "problem" of the entire world climate. Instead, the world is divided into an array of grid boxes, and conditions for each box (for example, wind, ocean currents, temperature, moisture content, rainfall, etc.) are estimated for a period of time. The result is an estimate of global climate that is constrained by the fundamental physical laws that govern our climate system. The exact representations of each physical process differ between models, resulting in a range of plausible future climate scenarios. This range of plausible future climates is vital for informed decision-making and, as such, is an essential component of WICCI's efforts at projecting climate change.

For projecting future climates, these models include estimates of the changes in the atmospheric concentrations of greenhouse gases. For example, the A1B scenario is based on carbon dioxide levels rising from 390 parts per million today to at least 550 parts per million by the mid-2050s. Following the basic laws of physics, this increase will enhance the atmosphere's greenhouse effect, a fundamental reason why the models project a significant warming trend for the planet and many other physically related changes in the hydrological cycle.



Source: David Lorenz, Nelson Institute Center for Climatic Research, University of Wisconsin-Madison

Climate models can depict large-scale trends, but they are limited in what they can tell us about conditions at smaller scales, like a county in Wisconsin. Each grid unit on a global model typically covers several hundred square miles, which does not allow detailed analysis at a local or even state level. To overcome these limitations, UW-Madison climate scientists used a technique known as *downscaling*.

Downscaling is a way to derive locally relevant projections from global models using a statistical method. The method involves relating large-scale variables derived from global models to local-level climate conditions. Once these relationships have been developed and tested on past and current climate conditions, they can be used to project climate change locally from the global models. The UW-Madison climate scientists used the historic Wisconsin climate data analyzed in this report to develop and validate their technique.

Spring: Springtime temperatures are projected to increase by 3-9° F by the mid-21st century, with the largest increases across northern and central Wisconsin.

Summer: Climate models show that Wisconsin's warming is projected to be weakest in summer, with increases of 3-8° F by the mid-21st century and greatest across the northern part of the state.

Autumn: Wisconsin autumns are projected to warm uniformly across the state, with an increase in the range of 4-10° F by the mid-21st century.

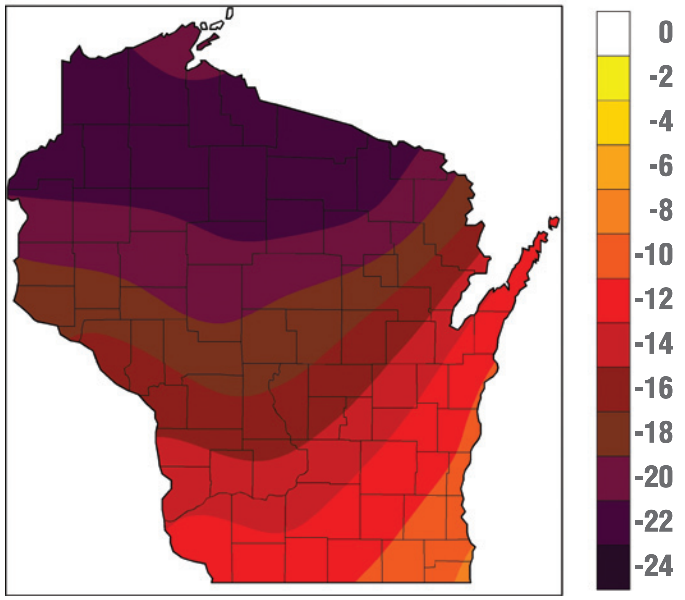
Extreme temperatures: Climate models project significant changes at both ends of the state's temperature spectrum. Today, daily high temperatures exceed 90° F about 12 times per year in southern Wisconsin and five times per year in northern Wisconsin. By the middle of this century, the frequency of very hot days will likely more than double to about 25 times per year in the south and 12 times per year in the north. That translates to about one to four more weeks each year with daily high temperatures topping 90° F.

Our state will experience as many as three fewer weeks each year during which temperatures fall below zero.

At the same time, winters will continue to shift toward fewer extremely cold nights. Between 1950 and 2006, northern Wisconsin averaged 40-45 days when the temperature dropped below 0° F; southern Wisconsin experienced about 15 such days on average. Daily low temperatures below 0° F are projected to be much less common, ranging from six fewer subzero nights in southeastern Wisconsin to 22 fewer in the north. In other words, our state will experience as many as three fewer weeks each year during which temperatures fall below zero (figure 11).

Growing season: The projected warming across all seasons in Wisconsin implies that the recent historical trend toward longer growing seasons will continue. By mid-century, the last spring frost and first fall frost are

PROJECTED CHANGE IN THE FREQUENCY OF NIGHTS BELOW 0°F PER YEAR FROM 1980 TO 2055



PROJECTED CHANGE IN THE FREQUENCY OF 90°F DAYS PER YEAR FROM 1980 TO 2055

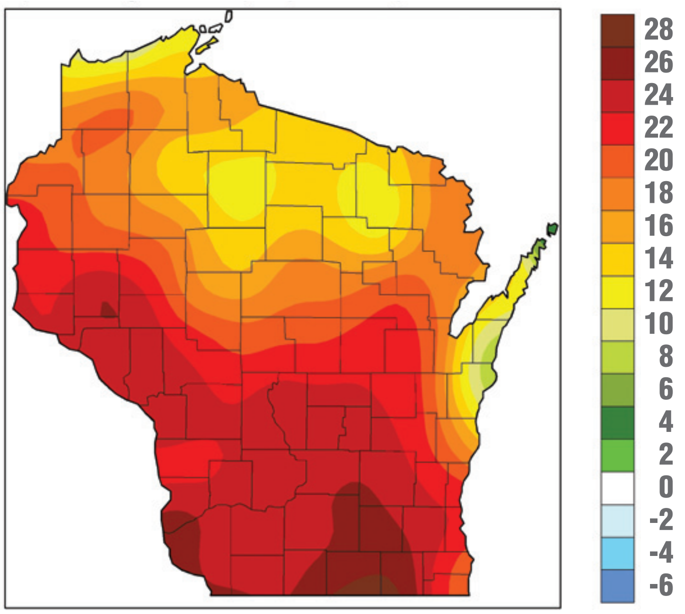


Figure 11: Wisconsin is likely to see fewer very cold nights and many more hot days in the decades ahead.

expected to diverge by four weeks, lengthening Wisconsin's growing season by a full month over the current averages (130 days in the north and 160 days in southern Wisconsin). In addition, the plant hardiness zones defined by the U.S. Department of Agriculture are likely to change. Wisconsin's plant hardiness zones currently range from a low of 3b in Washburn County to a high of zone 5b in Milwaukee County. By mid-century, warming will likely shift hardiness zones to growing conditions typically found one or two zones farther south, with Washburn County warming to zone 4b and Milwaukee County becoming zone 6a. (Please see Chapter Five for a more detailed discussion of the growing season.)

A NOTE ABOUT THE MAPS OF PROJECTED CHANGES

A key element of this assessment report is the use of probabilities in describing climate change in Wisconsin. The maps of projected changes used throughout this chapter represent the averaged findings from the 14 global circulation models on which the projections are based. These models indicate a range of possibilities for the state's future climate. The more the models agree on a particular result, the more confident scientists are that it will occur. Thus, the maps used here roughly represent the 50 percent probability level in each case – that is, there's a 50 percent probability that the changes could be greater than depicted by each map and a 50 percent probability that they could be lesser.

As another example, the projection that Wisconsin's annual average temperature is likely to warm by 4° - 9°F by the middle of the century represents a quantifiable range under the probability-based approach developed by WICCI climate scientists. In other words, there is a 90 percent probability that the warming will be greater than 4°F and a 10 percent probability that it will exceed 9°F; the maps roughly depict the mid-point of that range.

NATURAL CYCLES AFFECTING WISCONSIN'S CLIMATE

The global climate is driven by a very complex relationship between the ocean and atmosphere, including a number of natural cycles that occur on timescales of years, decades or longer. The best-known of these is the El Niño/La Niña-Southern Oscillation, or ENSO, a warming and cooling pattern that occurs across the tropical Pacific Ocean roughly every three to seven years. ENSO is characterized by variations in ocean surface temperatures in the tropical Pacific, which can create atmospheric effects leading to floods, droughts and other weather disturbances in many regions of the world.

Other natural variations occur on even longer time scales. For example, the Pacific Decadal Oscillation (PDO) is similar to ENSO but tends to vary on a much longer time scale. This manifestation of natural climatic variability occurs in the North Pacific and is associated with climate variations over North America. According to scientists, two "cool" PDO periods occurred from 1890-1924 and 1947-1976, while "warm" PDO periods occurred from 1925-1946 and 1977-1996. Other natural variations include the North Atlantic Oscillation or Arctic Oscillation (AO), which also is associated with temperature and weather variations over North America.

Many of these long-term variations affect Wisconsin's climate and must be accounted for when identifying possible climate change. According to the U.S. Global Change Research Program, "Estimates can now be made as to how each of these oscillations contributes regionally to the recent wintertime warming trend. For example, average wintertime temperatures for the period 1988 through 1997 have been warmer than normal for the whole U.S., with anomalies of over 1 degree C (1.8º F) for much of the country, and anomalies on the order of 1.5 degrees C (2.7º F) for the upper Midwest. The predominately warm phase of the AO during this period contributes to the warming over much of the country, with the strongest impacts located in the upper Midwest."

Climate scientists consider these natural cycles and their interaction with longer-term changes in climate, including those caused by greenhouse gas emissions.

Wisconsin's Recent Historical Precipitation Trends

From 1950 to 2006, Wisconsin as a whole became wetter, with a 10 percent increase in annual precipitation (3.1 inches). The increase occurred primarily in southern and western Wisconsin, while northern Wisconsin experienced some drying (see figure 3). It is unclear whether these trends in precipitation are due to climate change or represent natural variation in rainfall over Wisconsin.

As with temperature trends, differences were significant from season to season (figure 12).

Winter: A modest increase in wintertime precipitation of 0.5 inch occurred from 1950 to 2006 in Wisconsin, an increase of about 14 percent.

Spring: Springtime precipitation also increased by half an inch on average during recent decades, an increase of about 6 percent. The most distinct increases, on the order of 1-2 inches, were seen over southern and western Wisconsin.

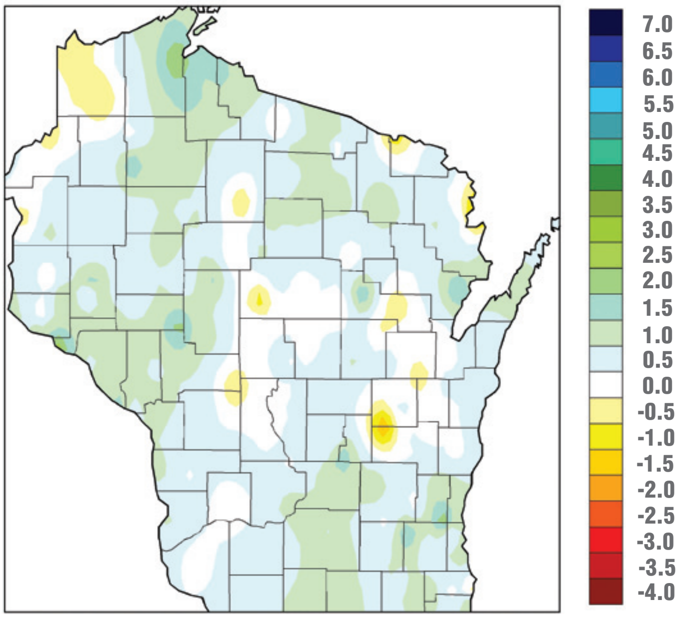
Summer: From 1950 to 2006, summertime precipitation decreased by 2-4 inches across northern Wisconsin and increased by 2-3 inches across southern and central Wisconsin. Summer precipitation for Wisconsin as a whole changed very little, increasing only 0.3 inch (a 2 percent increase).

Autumn: Most of the increase in precipitation across Wisconsin during 1950 to 2006 occurred in the fall. The state averaged an additional 1.8 inches, a 21 percent increase, with northwestern counties averaging increases of 2.5 to 3.5 inches in the fall.

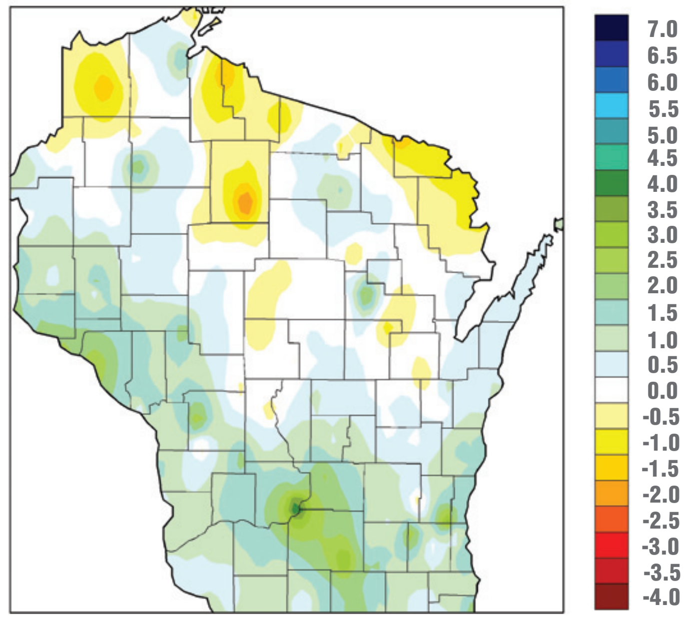
Intense precipitation events: Both the frequency and magnitude of heavy rainfall event events have been increasing in Wisconsin. Madison, for example, has experienced a large number of intense precipitation events in the past decade: 24 days of two inches or more rainfall (compared with the previous maximum of 12 per decade since the 1950s) and nine days per decade of three inches or more rainfall (nearly as many as the five previous decades combined).

Photo: Avery Dorland

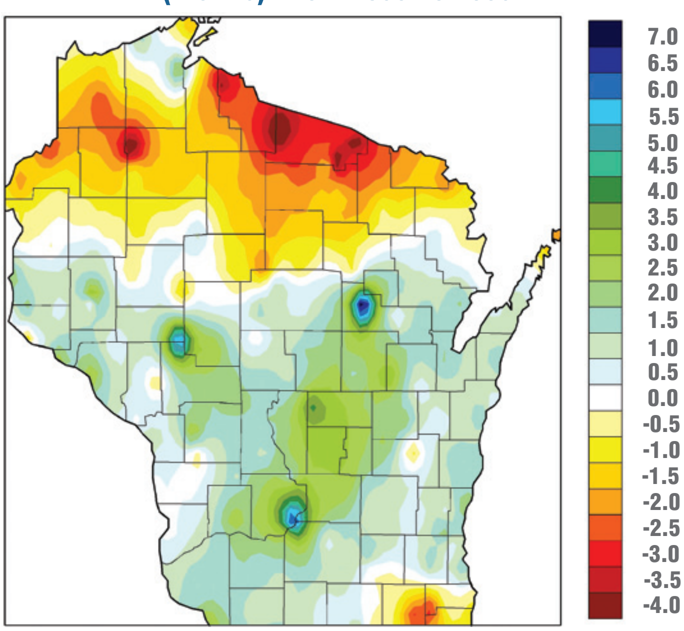
CHANGE IN WINTER AVERAGE PRECIPITATION (INCHES) FROM 1950 TO 2006



CHANGE IN SPRING AVERAGE PRECIPITATION (INCHES) FROM 1950 TO 2006



CHANGE IN SUMMER AVERAGE PRECIPITATION (INCHES) FROM 1950 TO 2006



CHANGE IN AUTUMN AVERAGE PRECIPITATION (INCHES) FROM 1950 TO 2006

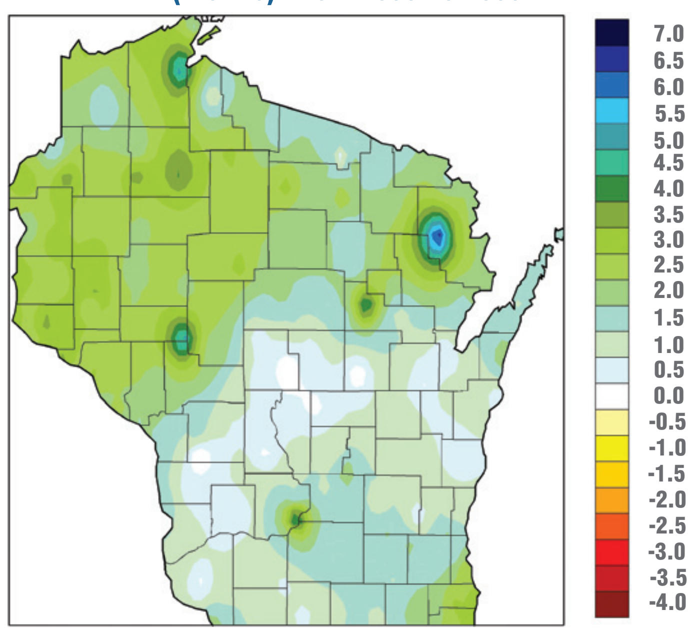


Figure 12. Precipitation generally increased across Wisconsin between 1950 and 2006, though the north saw a drying trend in spring and especially summer.

Source: Kucharik et al., 2006.

Projected Changes in Precipitation

Projections of precipitation are less certain than projections of temperature, with considerable disagreement among climate models. However, WICCI climate scientists say the models do indicate a 75 percent probability that annual average precipitation will increase. When broken down by season, a more interesting picture emerges. The models are in considerable agreement that precipitation will increase during winter and that more of that precipitation is likely to fall as rain rather than snow due to the rise in winter temperatures. The models also allow a fair level of confidence that spring and fall precipitation will increase, and total rainfall and intense rainfall events are projected to increase significantly during the winter and spring months from December to April. However, climate models do not agree on how precipitation patterns are likely to change in the summers ahead.

> WICCI climate scientists say the models do indicate a 75 percent probability that annual average precipitation will increase.

PROJECTED CHANGE IN WINTER AVERAGE PRECIPITATION (INCHES) FROM 1980 TO 2055

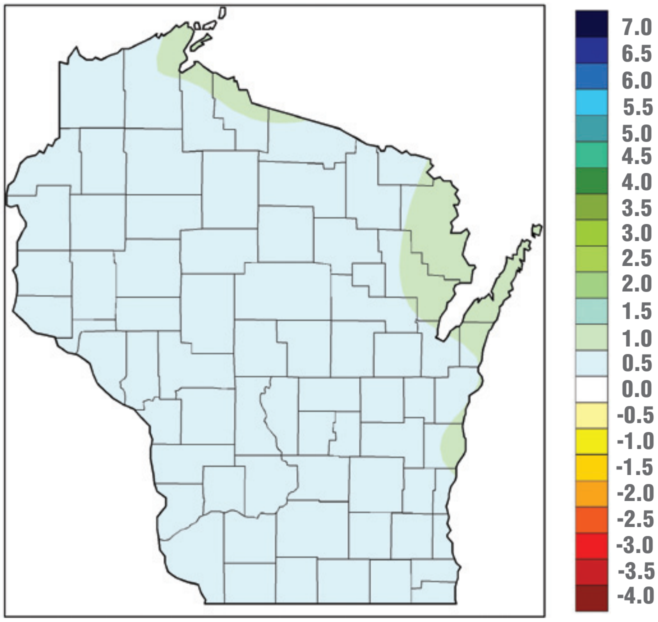
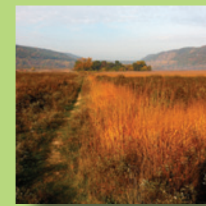


Figure 13. Winter precipitation is projected to increase by about 25 percent over most of Wisconsin by mid-century.

Winter: Wintertime precipitation is projected to increase by 0.1 to 1.2 inches by the mid-21st century, with the average of the climate models showing about a 25 percent increase over most of the state (figure 13). Statewide, the amount of precipitation that falls as rain rather than snow during the winter is also projected to increase significantly, and freezing rain is more likely to occur. As a result, snowfall, snow depth and the extent of snow cover across the state are all expected to decrease significantly by mid-century (figure 14).

Spring: Model projections show Wisconsin receiving more precipitation and more frequent intense events, especially during early spring. As in winter, early spring precipitation will be more likely to fall as rain than as snow. For example, the monthly precipitation as rainfall for March is projected to increase from 1.01 to 1.83 inches by the 2046-2065 time period, which represents a 50 percent increase in the amount of precipitation falling as rain rather than snow during that month.



Summer: Summertime precipitation projections are the least certain, with little agreement among climate models. This uncertainty creates challenges for predicting impacts from precipitation (or the lack thereof) during summer.

Autumn: Fall precipitation is projected to increase slightly by mid-century, somewhat more in the northern half of the state than the southern half, with most of this small change taking place in November.

PROJECTED SNOW

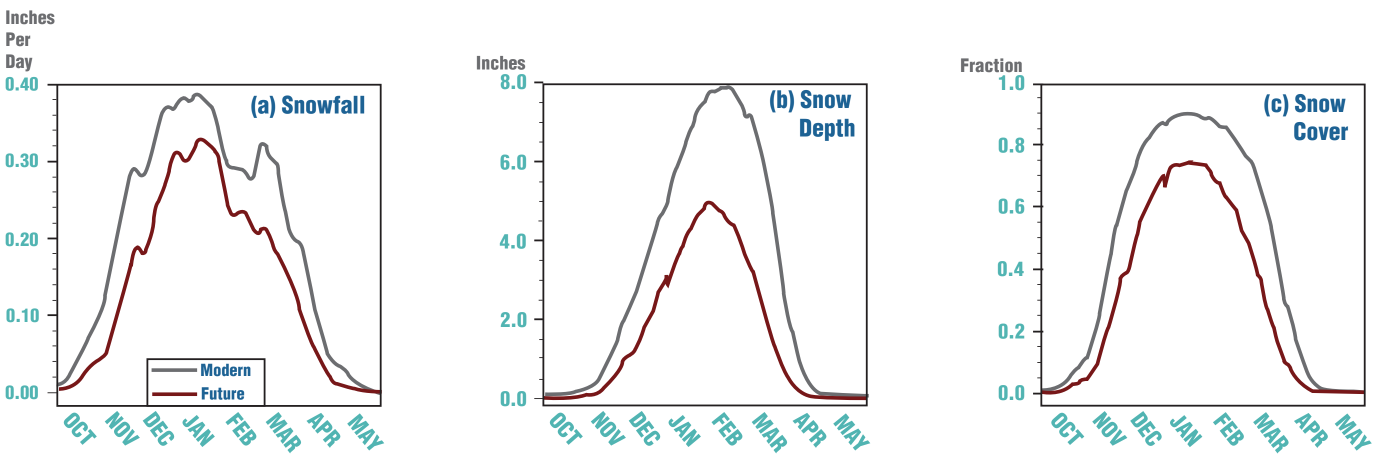


Figure 14. Projections of snowfall, snow depth and snow cover for Wisconsin for the mid-21st century show expected reductions as temperatures warm and more precipitation falls as rain rather than snow. The mean projection for the mid-21st century, when averaged across the state of Wisconsin, is a reduction in annual snowfall of 14 inches, or 29 percent. The greatest reductions in snowfall are likely on the flanks of the snow season, particularly in spring, resulting in a shortened snow season. For example, March snowfall may be reduced by at least three inches across the state. Due to both a reduction in the amount of snowfall and an increase in the rate of snowmelt, a dramatic reduction in snow depth is expected by the mid-21st century. In particular, snow depth may shrink by four inches in mid-March across Wisconsin, with decreases of 6-8 inches across northern counties. Snow projections for areas with lake-effect snow are less reliable due to limitations of the models.

Source: Notaro, M., D. Lorenz, D. Vimont, S. Vavrus, C. Kucharik, and K. Franz, 2010: 21st century Wisconsin snow projections based on an operational snow model driven by statistically downscaled climate data. International Journal of Climatology, DOI: 10.1002/joc.2179.

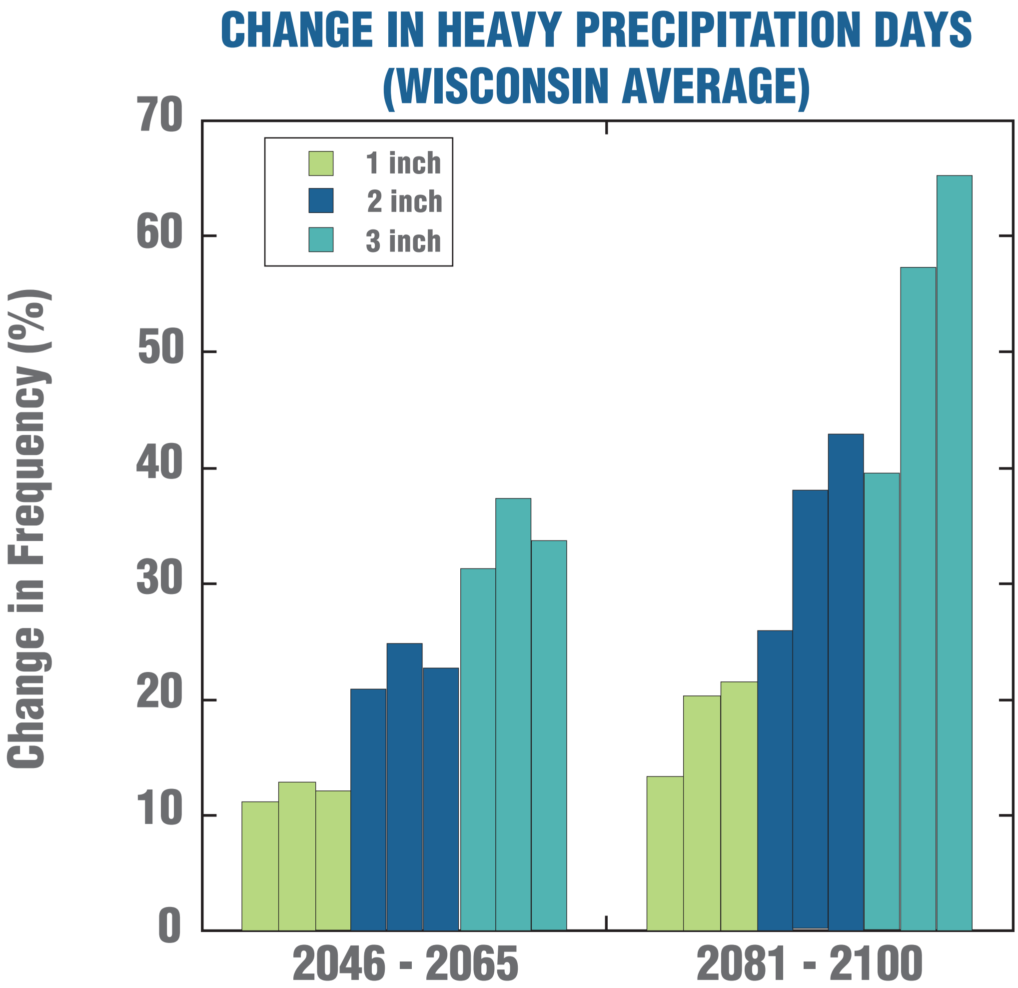


Figure 15. Intense rain events are more likely in the decades ahead. Each set of bars in each time period represents the expected increase in the frequency of intense rain events under the three greenhouse gas emission scenarios used by the Intergovernmental Panel on Climate Change. The colors represent daily rainfalls of at least one inch (green), two inches (blue), and three inches (teal). Within each trio of same-color bars, the left bar corresponds to the lower (B1) emission scenario, which assumes large reductions in emissions after the year 2050, the middle bar corresponds to the (A1B) scenario used as the basis for this report, and the right bar represents intense rain events under the higher (A2) carbon emissions.

Intense precipitation events: Typically, heavy rainfall events – at least two inches in a 24-hour period – are recorded at rain gauges roughly 12 times per decade in southern Wisconsin and seven times per decade in northern Wisconsin. By the mid-21st century, Wisconsin will likely have two or three more of these intense events per decade, about a 25 percent increase in their frequency (figure 15), with these changes concentrated in spring and fall. The heaviest rainfall events will also increase slightly in magnitude, according to the models. For example, averaged over the state, the magnitude of a 100-year storm event (five to seven inches of precipitation in a 24-hour period) is expected to increase by about 10 percent.

Drought: A change toward more heavy rainfall events but little change in total summertime rainfall implies more dry days in Wisconsin during the summer. More dry days, coupled with higher summer temperatures and increased evapotranspiration, can be associated with an increase in the likelihood of summer drought.

Evapotranspiration: Evapotranspiration – the amount of water that evaporates from land, water bodies and plants – is driven largely by temperature and solar radiation. An increase in temperature results in an increase in evapotranspiration; on the other hand, an increase in atmospheric moisture or cloud cover results in reduced sunlight hitting the Earth's surface and thus reduced evapotranspiration. Evapotranspiration is projected to increase across Wisconsin by mid-century, most notably in spring and fall, when a combination of higher temperatures and reduced cloud cover is projected by the climate models.

By the mid-21st century, Wisconsin will likely have two or three more intense rainfall events per decade, about a 25 percent increase in their frequency. The heaviest rainfall events will also increase slightly in magnitude.

For details on the methods used by the WICCI Climate Working Group, please visit www.wicci.wisc.edu, where the working group's full report is available.

Conclusion

Climate change is a reality for our planet and for Wisconsin. To better anticipate how climate change will affect Wisconsin, WICCI has undertaken a detailed study of recent historical trends in Wisconsin's climate. WICCI scientists have also developed projections of our state's future climates using some of the world's most advanced computer models. These studies reveal an emerging consensus on the range of possible climate changes that Wisconsin will experience. In particular, these studies find that Wisconsin is likely to become a much warmer state over the next few decades, with average temperatures more like those currently experienced in states hundreds of miles to our south. Our state is also likely to become somewhat wetter, with a modest increase in total precipitation and in the number of intense rainfall events. The amount of climate change varies by season, with winter experiencing the greatest warming and most likely increase in precipitation.

The WICCI climate analysis illuminates a growing need for more climate information in the years ahead. Wisconsin's climate monitoring network should be improved and maintained, and the Wisconsin State Climatology Office supported, to provide continued high-quality data to enable both short- and long-term climate impact modeling at a scale appropriate to support decision-makers in both the public and private sectors.

The next phase of WICCI climate research will include regional modeling that better incorporates the effects of the Great Lakes and more detailed analysis of evapotranspiration, net water balance and other climate factors.