Confronting Climate Change in the Great Lakes Region

Technical Appendix
Climate Change Projections

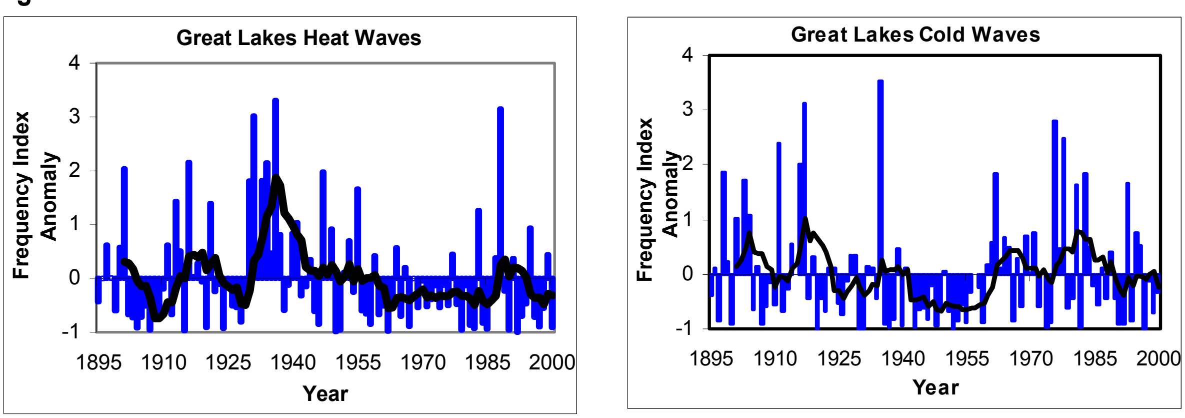
EXTREME EVENTS

Human health and well-being, as well as energy requirements, building standards, agriculture and economic welfare will certainly be affected by the many changing climate features already described. However, there are additional climate characteristics that capture specific impacts related to these areas of concern. Many of these are related to the frequency of extreme events. In this study we examined two types of extreme events: (1) temperature threshold exceedances, and (2) heavy rainfall events.

Temperature Threshold Exceedances

The frequency and duration of high temperature events, ranging from the number of days per year that exceed a certain threshold temperature to extended heat waves, are correlated with human health concerns, mortality rates, air quality, and specific cooling loads. Based on an analysis of historical data over the past century, the high frequency of extreme heat occurring in the 1930s has no comparable multi-year period occurring elsewhere in the time series, although 1988 was characterized by very frequent heat waves, including one in Chicago that was directly or indirectly responsible for over 200 deaths (Figure 1).

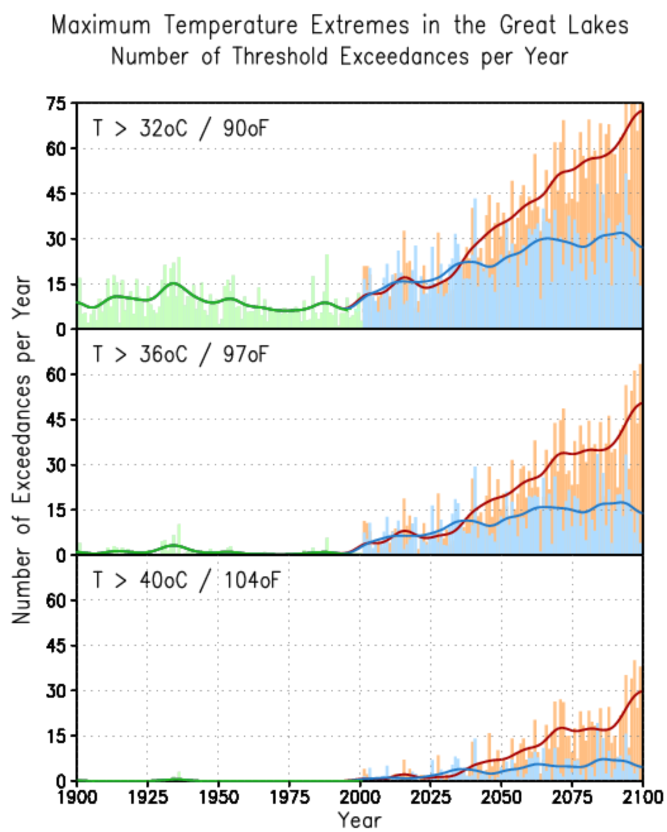
Figure 1. Observed trends in heat waves and cold waves from 1895 to 2000.



Over the last 100 years, average daily maximum temperatures over the Great Lakes region exceeded 32°C or 90°F anywhere from 5 to 25 times per year. However, temperatures rarely exceeded the 36°C or 97°F threshold except during the 1930's and 1990's, with a maximum exceedance of 8 times in 1999

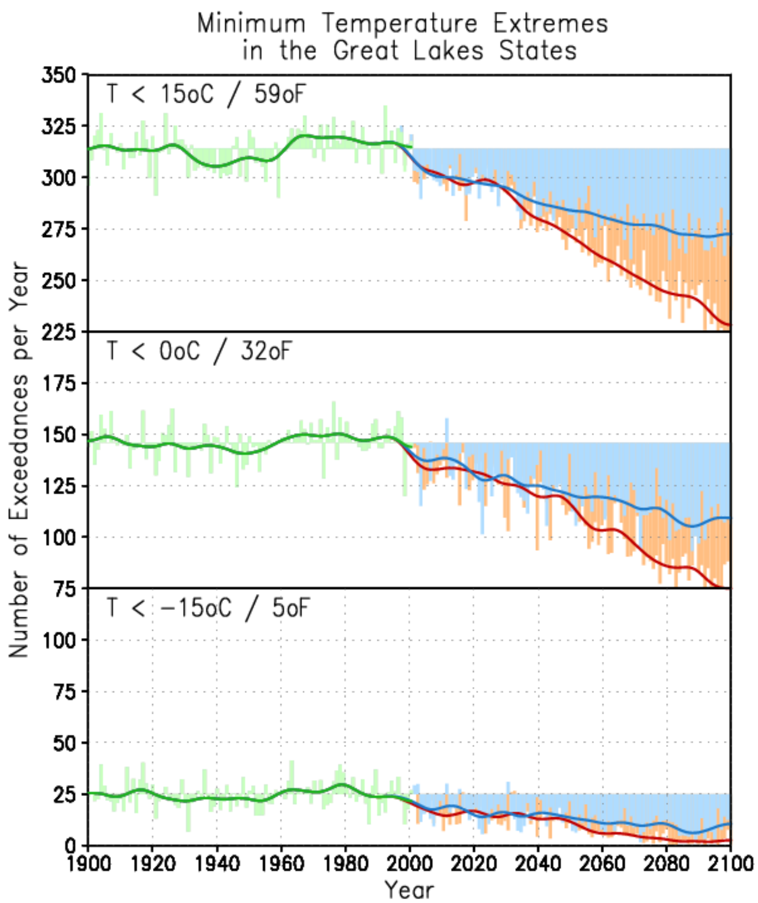
(Figure 2). In the future, similar conditions to those experienced in the 1990's are projected to hold through the next several decades. However, beginning around 2030, the modeling studies suggest that the number of threshold exceedances may rise sharply. By the end of the century, temperatures are projected to exceed 90^{o}F or 32^{o}C anywhere from 20 to 50 times per year, with a corresponding increase in the frequency of multi-day heat waves. This implies significant increases in heat-related illnesses and mortality rates. It also suggests much higher cooling loads in summer that extend further into spring and fall as well.

Figure 2. Extreme high temperature threshold exceedances in the Great Lakes. Historical data from 1900-2000 is shown in green while future projections from 2001-2100 are plotted in red for the 'high' A1FI scenario and in blue for the 'low' B1 scenario. Bars show year-to-year variability, while solid lines indicate 10-year running means.



Cold temperatures in the Midwest are also related to human health issues, as well as to forecasts of heating loads based on the number of days below certain threshold temperatures. In terms of historical patterns, cold waves occurred frequently throughout the early part of the 20th century as well as during the late 1970s and early 1980s. In the 1990s, however, most years saw a below-average number of cold waves. The number of days below certain threshold temperatures (15°C or 59°F, 0°C or 32°F and -15°C or 5°F) has been decreasing steadily since the mid 1980's (Figure 3). By the end of the century, there may only be approximately 75 to 110 days that reach below 0°C or 32°F, while less than 10 days per year may fall below –15°C. This suggests a positive impact during the winter on cold-related illnesses and deaths, as well as a decreased demand for heating during that time. However, such a change in climate would likely have an adverse impact on winter kill-off of pests affecting agriculture and ecosystems, and could lead to increased health-related concerns as populations of mosquitos and other disease carriers grow.

Figure 3. Extreme low temperature threshold exceedances in the Great Lakes region. Historical data from 1900-2000 is plotted in green, while future projections are plotted in red for the 'high' A1FI scenario and in blue for the 'low' B1 emission scenario based on calculations by the HadCM3 model. Bars show year-to-year variability while solid lines indicate 10-year running means.



Heavy Rainfall Events

In terms of extreme precipitation events, changes in regional precipitation, groundwater, and the frequency of floods and droughts carry important consequences for both ecosystems and society. Short-lived extreme events such as storms and tornadoes are difficult to predict and how the frequency of these events will change in the future is still subject to major uncertainties. However, in the past 15 years, an increasing number of severe weather events occurred in Illinois alone. These include the severe drought of 1988, two Mississippi River floods, and numerous occurrences of tornadoes and severe storms (Chagnon and Kunkel, 1995).

Analysis of the heaviest rainfalls since 1900 clearly indicates an increase in frequency in both 1-day and 1-week events towards the end of the century (Figure 4). Over the past three five decades, the frequency of 24-hour and 7-day heavy rainstorms that result in flooding of streams and rivers has been fairly high relative to the long-term average, with the majority of historical events occurring within the last few decades. In the future, it is fairly certain that the frequency of heavy rainstorms – both 24-hour and multi-day events – will likely continue to increase over the next century and may double by 2100 (Figure 4). At a low confidence level, there is some indication for an increase in the intensity of these events as well. Increases in heavy rainfall events are likely to increase the risk of flooding (Changon and Kunkel, 1995), with serious repercussions on human and ecosystem welfare.

The frequency of *historical* events was determined by locating the 101 most dramatic events from 1900 to 2000, such that the average was one event per year. In some years, this meant that were no events in certain areas while in other years there could be multiple events. The events were then averaged over the entire Great Lakes region and plotted according to the year in which they occurred.

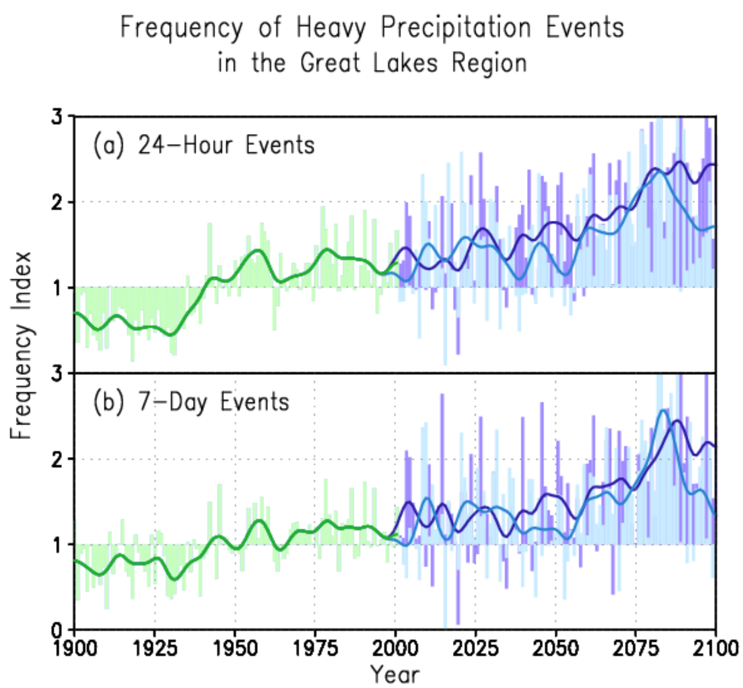
An analogy to this analysis would be to search through Olympic and World records to find the 101 furthest long-jumps since 1900. Plotting these events by the year in which they occurred, it would then be possible to see whether humans have improved their ability to jump long distances over the last century. If so, we would be able to detect a trend in long jumps that increased over time. In other words, this analysis would show whether record-breaking long jumps were becoming more frequent over time. Similarly, plotting the heaviest rainfalls since 1900 enables us to see whether heavy rainfalls are becoming more frequent as well.

When the heaviest rainfalls over the last century are plotted (Figure 4), it is clear that the frequency of both 1-day and 1-week events has increased significantly towards the end of the century, with the majority of historical events occurring within the last few decades.

Frequency of *future* events was determined by taking the magnitude (i.e., the total rainfall amount) for the 101^{th} historical event in each grid box as the threshold of what determined a heavy rainfall event. The analysis then counted the number of model-projected events that lay above this threshold for each grid box. Results were normalized by the difference between modeled vs. observed historical events over the reference period 1961-1990 to ensure that model bias would not distort future projections.

Two of the SRES emission scenarios were used for the analysis – A2 (‘higher mid-range’) and B2 (‘lower mid-range’). Results from the two scenarios show remarkably similar trends of frequencies remaining well above average for the next few decades and more than doubling by the end of the century.

Figure 4. Analysis of (a) 24-hour and (b) 7-day heavy precipitation events in the Great Lakes region from 1900-2100. A frequency anomaly index greater than one indicates a higher than average number of events that year, while an index less than one indicates a lower-than-average number of events. This average is determined based on the number of events recorded in the historical data over the past 101 years from 1900-2000. Historical data from 1900-2000 is plotted in green, while future projections are plotted in dark blue for the ‘higher mid-range’ A2 scenario and in light blue for the ‘lower mid-range’ B2 emission scenario based on calculations by the HadCM3 model. Bars show year-to-year variability while solid lines indicate 10-year running means.



References

Changnon, S.A., and K.E. Kunkel, 1995. Climate-related fluctuations in Midwestern flooding. J. of Water Resources Planning and Management Division, 121, 326-334.