Climate Change in Wisconsin:

The Historical Record & Future Projections

Submitted by the Wisconsin Initiative on Climate Change Impacts
Climate Working Group

Our Earth's climate is rapidly changing. According to the *Climate Science Special Report of the Fourth US National Climate Assessment* (USGCRP 2017), global temperatures have risen by about 1.8 °F from 1901-2016, with most of that warming occurring in the last six decades. At the same time, carbon dioxide (CO_2) continues to rise due to human emissions. Ice core records tell us that over the last 800,000 years (which extends well beyond the first fossil evidence of homo sapiens), atmospheric CO_2 levels have naturally fluctuated between about 150 parts per million (ppm) and 300 ppm. In April 2014, monthly CO_2 concentration at Mauna Loa observatory passed 400 ppm, probably for the first time in the history of human occupation of our planet. We know, from carbon isotope ratios and other lines of evidence that the increase in CO_2 that Earth has experienced over the last six decades is due to human emissions. Furthermore, data and scientific evidence shows that it is extremely likely that the warming our planet has experienced over the last 60 years is due to human activity, especially increases in CO_2.

Over the last six decades, Wisconsin has experienced similar climatic changes. In 2011, the Wisconsin Initiative on Climate Change Impacts (WICCI) issued its *First Assessment Report* (WICCI 2011) describing how climate has changed in Wisconsin, and will likely to continue to change, together with ways that those climatic changes may affect Wisconsin's natural and built resources and economic interests. Since then, WICCI has continued to investigate historical and projected climatic changes in Wisconsin and to develop new tools for assessing possible future impacts. Some of these results are summarized here for Dane County by leading WICCI climate scientists – Dan Vimont, Michael Notaro, Steve Vavrus, and David Lorenz.

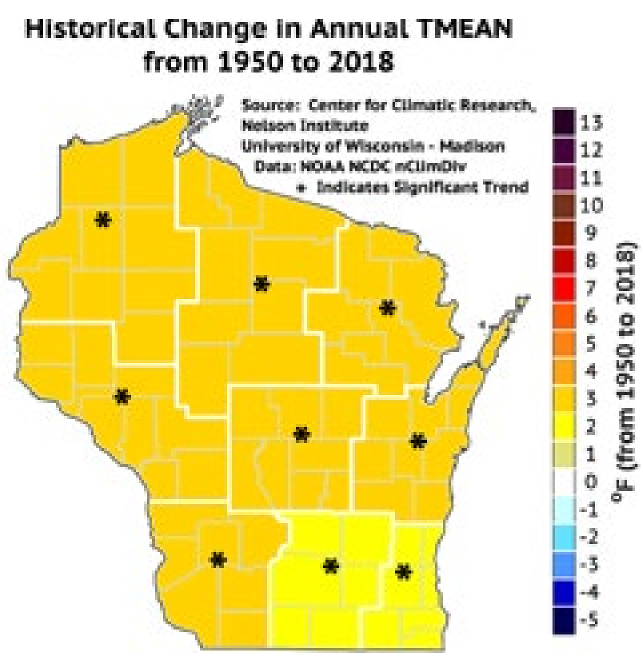
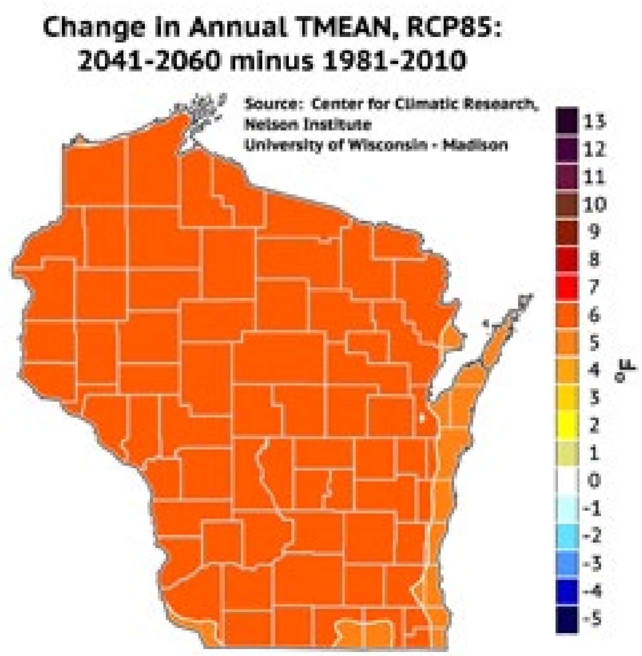


Fig. 6.1: Annual average temperature change for each of Wisconsin's nine climate divisions from 1950-2018. Asterisks indicate that the linear trend from 1950-2018 is statistically significant. See Methods section for a description of data and trend calculations.

Fig. 6.2: Projected change in annual mean temperature in Wisconsin by 2050, shown as the average from 2041-2060 minus the average from 1981-2010. The map shows the average change across all 24 models contributing to the representative concentration pathway 8.5 (RCP8.5) scenario in the UWPD2.0 data set.



Temperature

The historical record indicates that south-central Wisconsin's average temperature has warmed by about 2 °F since 1950. This warming is robust, with statistically significant trends during all seasons of the year for South Central Wisconsin. The warming is not uniform throughout the year, though, with the greatest amount of warming occurring during the winter season (December-February average warming of about 4 °F) and the least during summer (June-August average warming of about 1 °F). Both spring and fall have warmed by about 2-3 °F. Warming is more pronounced in the nighttime minimum temperatures, which have warmed by about a degree more than the daily maximum temperatures.

Future projections indicate that Wisconsin will continue to warm by about 6 °F (3-9 °F) by 2050 (Fig. 6.2). Like the historical record, this warming is slightly more pronounced during winter (3-11 °F) than summer (3-8 °F) and shows the least amount of warming during spring (2-8 °F). Projections are robust in showing that nighttime low temperatures will warm by about 1 °F more than

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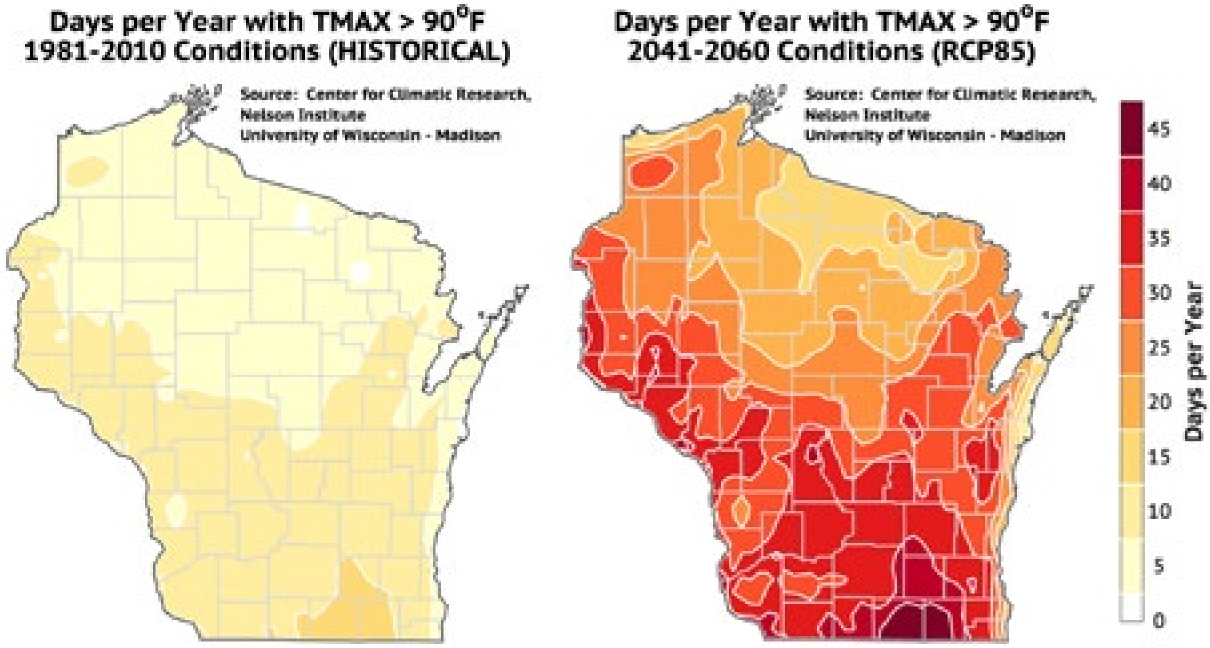


Fig. 6.3: Average number of days per year when then daily high temperature exceeds 90 °F. Left: 1981-2010 conditions. Right: 2041-2060 conditions. Maps show the number of extreme days averaged across all 24 models contributing to the RCP8.5 scenario in the UWPD2.0 data set.

daytime high temperatures. We note that the seasonal warming differences are largely due to three models that show warming of 10-13 °F during winter; the remaining models show relatively consistent warming of about 3-8 °F throughout the year by mid-century. Further, dynamically downscaled model simulations (that may include more realistic representation of land surface processes) suggest that summer temperatures will warm more than winter temperatures (Notaro et al. 2015). While the differences between daytime and nighttime temperature changes are robust, work is underway to better understand the differences in seasonal projections.

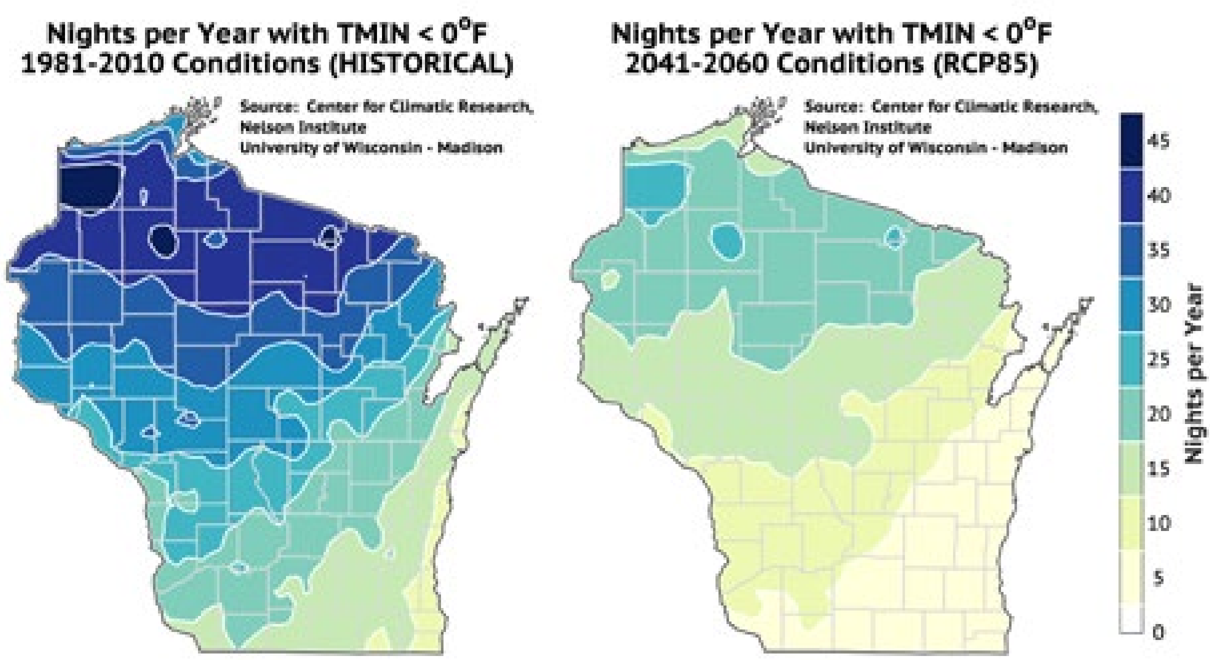
In the historical record, it is rare to experience a year in which a daily high temperature exceeds 100 °F; by mid-century, it is likely that these kinds of events will occur three to four times each year.

One way that we will experience this change in temperature is through a change in extreme daily temperatures. In the historical record in southern Wisconsin, daily high temperatures typically exceed 90 °F on 10-15 days per year (Fig. 6.3). By 2050, that frequency triples, with daily high temperatures expected to exceed 90 °F on 30-40 days per year. Southern Wisconsin may also see unprecedented high temperature events.

In addition to extreme daytime highs, extreme nighttime lows are expected to change as well. During winter, we will see a decrease in extremely cold days (Fig. 6.4). In the historical record, low temperatures dip below 0 °F on 15-20 nights per year. By 2050, these cold nights are expected to occur only about five times per year. During summer, extremely warm nights have a disproportionately high impact on human health. From 1981-2010, nighttime low temperatures remain above 70 °F about six times per year. This kind of event is likely to quadruple by 2050, with nighttime lows exceeding 70 °F for 25-30 days each year. This suggests that this kind of currently rare event will become a regular occurrence during summers by 2050.

Wisconsin's warming temperatures will also affect other climatic conditions. For example, warming winter temperatures will be experienced as changes in the characteristics of winter. Historical data shows significant decreases in the duration of lake ice around the world, including Lake Mendota (Sharma et al. 2019), that are consistent with warmer winter weather. These trends toward

Fig. 6.4: Average number of nights per year when then daily low temperature dips below 0°F. Left: 1981-2010 conditions. Right: 2041-2060 conditions. Maps show the number of extreme days averaged across all 24 models contributing to the RCP8.5 scenario in the UWPD2.0 data set.



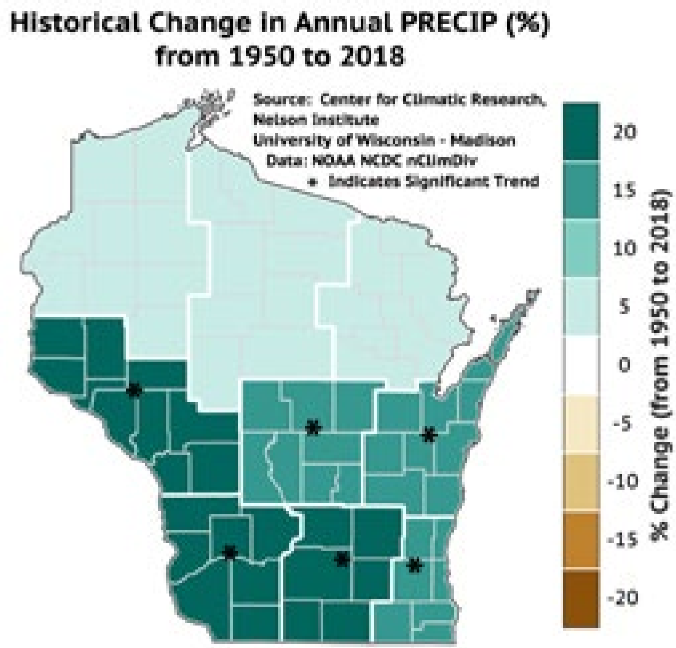
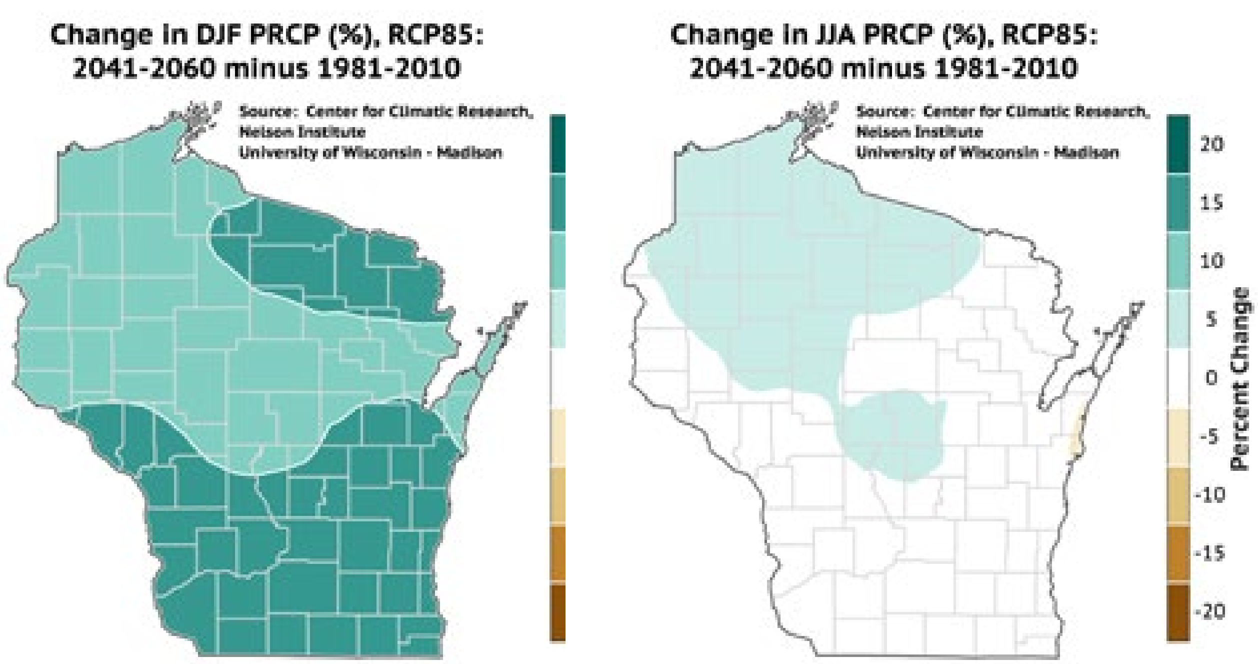


Fig. 6.5: Total annual precipitation change (in percent) for each of Wisconsin's nine climate divisions from 1950-2018. Asterisks indicate that the linear trend from 1950-2018 is statistically significant. See Methods section for a description of data and trend calculations.

Fig. 6.6: Projected change in (left) winter and (right) summer precipitation in Wisconsin by 2050, shown as the percent change by 2041-2060 relative to the 1981-2010 average. The map shows the average percent change across all 24 models contributing to the RCP8.5 scenario in the UWPD2.0 data set.

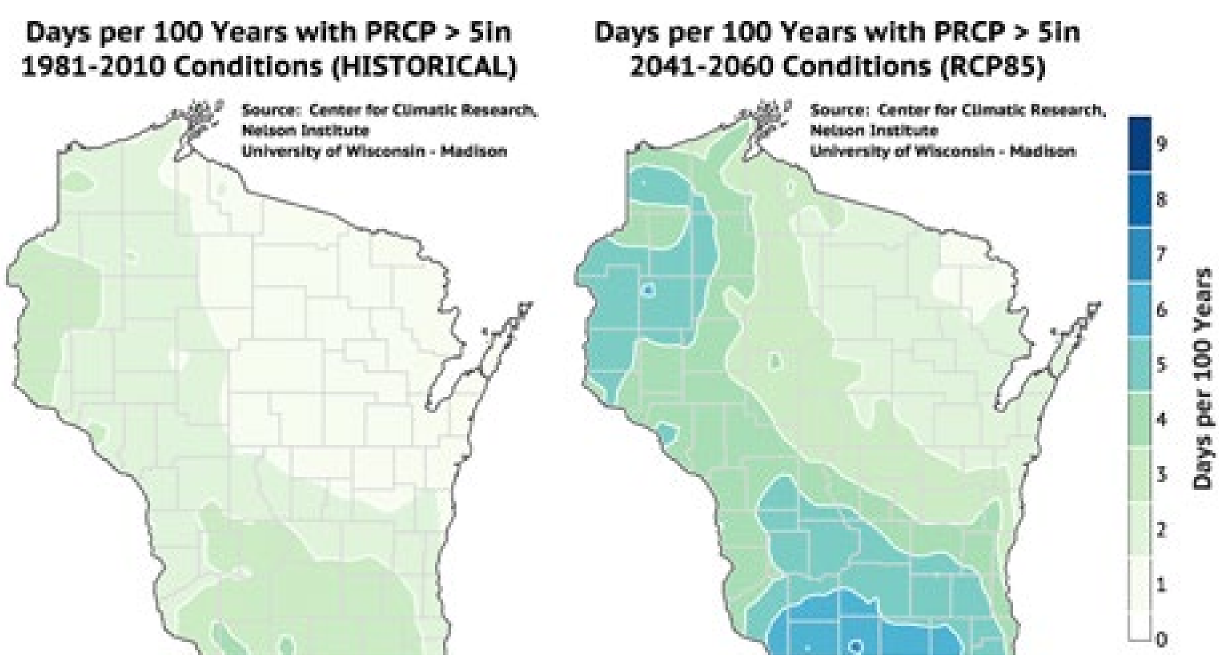


reduced lake ice are expected to continue. Warming winter also translates to large reductions in snowfall, snowfall events, and snow depth in Wisconsin (Notaro et al. 2014). This reduction in snow will also be experienced as an overall shorter snow season for southern Wisconsin (Notaro et al. 2010). During summer, warmer temperatures tend to increase evaporation and reduce soil moisture, resulting in expected changes in vegetation across Wisconsin (Notaro et al. 2012).

Precipitation

Precipitation is much more variable than temperature, and as a result, changes in precipitation during the historical record are more difficult to attribute to anthropogenic climate change than changes in temperature. Further, precipitation in Wisconsin undergoes a large seasonal cycle with little total precipitation during winter and large total precipitation during summer. In southern Wisconsin annual total precipitation has increased by about 20% since 1950 (Fig. 6.5), while annual total precipitation in northern Wisconsin has experienced no significant change.

Fig. 6.7: Extreme precipitation occurrence in Wisconsin, denoted as the number of days per century that a given location is likely to experience a daily precipitation event equal to or greater than 5 inches. Left: 1981-2010 historical conditions. Right: 2041-2060 conditions. Maps show the number of extreme days averaged across all 24 models contributing to the RCP8.5 scenario in the UWPD2.0 data set.



Projections indicate that total precipitation will likely increase in Wisconsin by 2050. The change in precipitation is seasonally dependent (Fig. 6.6), with winter and spring experiencing the most robust increase of about 10-15% (increases ranging across models from 0-25% in winter and 0-20% in spring) and summer experiencing the least robust change of about 0% (with models varying between a 10-15% loss to a 10-15% increase in total precipitation).

In addition to changes in seasonal total precipitation, it is highly likely that large precipitation events will increase in frequency and intensity by mid-century. During the historical record, a given location in southern Wisconsin experiences an average of 12 two-inch (or greater) precipitation events each decade. By mid-century, this increases to about 16 two-inch (or greater) precipitation events per decade, equivalent to a 33% increase. Extremely large precipitation events are likely to experience an even greater increase in frequency. For example, during the historical record a five-inch precipitation event (Fig. 6.7) is likely to occur at a given location in south-central Wisconsin about three times per century (approximately a 30-year event), and by mid-century this kind of event is projected to nearly double in frequency, occurring five to six times per century (a 15- to 20-year event).

Conclusions

Historical records and future projections show consistent climatic changes across Wisconsin. In particular, the historical record indicates that Wisconsin has warmed by 2-3 °F since 1950, and models project an additional 3-9 °F of warming by mid-century. Importantly, the models and historical records both agree on the characteristics of the warming as well, with both indicating the most change occurring for winter nighttime low temperatures and the least amount of change for summer daytime high temperatures. In addition, model projections show an approximate tripling to quadrupling of extremely hot days and nights in Wisconsin. Precipitation changes are less robust, but model projections suggest a slight increase in total precipitation in Wisconsin. The total change, though, is strongly dependent on the amount of rain that falls during summer which could increase, decrease, or stay the same. Robust increases in winter and spring precipitation are expected by the middle of the 21st century.

Methods, see Appendix 3.