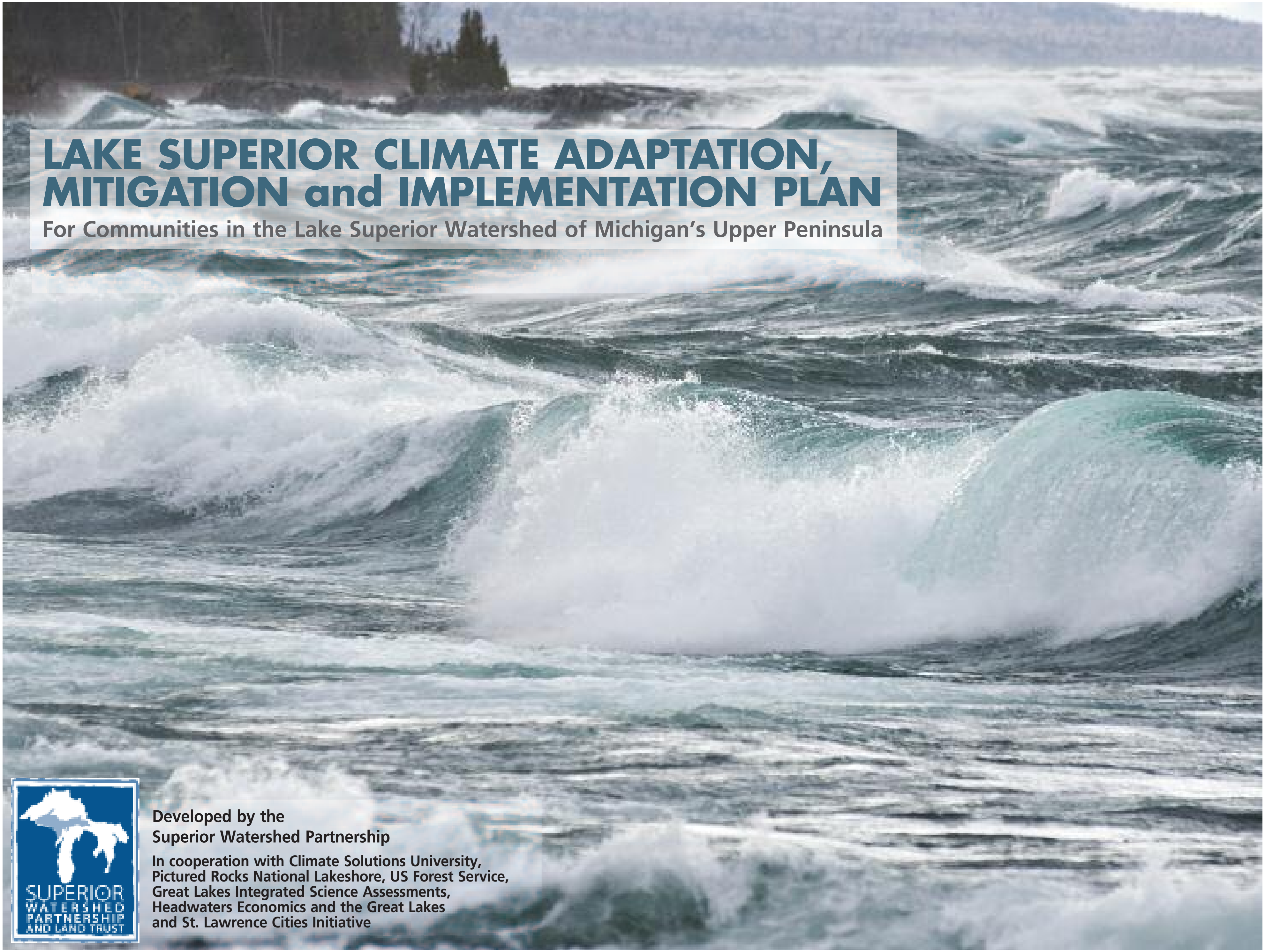


LAKE SUPERIOR CLIMATE ADAPTATION, MITIGATION and IMPLEMENTATION PLAN

For Communities in the Lake Superior Watershed of Michigan's Upper Peninsula

SUPERIOR WATERSHED PARTNERSHIP AND LAND TRUST

Developed by the Superior Watershed Partnership

In cooperation with Climate Solutions University, Pictured Rocks National Lakeshore, US Forest Service, Great Lakes Integrated Science Assessments, Headwaters Economics and the Great Lakes and St. Lawrence Cities Initiative

TABLE OF CONTENTS

Contributing writers include the following SWP staff members; Andrea Chenowyth, Jennifer Klipp, Carl Lindquist, Geri Grant, Beth Tiller and Hunter King. Additional technical assistance provided by; Climate Solutions University, Pictured Rocks National Lakeshore, Great Lakes and St. Lawrence Cities Initiative, Headwaters Economics, US Forest Service and Great Lakes Integrated Science Assessments (GLISA).

Photo Credits: Aaron Peterson, Tom Buchkoe, SWP staff.

EXECUTIVE SUMMARY

Global climate change is a reality. 2012 was the hottest year on record. The impacts of climate change have been documented from pole to pole but the impacts vary widely depending on where you are on earth. The Great Lakes are no exception. Many consider Lake Superior the “canary in the coal mine” when it comes to Great Lakes climate change. Consider these statistics;

- In 2012 Lake Superior had the highest surface water temperature ever recorded (71 degrees Fahrenheit).
- 2012 was also the first year that Marquette, Michigan was forced to close public beaches due to high bacteria counts directly linked to the high water temperatures of Lake Superior.
- Lake Superior has experienced a 70% loss in ice cover over the last 40 years.
- Three Lake Superior communities (Duluth, Thunder Bay, Wawa) experienced unprecedented severe rain and flooding events in 2012 that caused millions in damage.
- A dramatic decline in snowfall has exacerbated drought conditions, impacted lake levels and threatens regional economic sustainability, specifically the tourism and shipping industries.
- Slower, more subtle changes include loss of rare sub-arctic plant species, changes in animal migration patterns and changes in forest cover types which could have long term economic impacts for the forest product industry.

However, there is good news too! The Superior Watershed Partnership (SWP) has developed the Lake Superior Climate Adaptation, Mitigation and Implementation Plan specifically for coastal communities in the Upper Peninsula of Michigan. The plan provides a summary of current conditions, potential impacts and recommendations for mitigating and adapting to climate change in the Lake Superior watershed.

In addition, the SWP and project partners have initiated the most important part of any plan…working directly with coastal communities to identify and prioritize on-the-ground projects and outreach activities to better prepare for a changing climate. The SWP is also assisting communities in securing funding in order to implement high priority climate projects as soon as possible.

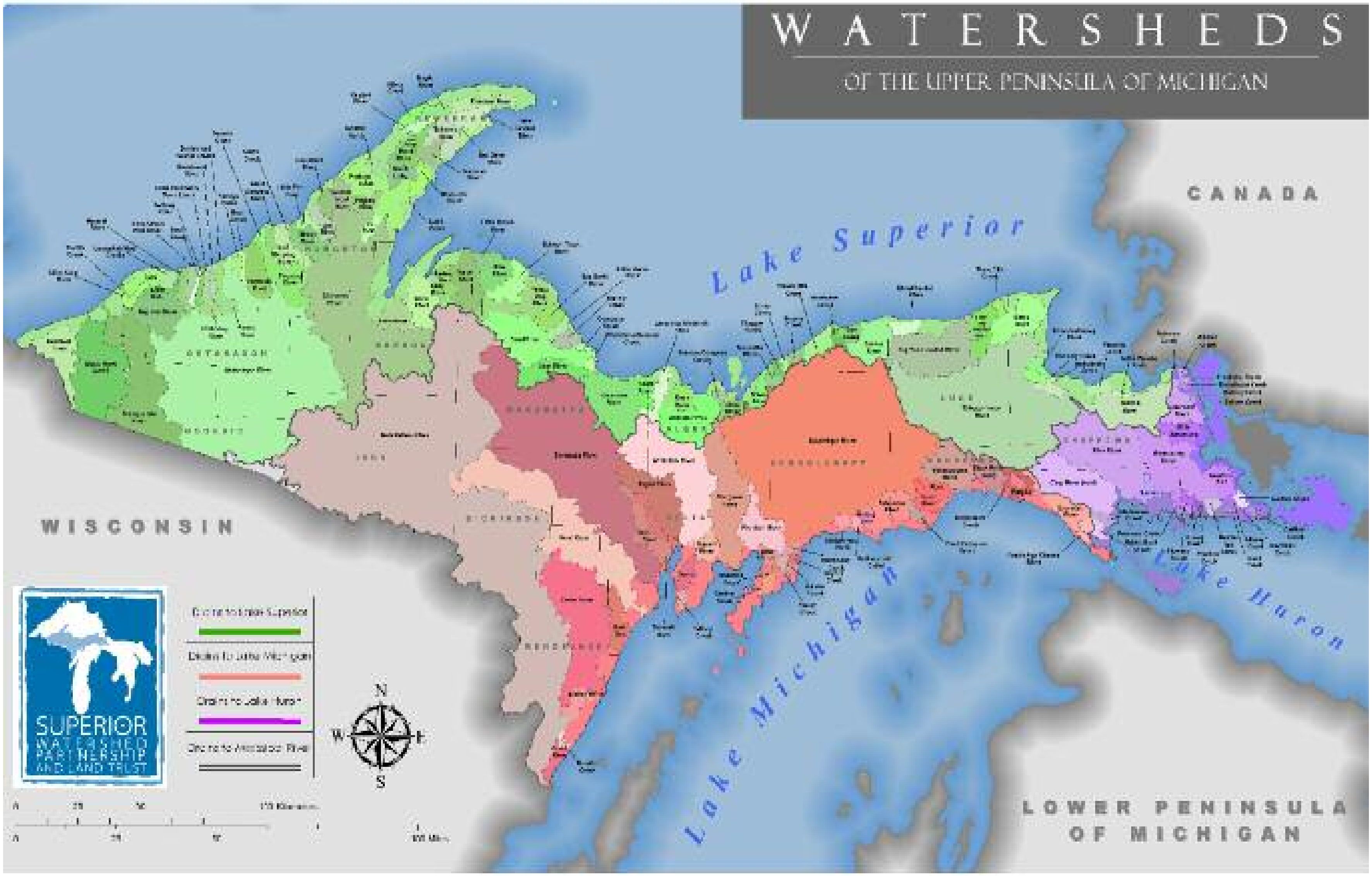
For almost twenty years the SWP has been working with communities to promote watershed protection and restoration (storm water management, energy conservation, wetland restoration, water conservation, buffer restoration, land use planning, community education and more). Did you know that most of the practices in “watershed planning” are the same practices now recommended in “climate planning”? So, the good news is that many Upper Peninsula communities are already ahead of the game when it comes to preparing for climate change (Marquette is just one example)!

But there is more to do and the time for action is now! Please accept this climate adaptation, mitigation and implementation plan as the starting point for your community to become more “climate resilient”. The SWP is available to assist your community in identifying and prioritizing specific projects and action steps. Please do not hesitate to contact the SWP for more information. There really is no time to waste!

Sincerely,

Carl Lindquist

Carl Lindquist, Superior Watershed Partnership


WATERSHEDS
OF THE UPPER PENINSULA OF MICHIGAN
CANADA
Lake Superior
WISCONSIN
Lake Michigan
Lake Huron
LOWER PENINSULA OF MICHIGAN
SUPERIOR WATERSHED PARTNERSHIP AND LAND TRUST
N
S
W
E

INTRODUCTION

The Upper Peninsula (UP) is a vast and unique bioregion of deep woods and pristine inland lakes — a mosaic of unspoiled wild lands that include sheltered bogs and fens, dense hemlock groves, towering cliffs, secluded beaches, famous waterfalls and crystal clear trout streams. Moose and wolf wander through rich forests of white birch and maple, spruce and fir. With over 4.5 million acres of land open to the public, perhaps no other area in the Midwest offers so many opportunities for outdoor recreation and solitude.

This region's special character has been shaped primarily by the presence of Lake Superior, which exerts a powerful, almost oceanic effect on the UP's climate. Cold, clear and nearly untouched by human development or visible pollution, Lake Superior's moderating effect on the environment results in generally cooler summers and warmer winters compared to other northern regions. This creates a rich diversity of microclimates and habitats where rare plants thrive. Deep lake-effect snows provide needed cover for various animal species. The lake's legendary storms sculpt both rock and sand, creating magnificent national treasures such as the colored cliffs of Pictured Rocks National Lakeshore.

But like other natural ecosystems around the world, Lake Superior (as well as the Upper Peninsula in general) is feeling the effects of climate change. The lake has warmed 4.5° F degrees in only 30 years, a fact that astonished the scientists who studied it.[1] Air temperatures have also risen and if these trends continue, Michigan could have a summer climate similar to Missouri and Arkansas by the end of the century (Fig. 1).[2] The resulting changes will have significant consequences for infrastructure, human health, and the economy. Additionally, shifts of natural plant and animal communities would greatly change the UP's unique forests, wetlands and coastal ecosystems that currently draw millions of tourists each year.

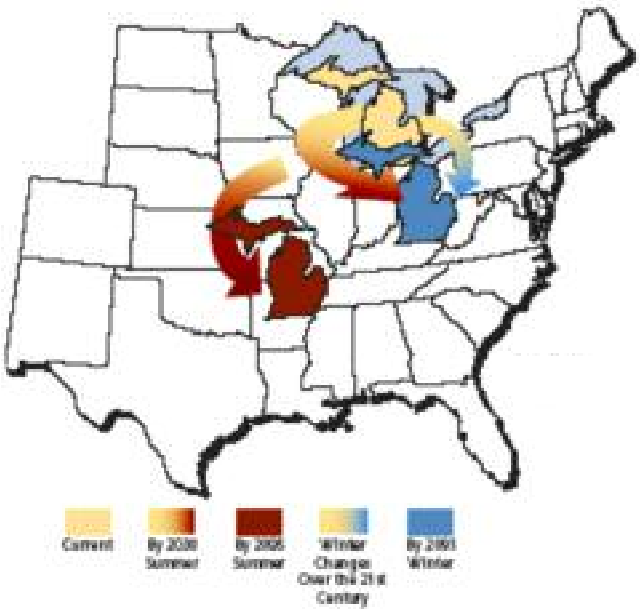


Fig. 1: Migrating Climates - Union of Concerned Scientists

Michigan's Upper Peninsula is a distinctive part of the Midwest due to its vast expanses of open land and sparse population. It includes about a quarter of Michigan's land area, but only 3 percent of the population (300,000). Over 84 percent of the land is covered by large forested tracts.[3] Agriculture is limited by the amount of suitable land, soil conditions and long, harsh winters. The majority of land is available for public access, which is unusual for any state east of the Mississippi. Nearly half of its 10.5 million acres are held in federal, state or county forests and parks.[4] For rural counties like Alger and Baraga with no large cities, there are about 60 acres per person, compared to the average for the whole state: 3.6 acres per person.

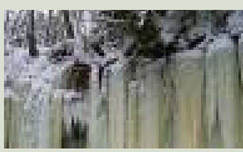
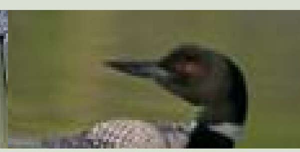
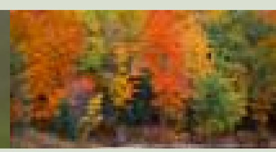
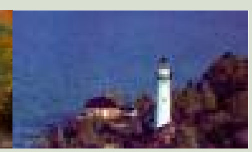
The largest city is Marquette (population 21,355 as of the 2010 census); other large towns are Sault Ste. Marie, Escanaba, Menominee, Iron Mountain and Houghton. The Upper Peninsula is an area that has been hit hard by declining population and unemployment. Of the 15 UP counties, 12 had a decline in population between the 2000 and 2010 censuses. Non-farm employment fell in all but one county, in some cases by as much as 60%.[5] Most jobs have traditionally been in the timber, mining and tourism industries. This is an area that is ripe for new economic opportunities, which climate change adaptation could provide by expanding "green" jobs in the clean energy industry and through infrastructure improvement projects.

This plan primarily encompasses those UP counties that contain the Lake Superior Watershed. About 94 smaller UP watersheds (59% of total) drain into Lake Superior, with the rest flowing into Lake Michigan and Lake Huron. Eleven of the UP's 15 counties have watersheds that drain in Lake Superior (Fig. 2). Michigan has 917 miles of Lake Superior shoreline — nearly twice as much as the other two states that border the lake: Wisconsin and Minnesota.

Due to Lake Superior's ability to modify climate, generate large amounts of snow and create a variety of microhabitats, its watershed has unique characteristics that distinguish it from the rest of the Upper Peninsula. **Therefore, this Plan will focus on climate change adaptation concerns and actions specific to the Lake Superior Watershed, its ecosystems and its human inhabitants.**

What's Special Here in the Upper Peninsula's Lake Superior Watershed?

- Lake Superior, the world's largest freshwater lake
- Pristine shoreline cliffs, beaches, bays and dunes
- Hundreds of sparkling inland lakes and streams
- Millions of acres of forest accessible to the public
- Wilderness habitat for moose, wolf and loon
- Snow capitol of the Midwest
- Unparalleled winter sports, fairs and festivals
- Boreal forest habitats for rare Arctic plants and other species
- Wild blueberries, wild cranberries and wild rice
- Pictured Rocks National Lakeshore, Hiawatha and Ottawa National Forests
- Nearly 200 waterfalls that draw visitors in summer and winter
- Historic lighthouses, shipwrecks and Native American sites
- Spectacular fall color season
- Seney National Wildlife Refuge

REGIONAL CLIMATE CHANGE ADAPTATION PLANNING

The Superior Watershed Partnership and Land Trust (SWP) in partnership with the Model Forest Policy Program's Climate Solutions University (CSU) began working on a climate change adaptation plan in the winter of 2011 for Alger County in Michigan's Upper Peninsula. The SWP, a regional leader in freshwater protection, participated in CSU's rigorous course work, gathered and assessed a variety of data, and solicited the help of other regional experts to create a comprehensive climate adaptation plan for Alger County. The Alger County Plan served as the catalyst and foundation for the development of this Regional Plan.

Many stakeholders were involved in creating this Plan, including Pictured Rocks National Lakeshore, the Forestland Group, LLC, U.S. Forest Service, Northern Institute of Applied Climate Science, local business owners and concerned citizens.

Seeking to enhance existing climate change efforts in the Lake Superior Watershed, and to serve as a model for communities around our state, the following broad goals were developed sing a risk assessment framework:

- Assist communities to prepare their infrastructure, built environment, health and human services for predicted climate changes.
- Strengthen the region's main economic bases, tourism and timber, by helping communities minimize negative climate change impacts on these industries, and take

Marquette Energy Conservation and Climate Mitigation Program:

The Superior Watershed Partnership and the City of Marquette have collaborated to offer the Better Buildings for Michigan Program to all city residents. This community approach to energy efficiency provides Marquette residents with a low cost energy assessment and generous financial incentives to install energy upgrades (insulation, solar panels, windows, furnaces, etc.). The Marquette Program has assessed over 675 homes to date, installed over a million dollars in energy efficiency improvements and is currently leading the state of Michigan in community participation.

For more information: www.superiorwatersheds.org

advantage of positive opportunities.

- Protect the Lake Superior shoreline from damage due to fluctuating lake levels, increased lake storm action, habitat loss and poorly regulated human development.
- Increase the ability of wetlands to withstand climate changes such as flooding, drought and intense storm events through on-the-ground projects and effective watershed management. Protect habitat for cold-water stream fish. Minimize damage from invasive aquatic species.
- Maintain forest ecosystem integrity, overall health and resilience. Protect habitat for specific endangered and vulnerable plant and animal species, and minimize damage from invasive species.
- Promote public education and awareness of the effects of climate change and the benefits of taking action through adaptation and mitigation strategies.

SWP will lead the implementation efforts and collaborate closely with its partners to carry out these education, policy and on-the-ground forest and water activities. SWP has been working with partners U.S. Environmental Protection Agency's Great Lakes Restoration Initiative and the National Park Service on mitigating greenhouse gas emissions throughout the UP. While this Plan focuses on adaptation, SWP is committed to a multi-pronged approach that includes education, mitigation and adaptation.

Climate Mitigation Success Story

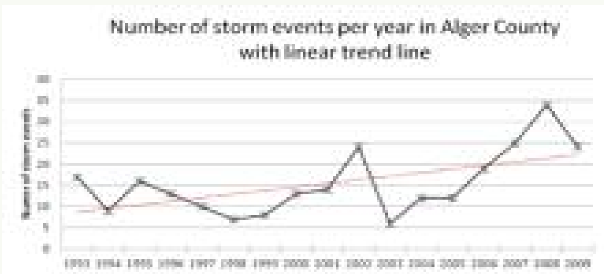
The SWP in cooperation with Pictured Rocks National Park coordinated the Alger Energy Saver's program which installed over 3,100 energy efficiency measures in Alger County residents' homes, and inspired almost 95% of participants to either take, or plan to take, next steps to improve their home energy efficiency. The AES business program provided energy assessments for 30 businesses and distributed over 520 free energy efficiency measures and matching funding to motivate businesses to take further energy efficiency steps. As part of the release of the National Park Service's Green Parks Plan, the initiative was highlighted as a success story for other national parks to replicate.

http://www.nps.gov/sustainability/parks/index.html

http://www.superiorwatersheds.org/energysavers.php

Storms on the Rise

The number of storm events per year is increasing in the Upper Peninsula.[11] Warmer air holds more moisture than cooler air, and this additional moisture provides "fuel" for extreme precipitation events. Storms in the Midwest increased by 31% over the past century. This is the second highest increase of any region of the country and well above the national average of 22%.[12]



CHANGES AND IMPACTS

Scientists for the Intergovernmental Panel on Climate Change (IPCC) have concluded that climate change due to the burning of fossil fuels is occurring, with a variety of results that can be measured and documented.[6] The global average surface temperature has risen 1.4° F in the last 100 years, and the rate of warming has doubled from the previous century. Around the world, glaciers are melting, polar arctic ice is disappearing, sea level is rising and extreme weather events now linking to climate change are increasing in frequency and intensity. Animals have been shifting their ranges pole-ward on all continents and significant changes in algal, plankton and fish abundance in high-latitude oceans have been observed.[7]

Temperatures have also increased significantly in the UP. Temperature data collected in Munising, MI since 1900 shows that the 2000s were the hottest decade, with temperatures rising 2.7° F over the historical average of the previous century. The 1990s were the second hottest decade, and the 1980s were the third hottest (Fig 3).[8] Summer temperatures in the Great Lakes region are projected to rise by between 5° F and 20° F by 2100. Already, temperatures in the region have warmed by almost 4° F in the 20th century — much faster than the global average.[9] Warmer and drier summers are causing drought conditions, which stress forest and agricultural resources and will result in greater fire danger in the future — currently rare in the UP's cool, moist woodlands. The summer of 2011 was one of the driest in Upper Peninsula history, with some areas reporting record drought.[10]

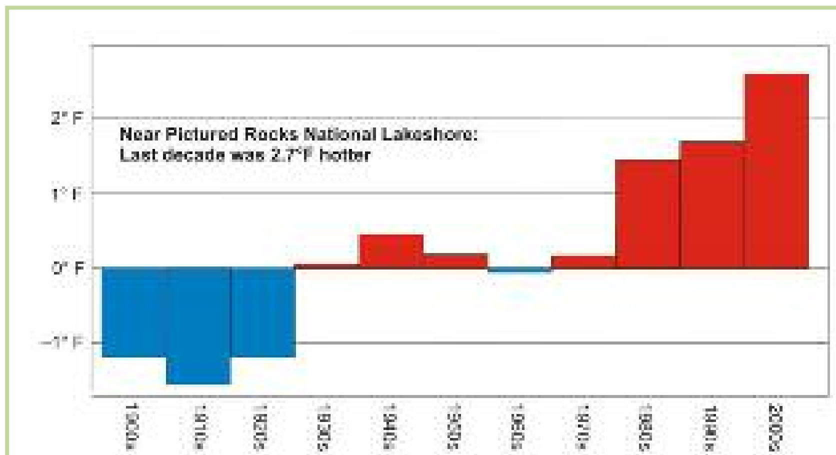


Fig. 3: Temperature Increase by decade in Alger County, MI.

Winter temperatures have also increased, resulting in a shorter winter season and fewer days with snow on the ground. While annual snowfall totals have been slowly increasing in the Superior Watershed region over the past couple of decades, predictions are for snow to melt more quickly and remain on the ground for shorter durations – a phenomenon already being noticed in parts of the UP for the past few years.

The effects, both psychological and economic, of the decline of snow cannot be overstated; "snow culture" is one of the defining characteristics of life in the Upper Peninsula. Its loss would have a profound impact on quality of life, winter tourism and local economics. Studies show that spring is arriving earlier each year and that plant hardiness zones are moving north. At least 15 bird species have advanced their spring arrival dates by one to eight weeks.[13] Animals such as cardinals, turkeys, opossum and mourning doves have migrated northward to the Upper Peninsula as winters have become milder. Certain trees species, such as Sugar Maple and Aspen, are already showing the effects of stress due to drought conditions that may be linked to climate change. Local residents have noticed more intense storm events in recent years, which scientists recently have been (cautiously, but with increasing confidence) connecting with climate change.

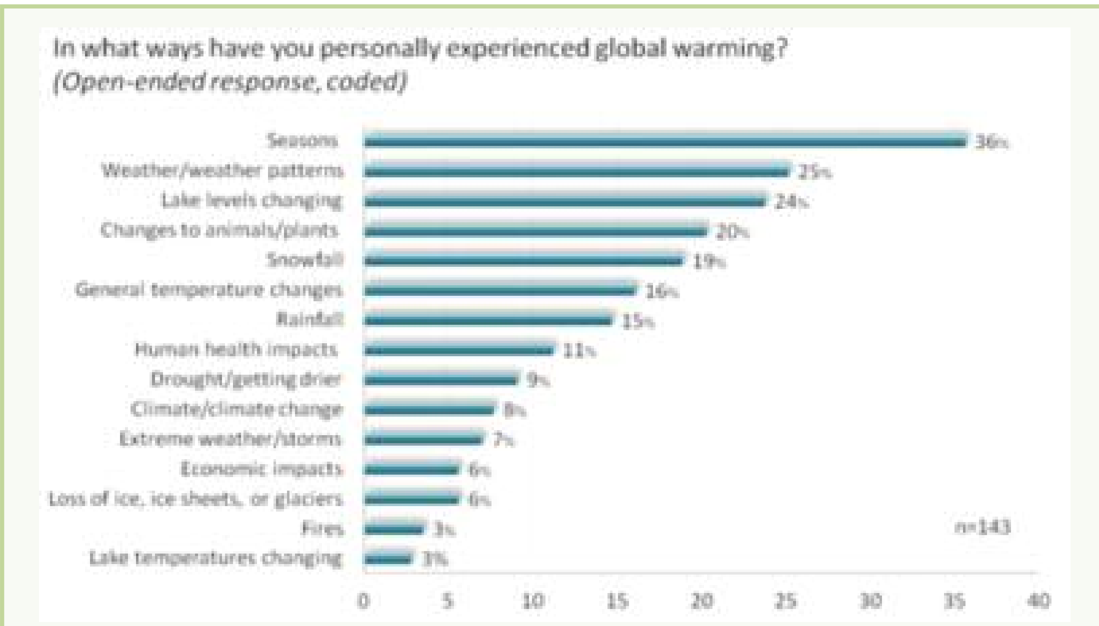


Fig. 4: Results of Alger County Climate Change Survey

Community Environmental Monitoring Program (CEMP)

The US Environmental Protection Agency recently reported that the Lake Superior watershed (US and Canada) is currently the most active region in the world for mining exploration and new mining operations. This is especially true for the Upper Peninsula of Michigan. The SWP has initiated a new program in cooperation with the Marquette County Community Foundation (MCCF) to monitor the potential impacts of the new Rio Tinto nickel and copper mine in Marquette County. The Community Environmental Monitoring Program or CEMP conducts independent monitoring of air quality, surface water, groundwater, wildlife and other potential impacts including climate change. CEMP also invites community input regarding additional monitoring. For more information on this globally unprecedented community program visit www.cemp.org or www.superiorwatershed.org.

Upper Peninsula residents are noticing other climate change trends in their daily lives. During a 2010 survey conducted by George Mason University, Center for Climate Change Communication, Alger County residents reported a variety of local changes they personally had observed or experienced. (Fig. 4.)[14]

Although effects will vary throughout the region, climate scientists have made general predictions for the upper Great Lakes, including Michigan's Upper Peninsula.[15] Not all climate changes are "negative" — some may have positive effects, including increased economic opportunities. All will have consequences to different degrees. Impacts of climate change on various sectors of the Lake Superior Watershed and its resources are explored in following sections.

A summary of these predictions (Fig. 5) highlights the main anticipated effects on both natural and human environments. It is important to note that many of these changes will add stress to species and habitats already challenged by other long-standing threats to the environment, such as habitat loss, pollution, human disturbance and disease.

Fig. 5: Climate Change Predictions for the Upper Great Lakes, including the Upper Peninsula

General Climate Change Predictions for the Upper Great Lakes	Predicted Impacts on Natural Ecosystems, Plants and Animals	Predicted Impacts on Human Environment, Health, Economics
• Warmer, drier summers; warmer, wetter winters. • Continuing increase in air and water temperatures. • Spring coming earlier/first autumn frost coming later. • Shorter winters in general. • Annual increase in precipitation, but overall the region will get drier due to warmer summers and increased evaporation. • More winter precipitation as rain; perhaps more sleet/ice and more "rain on snow" episodes. • Wetter springs followed by small summer droughts. • Unreliable lake-effect snow; may have more intense episodes, but snow may not last. • Possible decline in snow depths overall; less days with snow on the ground. • Later freeze-up and earlier ice break-up and snow melt. • Less ice cover on Lake Superior; more wave action, increased evaporation. • Increasing storm intensity; more downpours, more flooding.	• Habitats will shrink or disappear for species at the edges of their ranges. • Cold water fish habitat declines; warm water fish habitat increases. • Change in forest tree composition; decline of several species such as Sugar Maple, Birch and Jack Pine. • New species moving northward into region; but overall a net loss of current species. • Increases in non-native invasive plants, animals, forest pests and diseases • Changes in phenology, potentially disconnecting some critical ecological interactions • Increased danger of forest fires. • Habitat for endangered species, such as Kirtland's Warbler and Pitcher's Thistle likely to be negatively impacted. • Drying of ephemeral wetlands • Risk of degradation and damage to wetlands due to flooding, erosion and siltation. • Increased damage/erosion to Lake Superior beaches and cliffs due to increased wave action. • Lower Lake Superior water levels. • Possible damage to whitefish eggs in Lake Superior due to loss of ice cover; diatom population also impacted.	• Longer summer recreation season; opportunities for increased tourism economy. • Shorter winter recreation season; decline in winter tourism will affect local economy. • Increased cost of living in summer due to air conditioning; decline in winter due to lower heating costs. • Fluctuating lake levels will threaten shipping and infrastructure. • Navigation hazards possibly exposed. • Recreational fishing quality will change. • Increased health problems due to heat events; more allergies, more asthma, more biting insects. • Severe weather events/ flooding affecting built environments. • Disruption to city services due to intense storms, flooding, and infrastructure damage. • Need for greater emergency services; impacts on energy and communication service. • Changes in outdoor recreation; more summer water sports, less snowmobiling and ice fishing, more "silent" winter sports. • Risk for degradation of cultural resources, such as shipwrecks, historic buildings. • Increase in green job opportunities and alternative energy. • New opportunities for agriculture, fishing, shipping, timber products.

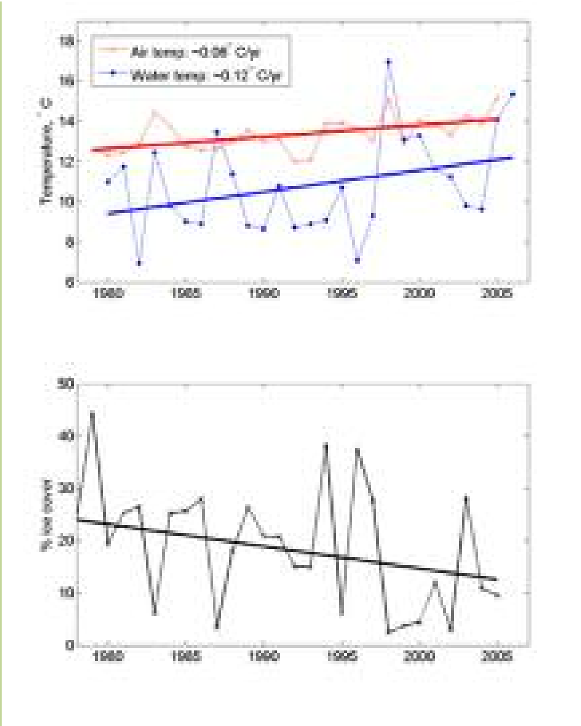
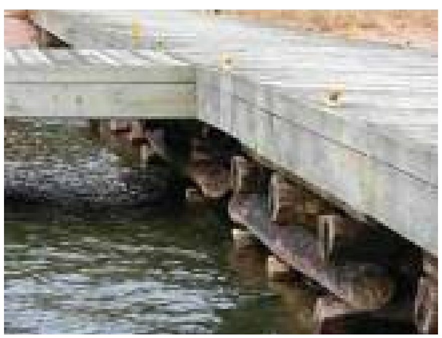


Fig. 6: Lake Superior Temperature Rise and Ice Cover



Lake Superior

Lake Superior itself is an immense ecosystem that wields great impacts on the lands that border it. It is the world's largest freshwater lake (by surface area), measuring 31,700 sq. miles. It is 350 miles long by 160 miles wide; the deepest point is 1,333 ft.

In 2007, studies by Dr. Jay Austin and colleagues at the University of Minnesota Duluth revealed that Lake Superior has been warming quicker than expected, about 4.5° F since 1980. This is almost twice as fast as air temperatures in the region over that same time period.16 Much of the lake warming is due to reduced ice cover, which has also been declining during the past 30 years (Fig. 6). The warmest surface lake temperature ever recorded was 71° F in 2012.

Loss of ice allows the lake to absorb more sun energy in winter as sunlight hits open dark water instead of reflective ice. Warming water transmits heat to nearby ice, which melts and creates more open water – causing the effect to accelerate. Some models predict that Lake Superior would have periods of little to no open-lake ice in a typical winter by typically ice-free in winter by 2040[17]. While the lake may still freeze over in certain years, the trend is toward more ice-free winters. During Marquette's warmest March on record (March, 2010) some hardy people took a plunge into ice-free Lake Superior on St. Patrick's Day!

A warming lake also means higher surface winds and more evaporation. Lake levels are lower than the historic average and have been for the past decade. During summer of 2011, the lake was 11 inches below the long-term norm for that time of year.[18] Until recently, levels were primarily determined by fluctuations in precipitation. However, many climate scientists now believe that increased evaporation rates due to warmer air and water temperatures are playing an ever-increasing role in lowering Lake Superior's water level.

Still, there is a great deal of complexity in determining the future of lake levels. Some models show a continuing decline, which would greatly affect commercial shipping and shoreline infrastructure. A loss of an inch in water depth translates into a loss of 270 tons of cargo for large vessels.19 Locks and berths may become too shallow. (On the other hand, longer ice-free periods will extend the shipping season and increase business opportunities.) At low water levels, recreational infrastructure such as fixed docks become too high to adequately accommodate boats, and ramps have to be extended. Navigational hazards are exposed and costly dredging becomes necessary. Cultural treasures such as shipwrecks in shallow water are at risk for air exposure and increased deterioration.

Warming waters will eventually have an effect on the lake's ecosystem and adjacent shore areas. Cold-adapted fish such as whitefish and lake trout may find themselves competing with fish better adapted to warmer conditions. Loss of ice cover could jeopardize whitefish reproduction in Lake Superior where ice protects eggs from winter storm disturbance. Diatoms (simple plankton that make up the base of the lake food chain) also fare better in winter when protected by a layer of ice. The federally endangered piping plover and Pitcher's thistle may be negatively impacted as increased wave action alters shorelines.

Warming also increases the amount of time the lake is "stratified" in summer, meaning that oxygen-rich upper layers do not mix with the oxygen-poor regions at the lake's depths. Temperature changes in fall allow Lake Superior (and inland lakes as well) to "roll over" and mix water at all levels. This is an essential process for oxygen to reach the lake's biologically productive lower levels. There are concerns that as the length of summer stratification increases, there is greater risk of oxygen depletion and formation of deep-water "dead zones" for fish and other organisms.

Greater storm runoff in watershed areas may deposit nutrients that will fuel algal blooms. (A visitor to Pictured Rocks National Lakeshore told a park ranger that this was the first time in 20 years he had ever seen algae on one of the park beaches.)

More alarming, warm temperatures and increased nutrients could also increase abundance of invasive species such as zebra mussels, which currently are limited in Lake Superior's cold, nutrient-poor water. Extremely prolific zebra and quagga mussels have already caused a great deal of environmental disruption in the other great lakes. Thousands of birds along Lake Michigan have died from eating these small mussels, which concentrate lake toxins in their tissues. Lake Superior currently contains 87 non-native animal species — of these 27 (including zebra mussel, spiny waterflea and sea lamprey) are considered economic and environmental threats.20

Sea lamprey is of particular concern, as it is one of the greatest threats to Lake Superior fisheries. Warmer waters are likely to increase production of sea lamprey, an invasive predator of native fish, particularly lake trout. Scientists predict that a warming trend will increase the lamprey's breeding and feeding cycle. Sea lamprey will increase in size and be more effective predators for a longer period of time each year.

As the Upper Peninsula experiences longer summers and shorter, milder winters, it may well become a more attractive destination for retirees and people looking to move from increasingly hot climates further south. This could result in unprecendented development along the Lake Superior shoreline and inland lakes as well. Careful planning is needed to

Algal bloom

Zebra Mussel

Spiny Waterflea

Sea Lamprey

prevent the loss of natural shoreline features, wetland degradation, habitat fragmentation, pollution threats to water resources and increased potential for flooding.

Wetlands

The Upper Peninsula has an abundance of wetlands, a gift left over from Michigan's robust glacial history. In addition to Lake Superior, water resources dot the landscape in the form of inland lakes, rivers, streams, bogs, fens, marshes, and tamarack/spruce swamps. This great variety of habitats supports abundant (and sometimes rare) plant and animal life. Healthy wetlands are essential waterfowl and amphibian breeding grounds. Young fish depend on them for shelter and food production. Moose forage in shallow pools for their favorite aquatic plants in spring and summer. Loons seek out quiet, undisturbed lakes where they can build their ground nests at the water's edge. Forested watersheds are essential to habitat and quality in the tributaries that feed Lake Superior.

Michigan's unspoiled wetlands also provide opportunities for fishing, boating and other water sports. Hiawatha National Forest alone contains more than 400 lakes. Nearly all of Michigan's 200 named waterfalls are in the UP and they draw visitors from all over the world. Several species of trout are important to the region's ecology, as well as the tourism industry. Anglers often travel great distances to reach some of the UP's more remote and pristine trout streams. However, as water temperatures in these streams rise, trout numbers could decline.

Warming temperatures will cause shallow wetlands to evaporate and shrink. As lakes dry they often create new wetlands along their edges; however, the quality of these new wetlands is hard to predict. Increased rain and storm events may trigger flooding, which would deposit silt in streams and marshes, degrade wildlife habitat and cause erosion to stream banks. Damaged wetlands have a limited ability to hold future storm water. Healthy wetland habitat needed by breeding wildlife may well decrease. Earlier ice breakup and early spring runoff could change flow pattern, timing and intensity. The UP's distinctive conifer lowlands (wet, boggy areas dominated by tamarack, black spruce and white cedar) are highly vulnerable to water level changes and will be stressed as wetland drying increases.

Recent studies have also shown wetlands to be an important ally in the fight against climate change. Like forests, wetlands are CO_2 sinks, absorbing and holding carbon. While wetlands also emit methane, a major greenhouse gas, over time they have a positive net effect on the fight against climate change through their carbon storage — as long as they are healthy.[21]

Wild Rice in Jeopardy

Perhaps no plant along Lake Superior is more important to Native American communities than wild rice. Known as *manoomin*, this sacred wetland plant has profound cultural and spiritual significance — and it's threatened by climate change. Wild rice is highly vulnerable to fluctuating water levels. Low water turns the rice beds into mud flats. Too much rain and intense storms cause flooding. Warm summers make the rice more susceptible to disease. Also, wild rice is a hardy northern plant and it needs cold winters in order for the seed to break dormancy.

Forests

Besides Lake Superior, the characteristic that best defines the Upper Peninsula is its forests. Moderated by Lake Superior, this region exists at the northern range of the beech-maple forest zone and the southern edge of the boreal spruce-fir zone. This overlap provides a rich diversity of tree species and a variety of habitats for understory plants and forest animals. The economic value of UP forests for tourism and the timber industry cannot be overstated. There are over 12,000 jobs in the UP associated with forest products industries, and almost 20% of the total industry output/sales in the UP come from these industries.[22] Forests are also enormously important as natural sinks for carbon dioxide. All plants use carbon dioxide during photosynthesis, transforming it into food energy and wood cellulose, and releasing oxygen as a byproduct. Healthy forests hold a great deal of carbon, releasing it slowly when trees die and decay.

As Michigan warms, cold-adapted trees will be stressed, which will make them more susceptible to forest pests and disease. Common northwoods species at risk for the largest decline of suitable habitat, coupled with higher sensitivity to climate-related disturbances such as soil drying, fire and higher air temperatures, include black spruce, balsam fir, quaking aspen, yellow birch, white birch, sugar maple, eastern hemlock and tamarack.[23] Eventually, they may no longer be able to tolerate the changing climate conditions, and will shift north. Trees more common to southern Michigan, such as oaks and hickories, will move in. However, the success of trees to "migrate" is currently being debated. Forests might therefore simply shrink in size. Ironically, Michigan's state tree, the white pine, may someday no longer be able to thrive in Michigan.

As plants rely on specific temperature and precipitation ranges, longer droughts, more flooding events and heat waves outside their normal range will stress them. In addition, less predictable winters with warm spells may cause trees and other vegetation to come out of dormancy, which increases their vulnerability to future cold snaps.

The Upper Peninsula's extremely valuable timber industry could be at risk as trees become strained by climate change conditions such as drought, fire and storm damage. Stressed trees are more vulnerable to invasive forest pests and diseases, such as the emerald ash borer and gypsy moth. Beech bark disease is currently decimating beech trees throughout the region.

Other pests not currently found in the UP but of concern include the hemlock wooly adelgid and the Asian longhorn beetle, which could move into the area in the future. While the presence of forest pests is not a direct result of climate change, a warmer, drier climate pro-

Arctic Visitors under Stress

Climate change threatens the existence of delicate cold-loving plants that are able to live in the Upper Peninsula because of Lake Superior's ability to keep summers cool. Known as **arctic disjuncts**, these are hardy plants whose normal range is far to the north in Canada, but they have found an "arctic-like" home in the colder, sheltered pockets of UP forests.

Arctic Crowberry and **Dwarf Raspberry** are two of just a handful of arctic disjuncts found in the Upper Peninsula. Listed as State Threatened on Michigan's Natural Features Inventory, they will likely disappear from the state if warming trends continue.

Arctic Crowberry (*Empetrum nigrum*)

Dwarf Raspberry (*Rubus acaulis*)

vides a more hospitable environment and longer reproductive season for pests. Disruption to the timber industry would have serious negative economic impacts on much of the UP. Diminished forest habitat would also affect the endangered Kirtland's warbler, threatened gray wolf and games birds such as partridge and grouse.

Warming temperatures will alter ecological relationships between forest plants and animals. For example, Canada yew is a plant that provides good nesting cover for songbirds such as warblers and sparrows. Deep snows protect Canada yew from being decimated by white-tailed deer. Canada yew is already in decline in the upper Great Lakes due to land clearing, ground fires and deer population growth. Diminished snow cover due to climate change could extirpate remaining populations, with unforeseen ecological consequences.

There are also concerns that long-distance bird migrants, such as wood warblers, will be out of sync with their spring insect prey, as these insects hatch earlier in a warming forest. Tanagers, warblers, thrushes and flycatchers may be at risk if local birds lay eggs and consume resources before these migratory birds even arrive.

Built Environment

Roads, buildings, bridges, stormwater control systems and other man-made structures will also be impacted by coming climate change, in both negative and positive ways. For example, wetter, heavier winter snows might overload weaker roofs, and erratic freeze/thaw events could damage roads. Intense storms could bring down power lines and cause flooding. Residents will need air conditioning as heat spells become more common. On the other hand, milder winter temperatures would result in lower heating bills. Snow removal costs might decrease. Impending climate change may be just the stimulus needed for communities to make long-needed improvements to their buildings and infrastructure in terms of strength, resilience and optimum energy efficiency.

Erratic and intense weather conditions will affect human-built structures. Increased precipitation in the form of intense downpours will challenge culvert capacity and other floodwater control systems. Roads may be impassable due to high water or downed trees. Docks may need costly renovations to adjust to lower lake levels.

Roads are at risk from increased degradation and damage due to intense storm events and occurrence of freeze/thaw situations that are predicted. If lake-effect snow events and ice/sleet conditions increase in frequency, this will challenge snow-removal and maintenance efforts in many communities. Furthermore, road maintenance, specifically snow management and removal itself, negatively affects the road surface quality and directly impacts the "green buffers" that separate highways from forests and wetlands through potential erosion and diminished ability to shed water effectively.

Irreplaceable cultural treasures such as lighthouses, historic houses and Native American sites are at risk for damage and deterioration due to weathering, erosion, flooding and wind. While UP communities are used to and well prepared for snowy winters, climate change may produce more ice and sleet than usual, which will bring new challenges to infrastructure maintenance.

Human Health and Services

Human health concerns and quality of life are extremely important aspects of climate change adaptation planning. More summer heat spells are expected as temperatures rise, with related health problems especially for the young and elderly. Higher humidity and an increase in ground-level ozone (moving into the area from large urban areas further south) may result in more poor air quality days. If forest fires increase, drifting smoke will cause respiratory distress for some residents. Higher temperatures often result in more allergies and asthma.

A warming climate is likely to increase the number of insects in the UP, and there will be a longer season for biting flies and mosquitos. Vector-borne illnesses, such as West Nile virus will become more prevalent. Ticks that carry Lyme disease have been steadily moving north, taking advantage of milder winters. Lyme disease ticks showed up for the first time on Isle Royale in Lake Superior — a location long thought to be much too cold for them to live.[24]

Extreme heat has also been linked to psychological stress and an escalation of domestic violence. Communities also need to be prepared for the emotional distress people experience when confronted by storm damage, flooding and other serious disruptive natural events. Winter too will bring is its share of health concerns. Wetter snows make shoveling more hazardous. Ice on roads results in treacherous traveling conditions. If winter tourism declines as predicted, economic worries will cause stress in many communities.

Erratic weather conditions such as storms, heat, and flooding can disrupt city services and therefore tourist vacations as well, impacting local economies. Communities need to be prepared for electrical outages and possible contamination of water supplies due to weather-related events. Traffic patterns, communications and energy supply might all be affected. Police, fire and ambulance services may be in higher demand. Roads could be blocked in the event of an emergency — or they may be covered in ice, which will hamper quick response. Public health and emergency service plans throughout the region need to be reviewed and updated in light of predicted changes.

The Economy

Communities in the UP depend heavily on both timber and tourism for their economic survival. The abundance of natural resources, scenic beauty and opportunities for recreation are the UP's greatest assets — however, most counties are struggling with rising unemployment and population decline. Climate change will bring about both threats and opportunities to every aspect of the economy.

Threats to the timber industry include an increase in invasive pests, changes to forest tree composition due to shifting temperature ranges, and stresses to tree health from drought, soil erosion due to flooding, increased fire risk and storm damage to tree crowns and limbs. Weather impacts to roads and infrastructure such as flooding could impede shipping.

The UP's reputation as the "Snow Capitol of the Midwest" is an economic asset that could be challenged by climate change. Of all tourism concerns, winter recreation that depends on consistent deep snow or ice (such as ice fishing) is most vulnerable as temperatures warm. Lake Superior moderates winter air temperature over much of the UP and therefore bitter cold is rare. Often just a few degrees separates snow from rain – if temps go up even slightly, snow will change to rain and create poor conditions for winter recreation.
Many communities rely on income from winter festivals that include snowmobile and dogsled races. In February 2011, the Upper Peninsula's celebrated UP 200, a dog sled race that services as a qualifier for the Iditarod, was cut short in Alger County due to lack of snow and poor conditions, costing businesses tourism income they were depending on. In February 2012, poor snow conditions again altered this event. The annual February Michigan Ice Festival in Munising took place with temperatures above freezing, and attendance at the event was down from the previous year.

Snowmobiling, a large part of the winter economy in watershed communities, has been down for the past few years due to poor snow and better conditions further south in Michigan.

Summer tourism will likely experience a boom if temperature increases are moderate and the UP enjoys long periods of pleasant summer conditions. The experience of "years without a summer" may come to an end as the climate along Lake Superior loses its "cool summer" reputation, and more boaters, swimmers and campers head to the area for their vacations.

Heat waves and high humidity however will inhibit visitation, as there is a certain point when it is too hot and uncomfortable for people to enjoy outdoor recreation. Campers and hikers will need to be prepared for a longer biting fly and mosquito season. Storms and winds may bring down trees, blocking access to popular hiking trails and waterfalls, which happened several times at Pictured Rocks National Lakeshore during the summer of 2011. Increased summer tourism will create a demand for more hotel/motel/property rental space, as well as opportunities for outdoor recreation supplies and services. The ability to meet the needs and expectations of visitors will be crucial to continued economic success. Aside from tourism, prospects in climate-adaptation based job growth (such as green technologies, alternative energy, infrastructure needs, building energy efficiency, new products and services, etc.) may prove beneficial to communities struggling with increasing unemployment and declining population. At the same time municipalities will need to create support services for people who lose their jobs due to climate change, such as businesses that rely on a reduced winter tourism season.

SYNTHESIS OF RISKS AND VULNERABILITIES

In order to determine appropriate adaptation goals and actions for this Plan, it was necessary to assess the level of ***Risk*** climate change is likely to bring to both natural resources and the human experience. In the following tables (Fig. 6 and 7, next page), ***Risk*** conveys both the **probability** and the **impac**t of the occurrence. Once the ***Risk*** was determined, it was necessary to assess the ability to cope with these impacts when and where they occur. The **ability to cope** is referred to as ***Vulnerability***.

Risks and ***Vulnerabilities*** were ranked as ***L*** (low), ***M*** (medium), or ***H*** (high). A High Risk category, such as flooding, indicates that an impact is both highly likely to occur and expected to have significant consequences. Conditions with a low ability to cope by either people or the ecosystem, such as shoreline/beach erosion, received a High vulnerability rating. It should be noted that impacts that received ***M/Hs*** or ***H/Hs*** denote scenarios that deserve the most focus and therefore guided the development of this Plan's goals and action steps.

In the following tables, the top anticipated changing climate conditions are analyzed for their impacts on natural resources and their impacts to the human population.

Projected Climate Changes	Risk/ Vulnerability	Impacts to Natural Resources	Risk/ Vulnerability
Seasonal and Weather Changes			
• Summers will be hotter, drier and longer	H/M	• Longer agricultural growing season	M/M
• Autumns will be warmer, last longer, and be wetter	M/M	• More flooding issues due to increased rain	H/M
• Winters will be shorter and milder	H/M		
• Springs will be wetter and longer	L/M		
• Increase in severe weather events	M/H		
Water Resources			
• Warming water temperatures	M/H	• Increased water temperatures will increase stress on cold-adapted fish such as salmon and lake trout	M/L
• Less ice on Lake Superior and inland lakes	M/H	• More invasive aquatic species due to warmer water	M/H
• Lake levels dropping	M/L	• More waves on Lake Superior due to lack of winter ice, leading to erosion of cliffs and beaches	M/H
• Increased turbulence on Lake Superior	M/M	• Lower lake levels may threaten shipping industry	M/L
		• Threats to wetlands due to lack of proper zoning ordinances or management plans	H/H
Forest/Wildlife Resources			
• Increase in invasive pests	M/M	• Pests and invasives not regulated by cold snaps	M/M
• Drought and changes to soil conditions	M/H	• Increased deer population	M/L
• Habitats likely to shift	H/H	• Decline in tree species, such as Sugar Maple, Hemlock, Paper Birch	M/M
		• Habitat for endangered and threatened species such as Kirtland's Warbler, Pitcher's Thistle, Piping Plover, and Gray Wolf will be negatively impacted.	H/H

Projected Climate Changes	Risk/ Vulnerability	Impacts to Human Population	Risk/ Vulnerability
Seasonal and Weather Changes • Summers will be hotter, drier and longer • Autumns will be warmer, last longer, and be wetter • Winters will be shorter and milder • Springs will be wetter and longer • Increase in severe weather events	H/M M/M H/M L/M M/H	• Increased summer tourism affecting hospitality • Decreased winter festivals, such as the U.P. 200 Dogsled Race, affecting hospitality industry. • Increased cost of living in summer (i.e. air conditioning) • Decreased cost of living in winter • Disruption to communities that do not have a solid emergency management plan for increasingly severe weather events	L/L H/H H/M L/L M/H
Water Resources • Warming water temperatures • Less ice on Lake Superior and inland lakes • Lake levels dropping • Increased turbulence on Lake Superior	M/H M/H M/L M/M	• Lower lake levels may threaten shipping industry • Damage to property as shorelines erode • Diminished cold water fish species may threaten sport/commercial fishing opportunities • Increased tourism opportunities for fresh water surfing and wind surfing, emerging sports in Great Lakes region	M/L M/M M/H L/L
Forest/Wildlife Resources • Increase in invasive pests • Drought and changes to soil conditions • Habitats likely to shift	M/M M/M H/H	• Pests and invasives not regulated by cold snaps • Increased deer population • Decreased tree population, specifically Sugar Maple, will negatively impact timber products industry and autumn tourism	M/M M/L H/H

GOALS AND ACTIONS

Climate Change Adaptation **Goals** and **Actions** for this Plan have been established in several categories. These goals and actions correspond to each of the sectors identified earlier as vulnerable to climate changes, and are found in Figure 8. For each action, the matrix includes the following information:

- **Time Frame**. These actions are labeled as either short term (ST) or long term (LT). Short term actions can be expected to be complete within three years, while long term actions are expected to occur more than three years in the future.
- **Type of Action**. Each adaptation action has been assigned to one of four action categories:
  - ***Outreach*** – actions related to increasing communication and collaboration between regional entities, counties, towns, and/or citizens
  - ***Research*** – actions related to study topics that should be undertaken in the near-term in order to identify and prioritize future actions
  - ***Policy*** – actions related to revising or creating policies or regulations that encourage behaviors that support adaptation
  - ***Action*** – "on the ground" projects or programs to help the region or locality adapt to climate change
- **Level of Action**. This section of the matrix identifies whether the action can be taken at the regional, county, or town level. In many cases, more than one level may apply to the action. In most of these cases, coordination will be required between the different levels of governance to achieve the stated goals for the region. For example, SWP can work with county or local officials to conduct prerequisite research or help implement a number of actions at the county or municipal levels.

In general, these goals and actions seek to minimize the negative effects of climate change throughout the watershed by promoting resistance and resilience of the region's natural systems, and by assisting human communities as they prepare for predicted changes. Some broader goals and actions will apply throughout the Lake Superior Watershed region; others are specifically targeted for the needs and resources of counties and communities.

Eleven of the UP's 15 counties have watersheds that drain in Lake Superior, and these counties can use this matrix as a starting point to develop customized goals and actions specific to their most important vulnerabilities: Alger, Baraga, Chippewa, Gogebic, Houghton, Keweenaw, Luce, Mackinac, Marquette, Ontonagon, and Schoolcraft. These towns and cities in the watershed can customize the goals and actions listed in the matrix to best address the needs of their individual vulnerabilities: Ironwood, Ontonagon, Houghton, Hancock, Copper Harbor, L'Anse, Marquette, Munising, Grand Marais, and Sault Ste. Marie.

SWP will take a leadership role in assisting with implementing these actions, working closely with many cooperating partners, stakeholders and other interested groups including:

- National Park Service
- U.S. Forest Service
- Michigan Department of Natural Resources
- Michigan Department of Agriculture
- County Chambers of Commerce
- Forest Products Industry Leaders
- County and Municipal Officials
- Northern Michigan University
    - Center for Economic Education and Entrepreneurship
- Michigan Technological University
- Regional School Boards
- Indian Tribal Groups
- School forests
- County Boards
- US Fish and Wildlife Service
- County/public health departments
- Tourism agencies: GreatWaters, UPTRA, Travel MI
- Environmental organizations
- Invasive/weed management groups
- Michigan natural features inventory
- Michigan State University extension, soil conservation districts, NRCS
- University/college natural resource classes

Fig. 8: Goals and Actions for the Lake Superior Watershed Region

GOALS AND ACTIONS FOR THE LAKE SUPERIOR WATERSHED REGION							
Sector	Goals	Actions	Time Frame	Action Type	Applicable to…		
					Region	Counties	Towns
All Sectors		• Hold meetings with public officials in communities to discuss how they can make climate readiness a routine part of future planning processes.	ST	Outreach	✓	✓	✓
		• Implement monitoring or data collection activities to develop a baseline against which to compare future changes.	ST	Action	✓	✓	✓
Lake Superior (and other water bodies)	**Protect the Lake Superior shoreline from damage due to fluctuating lake levels, increased lake storm action, habitat loss, and poorly regulated human development.**	• Determine projected changes in water levels and storm surge extents in the area.	ST	Research	✓		
		• Identify and map critical habitat to be protected along the Lake Superior shoreline.	ST	Research	✓	✓	✓
		• Identify beach/dune areas along shore in need of habitat restoration and resilience work. Secure funding to accomplish work.	ST	Research	✓	✓	✓
		• Expand existing programs and create new programs to restrict spread of invasive species in Lake Superior, including zebra and quagga mussels, sea lamprey, and spiny waterflea.	ST	Action	✓	✓	
		• Implement at least one habitat restoration project in each county, incorporating climate change impacts.	ST	Action	✓	✓	
		• Re-establish and maintain physical stability of streams. Protect river corridors and floodplains to accommodate river adjustment and floodplain processes.	ST	Action	✓	✓	✓
		• Remove barriers to aquatic organism passage.	ST	Action	✓	✓	
		• Devise grey water storage and reuse systems to recycle and utilize water resources more efficiently.	ST	Action	✓	✓	✓
		• Research current set-back ordinances and other zoning standards regarding shoreline development. Present recommendations to appropriate governing boards.	ST	Research	✓		
		• Establish shoreline protection zones for new development.	LT	Policy		✓	✓
		• Establish and enforce shoreline setback requirements.	LT	Policy		✓	✓

GOALS AND ACTIONS FOR THE LAKE SUPERIOR WATERSHED REGION							
Sector	Goals	Actions	Time Frame	Action Type	Applicable to…		
					Region	Counties	Towns
		• Place limits on density and infrastructure in coastal and transitional zones.	LT	Policy		✓	✓
		• Establish new street grade and building first floor elevation requirements that exceed current town, state, and FEMA standards.	LT	Policy			✓
		• Increase building "free board" above base flood elevation.	LT	Policy		✓	✓
		• Institute conservation rate pricing for water.	LT	Policy		✓	✓
		• Adopt net-zero runoff site plan requirements.	LT	Policy	✓	✓	✓
		• Establish policies that set new infrastructure farther back from water bodies and retain naturally vegetated buffers.	LT	Policy	✓	✓	✓
		• Develop State of Michigan-approved watershed management plans for priority watersheds in each county.	LT	Policy		✓	
		• Remove structures that harden coastlines, impede natural regeneration of sediments, and prevent natural inland migration of sand and vegetation.	LT	Action	✓	✓	✓
Wetlands	**Increase the ability of wetlands to withstand climate changes such as flooding, drought and intense storm events through on-the-ground projects and effective watershed**	• Develop working relationships with land-use agency staff and identify wetland adaptation projects on public lands to support and/or fund.	ST	Outreach	✓	✓	✓
		• Identify, map and prioritize wetland areas most vulnerable to flooding, erosion, siltation, degradation and invasive species.	ST	Research	✓	✓	✓
		• Assess status of current watershed plans in region and work with partners to update them to reflect climate change considerations.	ST	Research	✓	✓	
		• Incorporate climate change considerations into all habitat restoration planning.	ST	Policy	✓	✓	✓
		• Expand existing and create new programs to restrict spread of invasive aquatic plant and animal species in both Lake Superior and inland wetlands. Involve the public in on-the-ground projects.	ST	Action	✓	✓	✓

GOALS AND ACTIONS FOR THE LAKE SUPERIOR WATERSHED REGION							
Sector	**Goals**	**Actions**	**Time Frame**	**Action Type**	**Applicable to…**		
					Region	**Counties**	**Towns**
	management. Protect habitat for cold-water stream fish. Minimize damage from invasive aquatic species.	• Conduct targeted wetland restoration.	LT	Action	✓	✓	✓
Forests	**Maintain forest ecosystem integrity, overall health, and resilience. Protect habitat for specific endangered and vulnerable plant and animal species, and minimize damage from invasive species.**	• Develop working relationships with state and federal land-use agencies and other interested groups to identify forest adaptation projects to fund/support.	ST	Outreach	✓	✓	✓
		• Hold meetings with interested timber industry leaders to discuss predicted climate change impacts on infrastructure as it will affect the timber industry.	ST	Outreach		✓	✓
		• Create comprehensive mapping and inventory of region's forested land, focusing on location of microhabitats at risk, rare plants, fragmentation, migration corridors, etc.	ST	Research	✓	✓	✓
		• Form a temporary working group among interested stakeholders to create a five-year collaborative plan to address issues of forest fragmentation, deer management, invasive species and pest infestations.	ST	Policy		✓	
		• Expand existing programs and create new programs to eradicate and restrict spread of invasive species and forest pests. Involve the public in on-the-ground projects.	ST	Action	✓	✓	✓
		• Incorporate climate change considerations in all habitat restoration projects and forest management plans.	LT	Policy	✓		
		• Require sustainable forest management plans for all commercial logging.	LT	Policy	✓	✓	✓

GOALS AND ACTIONS FOR THE LAKE SUPERIOR WATERSHED REGION							
Sector	**Goals**	**Actions**	**Time Frame**	**Action Type**	**Applicable to…**		
					Region	**Counties**	**Towns**
		• Institute a ban on clear-cutting on existing forested areas for building lots and create standards for preparing a forested site for development.	LT	Policy		✓	✓
Built Environment	**Assist communities to prepare their infrastructure, built environment, health and human services for predicted climate changes.**	• Identify and prioritize communities in the region that would be in most need of assistance.	ST	Research	✓		
		• Inventory areas of infrastructure (roads, bridges, culverts, etc.) vulnerable to climate change impacts.	ST	Research	✓	✓	✓
		• Research roadway materials that are more tolerant to quick changes in hot or cold weather in order to decrease repair costs, enhance safety, and increase longevity of road surfaces.	ST	Research	✓		
		• Study design standards for buildings that currently handle weather conditions similar to those forecast for the Lake Superior Watershed (to help develop future building codes).	ST	Research	✓		
		• Identify low-risk areas that would allow for the safe burial of existing power lines to avoid power interruption from extreme weather events.	ST	Research		✓	✓
		• Continue to expand regional energy-efficiency programs for both residential and commercial buildings.	ST	Action	✓	✓	✓
		• "Lead by example" in government buildings by demonstrating how to reduce building energy demand to reduce peak electricity loads during extreme temperatures. This can be done through passive design, new building materials, improved insulation, etc.	ST	Action		✓	✓
		• Encourage development green infrastructure such as green roofs, rain barrels, rain gardens, permeable paving, swales, and water retention ponds.	ST	Action	✓	✓	✓
		• Promote green stormwater management, such as through a utility fee rate structure where rates are determined by the amount of impervious area on a property (e.g., Ann Arbor, MI).	LT	Policy	✓	✓	✓

GOALS AND ACTIONS FOR THE LAKE SUPERIOR WATERSHED REGION							
Sector	Goals	Actions	Time Frame	Action Type	Applicable to...		
					Region	Counties	Towns
		• Adopt building design standards that better reflect future climate conditions.	LT	Policy		✓	✓
		• Promote pitched roofs and incorporate design standards that consider snow stacking and ice falling zones.	LT	Policy		✓	✓
		• Incorporate building materials that improve the longevity of construction into building code requirements.	LT	Policy		✓	✓
		• Revise design standards for hydraulic structures like culverts and drainage systems.	LT	Policy		✓	✓
		• Improve existing energy conservation standards by a minimum of 25% through implementation of appropriate codes for commercial and residential development.	LT	Policy			✓
		• Utilize more climate-friendly roadway materials in infrastructure projects.	LT	Action	✓	✓	✓
Human Health and Services	**Collaborate and promote public education and awareness of the effects of climate change and the benefits of taking action through adaptation and mitigation strategies.**	• Identify all relevant major stakeholders in the region and meet with select groups to discuss their specific needs and concerns regarding climate change.	ST	Outreach	✓		
		• Assess readiness of local emergency response, public health, social services, communications, and energy plans to cope with projected climate changes.	ST	Research	✓		✓
		• Identify essential emergency services that are located in flood zones or that could be isolated by flooding and take action to ensure reliability of services.	ST	Research			✓
		• Review and update all county-wide emergency response and hazard mitigation plans; identify vulnerabilities and make recommendations for future improvements.	ST	Policy	✓	✓	
		• Collect regional climate change-related research for public dissemination.	ST	Action	✓		

GOALS AND ACTIONS FOR THE LAKE SUPERIOR WATERSHED REGION							
Sector	Goals	Actions	Time Frame	Action Type	Applicable to…		
					Region	Counties	Towns
		• Create an online regional newsletter to disseminate scientific findings and climate change assessments, warnings, tips, resources, etc. to all stakeholders on a regular basis.	ST	Action	✓		
		• Create generic climate change brochures, flyers and other written materials to be distributed region-wide.	ST	Action	✓	✓	
		• Write a series of articles about climate change for local newspapers, focusing on local impacts and educating the public on adaptation issues.	ST	Action		✓	✓
		• Create a public information booth and relevant displays/written materials to take to local fairs, special events, festivals, schools, etc.	ST	Action	✓	✓	✓
		• Develop a method for counties to share important weather and environmental conditions with the public on a regular and consistent basis, such as thin ice, snowmobiling conditions, and hazardous road conditions.	ST	Action	✓	✓	
		• Increase and expand current beach monitoring activities to detect presence of pathogens that could affect human health.	ST	Action			✓
		• Monitor specific locations for presence of ozone; determine appropriate monitoring activities.	ST	Action		✓	
		• Educate the public about mosquito and tick protection and disease prevention.	ST	Action	✓	✓	✓
		• Educate the public about any new emergency warning systems and response plans.	LT	Outreach	✓	✓	✓
		• Implement early warning systems and emergency response plans for extreme storms, floods, heat waves, poor air quality days, disease outbreaks, and test them.	LT	Action	✓	✓	✓
		• Establish a Reverse 911 automated call-back system in the community to notify residents of evacuation routes or other information in the event of an emergency.	LT	Action			✓

GOALS AND ACTIONS FOR THE LAKE SUPERIOR WATERSHED REGION							
Sector	**Goals**	**Actions**	**Time Frame**	**Action Type**	**Applicable to…**		
					Region	**Counties**	**Towns**
		• Identify alternate routes and modes for goods transportation and evacuation during emergency situations.	LT	Action		✓	✓
		• Connect emergency centers with onsite renewable energy systems to reduce susceptibility to lapses in the conventional energy supply.	LT	Action		✓	✓
		• Designate shelters for extreme cold and warm weather events, and advertise them to the public, particularly low-income residents and the elderly.	LT	Action		✓	✓
		• Modify disease surveillance programs to include potentially new disease risks due to climate change.	LT	Action	✓	✓	✓
Economy	**Strengthen the region's main economic bases, tourism and timber, by helping communities minimize negative climate change impacts on these industries, and take advantage of positive opportunities.**	• Hold meetings with local business leaders to initiate discussion and awareness of specific climate change concerns in each sector.	ST	Outreach	✓	✓	✓
		• Track economic trends for the region for a specific time period to gather important economic data that currently does not exist.	ST	Research	✓		
		• Identify vulnerable breeding grounds for cold-water fish such as brook trout. Obtain funding for and conduct habitat improvement activities where appropriate.	ST	Research	✓	✓	
		• Secure funding for and conduct feasibility studies on using locally and sustainably produced forest byproducts, creating new products and technology, and other methods to promote the local timber industry.	ST	Research		✓	✓
		• Research potential for bringing new investors in green technology, manufacturing, alternative energy or eco-friendly retail businesses into the region.	ST	Research	✓	✓	✓
		• Based on community discussion, develop a five-year plan and specific goals to help local businesses minimize economic losses and take advantage of increased tourism opportunities.	LT	Policy	✓	✓	✓

ADAPTATION OPTIONS FOR LAKE SUPERIOR COMMUNITIES

For each of seven categories, we present a selection of adaptation options that have been proposed or implemented in communities similar to those in the Lake Superior Watershed. Many options have benefits across sectors or categories, but are grouped according to their primary goal. Within each category, we have also identified whether any research would be required in order to carry out these adaptation measures.

Adaptation Option Categories:

Agriculture
Forestry
Coastal
Water
Land-Use Planning
Infrastructure
Public Health and Emergency Preparedness

Agriculture

- Educate and provide technical assistance to farmers as needed to introduce new crop varieties which might better suit evolving climate conditions.
- Increase the diversity of crops grown on local farms, as well as genetic diversity within crop species, to help farmers increase resilience to pathogen or weather-related stressors.
- Quarantine invasive and noxious plant species and pests.
- Identify and protect prime agricultural soils through ordinance, conservation measures, or other protection measures.
- Support local food initiatives through existing initiatives and state purchasing efforts.
- Develop a food security plan and work to increase local food production by working with farmers, protecting soils, and encouraging farmer's markets and food co-ops.

Research Needs:

- Identify crops that will be well-suited to future climate conditions (e.g., heat-tolerant, drought-tolerant, flood-tolerant).

Forestry

- Reduce non-climate stresses on forests, and maintain forest health through invasive plant management, reduced frequency of harvests, etc.
- Require sustainable forest management plans for all commercial logging.
- Create a ban on clear-cutting existing forested areas for building lots and create standards for preparing a forested site for development.
- Maintain or improve forest connectivity.
- Protect forest species diversity by retaining biological legacies during harvest, using intermediate treatments that enhance stand health and diversity, and allowing for appropriate recovery periods between regeneration harvests.
- Include climate change adaptation strategies in long-term and annual forest management plans.
- Preserve urban forest canopies, which filter air pollutants, absorb water to alleviate stormwater pollution, and moderate urban temperatures.

Coastal Sector

- Establish a comprehensive planning and zoning policy, considering projected water level changes:
  - Establish and enforce shoreline setback requirements
  - Place limits on density and infrastructure in coastal and transitional zones
  - Site and design all future public works projects with these projections in mind
- Establish new street grade and building first floor elevation requirements and infrastructure elevation that exceed current town, state and FEMA standards.
- Increase building "free board" above base flood elevation.
- Remove structures that harden coastlines, impede natural regeneration of sediments, and prevent natural inland migration of sand and vegetation.
- Establish policies that set new infrastructure further back from water bodies and retain naturally vegetated buffers to protect the infrastructure from the predicted higher frequency and magnitude of flooding and lake level fluctuations.

Research Needs:

- Determine projected changes in water levels and storm surge extents in the area for which these actions will be recommended.

Water Sector

- Devise grey water storage and reuse systems to recycle and utilize water resources more efficiently.
- Institute conservation rate pricing for water.
- Improve lakeshore protection and ecologically appropriate shoreline stabilization policies.
- Re-establish and maintain physical stability of streams. Protect river corridors and floodplains to accommodate river adjustment and floodplain processes.
- Protect and restore vegetated buffers on lakes, streams, and wetlands.

Land Use and Planning

- Adopt smart growth principles in the community's comprehensive master plan.
  - E.g., Revise conservation subdivision regulations to create incentives for developers to provide greater densities and community services in this type of development, while achieving open space conservation.
- Protect land from development to preserve vegetation, retain hydrologic features, and ecological services through:
  - Land acquisition through purchase
  - Conservation easements
  - Purchasing development rights
  - Establishing overlay zones, which apply additional regulations to development within the zone, such as setbacks, lot sizes, and impervious surface.
- Promote wetland protection through:
  - Evaluating existing wetland restoration policies and programs
  - Targeted wetland restoration
  - Dam removal or management
- Adopt net-zero runoff site plan requirements.
- Provide technical assistance and incentives for habitat management to landowners.
- Remove barriers to aquatic organism passage.

Research Needs:

- Conduct a hydrologic study to identify hydrologic areas most vulnerable to climate change and develop management plans for those areas.

Infrastructure

- Promote more pitched roofs and incorporate design standards that consider snow stacking and ice falling zones. This protects against structural damage from severe weather events.
- Incorporate building materials that improve the longevity of construction into building code requirements. This will improve the strength and durability of construction against a range of weather conditions.
- Increase airport runway lengths. Runways may need to be longer in the case of higher temperatures and/or changing wind patterns.
- Revise design standards for hydraulic structures like culverts and drainage systems.
- "Lead by example" in government buildings, demonstrating how to reduce building energy demand to reduce peak electricity loads during extreme temperatures. This can be done through passive design, new building materials, improved insulation, etc.
- Research and utilize roadway materials that are more tolerant to quick changes in hot or cold weather in order to decrease repair costs, enhance safety, and increase longevity of road surfaces.
- Develop green infrastructure such as green roofs, rain barrels, rain gardens, permeable paving, swales, and water retention ponds (see Great Lakes plan pages 15-16 for examples of local-level success stories).
- Promote green stormwater management, such as through a utility fee rate structure where rates are determined by the amount of impervious area on a property (e.g., Ann Arbor, MI).
- Require that utilities are buried in new construction during the construction phase. Underground utilities are less prone to disruption from extreme weather events.

Research Needs:

- Identify a new 100- or 200-year floodplain (which can be used to inform future development).
- Study design standards for buildings that currently handle weather conditions similar to those forecast for the Lake Superior Watershed (to help develop future building codes).
- Identify areas where increased infrastructure capacity is needed to manage stormwater.
- Identify low-risk areas that would allow for the safe burial of existing power lines to avoid power interruption from extreme weather events.

Public Health and Emergency Preparedness

- Identify alternate routes and modes for goods transport and evacuation during emergency situations.
- Address loss of cellular service and identify other means of communication that can be used when conventional systems are down.
- Establish a Reverse 911 automated call-back system in the community to notify residents of evacuation routes or other information in the event of an emergency or disaster (10 towns in New Hampshire currently have it in place).
- Connect emergency centers with onsite renewable energy systems to reduce susceptibility to lapses in the conventional energy supply.
- Designate shelters for extreme cold and warm weather events, and advertise them to the public, particularly low-income residents and the elderly.
- Implement early warning systems and emergency response plans for extreme storms, floods, heat waves, poor air quality days, disease outbreaks, and test them.
- Educate the public about any new emergency warning systems and response plans.
- Educate the public about mosquito and tick protection and disease prevention.
- Modify disease surveillance programs to include potentially new disease risks due to climate change.
- Monitor air, water, and soil quality for hazardous exposures following foods, windstorms, and wild fires.

Research Needs:

- Identify new diseases, vectors, or other public health risks that may be introduced to the region with a changing climate.
- Inventory telephone land-line availability in local business and residences to improve the reliability of emergency communications during severe weather events.

ANTICIPATED OUTCOMES

Implementation of this Plan will benefit the Lake Superior Watershed region by fostering resiliency and sustainability within natural ecosystems, maintaining environmental integrity, educating local residents, strengthening local business and industry, and preparing communities to minimize the negative impacts of climate change while capitalizing on emerging opportunities. It provides a road map for ensuring healthy water and forest resources, and in turn creates an economically viable region, one mindful of protecting its most precious assets.

It is anticipated that effective actions will:

- Help communities identify economic opportunities and reduce negative economic impacts from climate change.
- Assist local communities to update their municipal plans in preparing for climate change impacts.
- Provide climate change education through collaboration with public schools, local units of government, private industry and other vested agencies.
- Protect 612 miles of Lake Superior shoreline from further damage due to fluctuating lake levels, increased lake storm action, habitat loss, and poorly regulated human development.
- Strengthen the ability of wetlands to resist change due to flooding, drought and temperature rise.
- Update existing watershed management plans to reflect climate change concerns and create new ones where needed.
- Protect the breeding grounds of cold water fish species, such as the brook trout, Michigan's State Fish.
- Decrease the presence of both terrestrial and aquatic invasive species.
- Maintain the integrity and continuity of watershed forests.
- Protect habitat for threatened and endangered species such as the piping plover, Kirtland's warbler and gray wolf.
- Encourage climate change consideration to be part of all future habitat restoration and land-use management planning throughout the region.

THE ECONOMY

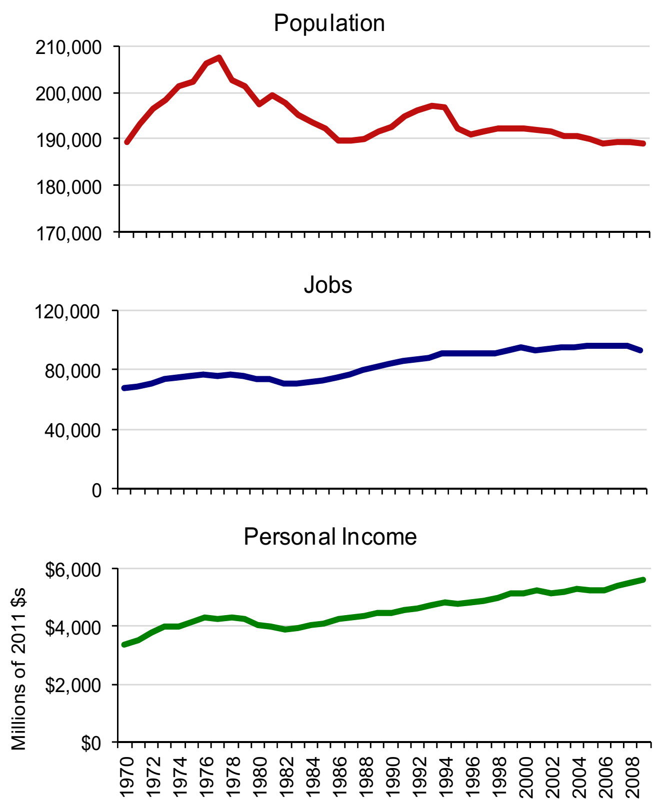
The economy of Michigan's Upper Peninsula has struggled in the most recent recession, but overall has performed as well if not better than the state of Michigan as a whole. Natural resources and extensive—and spectacular—public lands support tourism, timber, and mining industries. In addition there are three universities in the Upper Peninsula that offer a wealth of technical assistance on related climate issues (Northern Michigan University, Michigan Technological University and Lake Superior State University). Long-term fluctuations in population indicate the volatile nature of natural resource industries, and reliance on tourism and the timber industry, in particular may make the region more sensitive to the impacts of a changing climate.

This section describes key economic sectors and demographic characteristic of counties that might be sensitive to the impacts of a changing climate. The purpose is to start a conversation about new challenges and opportunities facing the region, and how communities might use climate, demographic, and economic data to inform economic development activities.

Over time, the population of the nine counties facing lake Superior has waxed and waned following booms and busts in the mining industry in the 1970's and subsequent ups and downs following the business cycle. In the last ten years three counties gained population (Marquette 3.8%, Houghton 1.7%, and Baraga 1.3%), and six experienced population declines (Ontonagon -13.3%, Keweenaw -6.3%, Luce -5.6%, Gogebic -5.4%, Alger -2.6%, and Chippewa -.1%). Overall Michigan was the only state to lose population in the last decade.

Employment trends followed the booms and busts in the 1970's, but jobs have increased steadily up to the onset of the national recession in 2007. This may indicate some decoupling from natural resources as the economy diversifies, but also reflect women entering the workforce at higher rates, and more people holding two or more jobs.

Long-Term Trends in the Nine Lake Superior Watershed Counties, 1970-2009

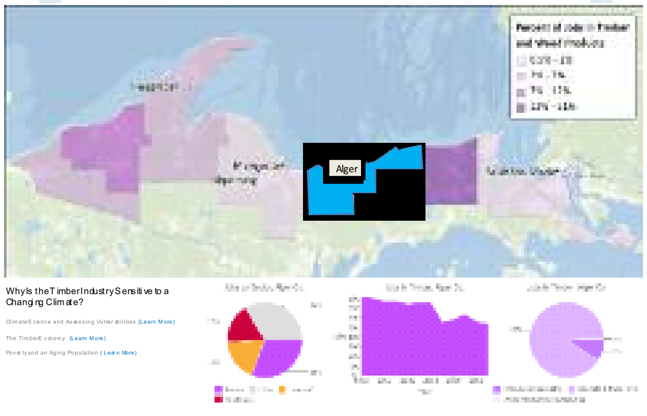


Population followed mining booms and busts in the 1970's, and subsequent ups and downs following the business cycle. The total population ended at 188,895 in 2009.

Jobs grew by 26,196 between the end of the national recession in the early 1980's to the onset of the recession in 2007, decoupling from mining and diversifying along the way. From 2007 to 2009, the economy lost 3,291 jobs and unemployment remains at 10.4 percent in 2012.

Personal income trended with employment until 2007 when income continued to grow, largely from non-labor income including retirment and medical transfer payments, and unemployment benefits.

Interactive Tool for Exploring Economics Sensitivity to Climate Change



The Superior Watershed Partnership and Headwaters Economics have developed an interactive tool that compares economic and demographic variables across the nine Lake Superior Watershed counties covered in this adaptation plan. The tool provides detailed links to additional information on climate science, socioeconomic profiles, and regional planning resources.

The tool can be accessed at [www.headwaterseconomics.org/superior watershed](www.headwaterseconomics.org/superiorwatershed)

High unemployment in recent years poses challenges similar to those facing rural areas nation-wide. Despite high unemployment, the region outperformed a horrific decade for Michigan. A new mining boom and the slow national recovery are starting to lift regional employment.

Personal income in the nine-counties continued to rise through the recession showing the contributions of non-labor income that made up 46 percent of all personal income in 2009. Dividends, interest, and rent (investment earnings) made up about a third of non-labor income while transfer payments from the government made up about two-thirds of non-labor income. Nationally, investment earnings and government transfer payments are about equal components of non-labor income, indicating a relatively greater dependence on government payments in the region. The majority of transfer payments include retirement and medical payments (Social Security, Medicare, and Medicaid), while only about 15 percent came from welfare and unemployment benefits (or about 7 percent of total personal income).

The importance of non-labor income is also apparent as average wages per job rose by 2.3 percent from 2000-2009 (adjusted for inflation) while per-capita income rose by 11.3 percent over the same period.

In addition to the potential impacts of climate change on important economic sectors, impacts related to the built environment and health and human services can impose costs and affect jobs and income. A growing elderly population that is more sensitive to climate related impacts, and a high percent of individuals and families below poverty that have reduced access to health care and other services can have economic impacts. The UP is well served via the use of entitlements, FQHC's County Hospitals and Private Hospitals and Clinics, but these services are potentially threatened in national budget and deficit discussions. As fuel prices rise and transportation, utility, and health care services are potentially exposed to increased incidences of severe weather, conversations about increased resilience in regional infrastructure and services are a key aspect of climate adaptation, and economic development and resilience over the long-term.

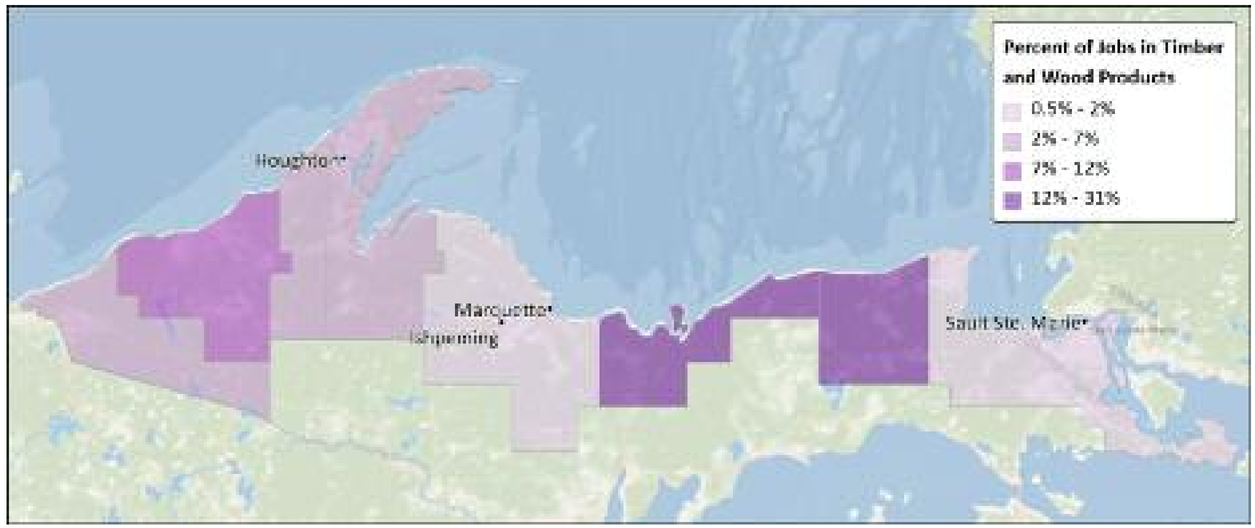
This next section profiles two economic sectors sensitive to climate change, the timber industry and industries including travel and tourism. It also provides demographic data on vulnerable populations, highlighting potential vulnerabilities and challenges facing the health care sector and community services. A series of maps and graphics show where these industries are most important in terms of their contribution to total employment by county.

The Timber Economy

The timber industry employs 1,848 people, not including about 240 proprietors working in the industry. In total, the industry accounts for four percent of all jobs in the nine Lake Superior Watershed counties in 2009. Job losses in the industry are likely coming from three points: mechanization including technology advancements in harvesting; the national housing slump and reduced demand for timber; and oversupply in the pulp and paper industry. Technology will continue to have an impact on job creation and skill requirements regardless of changes in price and demand for timber. However, the industry shows considerable stability and capacity despite the impacts of the national recession, and will likely remain an important sector of the economy in the future.

Map 1: Percent of Jobs in Timber and Wood Products

Map 1: Percent of Jobs in Timber and Wood Products



Alger and Luce counties will be disproportionately affected by potential new costs and further job losses. Alger county has 31 percent of all jobs in the timber industry in 2009, and in Luce county 17 percent of jobs were in timber in the same year. By comparison, only 4 percent of all jobs in the region are in timber. Houghton (3%), Keweenaw (2%), Marquette (1%), and Chippewa (<1%) counties have relatively few jobs in timber and will be less affected by potential impacts.

Threats to the timber industry include an increase in invasive pests, changes to forest tree composition due to shifting temperature ranges, extended drought, soil erosion due to flooding, increased fire risk and acute damage to infrastructure and forests from more frequent and more intense storms. These new challenges will further stress an industry that has lost more than 1,000 jobs over the last decade.

A study conducted by the University of Maryland, Center for Integrative Environmental Research also suggested the timber industry could suffer large economic impacts. The main climate related impacts include a shift in the range of forest tree species northward and greater damage from tree pests and disease. For example, the emerald ash borer, gypsy moth,

Figure 1: Percent of Jobs in Timber and Wood Products

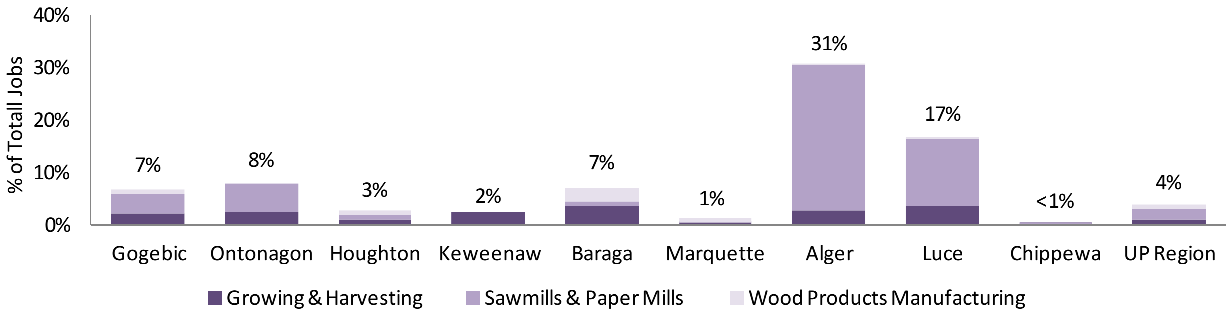
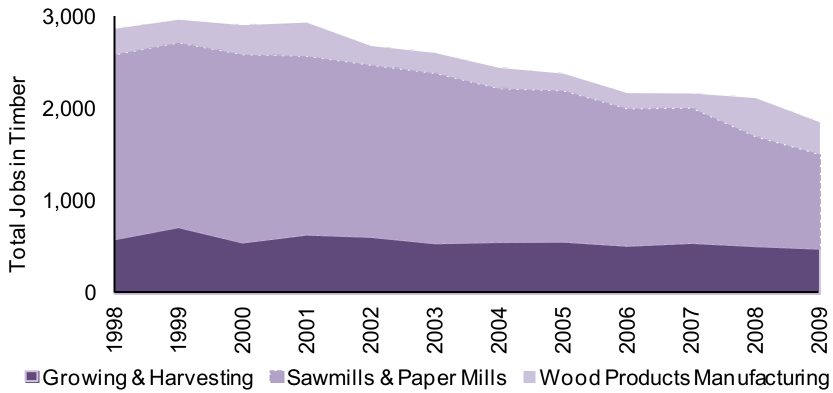


Figure 2: Jobs in Timber and Wood Products, 1998-2009[3]



and beech bark disease. Today, the dominant species that seems most important to the industry are the pines, aspens and maples.

The role of public forest lands are important to the timber industry in the region. The Forest Service manages 1.17 million acres in the nine counties, about 18 percent of the total land area, and the State of Michigan manages 1.14 million acres, about 17 percent of the land area. Average federal wages of $54,262 are higher than total private average wages of $32,879. Federal jobs are 1.4 percent of total employment but 2.5 percent of total personal income from labor sources. Commercial harvests have declined in recent years, but still accounted for more than 70,000 mbf from the Hiawatha and Ottawa National Forests with a cut value of more than $5 million in 2010. In addition to Federal lands, State lands contribute the largest share of timber harvests in the UP.

Forest restoration across the region is a growing opportunity for the industry. For example, the Great Lakes Restoration Initiative is investing significant funding into several areas related to forestry, including combating invasive species and forested watershed restoration to provide clean water and wildlife habitat that are important economic advantages for the Upper Peninsula. The Forest Service's new Planning Rule may also provide new opportunities. For example, the emphasis on watershed restoration through the Watershed Condition Framework will create new focus on restoration activities. Supporting value-added opportunities utilizing restoration products, including woody biomass energy and small diameter products will provide additional funding for restoration activities, and diversify contracting opportunities for local operators, utilizing the skills and capacity in the industry.

Industries Including Travel and Tourism

The UP's reputation as the "Snow Capitol of the Midwest" is an economic asset that could be challenged by climate change. Winter recreation based on consistent deep snow and lake ice is sensitive to warming temperatures, less predictable snowpack, and declining ice cover on Lake Superior. Lake Superior moderates winter air temperature over much of the UP and therefore bitter cold is rare. The moderating effect also means that if temperatures go up even slightly, snow will change to rain and create poor conditions for winter recreation.

Many communities rely on income from winter festivals that include snowmobile, nordic and alpine ski events, and dogsled races. In February 2011, the celebrated UP 200, a dog sled race that services as a qualifier for the Iditarod, was cut short in Alger County due to lack of snow and poor conditions, costing businesses tourism income. In February 2012, poor snow conditions again altered this event. The annual February Michigan Ice Festival in Munising took place with temperatures above freezing, and attendance at the event was down from the previous year.

Winter recreation is most important to Gogebic and Ontonagon counties. Winter recreation is important, but balanced with summer tourism opportunities in Marquette, Baraga, Houghton, and Alger Counties. Summer tourism dependent communities are mainly in Keweenaw, Luce, and Chippewa Counties.

This page shows jobs in economic sectors that provide goods and services to visitors to the local economy, as well as to the local population. It is not known, without additional research such as surveys, what exact proportion of the jobs in these sectors is attributable to expenditures by visitors, including business and pleasure travelers, versus by local residents. Some researchers refer to these sectors as "tourism-sensitive." They could also be called "travel and tourism-potential sectors" because they have the potential of being influenced by expenditures by non-locals. Here, they are referred to as "industries that include travel and tourism."

Map 2: Percent of Jobs in Industries that Include Travel and Tourism, 2009[3]

Figure 3: Percent of Jobs in Industries that include Travel and Tourism, 2009[10]

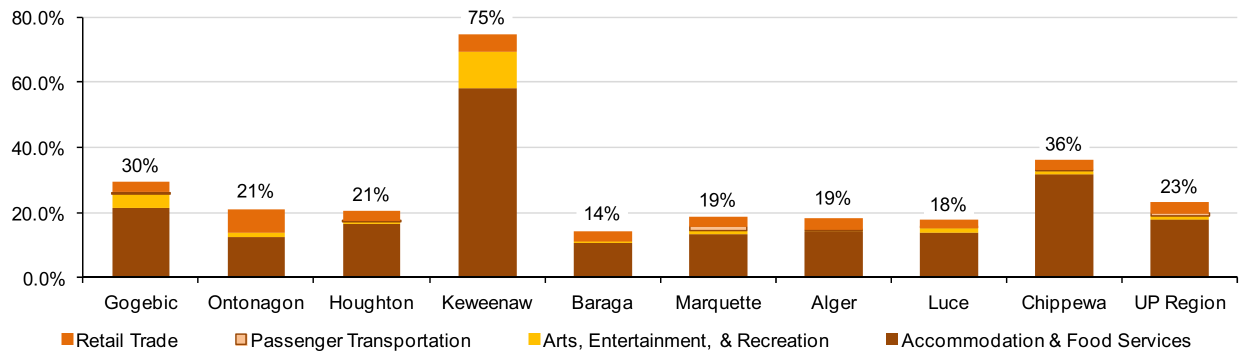
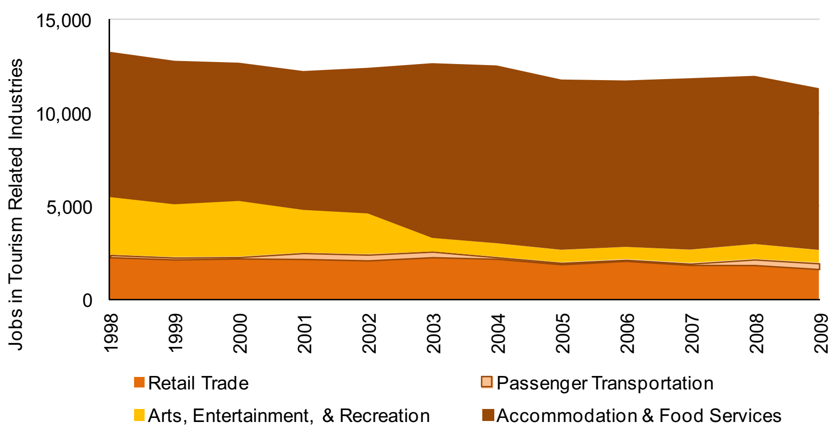


Figure 4: Jobs in Industries that include Travel and Tourism, 1998-2009



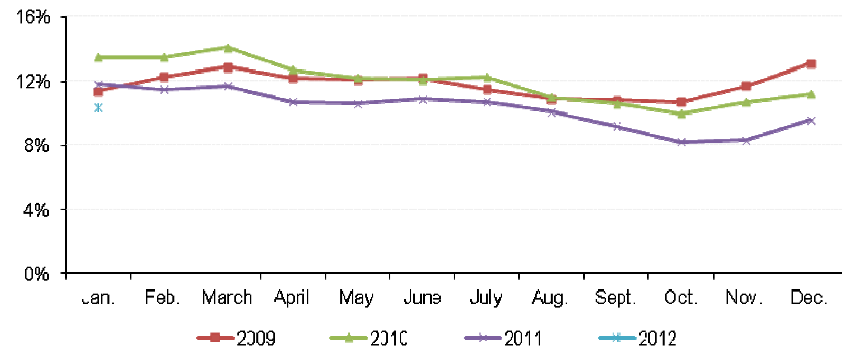
These data are useful for explaining whether sectors that are likely to be associated with travel or tourism exist, and as a result, which counties may be most sensitive to climate change that affects tourism related industries. While the share of the sectors shown here that corresponds to travel and tourism activities will vary between geographies, it is useful to point out that in five of the nine Lake Superior Watershed counties, industries including travel and tourism make up more than 20 percent of total employment. From 1998 to 2009, these industry sectors lost about 2,000 jobs, falling from 13,286 to 11,328 jobs, a 14.7% decrease.

Seasonal unemployment is another indication of an economy dependent on travel and tourism. The unemployment rate is high to begin with, with seasonal unemployment peaking in the winter months, Dec to March and falling to the lowest point in the fall (Sept to Nov).

Snowmobiling, a large part of the winter economy in watershed communities, has been down for the past few years due in part to poor snow and better conditions further south in Michigan. If this trend continues, winter tourism may increasingly turn to more silent sport (cross-country ski and snowshoe) enterprises. This could open up opportunities for more businesses – such as hut-to-hut skiing, snowshoe festivals or others and continue to support related activities tourists enjoy when they visit, including movie and museum visits.

Summer tourism, already increasing, may experience a boom if temperature increases are moderate and the UP enjoys long periods of pleasant summer conditions. The experience of "years without a summer" may come to an end as the climate along Lake Superior loses its "cool summer" reputation, and more boaters, swimmers and campers head to the area for their vacations. Travel Michigan indicates boaters don't for the most part travel with boats in tow so may not be relevant or may shift to comment on how this may open up more business opportunities for rentals or tours. Increased summer tourism will create a demand for more hotel/motel/property rental space, as well as opportunities for outdoor recreation supplies and services. The ability to meet the needs and expectations of visitors will be crucial to continued economic success.

Figure 5: Seasonal Unemployment in the Lake Superior Watershed region, 2009-2012



Aside from tourism, prospects in climate-adaptation based job growth (such as green technologies, alternative energy, infrastructure needs, building energy efficiency, new products and services, etc.) may prove beneficial to communities struggling with increasing unemployment and declining population. At the same time municipalities will need to create support services for people who lose their jobs due to climate change, such as businesses that rely on a reduced winter tourism season.

Climate related challenges to the tourism industry in summer may include heat waves and high humidity that can inhibit visitation, as there is a certain point when it is too hot and uncomfortable for people to enjoy outdoor recreation. Campers and hikers will need to be prepared for a longer biting fly and mosquito season. The Great Lakes may also experience increased and extended periods of poor water quality and algal blooms associated with warming temperatures that have public health affects and results in restricted access to beaches. Storms and winds may bring down trees, blocking access to popular hiking trails and waterfalls, which happened several times at Pictured Rocks National Lakeshore during the summer of 2011.

Michigan State University's recent Michigan Tourism Year-in-Review and Outlook profiles the industry, and includes a discussion of the potential impact of extreme weather on tourism.

In addition to tourism, the quality of life the region offers can attract families and businesses to the region. The role of the two National Parks and other public lands in economic development is also important. Research shows that people are drawn to areas for their quality of life and natural amenities, bringing investment income and business connections to the larger world. For example, across the Western U.S., protected federal lands such as national parks, monuments, and wilderness areas are associated with higher rates

Map 3: Percent of Jobs in Health Care, 2009

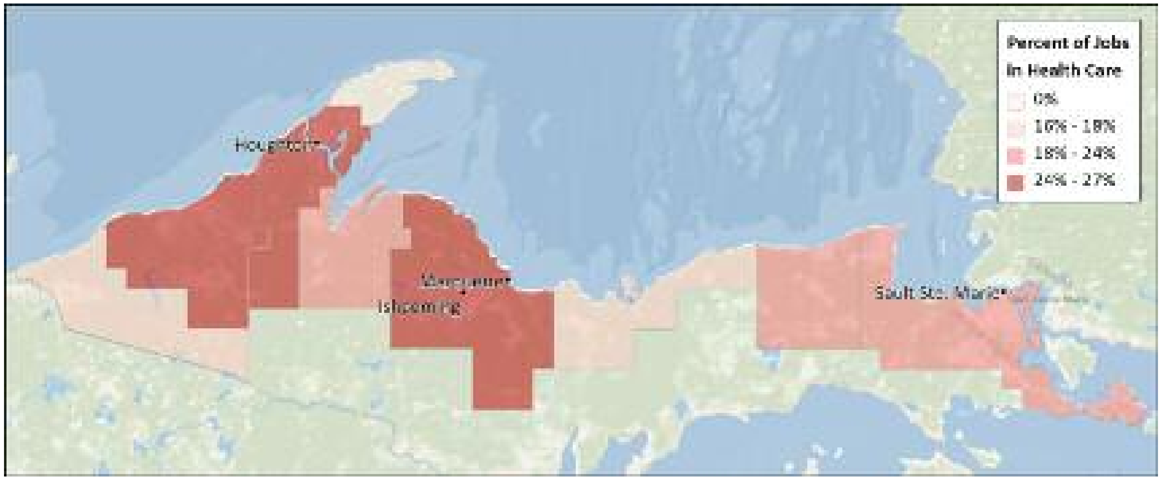


Figure 6: Percent of Jobs in Health Care Industries, 2009[13]

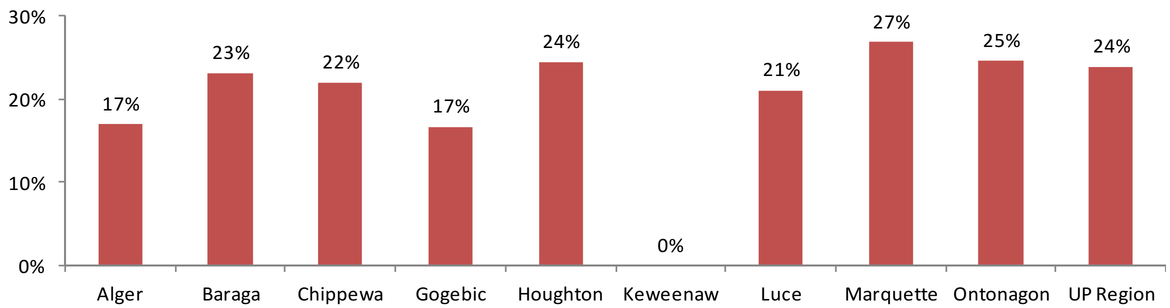
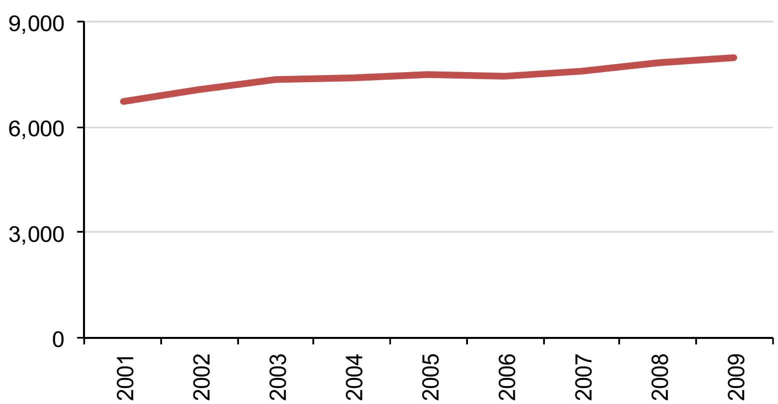


Figure 7: Jobs in Health Care Industries, 2001-2009[15]



of job growth, particularly in services industries that represent that majority of new job growth in the region and across the country. In the Upper Peninsula, clean water, forest restoration, and public lands provide the basis for economic growth.

Rural Health Care and Vulnerable Populations

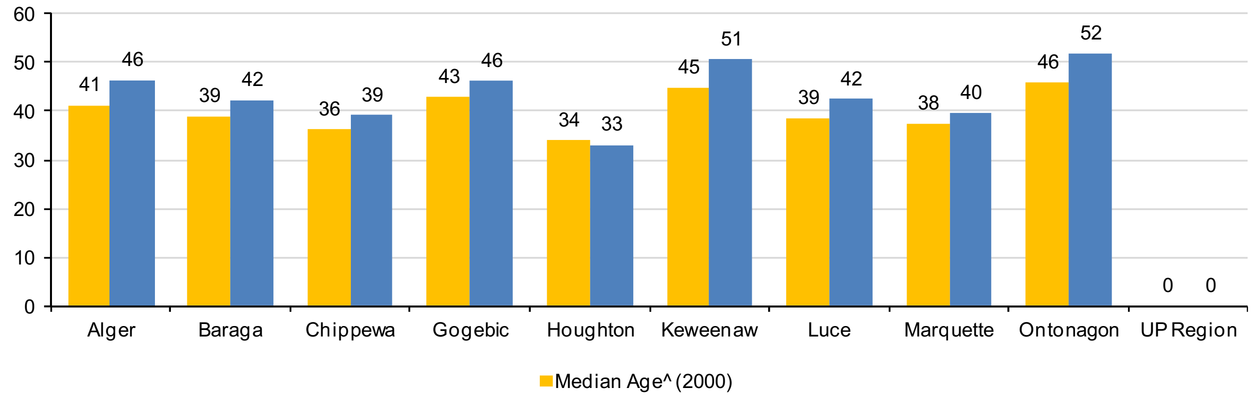
Human health concerns and quality of life are important drivers of rural economic development opportunities and public costs. Climate change will have impacts including heat-related deaths, a growing need for emergency services during extreme weather events, air quality concerns from more frequent forest fires, and the spread of vector-borne illnesses, such as West Nile Virus and Lyme disease.

Vulnerable populations, including people and families living below the poverty line, and the growing elderly population will be disproportionately affected. Retiring baby boomers will bring opportunity and new challenges for rural health care providers.

Health care is among the largest industry sectors in the U.P. region, contributing 24 percent of employment (11,750 jobs). Every county but Keweenaw has at least 17 percent of jobs in Health Care, with Marquette having the highest proportion at 27 percent. Health care is also one of the few industries growing quickly in the region, adding 1,230 jobs from 2001 to 2009

The population of the nine Lake Superior Watershed Counties is stable, growing by only 210 people between 2000 and 2010, a 0.1 percent change. However, the average age increased across every county except for Houghton as the population of people between 45 and 64 grew by 8,361 and the number of people over 65 increased by more than 1,200 from 2000-2010. Population declines were concentrated among people under 18 years old, and between 35 and 44.

Figure 8: Median Age, Change from 2000-2010[16]



Population growth in the 45 to 64 year old cohort is consistent with migration among baby-boomers who are looking to retire in rural areas with high quality of life and scenic beauty. Baby boomers will bring income and often business opportunities, adding to economic development in rural areas. However, they will also demand quality health care services and place new demand on existing services.

Figure 9: Age Distribution and Change, 2000-2010[17]

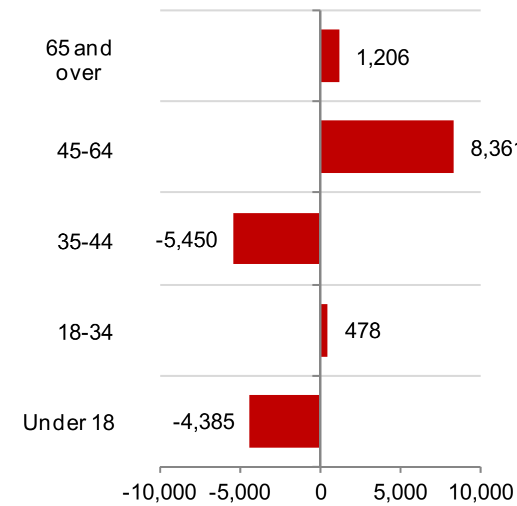
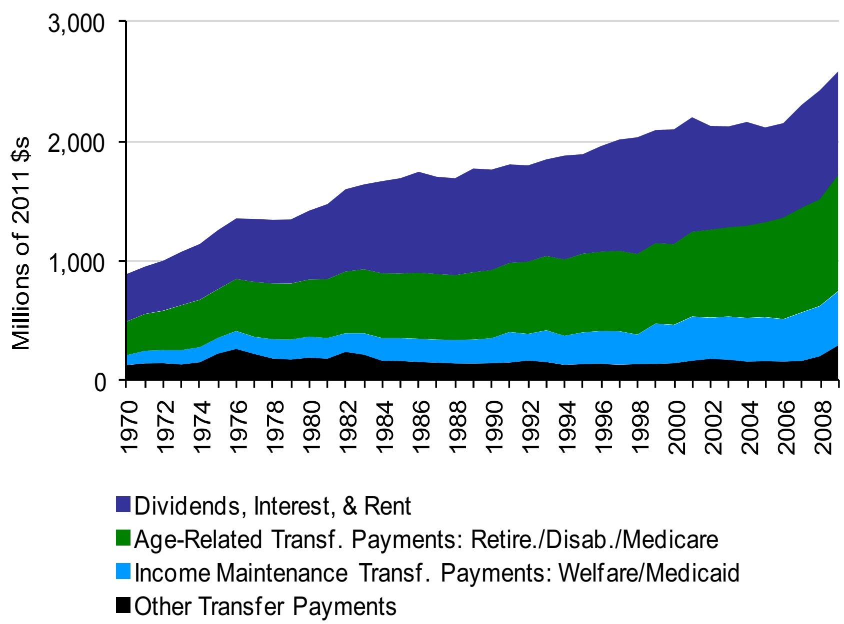


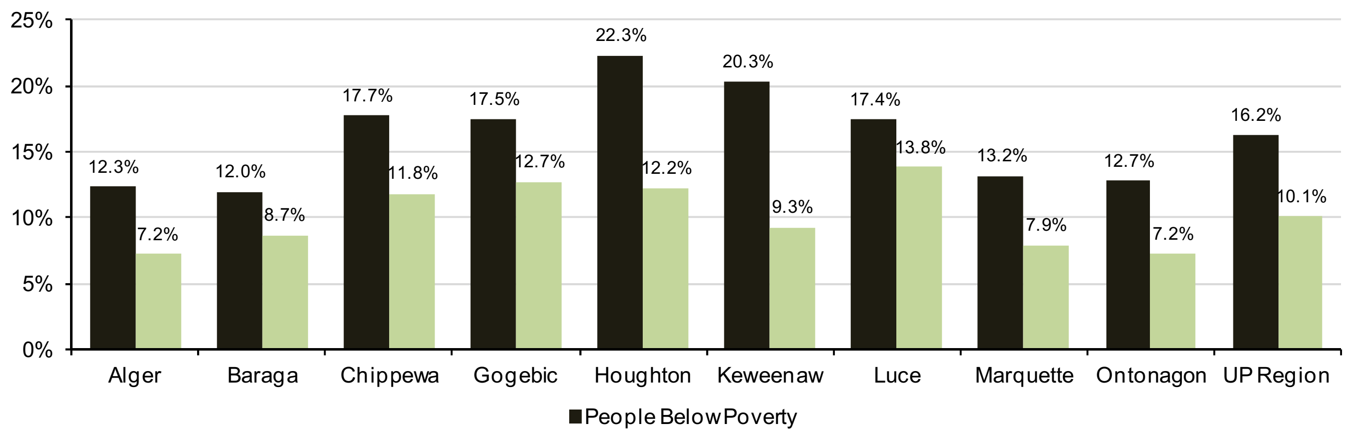
Figure 10: Components of Non-Labor Income, 2009[19]



Non-labor income is also rising, making up nearly half of all income in the nine county region. The portion of non-labor income from private investments had remained relatively flat over the last 20 years while transfer payments including retirement, medical, and unemployment payments has grown. The increasing important of non-labor income is both a reflection of retirement income and payments, and growing medical and unemployment payments.

Across the nine county region, 16 percent of people, and 10 percent of families live below the poverty line. The high rate of poverty in the region mean that many people will have few resources to deal with potential climate related impacts, including heat stress, disease, drought impacts on food production, and extreme weather. Governmental and private health care providers and other service providers may encounter rising costs and challenges in meeting the needs of populations below poverty.

Figure 11: Individuals and Families Living Below Poverty, 2010[20]



Climate Change in the Great Lakes Region

GLISA
GREAT LAKES INTEGRATED SCIENCES + ASSESSMENTS

There is a high level of scientific certainty that the climate has changed in significant ways in recent decades and that it will continue to change in the future. This is a summary of the potential changes and impacts of climate in the Great Lakes region from the best research available across many scientific disciplines.

Temperature

- Average temperatures increased by 2.3°F (1.3°C) from 1968 to 2002 in the Great Lakes region.
- By 2050, an average air temperature increase of 1.8 to 5.4°F (1 to 3°C) is projected.
- By 2100, an average air temperature increase of 3.6 to 11.2 °F (2 to 6.2°C) is projected.
- Winter temperatures will likely experience a greater increase than the summer months.

Precipitation

- Projections of future precipitation vary widely.
- Annual average precipitation will likely increase slightly or remain nearly stable.
- Winter and spring precipitation may increase more significantly.
- Warmer temperatures will lead to less precipitation falling as snow, and more falling as rain.
- Lake-effect precipitation may increase in some areas.

Extreme Weather Events

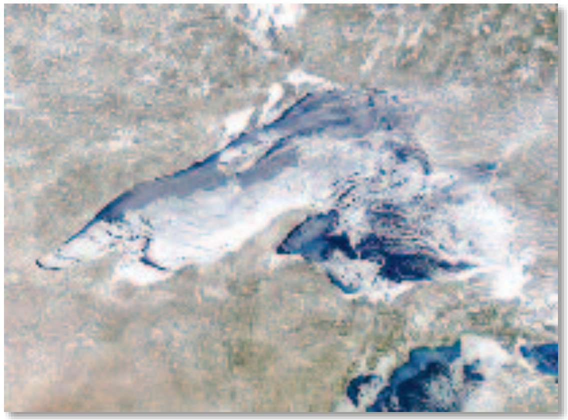
- The frequency and intensity of severe storms has increased, and current models suggest that this trend will continue as the effects of climate change become more pronounced.
- More severe storms may have a negative economic impact due to resulting damages and increased costs of preparation, clean up, and business disruption.

Water Quality and Stormwater Management

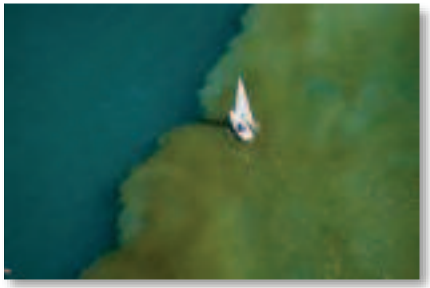
- Increased risk of droughts, severe storms, and flooding events may increase the risk of erosion, sewage overflow, lead to more interference with transportation, and more flood damage.
- Future changes in land use could have a far greater impact on water quality than climate change. The coupling of climate change and land use change could therefore result in even stronger effects in some areas.

Snow and Ice Cover

- Since 1975, the number of days with land snow cover has decreased by 5 days per decade, and the average snow depth has decreased by 1.7 cm per decade.
- From 1973 to 2010, annual average ice coverage on the Great Lakes declined by 71%.
- Snow and ice levels on the Great Lakes and on land will likely continue to decrease.
- Reduced lake freezing will result in more exposed water that could increase lake-effect precipitation.



Ice and snow cover on Lake Superior. Photo courtesy of NASA.



A sailboat on Lake Michigan near Milwaukee in a sewage overflow plume. Photo: Milwaukee Journal Sentinel

Lake Erie algal bloom, Oct. 20, 2011.
Photo courtesy of NASA.

- Earlier spring warming may decrease the length of the snow season and cause precipitation in some lakeeffect events to fall as rain rather than snow.

Lake Temperature and Stratification

- Lake temperatures have been increasing faster than surrounding air temperatures.
- Both inland lakes and the Great Lakes will likely experience longer warm seasons.
- Warmer water surface temperatures may increase the stratification of the lakes, decrease vertical mixing in the spring-winter, and lead to more low-oxygen, "dead zones" and toxic algal blooms.

Fish and Wildlife

- Coldwater fish populations will likely decline in population as warmwater fish populations become more abundant.
- Overall biomass productivity in lakes and waterways could be reduced by lake stratification and increased frequency of hypoxic conditions.
- In general, many animal species may need to migrate north to adapt to rising temperatures, and increased evaporation rates may decrease total wetland area in the region, both of which may lead to additional stresses on some species.

Forests

- Climate change will likely have mixed effects on forests that vary based on the species involved and other factors.
- With increasing atmospheric CO2, forest productivity will likely increase until other impacts of climate change, such as increased risks of drought, forest fire, and invasive species present additional stressors to forests.
- As temperatures rise, the distribution and composition of tree species will likely shift northward.

Lake Levels

- Water levels in the Great Lakes have been decreasing since a record high was reached in 1980.
- Lake levels are rising and falling a month earlier than during the 19th century.
- Other factors, such as land use and lake regulations also affect lake level, however, and it is still unclear how much of the recent trend in lake levels may be attributed to climate change.
- Future projections of lake levels for the Great Lakes vary, though most indicate a greater decline in lake levels with increasing greenhouse gas emissions.

Water Availability

- Overall, the Great Lakes region is expected to become drier due to increasing temperatures and evaporation rates.
- More frequent droughts could affect soil moisture, surface waters, and groundwater supply.
- The seasonal distribution of water availability will likely change. Warmer temperatures may lead to more winter rain and earlier peak streamflows.

Agriculture

- The growing season will likely lengthen and positively impact some crop yields.
- An increased frequency and intensity of severe weather, increased flooding and drought risks, as well as more pests and pathogens will likely negatively impact crop yields.
- Water availability and quality will likely pose challenges for agriculture.

Energy and Industry

- Drier summers may lead to reduced hydroelectric output during periods of peak usage.
- Reduced water availability may interfere with some industrial operations.
- Warmer temperatures and more frequent heat waves will likely increase electricity demands, particularly in urban areas and during the summer months.

Transportation

- With increasing temperatures, damage to paved surfaces due to expanding and softening pavement is more likely.
- The most significant impact on roadways will likely be the increased risk of flood damage.
- Shipping lanes will likely be open earlier and longer due to reduced ice cover on the Great Lakes.
- Lower lake levels may lead to decreased depth of navigation channels and a reduction in the maximum loads carried by vessels.

Public Health

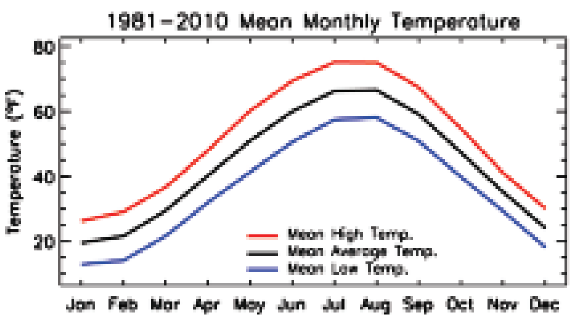
- Increased risk of heat waves and increased humidity may increase the number of heat-related deaths and illnesses.
- Increased frequency of flooding events may lead to watershed contamination, while warmer surface waters could mobilize pollutants in sediment and contaminate fish.
- Diseases such as West Nile virus and Lyme disease may become more widespread since carrier insects will be more likely to survive milder winters.

Tourism and Recreation

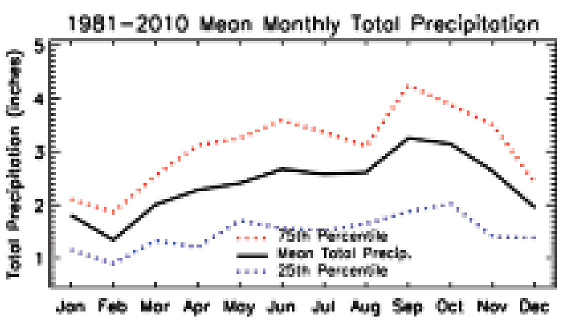
- Winter recreation and tourism are likely to suffer due to reduced snow cover.
- Many species of fish important to recreation are likely to decline while the populations of some warmwater species may grow.
- Increased lake contamination and decreasing lake levels may lead to less desirable shorelines, but increasing summer temperatures and a longer summer season, may increase demand for beaches and some summer activities.

Winter tourism and recreation may decline as summer tourism grows.

Photos courtesy of Shanty Creek Resorts and the National Park Service.



Mean monthly high, average, and low temperatures for the period 1981-2010.

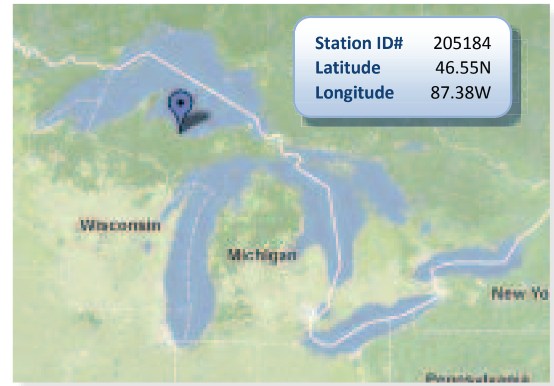


Mean monthly total precipitation with the 25th and 75th percentiles for the period 1981-2010.

Historical Climatology: Marquette, Michigan

Geography

Marquette, Michigan is located on the shore of Lake Superior in Marquette County. As of the 2010 census, the population was 21,355. The city actually includes several small nearby islands, and the Marquette Underwater Preserve lies immediately offshore. Parks, beaches and other recreational areas are abundant throughout the city and in the surrounding area. The terrain is mostly forested, and a number of large hills are prominent in the area.



Map generated with Google Maps

Overview

As is true for most of the Upper Peninsula of Michigan, Winters in Marquette tend to be long, cold, and snowy, and because of its northern latitude, it receives roughly 8 hours of sunlight per day during the winter. Lake Superior does, however, moderate temperatures in Marquette. In comparison to continental locations at similar latitudes, the area typically experiences warm but cooler temperatures during the late spring and early summer, and warmer temperatures during the late fall and early winter. In the late winter, as ice builds up on Lake Superior, Marquette experiences larger temperature variations similar to those seen at inland locations. Diminished wind speeds or winds which do not traverse large unfrozen lakes often produce clearing skies and the colder temperatures expected at continental locations. The lake effect also increases cloudiness and snowfall during the fall and winter. Through 2002, Marquette averaged 141 inches of snowfall per year, and was the fifth snowiest city in the United Stated large enough to be reported. Sudden, severe periods of lake-effect precipitation are relatively common.

1981-2010 Temperature and Precipitation Summary

Mean Annual Temperature (°F)	43.5
Mean Annual Minimum Temperature (°F)	35.7
Mean Annual Maximum Temperature (°F)	51.3
Mean Number of Days per Year that exceed 90°F	3
Mean Number of Days per Year that fall below 32°F	147
Lowest Mean Annual Temperature (°F)	40.6
Highest Mean Annual Temperature (°F)	47.5
Mean Annual Total Precipitation (inches)	28.7
Lowest Mean Total Precipitation (inches)	19.4
Highest Mean Total Precipitation (inches)	39.4
Mean Number of Days/Year with > 0.1" Precip.	67
Mean Number of Days/Year with > 0.25" Precip.	35
Mean Number of Days/Year with > 0.5" Precip.	14
Mean Number of Days/Year with > 1" Precip.	4

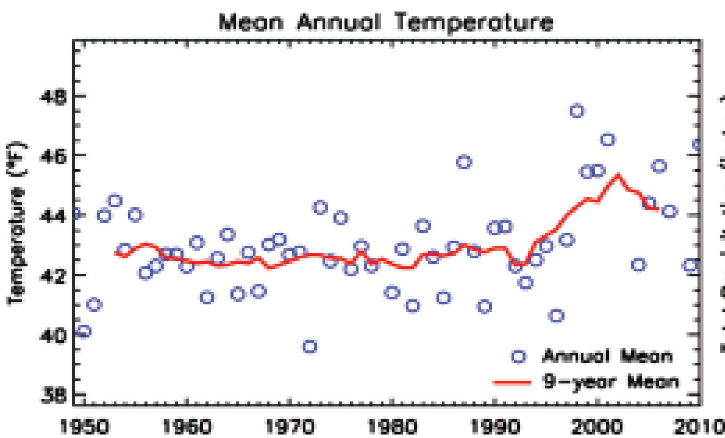
GLISA

Changes in Mean 1981-2010 Temperature from 1951-1980 (°F)

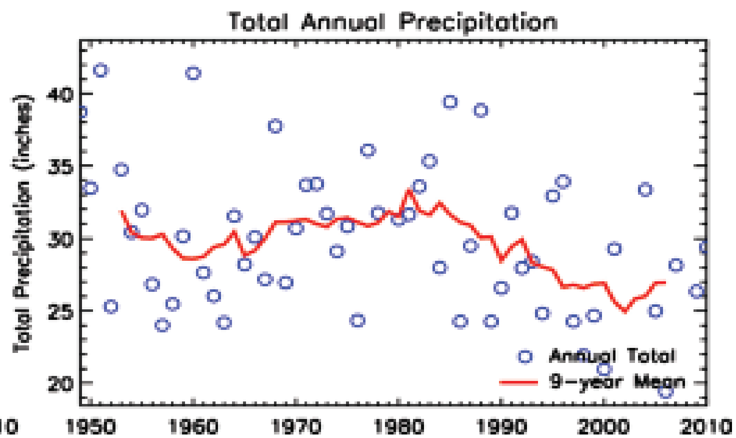
Annual	0.9
Winter, December-February	1.5
Spring, March-May	1.0
Summer, June-August	0.4
Fall, September-November	0.5

Change in Mean 1981-2010 Total Precipitation from 1951-1980 (%)

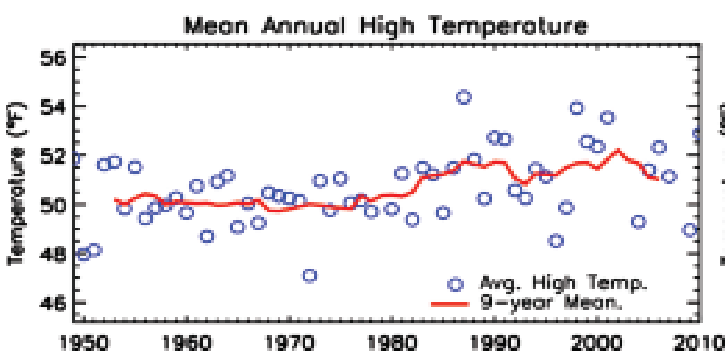
Annual	-6.0
Winter, December-February	-2.8
Spring, March-May	-4.9
Summer, June-August	-6.8
Fall, September-November	0.5



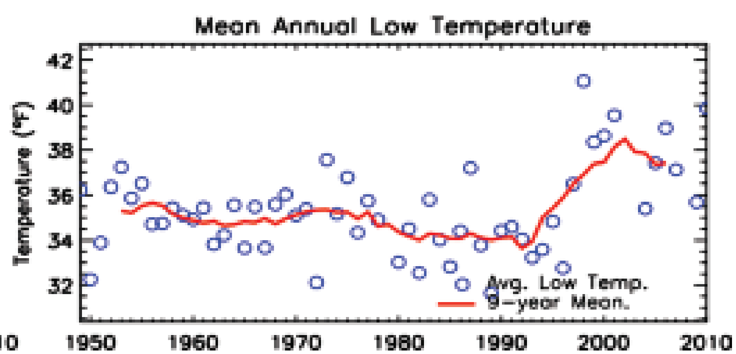
Mean annual temperatures from 1900 to 2010. An open circle represents the average temperature of a single year. The solid line represents the 9-year running mean.



Mean annual precipitation totals from 1900 to 2010. An open circle represents the total precipitation for a single year. The solid line represents the 9-year running mean.



Mean annual high temperatures from 1900 to 2010. An open circle represents the average high temperature of a single year. The solid line represents the 9-year running mean.

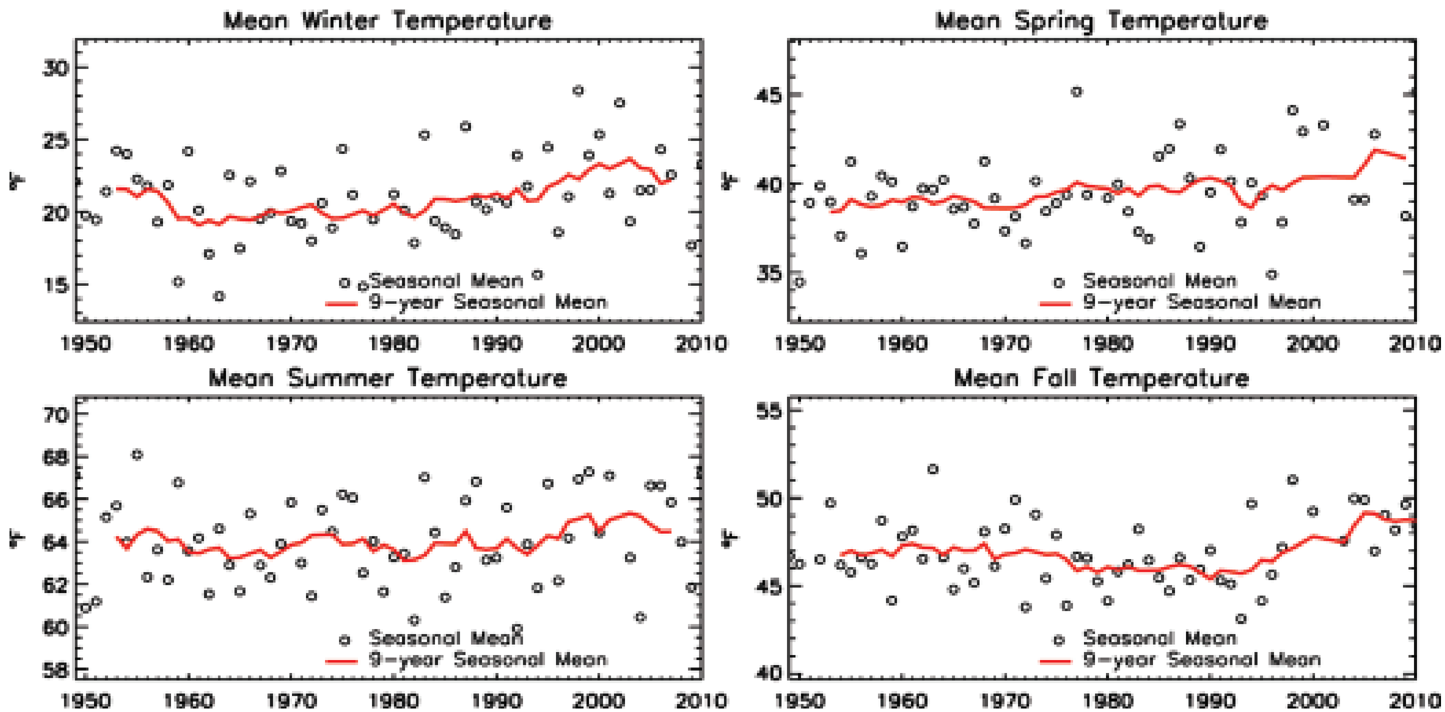


Mean annual low temperatures from 1900 to 2010. An open circle represents the average low temperature of a single year. The solid line represents the 9-year running mean.

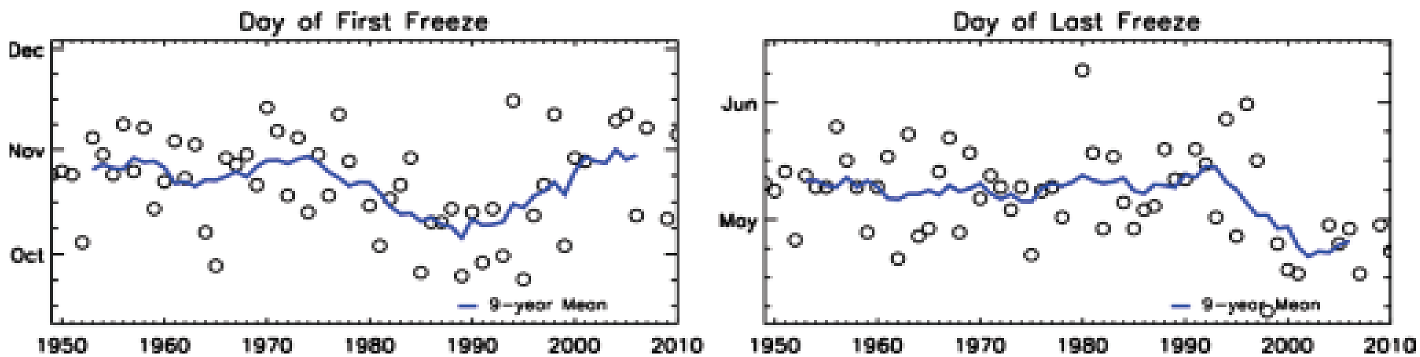
Unless otherwise stated, daily observations are used to calculate quantities in this document only if they satisfy a number of quality control tests and there is a high level of data coverage for the period in question. Nine-year running means are calculated for periods only when at least 5 of the 9 years are available. For more information on quality controls and data reliability requirements please see the Historical Climatologies: Quality Control document available on the GLISA website or email GLISA-info@umich.edu.

Many factors can influence long-term trends in precipitation and temperature. While human-caused climate change may be a major driver, other factors, such as natural variability, changes in nearby land use, urban heat-island effects, movement of the exact location of the observing station, and changes in measurement procedure can also play a role in climate trends over the station record.

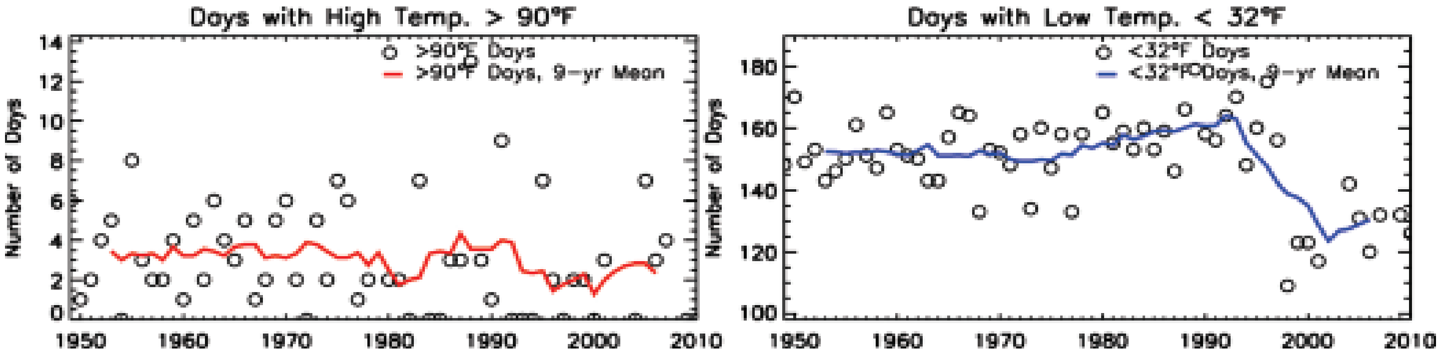
The measurements of a single station do not necessarily represent global or regional trends in temperature and precipitation. Each station records the conditions at a given place over time.



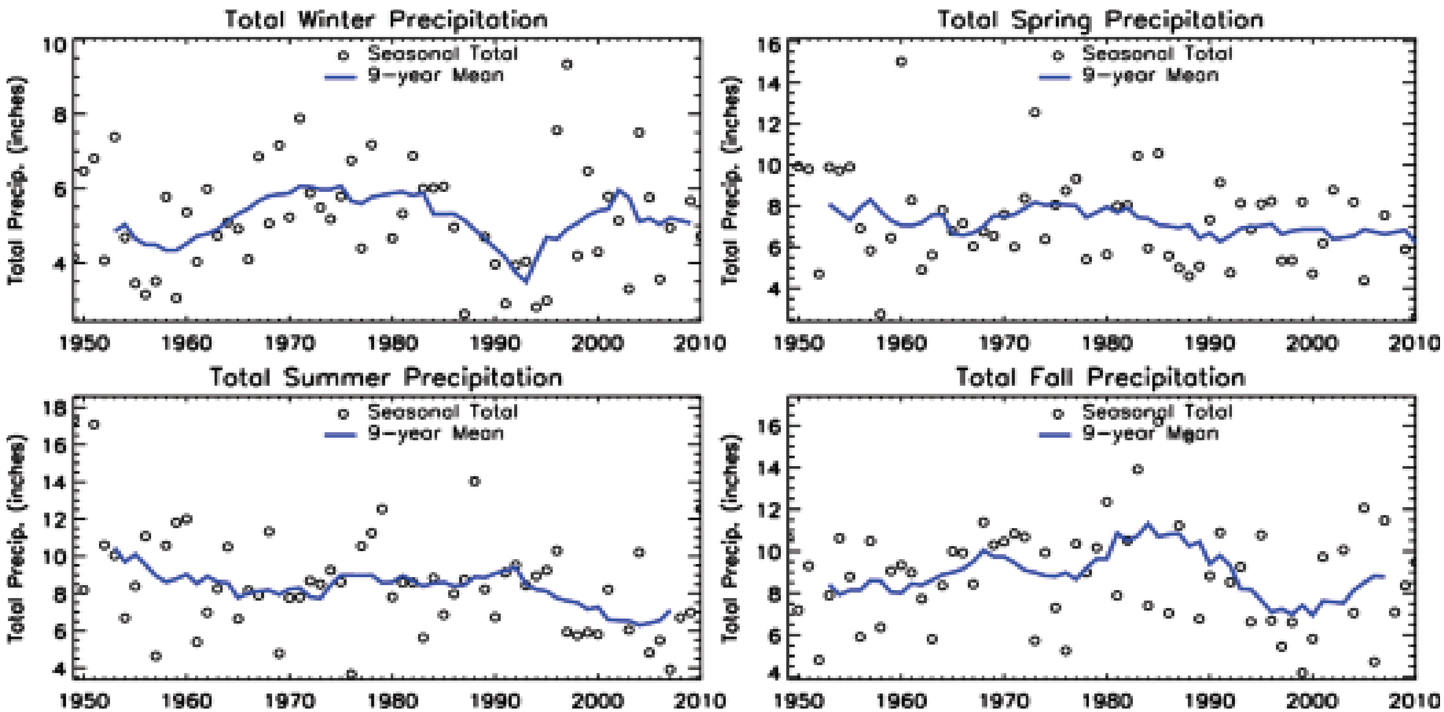
Mean seasonal temperatures from 1900 to 2010. An open circle represents the average seasonal temperature of a single year. The solid line is the 9-year running mean.



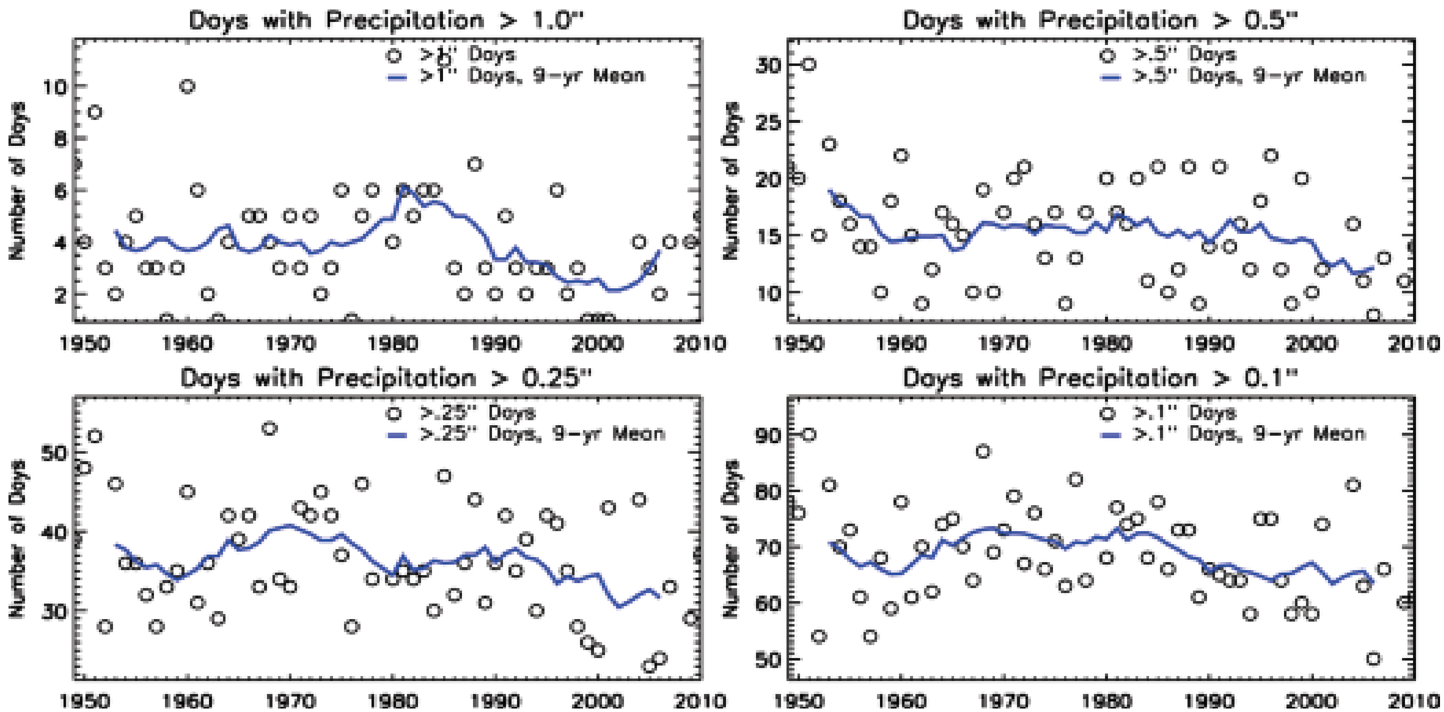
Open circles represent the first winter freeze of the year (daily low temperature < 32°F) from 1900-2010. The solid line is the 9-year running mean.



Open circles represent the number of days per year in which the daily high temperature exceeded 90°F (left) and where the daily low temperature dropped below 32°F (right) in a single year. The solid line is the 9-year running mean.



Mean total precipitation by season from 1900 to 2010. An open circle represents the total seasonal precipitation for a single year. The solid line represents the 9-year running mean of the total seasonal precipitation.



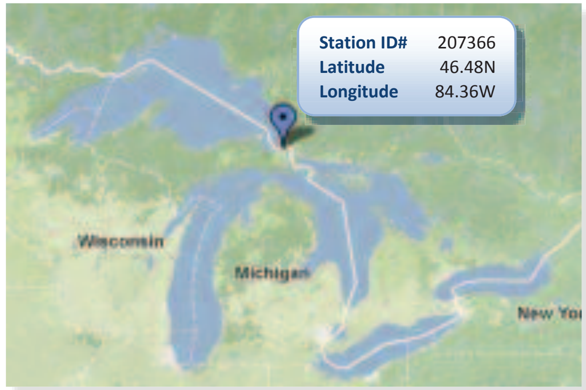
Number of days per year that exceeded the indicated daily precipitation totals. The solid line represents the 9-year running mean. Days that exceeded a higher threshold are included in days exceeding lower thresholds.

Historical Climatology: Sault Ste. Marie, Michigan

GLISA
GREAT LAKES INTEGRATED SCIENCES + ASSESSMENTS

Geography

Sault Ste. Marie, Michigan is located on the St. Marys River across from Sault Ste. Marie, Ontario and between lake Superior and Lake Huron. As of the 2010 U.S. census, the population approximately 14,000. The surrounding terrain is hilly and wooded.



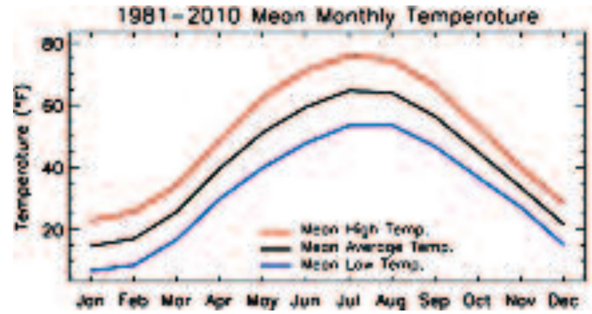
Map generated with Google Maps

Overview

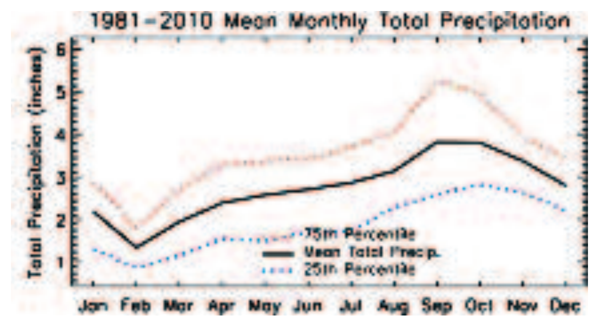
As is true for most of the Upper Peninsula of Michigan, Winters in Sault Ste. Marie tend to be long, cold, and snowy, and because of its northern latitude, it receives roughly 8 hours of sunlight per day during the winter. Its close proximity to Lake Huron and Lake Superior does, however, moderate temperatures. In comparison to continental locations at similar latitudes, the area typically experiences warm but cooler temperatures during the late spring and early summer, and warmer temperatures during the late fall and early winter. In the late winter, as ice builds up on Lake Superior, Sault Ste. Marie experiences larger temperature variations similar to those seen at inland locations. Diminished wind speeds or winds which do not traverse large unfrozen lakes often produce clearing skies and the colder temperatures expected at continental locations. Sault Ste. Marie is one of the snowiest places in Michigan. It attracted national media attention in December of 1995 when the annual total snowfall topped 209 inches (5.3 m), after 62 inches (1.6 m) fell during a continuous five-day snowstorm, and 28 inches (710 mm) fell in 24 hours. Its immediate region is also the cloudiest in Michigan's Upper Peninsula, having over 200 cloudy days a year.

1981-2010 Temperature and Precipitation Summary

Mean Annual Temperature (°F)	41.2
Mean Annual Minimum Temperature (°F)	32.0
Mean Annual Maximum Temperature (°F)	50.4
Mean Number of Days per Year that exceed 90°F	1
Mean Number of Days per Year that fall below 32°F	163
Lowest Mean Annual Temperature (°F)	38.3
Highest Mean Annual Temperature (°F)	45.5
Mean Annual Total Precipitation (inches)	32.9
Lowest Mean Total Precipitation (inches)	22.4
Highest Mean Total Precipitation (inches)	45.9
Mean Number of Days/Year with > 0.1" Precip.	79
Mean Number of Days/Year with > 0.25" Precip.	43
Mean Number of Days/Year with > 0.5" Precip.	17
Mean Number of Days/Year with > 1" Precip.	4



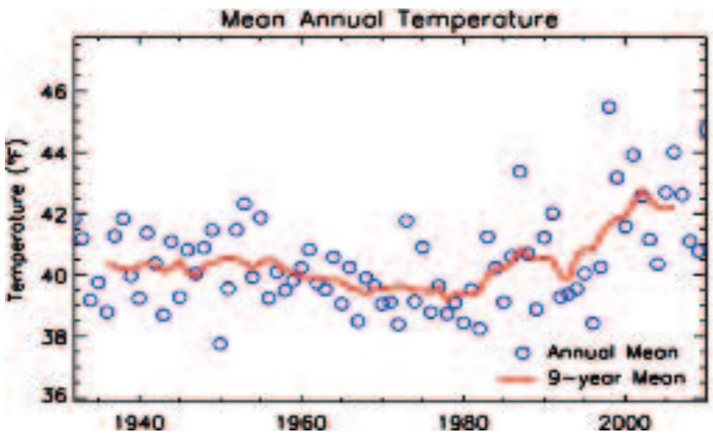
Mean monthly high, average, and low temperatures for the period 1981-2010.



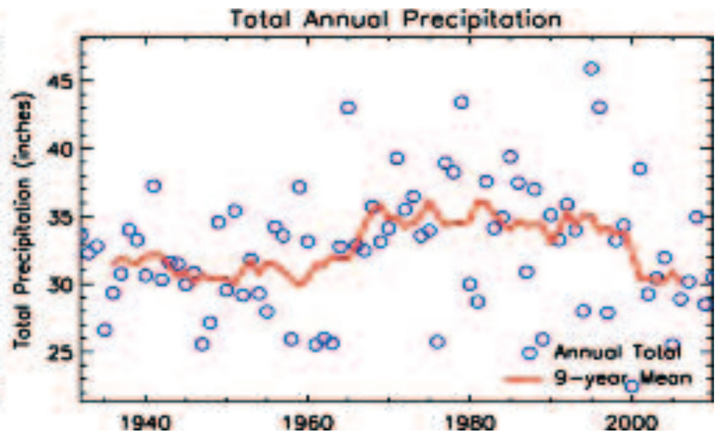
Mean monthly total precipitation with the 25th and 75th percentiles for the period 1981-2010.

Changes in Mean 1981-2010 Temperature from 1951-1980 (°F)	
Annual	1.4
Winter, December-February	1.9
Spring, March-May	1.6
Summer, June-August	1.1
Fall, September-November	0.7

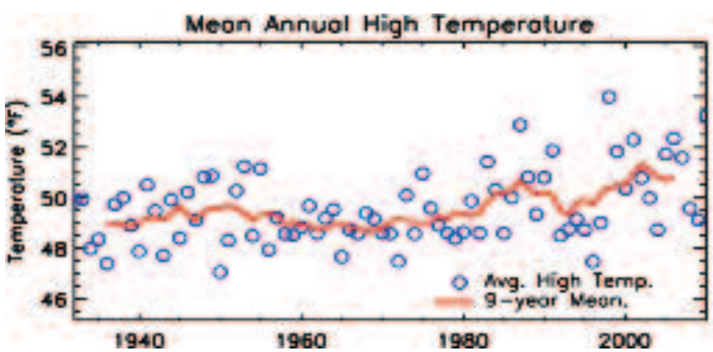
Change in Mean 1981-2010 Total Precipitation from 1951-1980 (%)	
Annual	-0.6
Winter, December-February	-0.7
Spring, March-May	-1.5
Summer, June-August	-3.9
Fall, September-November	4.9



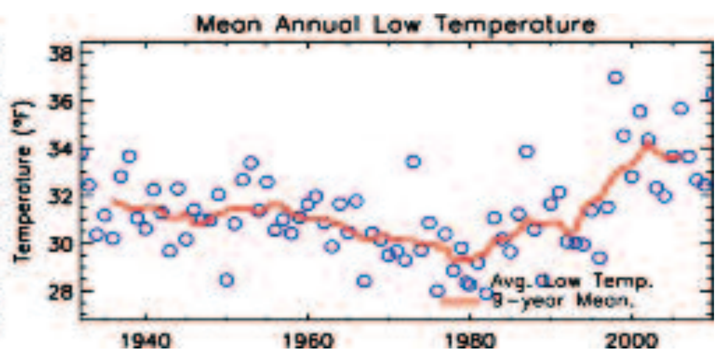
Mean annual temperatures from 1900 to 2010. An open circle represents the average temperature of a single year. The solid line represents the 9-year running mean.



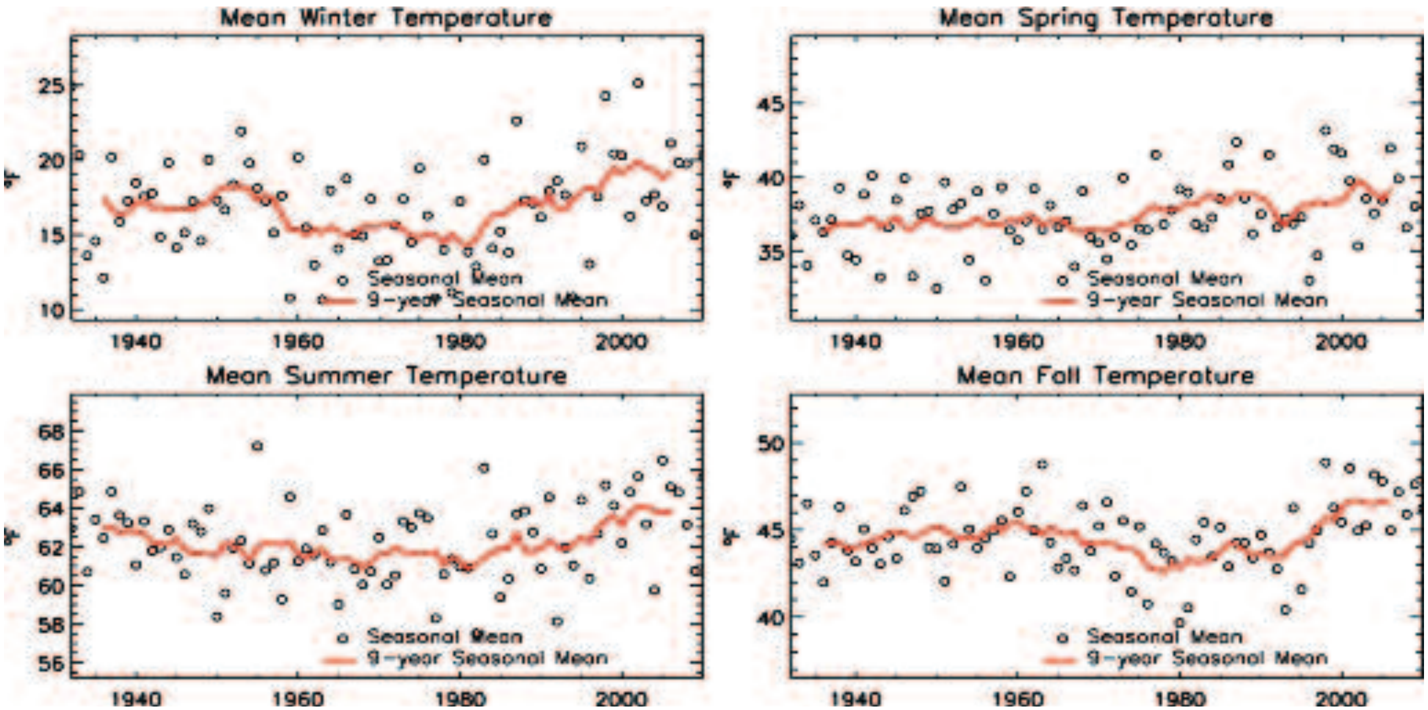
Mean annual precipitation totals from 1900 to 2010. An open circle represents the total precipitation for a single year. The solid line represents the 9-year running mean.



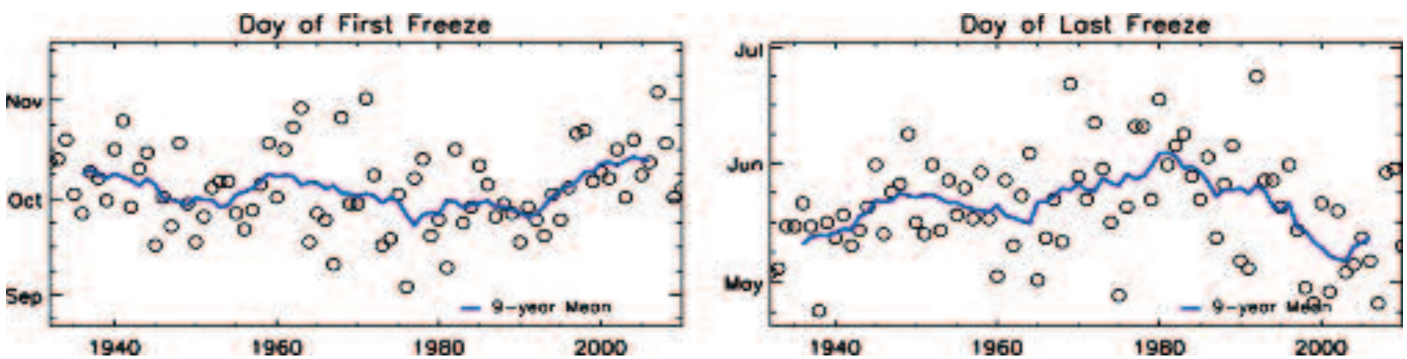
Mean annual high temperatures from 1900 to 2010. An open circle represents the average high temperature of a single year. The solid line represents the 9-year running mean.



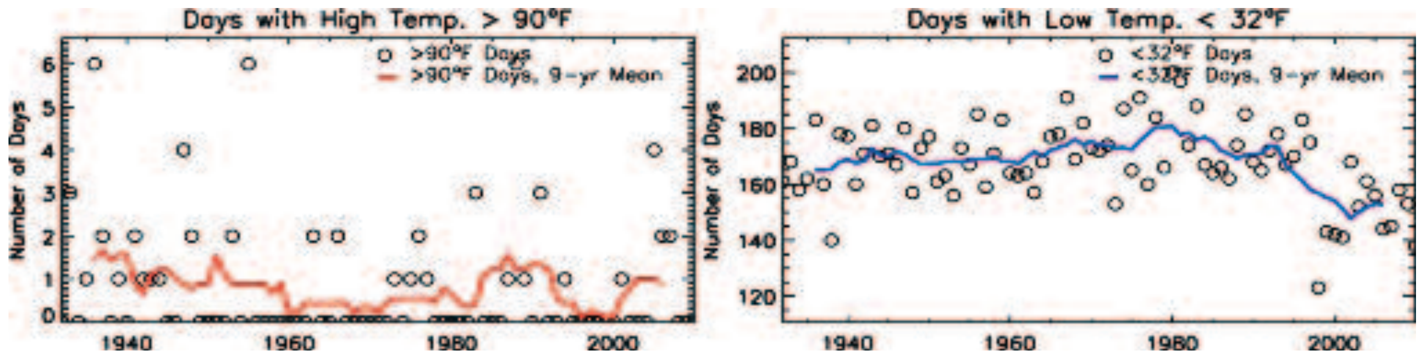
Mean annual low temperatures from 1900 to 2010. An open circle represents the average low temperature of a single year. The solid line represents the 9-year running mean.



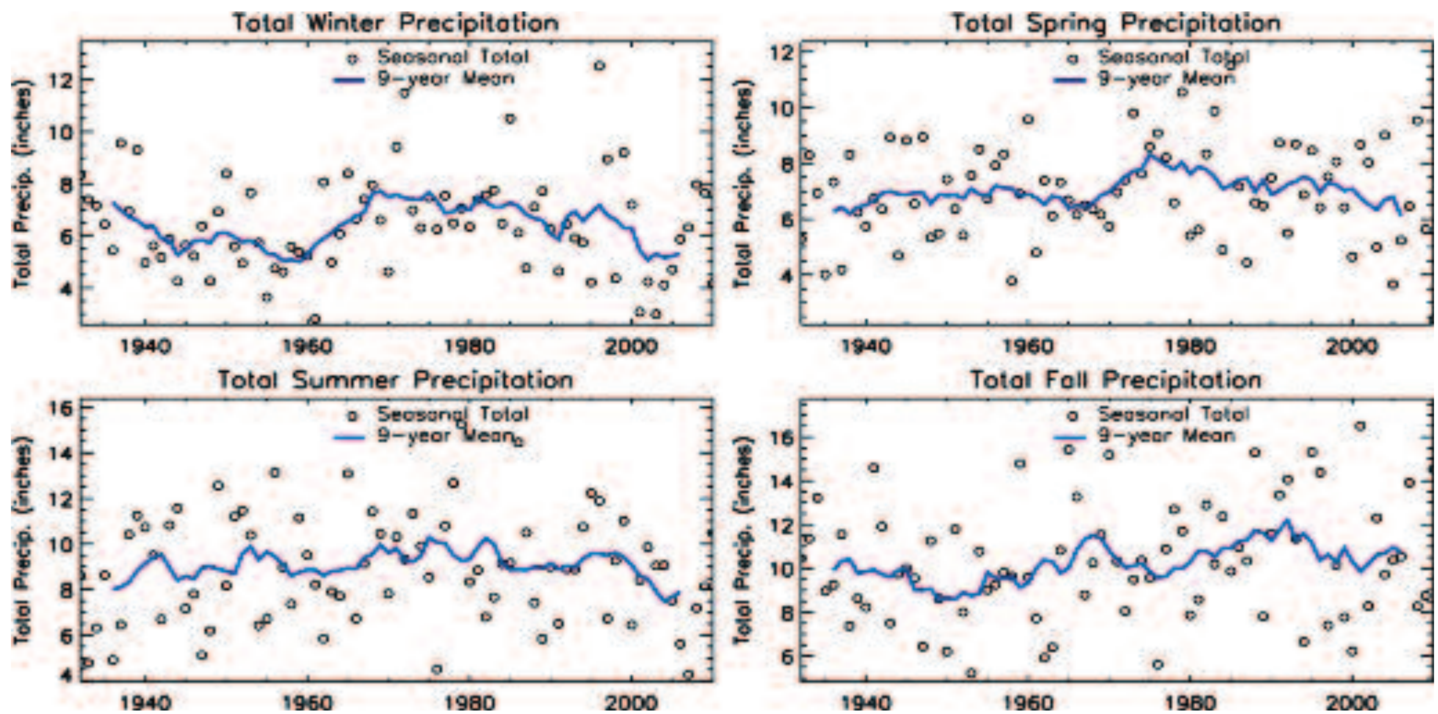
Mean seasonal temperatures from 1900 to 2010. An open circle represents the average seasonal temperature of a single year. The solid line is the 9-year running mean.



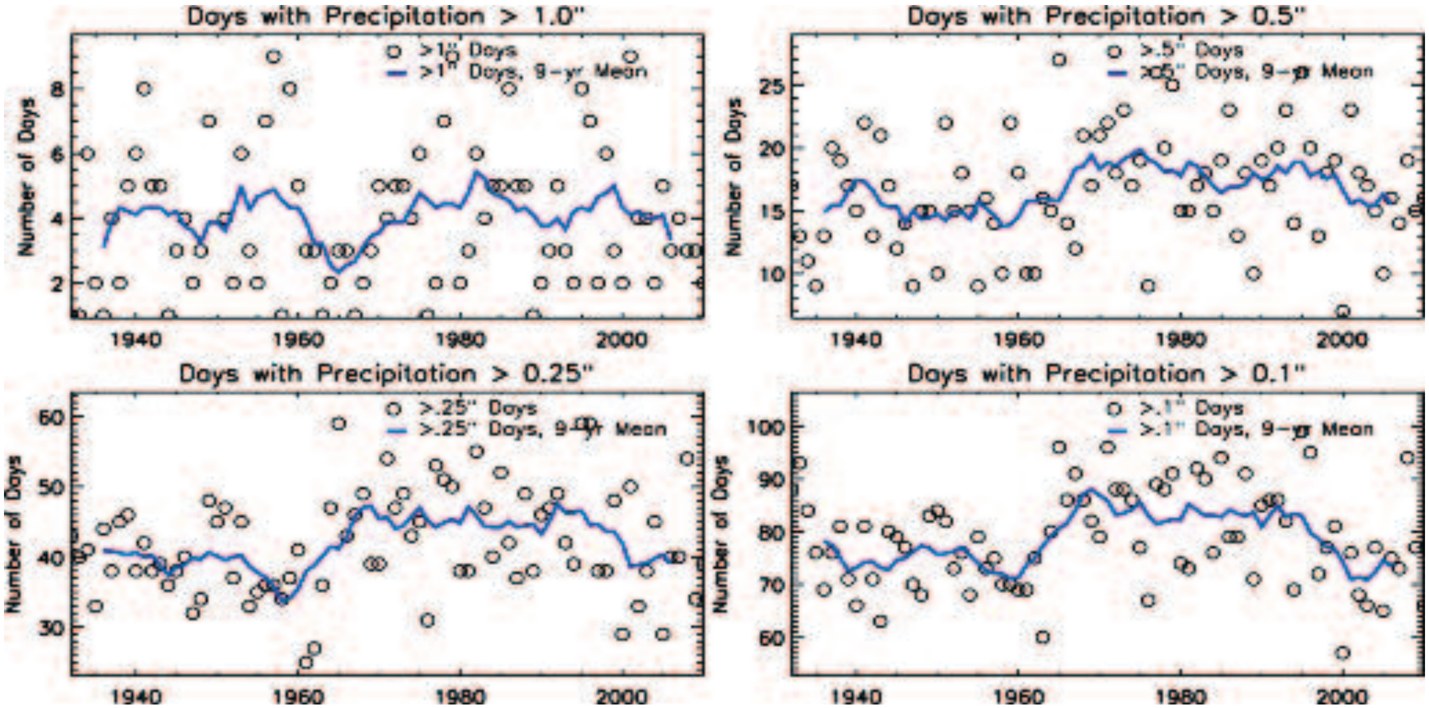
Open circles represent the first winter freeze of the year (daily low temperature < 32°F) from 1900-2010. The solid line is the 9-year running mean.



Open circles represent the number of days per year in which the daily high temperature exceeded 90°F (left) and where the daily low temperature dropped below 32°F (right) in a single year. The solid line is the 9-year running mean.



Mean total precipitation by season from 1900 to 2010. An open circle represents the total seasonal precipitation for a single year. The solid line represents the 9-year running mean of the total seasonal precipitation.



Number of days per year that exceeded the indicated daily precipitation totals. The solid line represents the 9-year running mean. Days that exceeded a higher threshold are included in days exceeding lower thresholds.

Unless otherwise stated, daily observations are used to calculate quantities in this document only if they satisfy a number of quality control tests and there is a high level of data coverage for the period in question. Nine-year running means are calculated for periods only when at least 5 of the 9 years are available. For more information on quality controls and data reliability requirements please see the Historical Climatologies: Quality Control document available on the GLISA website or email GLISA-info@umich.edu.

Many factors can influence long-term trends in precipitation and temperature. While human-caused climate change may be a major driver, other factors, such as natural variability, changes in nearby land use, urban heat-island effects, movement of the exact location of the observing station, and changes in measurement procedure can also play a role in climate trends over the station record.

The measurements of a single station do not necessarily represent global or regional trends in temperature and precipitation. Each station records the conditions at a given place over time.

Munising, Michigan
Historical Climatology

Map generated with Google Maps

1981-2010 Mean Annual Temperature and Precipitation Summary

Mean Annual Temperature (°F)	42.53
Mean Annual Minimum Temperature (°F)	34.25
Mean Annual Maximum Temperature (°F)	50.85
Mean Number of Days per Year that exceed 90°F	1.57
Mean Number of Days per Year that fall below 32 degrees F	150.25
Lowest Mean Annual Temperature (°F)	36.69
Highest Mean Annual Temperature (°F)	47.70
Mean Annual Total Precipitation (inches)	33.80
Lowest Mean Total Precipitation (inches)	3.04
Highest Mean Total Precipitation (inches)	48.25
Mean Number of Days per Year that exceed 0.5" of Precipitation	18.14
Mean Number of Days per Year that exceed 1" of Precipitation	4.69

Geography

Munising, located in north central Alger County, is on the south central shore of Lake Superior. Munising is Grand Island, just north of Munising, acts as a barrier to the brisk winds blowing off Lake Superior and protects Munising's excellent natural harbor. Just east of the harbor entrance stands the multi-colored sandstone cliffs of the Pictured Rocks National Lakeshore. The surrounding terrain is hilly and approximately 50% forested. Soils are predominantly sand.

Overview

Because of Munising's location on the lake shore, the effect of Lake Superior on its climate is quite strong throughout the year. The lake effect increases cloudiness and snowfall during the fall and winter and also modifies temperatures, keeping them cooler during the late spring and early summer, and warmer during the late fall and early winter. In the late winter as ice builds up on the lakes, Munising is subjected to temperature variations which are more closely associated with interior locations. Diminished wind speeds or winds which do not traverse large unfrozen lakes often produce clearing skies and the colder temperatures expected at continental locations. Because the day-to-day weather is controlled by the movement of pressure systems across the nation, this area seldom experiences prolonged periods of hot, humid weather in the summer or extreme cold during the winter. Summers are dominated by moderately warm temperatures and the lake influence evident in cool minimum temperatures. Precipitation is well distributed throughout the year. Summer precipitation comes mainly in the form of afternoon showers and thundershowers.

Mean Monthly Temperature (°F) 1981-2010

Month	*Average*	*Maximum*	*Minimum*
January	17.4	27.7	7.8
February	19.4	30.1	10.5
March	27.8	33.9	21.1
April	39.1	44.7	32.5
May	50.3	56.4	43.2
June	59.1	65.1	52.9
July	65.0	71.0	58.7
August	64.7	69.3	58.7
September	57.5	61.6	53.6
October	45.8	51.7	40.9
November	34.5	40.5	27.6
December	23.5	30.2	13.2

Monthly Accumulated Precipitation (in) 1981-2010

Month	*Average*	*Maximum*	*Minimum*
January	3.36	8.11	1.61
February	2.33	5.48	0.44
March	2.36	5.28	0.05
April	2.20	6.92	0.27
May	2.70	5.42	1.13
June	2.90	8.32	0.93
July	3.31	6.83	0.57
August	3.17	7.30	0.20
September	3.99	9.36	1.36
October	4.14	8.26	1.34
November	3.30	7.03	0.74
December	3.60	8.06	0.68

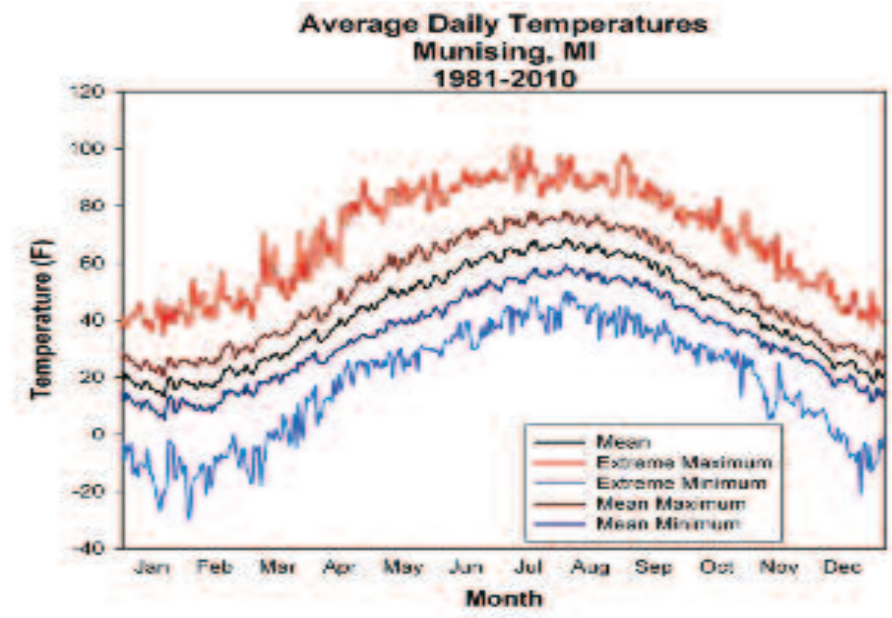


Figure 1. Mean, maximum, and minimum temperatures for the period 1980 through 2010.

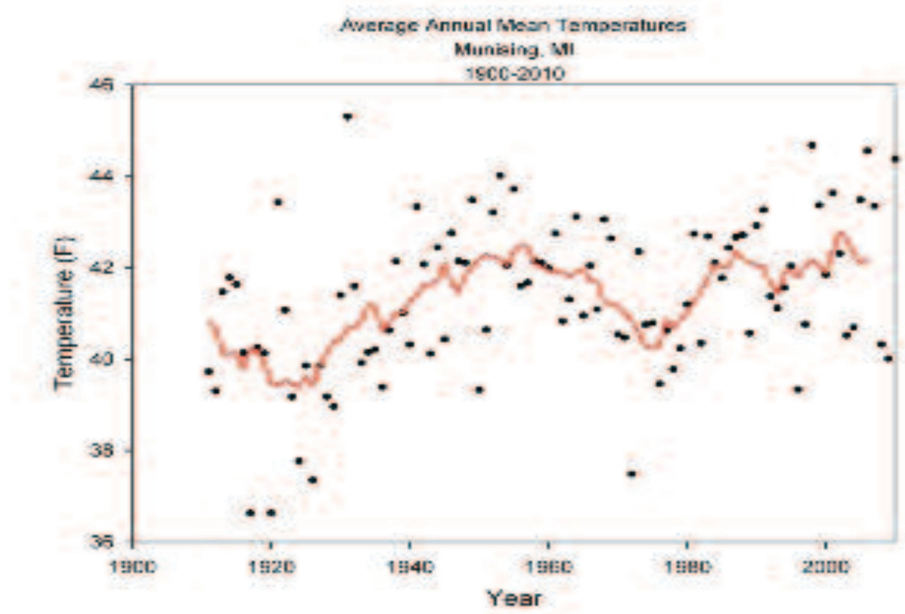


Figure 2. Average annual mean temperatures from 1900-2010.

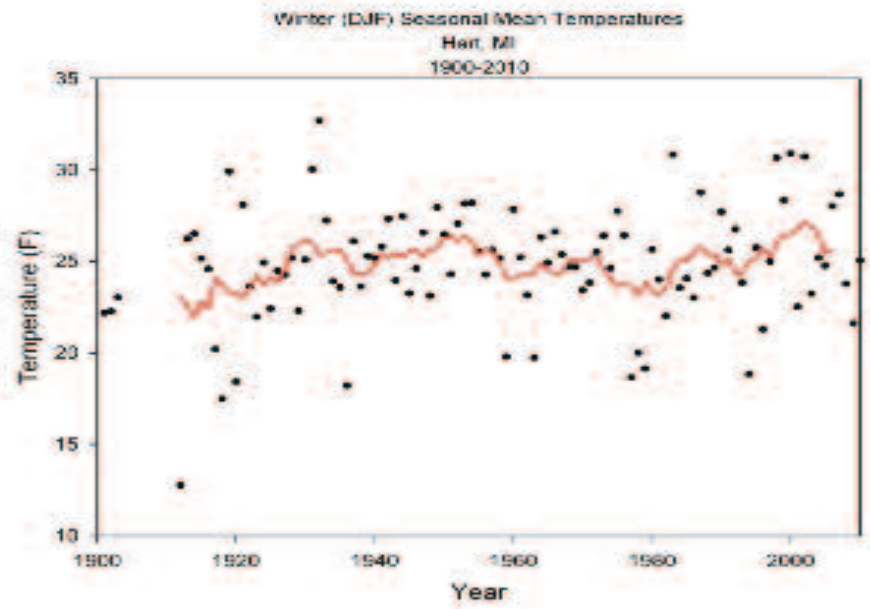


Figure 3. Average winter (December through February) mean temperatures from 1900-2010.

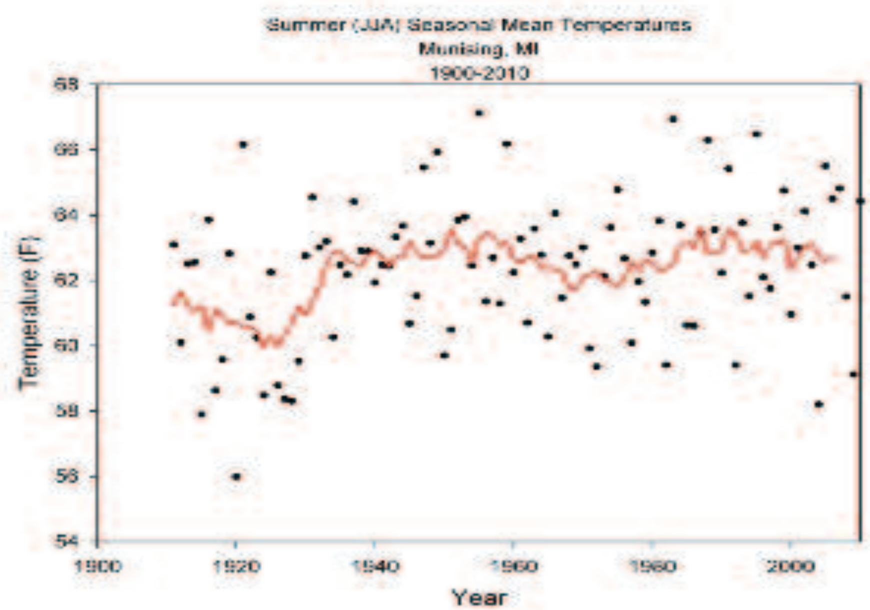


Figure 4. Average summer (June through August) temperatures for the period 1900-2010.

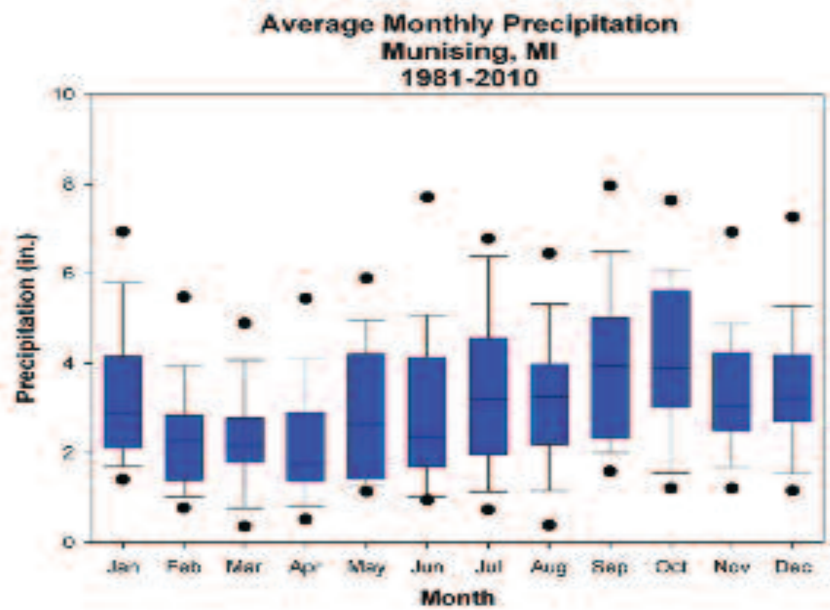


Figure 5. Average monthly precipitation for the period 1980 through 2010. The central lines indicate median values. The boxes indicate 75th percentiles, and the whiskers indicate the 95th percentiles.

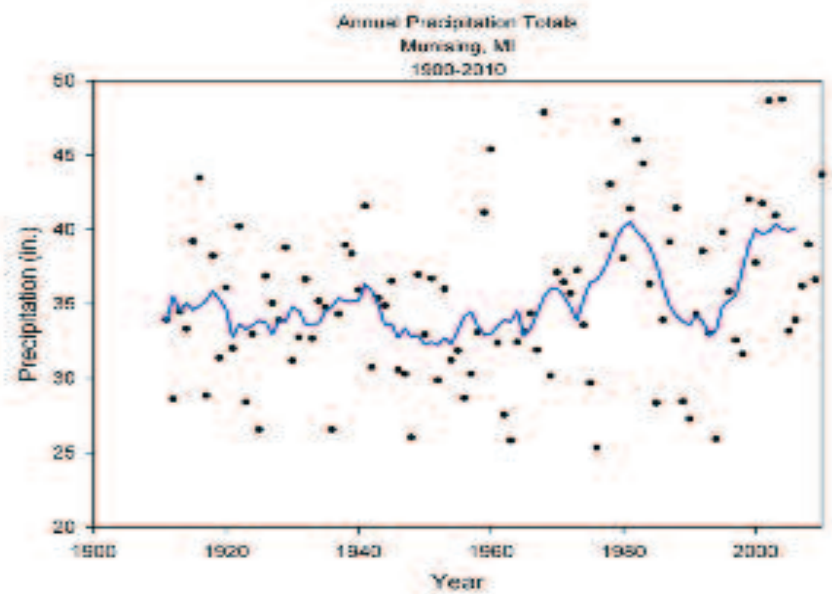


Figure 6. Annual total precipitation from 1900-2010.

Provided in cooperation with the Office of the Michigan State Climatologist

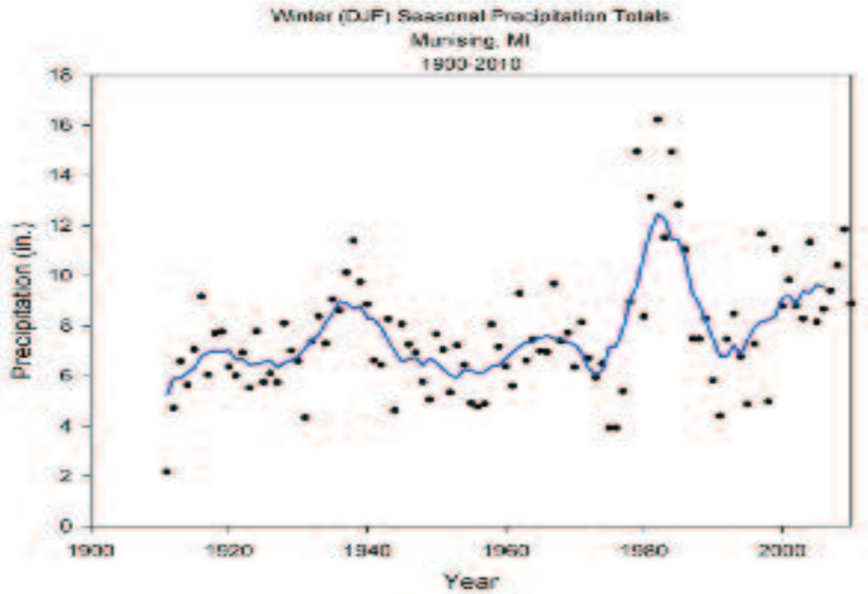


Figure 7. Winter June-August total precipitation from 1900-2010.

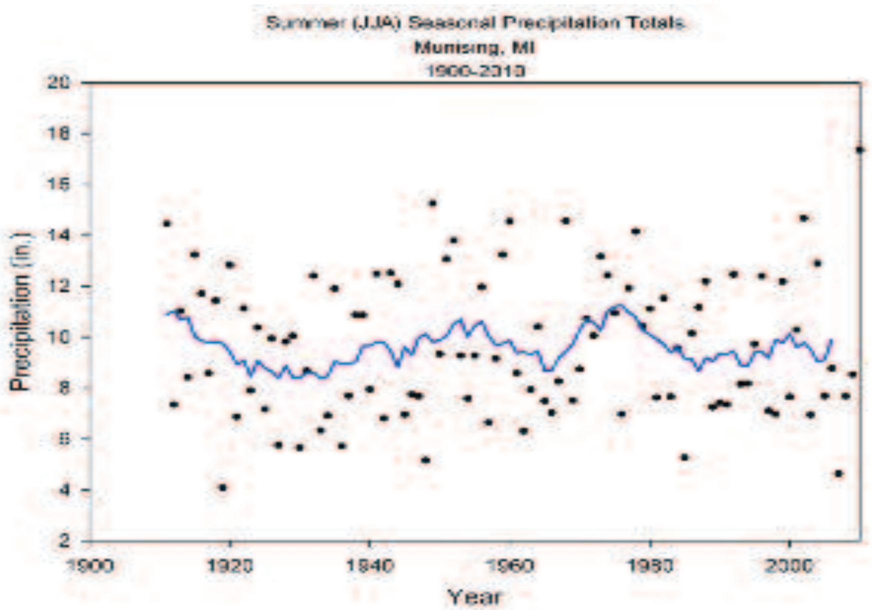
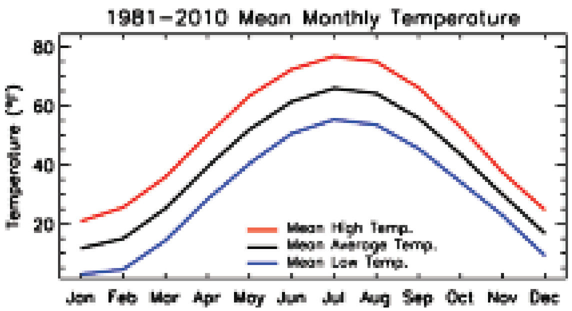


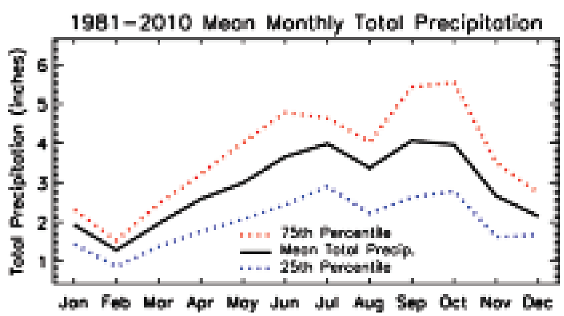
Figure 8. Summer June-August total precipitation from 1900-2010.

Station climatology summaries distributed by the Great Lakes Integrated Sciences and Assessments Center include data that has been quality controlled and any analyses presented may be subject to revision. The accuracy and consistency of data varies from station to station and throughout the data record. Information in this document is based primarily on data that is publically available through the NCDC at [http://www.ncdc.noaa.gov/cdo-web/search.](http://www.ncdc.noaa.gov/cdo-web/search)

Historical Climatology: Ironwood, Michigan



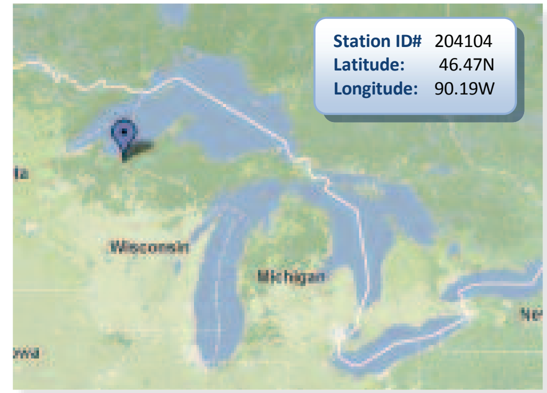
Mean monthly high, average, and low temperatures for the period 1981-2010.



Mean monthly total precipitation with the 25th and 75th percentiles for the period 1981-2010.

Geography

Ironwood, located in western Gogebic County, is 1 mile north of the Wisconsin border and 12 miles southeast of Lake Superior. The surrounding terrain is rolling to hilly and mostly forested. Recreational use of the lakes, rivers, and forest areas has increased rapidly in recent years. Soils are predominantly stony sandy loams, loams, and silt loams..



Map generated with Google Maps

Overview

Ironwood is on the west edge of the Lake Superior "snowbelt" which extends northeastward along the center ridge of the Keweenaw Peninsula. This ridge, which rises quite abruptly as much as 1200 feet above Lake Superior, has a strong influence on the development of the heavy snow squalls observed during the winter months. The lake effect also increases cloudiness during the fall and winter and also modifies temperatures, keeping them cooler during the late spring and early summer, and warmer during the late fall and early winter. In the late winter as ice builds up on the lakes, Ironwood is subjected to temperature variations which are more closely associated with interior locations. Diminished wind speeds or winds which do not traverse large unfrozen lakes often produce clearing skies and the colder temperatures expected at continental locations. As the day-to-day weather is controlled by the movement of high and low pressure systems across the continent, this area seldom experiences prolonged periods of hot, humid weather in the summer or extreme cold during the winter.

1981-2010 Temperature and Precipitation Summary

Mean Annual Temperature (°F)	40.3
Mean Annual Minimum Temperature (°F)	30.3
Mean Annual Maximum Temperature (°F)	50.2
Mean Number of Days per Year that exceed 90°F	1
Mean Number of Days per Year that fall below 32°F	179
Lowest Mean Annual Temperature (°F)	36.6
Highest Mean Annual Temperature (°F)	44.6
Mean Annual Total Precipitation (inches)	34.8
Lowest Mean Total Precipitation (inches)	25.9
Highest Mean Total Precipitation (inches)	46.3
Mean Number of Days/Year with > 0.1" Precip.	75
Mean Number of Days/Year with > 0.25" Precip.	43
Mean Number of Days/Year with > 0.5" Precip.	19
Mean Number of Days/Year with > 1" Precip.	6

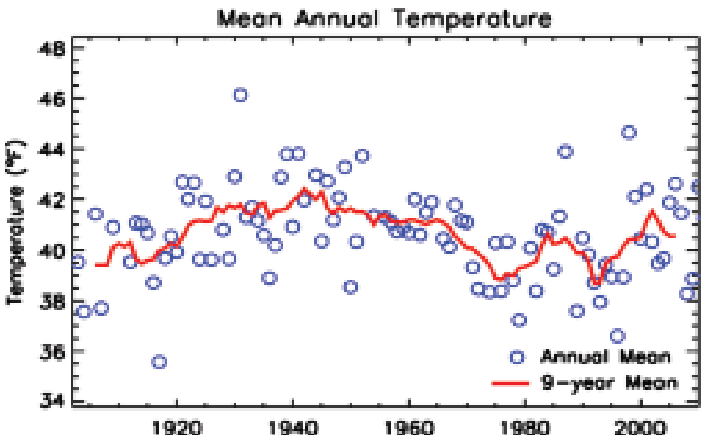
Historical Climatology: Ironwood, Michigan

Changes in Mean 1981-2010 Temperature from 1951-1980 (°F)

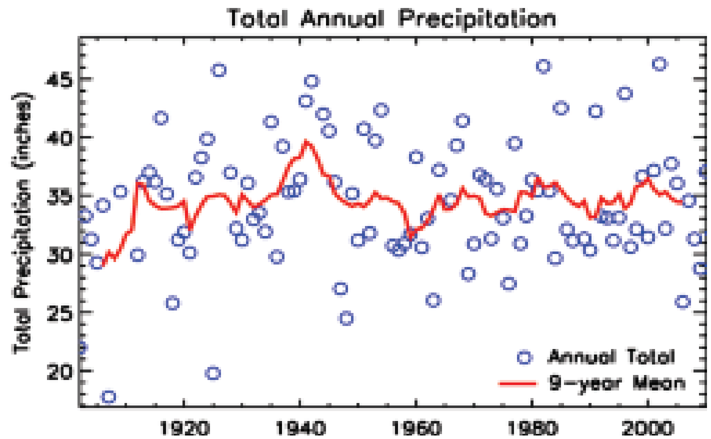
Annual	-0.2
Winter, December-February	0.6
Spring, March-May	-0.3
Summer, June-August	-0.6
Fall, September-November	-0.9

Change in Mean 1981-2010 Total Precipitation from 1951-1980 (%)

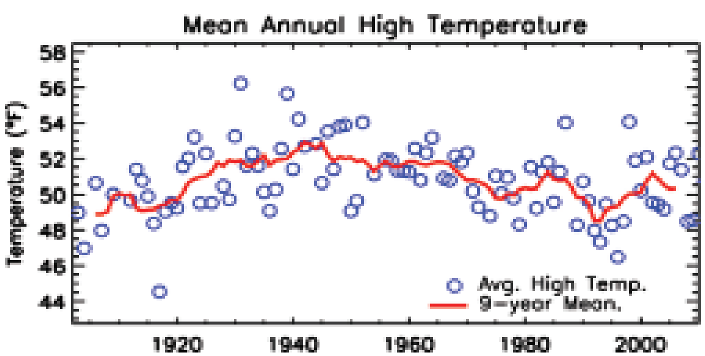
Annual	1.6
Winter, December-February	2.4
Spring, March-May	-1.3
Summer, June-August	-5.9
Fall, September-November	7.6



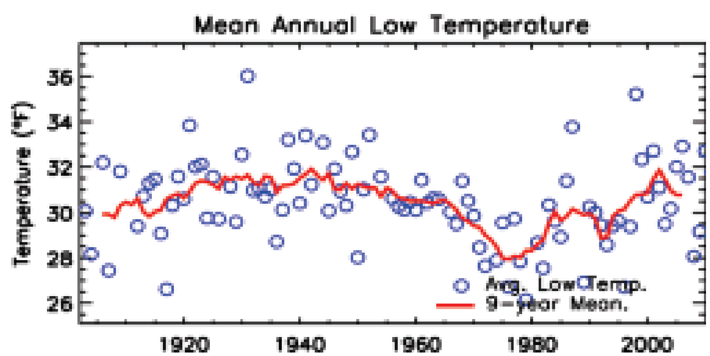
Mean annual temperatures from 1900 to 2010. An open circle represents the average temperature of a single year. The solid line represents the 9-year running mean.



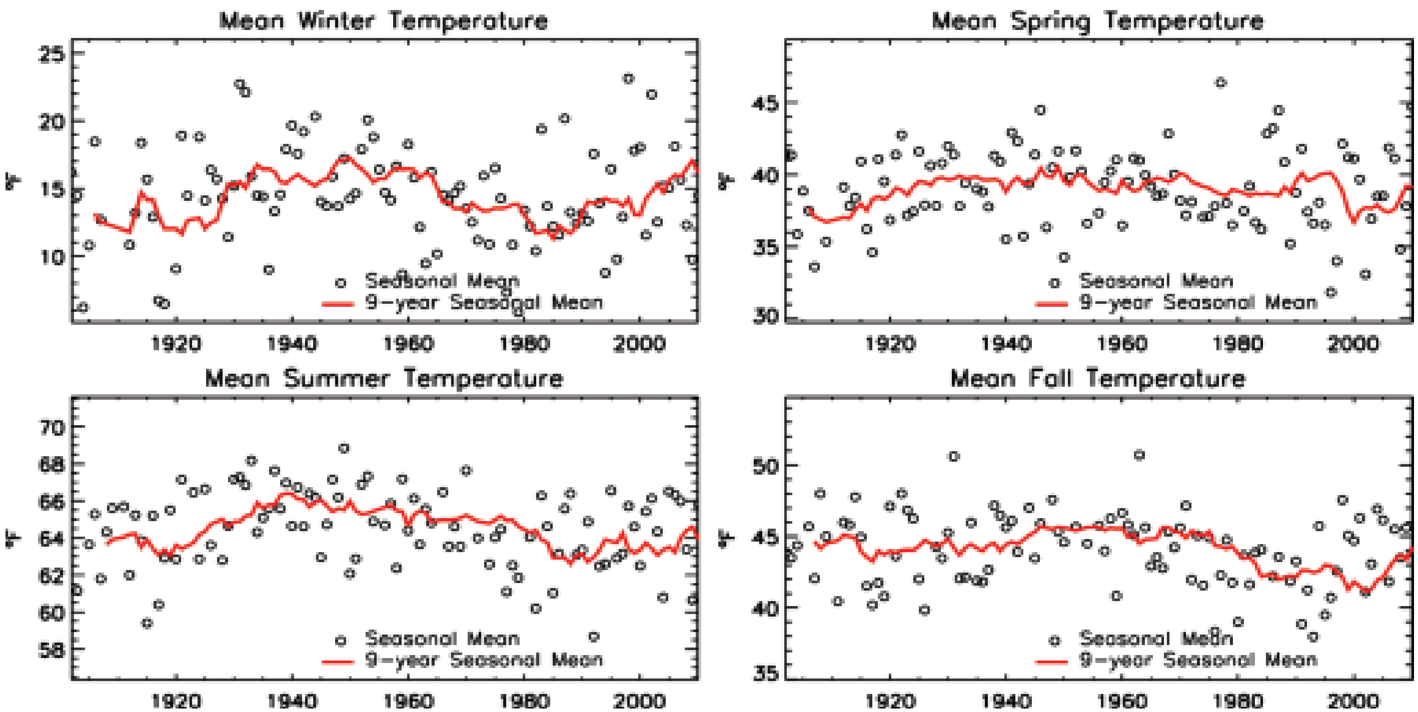
Mean annual precipitation totals from 1900 to 2010. An open circle represents the total precipitation for a single year. The solid line represents the 9-year running mean.



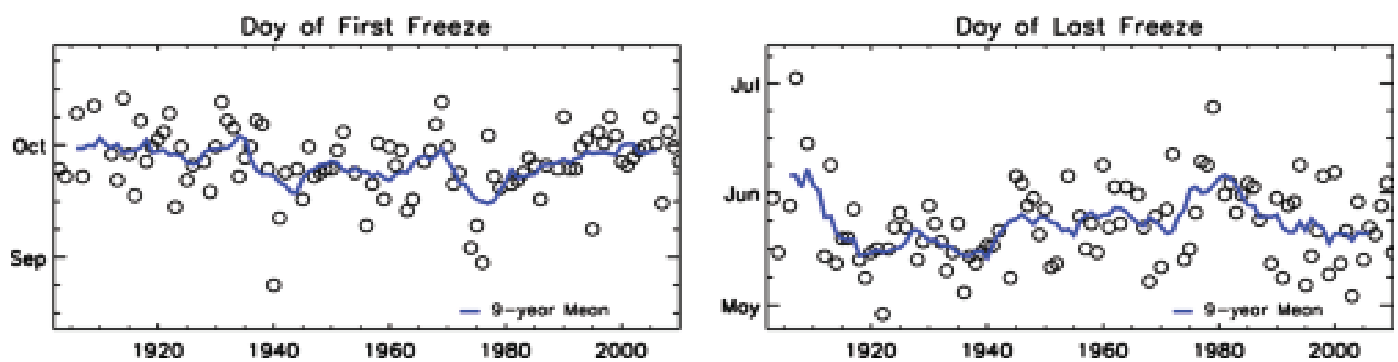
Mean annual high temperatures from 1900 to 2010. An open circle represents the average high temperature of a single year. The solid line represents the 9-year running mean.



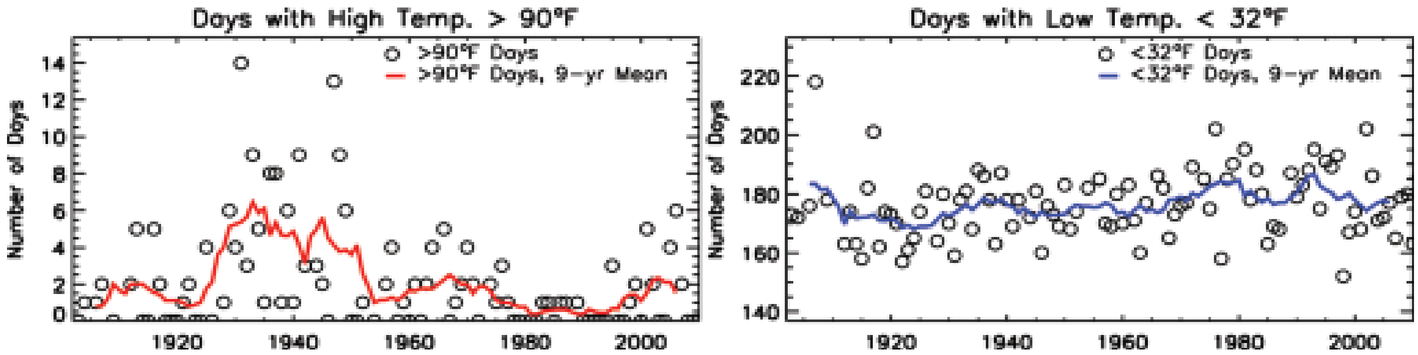
Mean annual low temperatures from 1900 to 2010. An open circle represents the average low temperature of a single year. The solid line represents the 9-year running mean.



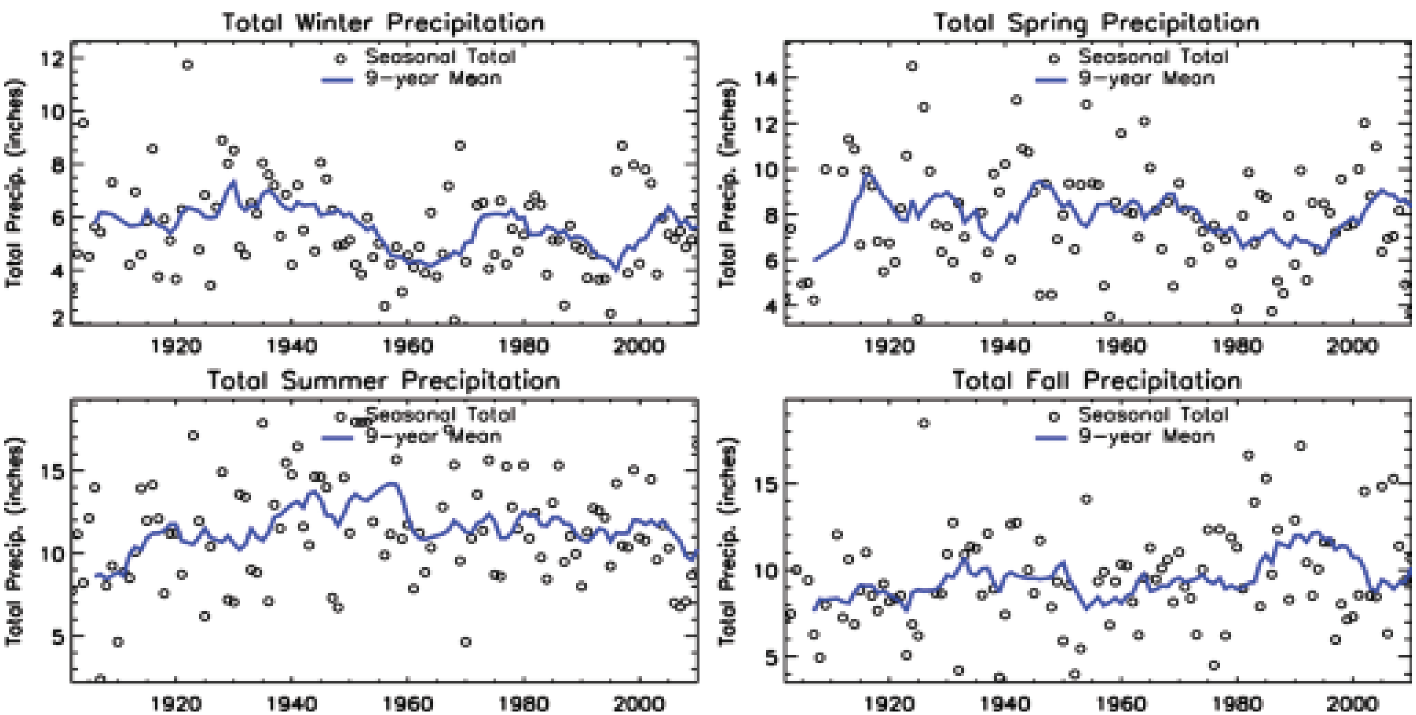
Mean seasonal temperatures from 1900 to 2010. An open circle represents the average seasonal temperature of a single year. The solid line is the 9-year running mean.



Open circles represent the first winter freeze of the year (daily low temperature < 32°F) from 1900-2010. The solid line is the 9-year running mean.



Open circles represent the number of days per year in which the daily high temperature exceeded 90°F (left) and where the daily low temperature dropped below 32°F (right) in a single year. The solid line is the 9-year running mean.

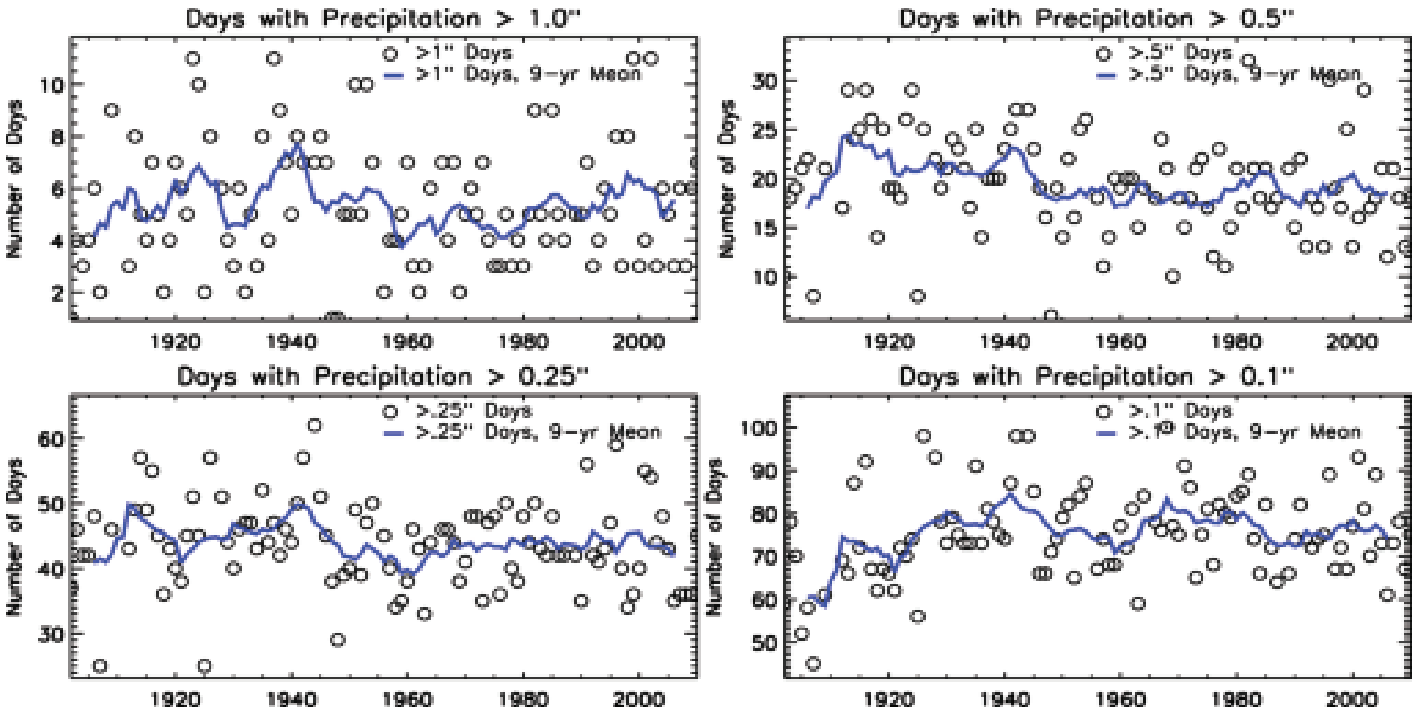


Mean total precipitation by season from 1900 to 2010. An open circle represents the total seasonal precipitation for a single year. The solid line represents the 9-year running mean of the total seasonal precipitation.

Unless otherwise stated, daily observations are used to calculate quantities in this document only if they satisfy a number of quality control tests and there is a high level of data coverage for the period in question. Nine-year running means are calculated for periods only when at least 5 of the 9 years are available. For more information on quality controls and data reliability requirements please see the Historical Climatologies: Quality Control document available on the GLISA website or email GLISA-info@umich.edu.

Many factors can influence long-term trends in precipitation and temperature. While human-caused climate change may be a major driver, other factors, such as natural variability, changes in nearby land use, urban heat-island effects, movement of the exact location of the observing station, and changes in measurement procedure can also play a role in climate trends over the station record.

The measurements of a single station do not necessarily represent global or regional trends in temperature and precipitation. Each station records the conditions at a given place over time.



Number of days per year that exceeded the indicated daily precipitation totals. The solid line represents the 9-year running mean. Days that exceeded a higher threshold are included in days exceeding lower thresholds.

REFERENCES

1. Austin, J.A. and S.M. Colman. (2007). **Lake Superior summer water temperatures are increasing more rapidly than regional air temperatures: A positive ice-albedo feedback**, Geophysical Research Letters, 34(6) Accessed online at: http://www.agu.org/pubs/crossref/2007/2006GL029021.shtml

2. Union of Concerned Scientists. (2009). **Migrating Climates: Michigan** Accessed Online at: http://www.ucsusa.org/greatlakes/winmigrating/glwinmig_mi.html

3. Dickmann, D. and L. Leefers. (2003). **The Forests of Michigan**. University of Michigan Press.

4. Froese, R. and others. (2007). **Large-tract Forestland Ownership Change: Land Use, Conservation, and Prosperity in Michigan's Upper Peninsula.** National Wildlife Federation and Michigan Tech University. Accessed online at: http://forestlands.mtu.edu/products/UP_Corporate_Forest_Land_Report.pdf

5. U.S. Census Bureau. (2010). Washington, D.C.; Department of Commerce. Accessed online at: http://quickfacts.census.gov/qfd/states/26000.html

6. IPCC (Intergovernmental Panel on Climate Change). (2007). **Summary for policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change** [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York. Accessed online at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf

7. Natural Resource Program Center, National Park Service, U.S. Department of the Interior. (2010). **Understanding the Science of Climate Change. Talking Points – Impacts to the Great Lakes.** Natural Resource Report NPS/NRPC/NRR – 2010/XXX. Accessed online at: http://www.nps.gov/climatechange/docs/GreatLakesTP.pdf

8. Saunders, S., D. Findlay and T. Easley. (2011). **Great Lakes National Parks in Peril: The Threats of Climate Disruption.** The Rocky Mountain Climate Organization and National Resources Defense Council. Accessed online at: http://rockymountainclimate.org/images/GreatLakesParksInPeril.pdf

9. National Assessment Synthesis Team (NAST). (2000). **Climate change impacts on the United States: the potential consequences of climate variability and change.** US Global Change Research Program. Washington DC. Accessed online at: http://usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm.

10. National Climatic Data Center (NCDC). (2011). National Oceanic and Atmospheric Administration. **June - September 2011 Precipitation Map**. Accessed online at: http://www.ncdc.noaa.gov/img/climate/research/2011/sep/div-precp-prank-201106-201109.gif

11. Aklerlof, K. (2010). **Final Report - Assessing Household Energy Use and Global Warming Opinion: Alger County 2010**. George Mason University.

12. U.S. Global Change Research Program (USGCRP), T. R. Karl, J. M. Melillo, and T. C. Peterson, editors. (2009). **Global Climate Change Impacts in the United States**. Cambridge University Press. New York. Accessed online at: http:/www.globalchange.gov/publications/reports/scientific-assessments/usimpacts.

13. McKinney, M. ed. (2004). **Outlooks: Readings for Environmental Literacy, 2nd Edition**. p. 97. Jones and Bartlett Publishers.

14. Aklerlof. **Final Report**. (See Reference 11).

15. G. W. Kling and others. (2003). **Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems**, report of Union of Concerned Scientists and Ecological Society of America, Cambridge, MA. Accessed online at: http://www.ucsusa.org/greatlakes/glchallengereport.html.

Wuebbles, D.L. and K. Hayhoe. (2003). **Climate Change Projections for the United States Midwest**. Mitigation and Adaptation Strategies for Global Change 9: 335-363. Accessed online at: http://www.springerlink.com/content/k066717671581161/

Union of Concerned Scientists. (2009). **Confronting Climate Change in the U.S. Midwest – Michigan**. Accessed online at: http://www.ucsusa.org/assets/documents/global_warming/climate-change-michigan.pdf

Saunders, et al. **Great Lakes National Parks in Peril**. (See Reference 8).

16. Austin and Colman. **Lake Superior Summer Water Temperatures**. (See Reference 1).

17. Austin and Colman. **Lake Superior Summer Water Temperatures**. (See Reference 1).

18. Duluth News Tribune. (29 June 2011). **Lake Superior Rising Faster Than Normal**.

19. Moen, S. **Ice Cover Lacking on Lake**. (April 2006). Minnesota Sea Grant. University of Minnesota Extension. Accessed online at: http://www.seagrant.umn.edu/newsletter/2006/04/ice_cover_lacking_on_lake.html

20. Minnesota Sea Grant. (2009). **Aquatic Invasive Species.**
Accessed online at: http://www.seagrant.umn.edu/ais/overview.

21. **Climate Change and Great Lakes Wetlands Webinar Transcript.** (2011) Ohio State University.
Accessed online at: http://changingclimate.osu.edu/webinars/archives/2011-11-08/

22. Leefers, L. (2007). **The U.P. Economy and Role of Forest Products Industries.** Prepared for People and Land (PAL) 2006 Higher Education Grant and Land Policy Institute, Michigan State University. Accessed online at:
http://forestlands.mtu.edu/products/Appendix%20B%20Economic%20Impacts%20V1.pdf

23. USDA National Forest Service, Northern Research Station. (2011). **Ecosystem Vulnerability Assessment and Synthesis: A Report from the Climate Change Response Framework Project in Northern Wisconsin.** General Technical Report NRS 82.

24. Saunders, et al. **Great Lakes National Parks in Peril.** (See Reference 8).

RESOURCES USED TO DEVELOP LIST OF ADAPTATION OPTIONS

New Hampshire

- Keene, New Hampshire, Adapting to Climate Change: Planning a Climate Resilient Community, November, 2007.
  http://www.ci.keene.nh.us/sites/default/files/Keene%20Report_ICLEI_FINAL_v2_0.pdf

- Seabrook, New Hampshire, Adaptation Strategies to Protect Areas of Increased Risk From Coastal Flooding Due to Climate Change, July 2009.
  http://des.nh.gov/organization/divisions/water/wmb/coastal/documents/seabrook_adaptation.pdf

Pennsylvania

- Climate Change in Pennsylvania: Impacts and Solutions for the Keystone State, October 2008.
  http://www.northeastclimateimpacts.org/assets/climate-change-in-pennsylvania_impacts-and-solutions.pdf

Vermont

- Vermont climate change adaptation white papers, 2011-2012.
  http://www.anr.state.vt.us/anr/climatechange/Adaptation.html

Great Lakes Region

- Preparing for Climate Change in the Great Lakes Region, February, 2009.
  http://www.miseagrant.umich.edu/downloads/climate/Climate_Workshop_Report.pdf

Northeast

- Northeast Climate Impacts Assessment, Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions, July 2007.
  http://www.northeastclimateimpacts.org/

- Manomet Center for Conservation Sciences, Forestry Adaptation and Mitigation in a Changing Climate: A forest Resource Manager's Guide for the Northeastern United States, May 2009.
  http://www.manomet.org/sites/manomet.org/files/Forestry%20Adaptation%20and%20Mitigation%20in%20a%20Changing%20Climate-%20A%20Forest%20Resource%20Manager's%20Guide%20for%20the%20Northeastern%20United%20States..pdf

National

- National Research Council (NRC), America's Climate Choices: Adapting to the Impacts of Climate Change, 2010.
  http://www.nap.edu/catalog.php?record_id=12783

[1] U.S. Department of Commerce. 2011. Census Bureau, County Business Patterns, Washington, D.C. Figure does not include employment data for government, agriculture, railroads, or the self-employed because these are not reported by County Business Patterns.

[2] Ibid.

[3] Ibid.

[4] Karetnikov, D., M. Ruth, K. Ross, and D. Irani. 2009. Economic Impacts of Climate Change on Michigan. The Center for Integrative Environmental Research, University of Maryland.

[5] Conservation Biology Center, 2006. Accessed from the Economic Profile System-Human Dimensions Toolkit, Land Use Profile. Headwaters Economics, Bureau of Land Management, U.S. Forest Service. http://headwaterseconomics.org/tools/eps-hdt. The U.S. Census Bureau county boundaries extend over significant portions of Lake Superior, meaning 60% of the regional area is classified as water. We subtracted water from the land area to calculate the percent of land area managed by the Forest Service and the State of Michigan.

[6] U.S. Department of Labor. 2011. Bureau of Labor Statistics, Quarterly Census of Employment and Wages, Washington, D.C.

[7] U.S. Department of Commerce. 2011. Bureau of Economic Analysis, Regional Economic Information System, Washington, D.C. Table CA25N

[8] USDA Forest Service Forest Management. FY 1980 to FY 2011 Cut and Sold Reports. Convertible Products by State, National Forest, and Region.

http://www.fs.fed.us/forestmanagement/products/sold-harvest/index.shtml/cut-sold.shtml.

[9] U.S. Forest Service Watershed Condition Framework. http://www.fs.fed.us/publications/watershed/.

[10] Data Sources: U.S. Department of Commerce. 2011. Census Bureau, County Business Patterns, Washington, D.C.

[11] Drs Sarah Nicholls and Dan McCole. Michigan Tourism Year-in-Review and Outlook. Presented at "Pure Michigan Governor's Conference on Tourism" in Grand Rapids on March 27 2012. http://www.carrs.msu.edu/docs/pdfs/msutourismoutlook2011-2012.pdf.

[12] Lorah, P. R. Southwick, et al. 2003. Environmental Protection, Population Change, and Economic Development in the Rural Western United States. Population and Environment 24(3):255-272; McGranahan, D. A. 1999. Natural Amenities Drive Rural Population Change. E. R. S. U.S. Department of Agriculture. Washington, D.C.; More than 100 economists recently urged the President to protect federal lands as an important economic asset. See: http://headwaterseconomics.org/land/reports/economists-president-public-lands.

[13] U.S. Department of Commerce. 2011. Bureau of Economic Analysis, Regional Economic Information System, Washington, D.C. Table CA05N.

[14] U.S. Department of Commerce. 2011. Census Bureau, County Business Patterns, Washington, D.C. Data do not include employment data for government, agriculture, railroads, or the self-employed because these are not reported by County Business Patterns.

[15] Ibid.

[16] Data Sources: U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C.; U.S. Department of Commerce. 2000. Census Bureau, Systems Support Division, Washington, D.C.

[17] Ibid.

[18] Cromartie, John and Peter Nelson. 2009. Baby Boom Migration and Its Impact on Rural America. U.S. Department of Agriculture Economic Research Report No. (ERR-79) 36 pp.

[19] Data Sources: U.S. Department of Commerce. 2011. Bureau of Economic Analysis, Regional Economic Information System, Washington, D.C. Tables CA05N & CA35.

[20] U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C. Poverty data are calculated by ACS using annual surveys conducted during 2004 to 2010 and are representative of average characteristics during this period.