EXECUTIVE SUMMARY

Part of a National Assessment

The US Global Change Research Program (USGCRP) is conducting its first National Assessment of the Potential Consequences of Climate Variability and Climate Change. This National Assessment is motivated by recently documented evidence of warming across much of the United States, and a concern about what future climate change may bring to the Nation in terms of water resources, ecology, coastlines, and human health to name a few. The Assessment has three major components including 16 regional assessments, of which the Great Lakes Regional Assessment is one. The results from the regional assessments will be combined with the results from five *sectoral analyses* (Agriculture, Forests, Human Health, Water, and Coastal Areas/Marine Resources) to create a *National Overview*.

Goals of the Great Lakes Regional Assessment

A team consisting of approximately thirty investigators from around the Great Lakes region was assembled to assess the potential impacts of climate change and variability in the region. The goals of the Great Lakes Regional Assessment were to identify:

> How key sectors in the region are sensitive to climate-change-related and non-climate-change related stresses
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> What information previous assessments can provide relating impacts of climate change on key sectors in the region
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> What the potential impacts of climate change on key sectors in the region will be based on climate change scenarios from the latest general circulation model simulations
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> How individuals and communities can take advantage of opportunities to reduce vulnerabilities resulting from climate change and variability
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> What additional information and research are needed to improve decision making related to impacts from climate change and variability.

The specific sectors that were chosen for assessment were motivated in part by findings from a regional workshop that was held at the University of Michigan in May 1998. The assessments are challenging because of uncertainties in climate change projections, socioeconomic change projections, and because of a lack of information and models that link changes based on these projections across sectors.

The Great Lakes Region – Now and in the Future

The Great Lakes region, for the purposes of this assessment, consists of the Great Lakes drainage basin, and all of Minnesota, and Wisconsin. The population of this region has increased from roughly 10 million in 1900 to over 40 million currently. Lumbering, farming, and mining played a big role in the development of the region during the last half of the 19th century. Steel manufacturing and the automobile industry dominated the last half of the 20th century.

The importance of the region is related strongly to the fact that the Great Lakes constitute the single largest source of fresh water in the world (except for the polar ice caps). The Lakes themselves are a linchpin for drinking water, hydroelectric power, commercial shipping, and recreation to name but a few. Additionally, the Lakes and the shorelines provide various habitats for numerous plant and animal species.

The unique location of this region – halfway between the equator and North Pole within a large continental land mass and colocated with the largest lakes in the world – gives it a unique climate. This climate is characterized by warm summers, cold winters, and significant precipitation year-round. Additionally, the Great Lakes have a considerable influence on the subregional climates around the lakeshores, particularly in winter in the form of lake-effect snowstorms in winter. These storms contribute up to 50% of the annual snowfall totals in areas around the lakes (e.g., the snowbelts).

Climate scenarios from two General Circulation Models: the Canadian Climate Center Model (CGCM1) and the United Kingdom Hadley Center Model (HadCM2) suggest that the climate will be 2-4°C (3.6-7.2°F) warmer and about 25% wetter by the end of the 21st century. There will also be fewer cold air outbreaks and less lake-effect snow in winter – especially around the southern lakes (Erie and Ontario). Such changes in snowstorm frequency would decrease the cost of snow removal and decrease the frequency of transportation disruptions. However, there would be adverse consequences to the winter recreational industry in southern portions of the Great Lakes. Summertime heat waves and heavy precipitation events will become more frequent.

Key Findings

This regional assessment focused on how a warming climate might impact levels of the Great Lakes, streamflow, aquatic and terrestrial ecosystems, agriculture, and quality of life. Key findings are presented below.

Water Resources

The Great Lakes have historically enjoyed a relatively small range in lake levels – 6.5 feet from the recorded monthly maximum to the recorded monthly minimum. Superimposed on these levels are seasonal cycles of 10-12 inches. Recent declines from record high levels in the 1980s have caused concern among commercial shippers, hydroelectric companies, and recreational boaters. The dredging activities that may be used to offset some of the effects from low lake levels and channel depths are not without their own potentially negative consequences – namely the cost involved and the resuspension of pollutants that have remained dormant at the bottoms of channels for decades.

Previous assessments of how climate change would impact lake levels using output from steady-state GCMs have suggested that lake levels may decline by 1.5 – 8 feet by the end of the 21st century. In the current assessment, output from the CGCM1 model suggests that the evolution of a long-term trend toward lower Great Lakes levels may reach magnitudes of approximately a 1.5 to 3 feet drop on the various lakes within a time frame of about 3 decades. Output from the HadCM2 model suggests no change to a slight increase in lake levels. Ice cover will also likely decrease – both in terms of days with ice cover and thickness of ice.

Water regulation strategies should be developed that are robust enough for either high or low water levels. Water regulation models need to be developed to deal with some of the lake level changes that are anticipated from climate change.

Water Ecology

Aquatic life in the Great Lakes depends critically on how surface nutrients and oxygen are mixed throughout the depth of the lakes. The mixing in turn depends on the seasonal cycles of lake and air temperatures, sunshine, and winds.

The CGCM1 and HadCM2 models both suggest not only that the Great Lakes will be warmer, but that they will also remain more stable for a longer portion of the year by the end of the 21st century. As a result, not as much oxygen will mix down from the surface to greater depths. This would effectively reduce the biomass productivity by around 20%.

The flow from the streams and rivers that feed into the lakes will also likely change. Inland rivers in the Great Lakes region that are primarily snowmelt driven (e.g., peak flows in early spring) may have earlier peaks as a result of less snow and more rain. Changes in summer flows for all rivers will likely depend on how the future increased precipitation that is suggested by the GCM simulations is balanced by evapotranspiration within watersheds.

The projected decline in primary production may require implementing stocking strategies to rebuild stocks of native species that have survived in the lakes through centuries of postglacial change and appropriate public education programs to explain such changes. Dredging attempts to maintain shipping channels should strive to minimize impacts on critical habitat required for spawning of native species and the nurturing of young.

Critical information needs include a better knowledge of how future precipitation and wind patterns will change over the Great Lakes drainage basin, how land-use practices will change, and how the links in the food web operate between the primary producers and the top, economically important fish.

Land Ecology

Three gradients characterize the natural ecosystems of the region: a southwest to northeast gradient from prairie to forest in Minnesota, a south to north gradient from Eastern deciduous to Northern mixed hardwood forests in Michigan and Wisconsin, and the Southern edge of the boreal forest extends into the region. The diversity of forest ecosystems throughout the region has contributed greatly to its prosperity and quality of life as well as its cleaner air and water, and the reduction of soil erosion.

Economically significant trees like quaking aspen, yellow birch, jack pine, red pine, and white pine may no longer be able to grow in the Great Lakes region because summers may become too warm. Other trees like black walnut and black cherry may eventually migrate northward into the region – given enough time. Productivity may ultimately increase, but only after a decline during the transition (a "dieback phenomenon"), as communities adjust to a changing environment. Because managed landuse accounts for as much as three-quarters of the land area of natural ecosystems (i.e., grasslands), more information is needed on both the impacts that current land management has on the ability of vegetation communities to respond and how the dynamics of land use and management will interact with climate change.

Changes in the Great Lakes distributions of upland game birds may also occur. There may be more opportunities to hunt the Ring-necked Pheasant and Northern Bobwhite, but fewer to hunt the Sharp-tailed Grouse or Gray Partridge. There may also be fewer duck-hunting opportunities in the Great Lakes region. These changes are supported by recent observations. Some models project additional losses of neotropical migratory bird species in Michigan (32%), Minnesota (20%) and Wisconsin (32%). Particularly hard hit would be the wood warblers with large numbers of species projected to be extirpated from Michigan (61% lost), Minnesota (52% lost) and Wisconsin (67% lost). Losses are also projected for the other states within the Great Lakes region. These avifaunal changes will likely have negative impacts on the ecotourism and on ecosystem health in the region.

Reasonable response strategies within the forestry and land management communities include monitoring the health of the forests within their changing environment; implementing policies, such as land use planning and/or "sprawl" taxes to minimize land use conflicts; facilitating the migrations of plant species with the shifting of ecological zones; and planting tree species that are better suited to a changed climate.

An important research need is to couple models of ecosystem productivity with models of land use change to study change under altered climate.

Agriculture

Agriculture ranks among the most important economic activities of the Great Lakes region, accounting for more than $15 billion in annual cash receipts. Livestock, including dairy, is the number one agricultural commodity group, comprising over half of the total. Dairy production alone produces almost $5 billion in receipts. Crop diversity is an important characteristic of agriculture in the region due at least partially to the moderating influence of the Great Lakes on regional climate. Over 120 commodities are grown or raised commercially in the region.

The warmer and wetter climate across the region portrayed by both GCMs and the positive effects of CO_2 enrichment suggest that future crop yields may be greater than historical yields. Some crop yields may be greater than historical yields through 2050, but may then decrease with time from 2051-2100, especially at western and southern locations. Interannual variability of all projected future crop yields may tend to decrease with time, especially after 2050. Greater agronomic potential may be possible for northern sections of the region, even with less suitable soils. Simple adaptations to a changing climate such as a switch to a longer-season variety or earlier planting date were found to result in significant increases in potential crop yield.

Further analysis of the model simulations suggest that for the assessment decade of 2025-2034 lake-modified regions surrounding Lake Michigan will experience a moderate increase in growing season length and seasonal heat accumulation and a decrease in the frequency of subfreezing temperatures. In addition, important growth stages for perennials (such as commercial fruit trees) will occur earlier in the calendar year than at present. Very large changes in temperature threshold parameters are projected for the assessment decade of 2090-2099, especially for the eastern shore of Lake Michigan. It is unclear for both assessment decades whether perennials (specifically, commercial fruit trees) will be more or less susceptible to damage from cold temperatures after critical growth stages have been reached. The simulations from the HadCM2 model suggest less susceptibility, whereas the simulations from the CGCMI model suggest greater susceptibility.

Improvements in technology, the CO_2 fertilization effect, and the use of adaptive farm management strategies will mitigate any negative effects of climate change for the majority of farm operations in the Great Lakes region. Adaptive farm management strategies include: changes in crop selection or variety; using crop varieties that are currently used in more southern regions; changes in the timing of planting and harvesting, and the development of new varieties of crops that are more adaptable to interannual variations of weather.

Better regional- or local-scale climate models and more sophisticated agricultural models that include pesticide, fertilization, and CO_2 enrichment effects, as well as resulting economic impacts are needed for future assessments.

Quality of Life

A major quality of life issue is human health. People who lack protection to high temperature extremes eventually suffer from heat stress, dehydration, respiratory distress, and occasionally heat stroke or cardiac malfunction. Heat waves in the Great Lakes region are still relatively rare. Output from the HadCM2 and CGCM1 models suggests significant increases in the number of days above 90°F. Additionally, interannual variability may decrease – so cool summers may not occur as frequently as they do now. Other impacts from short-term, extreme weather events such as floods, tornadoes, and blizzards, may also increase in the Great Lakes region, because these events are forecasted to occur with increasing frequency – particularly heavy precipitation events.

Air pollution associated respiratory disease has not been well studied in the Great Lakes region. Results suggest that air pollutants are but some of many factors involved in the etiology of respiratory diseases. A simple analysis of the GCM output from the CGCM1 and HadCM2 models suggests that the number of days with synoptic patterns that are conducive to high ozone will increase by the end of this century across much of the Great Lakes region.

Improved weather forecasting, information distribution, special assistance, and economic well-being will help high risk populations to better cope with high temperature extremes. Improving the construction of future dwellings and preventing construction too close to lakeshores will help people in the region to better cope with heavy precipitation events. The impacts of air pollutants on health can be decreased if susceptible people such as the elderly or those with preexisting respiratory disease are warned to stay indoors during severe conditions outside. In some cases, a response may be to move from more polluted urban areas, or even to leave the Great Lakes region entirely for cleaner and drier climates.

The uncertainties in both the forecasts of possible climate change and the effects on public health demonstrate that major research and monitoring efforts are needed. More research is needed to better identify and understand the relationships between environmental factors and diseases.

Future Work

This first Assessment of Climate Change in the Great Lakes region suggests possible impacts from climate change. More importantly, it demonstrates the complexities that are associated with such a multi-disciplinary study. The uncertainties associated with projections in climate change are almost of secondary importance compared to some of the uncertainties associated with some of the sector-sector interactions, which for the most part have been ignored. Future endeavors will begin to address some of these important interactions.