Welcome to this training on “Climate Ready Great Lakes!” This presentation features content that was developed on behalf of the NOAA Great Lakes Regional Collaboration Team and the Great Lakes Sea Grant Network.

This is the first of three modules developed to help people and communities in the Great Lakes region become more “climate ready.” This module provides insights into the question, “What am I adapting to?” – specifically, providing a general introduction to climate science and the trends and impacts of climate change specific to the Great Lakes region.

(Dr. Jane Lubchenco has been the under secretary of commerce for oceans and atmosphere and administrator of NOAA, the National Oceanic and Atmospheric Administration, since 2009.)

As Dr. Lubchenco points out, [CLICK and read… “the climate challenge before us is real…”) We seem to be at a turning point in the national dialogue about climate change. It is rare that a day goes by without the media covering some aspect of climate change, whether it is a new study documenting the impacts or an editorial about how to best respond to the climate change challenge.

Within NOAA, Dr. Lubchenco is providing important leadership—sending out the message that “climate change is real”—in the hopes that it will improve the capacity of individuals and communities to become climate ready
However, much of what we hear or read is about global climate change. This presentation is different. While we will discuss global climate change in the beginning of our presentation, the purpose of this training is to discuss how climate change may affect the Great Lakes region.

With that in mind, the goals of this training are to:

- Provide information on climate change in the Great Lakes, based on peer-reviewed science. The Great Lakes examples we describe here have all been taken from journals that adhere to the professional standards of peer-reviewed research. An annotated bibliography of these articles provides the basis for this training; we will pass out the bibliography handout after the presentation.

[CLICK] The second goal is to provide you with examples of ways that communities are preparing for a changing climate.

By the end of this training you should be able to...

[READ BULLETS]
Today’s presentation is broken up into six interrelated sections, which are listed in the toolbar at the bottom of the slide.

Part 1 of the presentation is divided into three sub-sections, which are designed to help you understand the fundamentals of climate change.

First, we’ll discuss the differences between **Weather** and **Climate**, and then we’ll discuss some basics about climate science to help you understand the concept of climate change.

Next, we’ll discuss changes that have **already been observed** in the earth’s climate system, as well as those **changes that are projected to occur**.

Finally, we’ll discuss the Great Lakes climate and projected changes for the region.

In part 2 of our presentation, we’ll discuss in more detail how changes in the Great Lakes weather and climate system will impact lake levels, ice cover, weather patterns, ecosystems, and human health and the economy.
Before we begin discussing how climate change might impact the Great Lakes region, let’s first review the key differences between weather and climate. An accurate understanding of the difference between weather and climate is critical to understanding the concept of climate change.

**Weather** is the state of the atmosphere at any given time and place (temperature, humidity, precipitation, cloudiness, wind, etc.).

**Climate** is the set of meteorological conditions that prevail in a particular place or region over a long period of time.

If I asked you what the weather was like today in Ann Arbor, you would tell me that “It’s partly cloudy and 68 degrees.” This is weather. If I were to ask you what the winter is like in Ann Arbor, you would tell me that “In general, it’s cold and snowy.” This is climate.

Image citations:
- Columbia Service Learning Program (CSLP). http://community.seas.columbia.edu/cslp/
- Hydrometeorological Prediction Center (HPC). http://www.hpc.ncep.noaa.gov/noaa/noaa.gif

Weather is highly **variable** and difficult to predict beyond one week. Weather varies over hours, days, and weeks.

Climate is less variable because it is “averaged weather” over a long period of time. Climate varies over seasons and years.
Climate Change: The Fundamentals

Climate • Climate describes how Weather varies at a particular location over a longer period of time. In other words, it’s the average of all the weather spread over a long period of time. Normals are derived from averaging the weather.

Climate Variability • Climate variability describes fluctuations in the Climate itself over time. These changes are usually natural and of a brief timescale.

Climate Change • Climate Change describes longer-term (decades or longer) and persistent changes in Earth’s Climate. This may be described as persistent or permanent changes in the Normals.

So to summarize...

[CLICK] Climate describes how Weather varies at a particular location over a longer period of time. In other words, it’s the average of all the weather spread over a long period of time. Normals are derived from averaging the weather.

[CLICK] Climate variability describes changes in the Climate itself over time. Such changes are usually natural and of a brief timescale.

[CLICK] Climate Change describes longer-term (decades or longer) and persistent changes in Earth’s Climate. This may be described as persistent or permanent changes in the Normals.

Global Climate Change: The Science

The Greenhouse Effect • The Greenhouse Effect is a vital and healthy planetary process that helps the Earth retain heat from solar radiation. However, increased amounts of greenhouse gases emitted into the atmosphere mean that an excessive amount of heat is retained—and less energy is able to escape Earth’s atmosphere. In this way, excessive greenhouse gases act like an atmospheric blanket. Thus, Earth’s surface heats up more quickly, creating an overall increase in the Earth’s temperature.

We know that increased human emissions of greenhouse gases are causing global climate change. Carbon dioxide and other pollutants collect in the atmosphere and trap the sun’s heat, gradually warming the planet.

In the U.S., coal-burning power plants are the largest source of carbon dioxide pollution: they produce 2.5 billion tons every year. Automobiles—the second largest source—create nearly 1.5 billion tons of carbon dioxide annually. In short, human emissions have amplified this natural thermal process.

Source citation: http://www.nps.gov/grba/naturescience/what-is-climate-change.htm

Now that you can distinguish between weather and climate, the next part of our presentation will focus on the observed changes in global climate.

The Greenhouse Effect is a vital and healthy planetary process that helps the Earth retain heat from solar radiation. However, increased amounts of greenhouse gases emitted into the atmosphere mean that an excessive amount of heat is retained—and less energy is able to escape Earth’s atmosphere. In this way, excessive greenhouse gases act like an atmospheric blanket. Thus, Earth’s surface heats up more quickly, creating an overall increase in the Earth’s temperature.

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Source citation: http://www.nps.gov/grba/naturescience/what-is-climate-change.htm
Part 1: Observed and Projected Global Changes

Slide 14

Part 1: Observed and Projected Global Changes

Slide 15

Global Climate Change: The Observations

So how do we know that human activity is amplifying the Earth’s greenhouse effect?

Carbon dioxide in the atmosphere is increasing: We have observed a rise from approximately 280 ppm (prior to the Industrial Revolution) to nearly 380 ppm today. That’s a 35% increase in CO2 emissions over the last 150 years.

Source citation:

Slide 16

Global Climate Change: The Observations

Coincident to these observed increases in atmospheric CO2, we have observed an increase in global average surface temperatures. The Earth has warmed approximately 1° Celsius (or 1.8° Fahrenheit) since the beginning of the Industrial Revolution. In the last 150 years, the warmest 12 years have been observed from 1990–2006.

Source citation:
Intergovernmental Panel on Climate Change, 4th Assessment Report
Along with an increase in global average temperatures, scientists have also observed significant changes in sea level and arctic ice over the last century.

Global sea level has risen between 4–8 inches (10–20 centimeters) over the past century.

Arctic sea ice has decreased nearly 10% (in its areal extent) each decade between 1973 and 2007. In fact, Arctic sea ice coverage was at a record low in 2010.

Climatologists have observed increases in northern latitude precipitation and decreases in subtropical regions.

**Aim:** This slide aims to present realities of global climate change (that is, the changes that have already occurred).

**Key Points:** This slide is fairly self-explanatory: it is a list of consequences that our planet has already experienced as a result of global climate change. Different from forecast or projected changes, this list of changes is already a reality—so, it is not necessary to emphasize uncertainty here.

**Figures:** There are 2 figures in play here. The next figure depicts recent rises in sea level; the colored area depicts various measurements and a black/red line represents a consensus. Finally, the last figure depicts recent reductions in Arctic sea ice coverage, which is self-explanatory.

Image citations:
Arctic Sea Ice image: http://www.nrdc.org/globalwarming/images/
So, what do scientists think might result from continued global climate change?

**Given an average of global carbon dioxide emissions scenarios...**

Northern latitudes will *likely* continue to become wetter, while subtropical locations will *likely* grow even drier. The map shows likely warming by 2020–2029 (as well as by 2090–2099). Notice that northern latitudes are *likely* to experience a greater degree of warming. “A1B” is simply the IPCC’s code for its “middle” ground emissions scenario.

**Aim:** This slide aims to present projections of global climate change (that is, changes that are forecast to occur).

**Key Points:** This slide is also fairly self-explanatory. It is important to convey uncertainty in a more direct manner by stating that such impacts are *likely to occur but not a certainty*. More will follow on this in a later slide.

**Graphics:** The word “likely” is in bold print in order to underscore how important it is to account for scientific uncertainty.

Source citations:
Intergovernmental Panel on Climate Change (IPCC).
Columbia University, Earth Institute.
http://www.ldeo.columbia.edu/edu/dees/V1003/images/projected.CO2.temp.jpg

Moreover...Globally-averaged surface temperatures will *likely* increase 1.8–4 degrees Celsius by 2100, with greater increases at northern latitudes. This graphic depicts likely increases in carbon dioxide concentrations by 2100—along with projected temperature increases given such carbon dioxide levels (“business as usual”).

Finally, Arctic Sea ice coverage is also *likely* to decrease even further (from approximately 7 million square-kilometers to 4 million square-kilometers) and will *likely* contribute to sea-level rises of 0.6–1.9 feet over the next century.
Aim: This slide aims to present projections of global climate change (that is, changes that are forecast to occur).

Key Points: This slide is also a fairly self-explanatory list. However, in this case, we are looking at a list of projected impacts, which scientists feel might result from continued global climate change. Thus, here it is important to convey uncertainty in a more direct manner by stating that such impacts are likely to occur but not a certainty. More will follow on this in a later slide.

Graphics: The word “likely” is in bold print in order to underscore how important it is to account for scientific uncertainty.

Source citations:
Intergovernmental Panel on Climate Change (IPCC).
Columbia University, Earth Institute.
http://www.ldeo.columbia.edu/edu/dees/V1003/images/projected.CO2.temp.jpg

Using climate models, scientists have been able to demonstrate how increases in global average surface temperatures are not just a result of natural forces.

Figure: As the blue band indicates, without human influences, global average temperature would actually have cooled slightly over recent decades. With human influences, it has risen strongly (black line), consistent with expectations from climate models (pink band).

Source citation: This figure shows that climate models using only natural forces cannot replicate observed warming – in fact, they would predict cooling. Only models including anthropogenic greenhouse gases can duplicate the observed warming trend.
(U.S. Global Change Research Program, Global Climate Change Impacts in the United States at 20 (2009).)
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<th>Slide 21</th>
<th><strong>Climate Models</strong></th>
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| - Computer models are essential for understanding the complexities of climate change.  
- Confidence in the ability of models to project future climate is growing. |

Global Climate Models also help us understand and quantify degrees of uncertainty associated with climate change forecasts.

Climate change uncertainties include questions regarding the degree of future greenhouse gas emissions, solar output, and variations in ocean circulation patterns—and the complexities of the interactions between such variables.

Our confidence in the ability of models to project future climate is growing.

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<th>Slide 22</th>
<th><strong>Climate models are scientific tools, not crystal balls.</strong></th>
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<tbody>
<tr>
<td>This figure is a bit complicated at first glance; however, it is simply a depiction of what a climate model’s “innards” look like, so to speak.</td>
<td></td>
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</tbody>
</table>

Understanding—as well as predicting—something as complex as the climate is not done with a simple hypothesis. Models simulate the physical, chemical, and earth processes that drive climate. Models are used to study past changes in the Earth’s climate—as well as project future changes.

These models are our best, collective guess as to how the climate system works, based on past and current observations—and tested against historic and prehistoric conditions using data records from the past. [CLICK]

It is important to understand that climate models are scientific tools, not crystal balls. They are, however, critical tools that are used by decision makers and planners to build our communities for the future.

Source citation: 
*Graphic sources unavailable at this time.*

<table>
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<tr>
<th>Slide 23</th>
<th><strong>Downscaling: Climate Change at a Regional Level</strong></th>
</tr>
</thead>
</table>
| - Climate change is global in its nature; however, its precise impacts will undoubtedly vary on a regional level—and the Great Lakes region is no exception.  
- Downscaling allows researchers to capture unique aspects of climate change in the Great Lakes region, while also providing a general picture of its impacts. |

Downscaling is a process of progression from a broad scale (in this case, global or national) to a narrower scale (such as regional or local). In the case of climate change, researchers are taking predictions made by Global Climate Models and extracting statistical information on a regional or even local scale. [CLICK]

Source citation: 
[http://ccr.aos.wisc.edu/model/ipcc10min/futclimateinfo.html](http://ccr.aos.wisc.edu/model/ipcc10min/futclimateinfo.html)
Why do we have to downscale global climate information to the regional scale? Global models don’t have the resolution to handle things (such as mountains, valleys, and lakes) that have an impact on local and regional climates. Thus, the larger global climate projections must be adapted (statistically) to account for the presence of these features.

Although scientists are increasingly moving towards the use of regional climate models for climate projections, many of the impacts in this presentation use climate scenarios based on global models.

So what makes regional climate change impacts for the Great Lakes different from GLOBAL climate change impacts?

What it really comes down to is the fact that we have a unique and diverse climate, influenced by its location in the middle of a large land mass (North America) and the presence of the Great Lakes. The Great Lakes represent about 84% of the surface freshwater resources in the United States, and they have 10,000 miles of coastline.

So let’s talk a little about how lake effects influence the region’s climate system…

[CLICK]

The Great Lakes have a big influence on the climate. Acting as a giant heat sink, the lakes moderate the temperatures of the surrounding land—cooling the summers and warming the winters. As a result, the climate is milder in portions of the basin as compared to other locations of similar latitude. The lakes also act as a giant humidifier, increasing the moisture content of the air throughout the year. In the winter, this moisture condenses as snow when it reaches the land, creating heavy snowfall in some areas (known as “snow belts”) on the downwind shores of the lakes. The shores of Lake Superior are prone to this “lake-effect” snow, and they have recorded up to 350 inches of snow in a
single year. During the winter, the temperature of the lakes continues to drop. Ice frequently covers Lake Erie, but seldom fully covers the other lakes.

We can see evidence of how the presence of the lakes impacts...

...temperature climate in most areas (particularly east and south of the lakes, where its generally warmer in the winter and summer). [Point to temperature along east and southern edges of the winter and summer slides.] Notice how Lake Superior’s southern shore is cooler (in the winter) than the land mass just south of it and warmer (in the summer) than the land mass north of it.

ON WINTER SLIDE: In the winter, most lakes remain ice-free—except Erie, which is the shallowest of the lakes.

... the length of the growing season along the shorelines. [Point to frost free map to demonstrate how the length of the growing season increases closer to shore, because the lakes moderate the temperature around the shore.]

...precipitation. In winter, heavy snow bands occur along the eastern and southern shorelines. Lake impacts can even reduce summer precipitation downwind of the shore (due to stabilizing lake breeze effects). [Point to precipitation and snow belts map to show how the air masses shown in the frost free map impact snowfall in the eastern and southern shoreline).

[NEXT SLIDE]

Using climate models, scientists have made the following projections about changes in the Great Lakes CLIMATE...

Average surface temperatures are likely to rise another 3–6 degrees Celsius (5–10 degrees Fahrenheit) by 2100.

Distribution of annual (yearly) average precipitation is likely to become increasingly uneven. In fact, the USGCRP predicts likely precipitation increases of 10–30% in wintertime and likely decreases of 5–25% in summertime.

While annual average precipitation may increase slightly, lake levels could potentially drop as a result of increased evaporation (as a result of warmer temperatures).

Lake ice coverage is also likely to drop as we head deeper into the 21st century.

**Aim:** The aim of this slide is to discuss the projected impacts of climate change in the Great Lakes region. It is important to recognize this slide is focusing on climatological impacts (such as changes to average temperatures, precipitation, and lake levels/ice coverage).

**Key Points:** The key to this slide lies in pinpointing projected impacts of climate change over the Great Lakes region. Said impacts are likely to occur; thus, it is necessary to emphasize uncertainty in a more direct manner. Also, this slide lists four distinct impacts of climate change and shows a related figure that compliments each point (in-depth discussion below).

**Figures:** The above figure provides an excellent snapshot of projected climate change impacts in the Great Lakes region. It offers excellent maps, which depict likely temperature and precipitation changes. Specifically, the figure directly relates to shifts in both temperature and precipitation (two of the four impacts discussed). The figure also indirectly explains both decreased water levels (which are related to increased evaporation due to warmer temperatures) and decreased lake ice coverage. (As average wintertime
temperatures rise—especially minimum temperatures—lake ice will not form as easily.) Furthermore, this figure is relatively easy to understand as well. The only potentially confusing point surrounds the depiction of projections from both the Canadian and Hadley models. Remind the audience of the fact that no projection is set in stone, and that different models help us to get a feel for the “range” of possibilities that exist.

**Graphics:** As in earlier slides, the word “likely” is typed in bold print in order to emphasize uncertainty’s importance.


The Great Lakes region is likely to experience changes as a result of climate change. However, in what ways might the Great Lakes themselves influence potential climate impacts?

- The Great Lakes gain and lose heat more slowly than surrounding land masses. **CLICK. Explain Lake Breeze Circulation diagram:** Warm temperatures over land rise and are cooled. A lake breeze front pushes the air up and over the lakes. Cooler air is blown off the lake toward the shore, cooling temperatures along the shoreline.] This will not change in light of broader-scale, climatic changes; however, it will have some important effects.

  - On a positive note, summer temperature increases will **likely** be less severe downwind of the Great Lakes as a result of lake-induced cooling. This could make parts of the region more appealing for summer tourism—as a place to “escape the heat.” **[CLICK]**
  
  - An increased difference between air and water temperatures in fall and early winter will **likely** lead to an increase in “lake-effect” precipitation. **[Point out graph on right: Warmer summer temperatures heat up the lake in the summer. In winter, cold air moving across a warmer lake results in lake-effect precipitation.]**

  - As lake ice coverage decreases, the Union of Concerned Scientists predicts a “cultural shift” may occur as wintertime recreation held on previously frozen lakes becomes more difficult.
These are simply examples of how weather, climate, and the lakes interact with each other.

So, how will climate change interact with the lakes to alter daily WEATHER patterns over region? It’s important to note that now we are talking about daily or weekly conditions—as opposed to the average changes mentioned in the previous slide.

Aim: This slide aims to summarize conditions that might become more prevalent over the Great Lakes region as climate change continues to play out. (Here we are talking about daily or weekly conditions, as opposed to the averages indicated in the previous slide.)

Key Points: Begin by briefly reviewing the distinction between Weather and Climate in order to separate this slide from Slide 12. Secondly, it is once again important to emphasize scientific uncertainty by describing projected impacts as being likely to occur.

Now we’re going to discuss, in more detail, the observed and projected impacts of climate change in the Great Lakes region.

For today’s presentation, potential climate change impacts have been broken into six, somewhat interrelated categories. All of the categories are centered around the principle that climate change will have consequences for the Earth’s system and human lives.

Let’s start with Lake Levels.
So, a big question is… will the level of the Great Lakes go up or down?

[WAIT FOR ANIMATED ARROWS TO COMPLETE]

There is still uncertainty about how exactly climate change will affect the levels of the Great Lakes. There is a range of predicted changes in lake levels over the next 50–100 years—with an overall downward trend in lake levels expected. However, that trend will be marked by significant variability and fluctuations due to changing climate variables that influence lake levels.

Source citation:

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In fact, lake levels are already in a constant state of flux; the Great Lakes’ water levels have varied considerably over the past several hundred years. As shown on this graph, over the last 150 years, Lake Superior has fluctuated about 2.6 feet (0.8 meters). The high water level in October of 1985 was 183.75 meters, and the low was in March of 1926 was 182.95 meters.

Source citation:
The data in this graph originated from the U.S. Army Corps of Engineers-Detroit District.

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The natural variation in lake levels is influenced by many environmental factors, including solar radiation, precipitation, humidity, evaporation, temperature, and wind speed. As climate change affects the relative strength and intensity of these environmental factors, natural lake level variation will likely become even more pronounced.

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To understand how lake levels vary, let’s take a look at how those environmental factors influence the hydrologic cycle. Precipitation falls (as rain or snow) and collects (as groundwater and in rivers and lakes). Plants give off moisture, which goes back into the atmosphere through transpiration; moisture is also returned to the atmosphere through evaporation from water bodies. Greater evaporation will result from (1) warmer temperatures in the summer and (2) less ice cover in the winter. As more water leaves the lakes and enters the atmosphere, there is the potential for...
water levels to drop—if all else is held constant in the environment.

Based on most peer-reviewed studies, scientists currently believe that lake levels will fall over the next century. However, there will continue be a great deal of year-to-year fluctuation or variability.

Source citation:

### Changes in lake levels will have an impact on the region’s shipping industry
Shipping is important in the Great Lakes region:
- 15 major international ports and approximately 50 smaller, regional ports in the Great Lakes-St. Lawrence River System
- Over 200 million tons of cargo per year

Fluctuating lake levels will impact shoreline infrastructure and harbors (recreational and commercial).

There are 15 major international ports and approximately 50 smaller, regional ports in the Great Lakes-St. Lawrence River System. These ports ship over 200 million tons of cargo per year. As we noted, there is a range of predicted changes in lake levels over the next 50–100 years, with an overall downward trend in lake levels expected—but that trend will be marked by significant variability and fluctuations. These fluctuations may affect shoreline infrastructure, requiring increased dredging of channels for port access. Recreational and commercial harbors will also be impacted by shifting lake levels.

Looking at how the salty coast deals with shifting water levels due to tidal influences could be a way for Great Lakes communities to make their shoreline infrastructure more adaptive to varying lake levels.

Source citations:

• There is a range of predicted lake levels, but the likely overall trend is downward.
• Lake levels are affected by environmental factors (e.g., solar radiation, precipitation, humidity, evaporation, temperature, and wind speed).
• Shifting lake levels will impact shoreline infrastructure and shipping.

Now let’s talk about how climate change will impact ice cover on the Great Lakes.

One predicted impact of rising temperatures in the Great Lakes is a reduction in seasonal ice cover. While this graph of ice cover in the Great Lakes indicates large year-to-year variations, there is a clear decrease in the extent of Great Lakes ice cover as shown by the red line.

So, just to recap, we’ve talked about lake level changes, projected temperature increases, and a reduction in ice coverage on the lakes.

Source citation:
Image citations:
•http://www.flickr.com/photos/henribonell/3376075968/sizes/m/
•http://www.flickr.com/photos/javatopia1/106474947/

Backup
Relate to snow cover: Isard et al. found that one impact of ice cover change is a reduction in soil temperatures. The authors suggest that the decrease is due to less snow cover, which insulates the ground from the frigid winter temperatures. Snow cover in the northern hemisphere has declined by 5% since 1975. If this trend continues, the decrease in soil temperatures will impact a variety of plants and animals in the region. Lower soil temperature might also impact growing seasons.
Now let’s discuss how climate change may affect severe weather patterns in the Great Lakes region.

While climate change is unequivocal and always occurring, the relationship between climate change and local weather is complex. These complexities limit the long-range predictability of predominant weather patterns. However, we can make some general predictions about how climate change will impact weather. For example, climate change is expected to result in more extreme weather events (such as floods and droughts).

More extreme weather events mean the frequency of heavy rain and flood events will likely increase (in late winter to early summer), due to increases in atmospheric heat and moisture capacity over the region. One recent study on future weather patterns in Southern Wisconsin concluded that the area will see a 10–40% increase in the intensity of heavy rain events by the end of the 21st century. This graphic is part of that study.

Let me explain: This graph depicts the 10 wettest days of the year in Southern Wisconsin both in the late 20th century (the open circles) and in the late 21st century (the grey, filled in circles). The horizontal axis shows the 10 wettest days of the year, while the vertical axis shows the theoretical daily precipitation amounts.

[CLICK so that arrow appears on 10th wettest day] Note that on the 10th wettest day of the year rainfall amounts may increase from around 1.5 inches to about 1.7 inches. [CLICK so that arrow appears on wettest day] Now look at the wettest day of the year. At the end of the 20th century, we might expect about 2 inches of rainfall; however, at the end of the 21st century, that amount would increased to more than 2 ¾ inches of
Severe Weather: Flooding

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Extreme weather events are high amounts of precipitation within a short period of time. In the United States, extreme weather events have made up a disproportionate share of the observed increases in total precipitation. For example, the number of days with precipitation greater than two inches has increased. Increases in precipitation accumulations has been the greatest in the Great Lakes, Southwest, and Midwest regions of the United States. One recent example in the Great Lakes region is the flooding that occurred in Milwaukee, Wisconsin, in July 2010. Over 6 inches of rain fell in 1 hour… and more than 9 inches in 12 hours. This resulted in around 2 billion gallons of combined sewer overflows (a mix of rainwater and raw sewage).

Extreme precipitation creates risks for flooding and erosion, water quality deterioration (due to entrainment of pollutants and sewer overflow), and human health concerns (such as more frequent outbreaks of water-borne diseases, especially in rural areas). More extreme precipitation events will also require more resources from local and state governments to deal with flood cleanup, increased maintenance costs, and increased water treatment costs.

Source citations:

Source citation:
One example of a community dealing with extreme weather is Milwaukee, Wisconsin. The city works with the Southeastern Wisconsin Watershed Trust to promote green infrastructure to help with more intense rain events. The partnership uses a comprehensive watershed management approach that helps address cross-jurisdictional issues (such as those between sewer districts, municipalities, and the Southeastern Wisconsin Regional Planning Commission). Projects include a land acquisition program, promoting downspout disconnection, and installing rain gardens.

Module 2 will provide more detail about adaptation strategies for dealing with climate impacts, but we wanted to give you an idea of different ways that communities are responding.

Source citations:
“Ask the Climate Question: Adapting to Climate Change Impacts in Urban Regions.” Center for Clean Air Policy. pp.19. (In M2 folder.)
Image citation:
http://www.sleepycreekwatershedassociation.org/Content/StormW aterMgmt/rain_gardens.htm

Paradoxically, the Great Lakes may also experience increased drought due to warmer temperatures and increased evaporation between rain events. As temperatures increase, the loss of soil moisture between rain events (due to evaporation) could more than offset projected increases in rainfall and flood events. The graphic above shows the severe drought occurring over the upper Great Lakes last fall.

For more information on drought, go to drought.gov.
Source:
http://www.drought.gov/portal/server.pt/community/drought_gov/20 2;jsessionid=C426B88FFC8230487C75790E640B7884
The Great Lakes region is already experiencing extreme weather events, which demonstrates the increased variability we will experience from climate change. For example, in August 2007, several Minnesota counties experienced drought conditions—while at the same time neighboring counties were experiencing flooding. Drought and flood conditions happening at the same time and in the same region point to the need for states to develop response plans for a variety of extreme weather events that occur simultaneously.

Image citation:
Mark Seeley. University of Minnesota Extension Climatologist.

### Severe Weather Summary
- Likely increase of heavy precipitation events
  - More severe
  - More frequent
  - More damaging
- Likely increase of drought due to warmer temperatures between rain events

### CLIMATE CHANGE IMPACTS
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Now that we’ve talked about impacts on severe weather events, let’s consider some ways that the Great Lakes ecosystem might be affected by climate change.

So, how will climate change affect Great Lake ecosystems? In order to understand how these changes would be possible, let’s first review the process of lake stratification to see how temperature and wind contribute to the seasonal differences we observe in the Great Lakes themselves.

Climate change will affect stratification of the lakes, which in turn impacts lake ecosystems. Stratification refers to a change in the water temperature at different depths in the lake, which is due to the change in the density (or weight) of water with temperature. An interesting characteristic of water is that its maximum...
density is at 4°C. Water that is colder than 4°C is therefore less dense, causing it to float to the surface where ice forms. In the spring, water warms as the ice melts, and winds cause water to mix (bringing nutrients up from sediments at the bottom and oxygen down to deeper water). This is called the spring turnover. In the summer, the temperature difference between warmer waters at the surface and cooler waters below is great enough to prevent the different parts of the water from mixing (due to differences in density). This is called summer stratification. In the fall, surface water cools again to a point where the the water has the same density at all depths. This allows it to mix again. In the winter, ice forms a barrier on top of the water, which prevents mixing from occurring.

In the Great Lakes region, a cyclical pattern of overturn occurs as the water warms and cools through the seasons. This process affects the biogeochemistry and ecology of the lake. This process will be impacted by climate change, with the spring turnover occurring earlier in the year and the fall turnover occurring later. Winter stratification will also be affected (if ice does not form due to warmer temperatures); with no ice to act as a wind barrier, lake turnover would happen continuously from fall until spring.

For example:
Lake Superior’s spring turnover has become earlier by about ½ day per year, leading to earlier summer stratification. The sun-warmed upper layer extends farther into the water column, resulting in a later fall mixing. The length of the stratified season has increased from 145 to 170 days over the last century.

Source citations:
Minnesota Sea Grant. “Climate Change and Lake Superior.” http://www.seagrant.umn.edu/climate/superior. Info for that website taken from:
Today, thermal stratification lasts about 135 days. Under some climate change scenarios, the period of thermal stratification could reach 225 days by the end of the century! [CLICK]

By lengthening the period of low-oxygen and low-nutrient water at the surface, fish and other animals will be stressed—and fish kills may be more prevalent.

In addition to the lakes themselves, the Great Lakes region includes numerous other ecosystems and habitats (such as coastal wetlands, northern hardwood and coniferous forests, beaches, and dunes). Many of these habitats have been stressed or altered by weather and human activities over time. On top of the changes humans bring to the ecosystem, relatively small changes in temperature or water levels can have a cascading impact through the system. For example, as habitats become drier, species may shift to remain in their preferred temperature range. These shifts can alter the relationships between species and how they use their habitats.

Image citations:
http://www.marietta.edu/~biol/biomes/images/alpine/cforestmt.jpg
http://www.uwgb.edu/biodiversity/econotes/2003/bradwetland2.jpg
http://www.northernlakesrealestate.com/i/p-cf0713-b.jpg
One of the major impacts of rising temperatures in the Great Lakes region will be shifts and expansion of species to the north. Numerous studies are documenting movements by species as they seek out the best conditions for their survival. 

[CLICK] Small mouth bass are an example of a warm-water fish that may see its habitat range expand. One study estimated an expansion all the way into northern Canada by the end of the century. This is great for sport fishermen who like to catch small mouth bass, but maybe not so great for those who like to catch lake trout and whitefish—since those species will decline if cold water areas shrink dramatically. 

[CLICK] A recent study tracking small mammals in Michigan found that the flying squirrels’ range has shifted north. The flying squirrel population is increasing in the upper peninsula, while their brethren below the bridge are having trouble. 

[CLICK] Native tree species are expected to move north as they are replaced by other trees from the south. A study in Ohio, Indiana, and Illinois predicted that northern conifers (such as eastern hemlock and white pine) and deciduous trees (such as the sugar maple) would be completely eliminated in these states, as their optimal growing conditions shift to the northeast. Researchers conclude that wetland habitats and species will be the most severely affected by climate change, because they are sensitive to water levels and hydrology. 

Citation: http://www.ucsusa.org/greatlakes/glregionmic_fis.html

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We can expect climate change to disrupt food webs in the Great Lakes, because of species shifts, habitat changes, and a lengthening of the thermal stratification period. A simplified version of a food web in the Great Lakes includes phytoplankton (drifting microscopic plants), zooplankton (drifting animals, such as larval fish and invertebrates), larger fish, and birds. Phytoplankton is at the base of the food web. Changes in the availability of phytoplankton (due nutrient depletion) will directly affect animals that consume them—and will indirectly affect animals higher in the food web. Changes in habitat conditions that affect species distribution can change food webs, because not all of the components may be equally sensitive to warmer conditions.
temperatures or lower water levels. So, species that shift their geographic distribution may also need to shift their diets. Changes in habitat conditions and disruptions to food webs may also increase the vulnerability of the Great Lakes to invasive species.


Pictures: Sources Unknown

An example of a community responding to ecosystem changes is the Conservation Resource Alliance (CRA), set in Northwest Lower Michigan, which works to protect regional watersheds. CRA is a grassroots network of local support for on-the-ground conservation action at all levels—from individual landowners and citizens to local, state, and federal governmental agencies to many of the large corporations and foundations in the Great Lakes region and around the country.

CRA has two programs that help address ecosystem challenges:
The Wild Link Program supplements public conservation areas by encouraging private landowners to help preserve connective corridors for wildlife. Wild Link is a voluntary program that assists private landowners in managing corridors on their property that wildlife may use to travel from one large parcel of land (such as a state forest) to another.

River Care is a watershed-based program through which CRA leverages financial and in-kind support to perform on-the-ground habitat improvement and restoration projects on a number of world-class trout streams in Northwest Lower Michigan. The image above shows removal of the aging Wheeler Creek Dam taking place, allowing Wheeler Creek to flow freely into the Manistee River (courtesy rivercare.org).

Source citation: http://www.greeninfrastructure.net/sites/greeninfrastructure.net/files/5-CRA%2008.30.05_0.pdf
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Slide 55
Ecosystem Changes Summary
- Lake stratification changes due to warming temperatures will affect the biogeochemistry and ecology of lakes.
- Plant and animal habitats will shift to the north.
- Food webs may change due to shifting species habitats.

Slide 56
CLIMATE CHANGE IMPACTS
Humans are an integral part of Great Lakes ecosystems. Let’s also talk about how human health and welfare might be affected by climate change.

Slide 57
Human Health Concerns
We’re going to talk about three concerns of specific interest in the Great Lakes: the effect of extreme weather on human health, the effect of climate change on water quality and disease, and the effects of climate change on agriculture.

Slide 58
Chicago Tribune, July 13, 1995
The 1995 Chicago heat wave: Record temperatures and humidity result in a deadly weekend
We’ll start with the impacts of heat waves on human health. Some of you may not know that extreme heat is the natural hazard that kills far more people than any other. In July of 1995, a severe, week-long heat wave hit Chicago.
Image citation: Chicago Tribune.
Temperatures peaked at 106 degrees Fahrenheit, with a heat index of 126 degrees. The use of electricity skyrocketed, resulting in power grid failures throughout the city. This was one of the worst weather-related disasters in Illinois history; 525 people died over a 5-day period. [CLICK to bring up red map] More frequent, extreme heat events are expected over the next century as a result of climate change. By 2080, the Midwest might see extreme heat events every three years. Note that definitions of “extreme heat” vary from location to location; extreme heat in Phoenix is different than extreme heat in Quebec. What qualifies as extreme heat depends on the local climate in a particular city and what its residents are acclimated to.

Considering higher emissions scenarios—and combining temperature increases with the urban heat island effect—we might see as many as 80 deadly, severe heat incidents in cities like Milwaukee or Chicago over a 30 year period. [CLICK to reveal summary points]


Heat can also impact air quality. During heat waves in the Midwest, air pollutants are trapped near the surface as atmospheric ventilation is reduced. Without strict attention to regional emissions of air pollutants, the undesirable combination of extreme heat and unhealthy air quality is likely to result. Climate change will likely cause an increase in surface ozone over the Midwest, partly driven by decreased ventilation due to warmer temperatures.

Slide 61

Combined Sewer Overflows

Climate change is also expected to have an impact on water quality. For example, we've noted that the frequency of heavy rain events will increase with climate change. During storms, combined sewer overflows can cause sewage to flow into lakes. How does this happen? Combined sewer systems collect runoff, sewage, and industrial water in the same pipe. This was economical when all wastewater was discharged directly to rivers (before we had treatment plants in the 19th century). Now, the system can handle the whole load during dry weather and direct it all for treatment.

[CLICK] But, during big storms, the plants can't handle the volume—and the systems are designed to overflow into lakes.

Slide 62

Combined sewer overflows cause:
- Water quality problems
- Beach closures
- Human health risks

When over a billion gallons of sewage is released into our rivers and lakes from combined sewer overflows during heavy rains, water quality diminishes and beaches are closed

Combined sewer overflows can also negatively affect human health, since waterborne diseases in drinking water can be more prevalent after heavy storm events. For example, in 1993, an outbreak of a parasitic disease (called Cryptosporidium) occurred in Milwaukee right after a large storm, causing 400,000 people to fall ill with diarrhea.

Of the 801 cities in the United States with active combined sewage systems, 65% are in Great Lakes states. NOAA scientists are improving their capabilities to forecast and warn people of poor water quality after storms.

Source citation: Picture Unknown

Slide 63

Agriculture Impacts

Climate change will also impact agriculture. For the Great Lakes agriculture community, this is good and bad news. The good news is that with rising temperatures and changes in precipitation, we expect longer and wetter growing seasons.

This picture shows how plant hardiness zones are expected to shift as the Earth warms. By the end of the century, plants now associated with the Southeast are likely to become established throughout the Midwest.

Source citations:
### Slide 64

**Changes in climate are expected to impact crop yields.** Several studies report that corn and soybean growing areas will shift north, and another study found that commercial fruit growing conditions will improve near the coasts of the Great Lakes.

It is also anticipated that a longer, warmer growing season will lead to an increased demand for water and, possibly, an increased risk of heat stress for crops.

On the flip side, longer growing seasons for crops also provide longer growing seasons for not-so-economically-important organisms (such as weeds and pests). **[CLICK]** Insect populations that have historically been controlled by cold winters will be more likely to survive during milder winters, which may mean larger populations in a warmer climate.

We should point out that even though the weather will become warmer and wetter, the soil will still be rocky in the northern Great Lakes region. It remains to be seen whether agribusiness can take advantage of shifts in climate.

### Slide 65

**Finally, climate change is expected to impact business operations in the Great Lakes region by providing both challenges and opportunities, including:**

- Increased energy and raw product market volatility
- Increased insurance premiums
- Reduced heating demand/costs in winter
- Increased cooling demand/costs in summer
- Shifts in business opportunities:
  - Longer summer tourism season
  - Longer construction season

- Reduced heating demand and lower heating bills in the winter
- Increased cooling demand and higher cooling bills in the summer
- Shifts in business opportunities (for example, there will be a longer summer vacation season and a longer...
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**Impacts on Community Operations**

- Reduced winter recreational activities, but increased warm-weather activities
- Reduced ice cover and varying lake levels will impact shipping/boating operations
- Shifts in resources for city operations:
  - Less need for salt/snow removal in winter
  - More need for Park and Recreation Dept budget for warm-weather activities

**Human Health and Economy**

**Summary**

- Increased number and intensity of heat waves
- Reduced air quality
- Increased risk of combined sewer overflows
- Altered crop distribution
- Shifts in business opportunities and community operations

**Climate change will also pose both challenges and opportunities for community operations. For example, there will be:**

Reduced winter recreational activities (such as skiing, snowmobiling, ice skating, ice fishing, and ice sailing), but increased warm-weather activities (such as swimming, boating, and golfing).

Less snow and ice will result in fewer shipping disruptions in the winter, but, on the flip side, varying lake levels may result in more shipping disruptions. City operations may have to shift their resources. For example, there may be less of a need for snow removal in the winter, but more of need for an expanded Parks and Recreation Department to deal with an increase in summer tourism activities.

**Source citation:**
*Preparing for Climate Change: A Guidebook for Local, Regional and State Governments.*
http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf

**Potential resource:**
*Economic Impact Analysis of Climate Change for the City of Chicago*
Image citations:greatlakesdayindc.blogspot.com auburn.edu

**Image citations:**
nwk.usace.army.mil
snowremovalservice.org
So now we know...
• Climate change uniquely impacts the Great Lakes
• Climate change in the Great Lakes affects:
  - Lake levels
  - Ice cover
  - Severe weather
  - Ecosystems
  - Human health

Let’s review what we have heard so far. [Pause to let people read about our understanding, then [CLICK] ]
The Great Lakes will have different and distinct climate challenges and opportunities compared to the rest of the country.

We obviously won’t have to cope with sea level rise, but our changing lake levels will create economic and ecological problems. A decline in lake ice is an issue that other parts of the country do not have to face. In other parts of the country, severe weather may bring hurricanes, but we will have heat waves and more rain and flooding. Our species distributions will shift. Open-water food webs driven by nutrients provided by lake turnover will change. People will be affected by extreme weather, potential declines in water quality, and agricultural shifts.

The bottom line is that the impacts of climate change will have various effects on life as we know it in the Great Lakes, and we need to be prepared for change.
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Slide 71

Global Temperature Change

Note: This hidden slide is really a background slide. Previous slides have sufficiently covered global observed temperature changes.

As was mentioned earlier in the presentation, one of the impacts of climate change is increasing temperatures. According to observations from the Intergovernmental Panel for Climate Change (IPCC), the average global surface temperature over the last 50 years has increased by 0.13°C per decade, which is nearly twice as much as the increase over the last 100 years.

Source citation:

Image citation:

Slide 72

Range Expansion Species To Date

Native to Lake Erie, expanding northward
Native to Lake Erie and Huron, invading Lake Michigan
Native to Lake Michigan, invading Lake Erie
Native in Lakes Superior, Michigan, Huron, and Ontario; introduced Lake Erie and Lake St. Clair

Slide 73

Recreation and Tourism

Shoreline infrastructure impacts shoreline and water quality.

• Water infrastructure in the Great Lakes is aging and in poor condition, increasing the risk of waterborne outbreaks of illness and disease (Patz et al., 2008).
• Changes in beach and water quality will impact tourist location preferences (Lise and Tol, 2002).

As precipitation events become more extreme, storm and waste water overflow events will likely result in poor water quality and increased risk to public health and safety. This will impact recreation and tourism in the Great Lakes.

Source citations:

Huntley, Melinda. 2009. “Climate Change and Great Lakes Tourism: Recommendations for Research, Education and Outreach.” Tourism Program Director, Ohio State University Sea Grant Extension.


The International Governmental Panel on Climate Change (or IPCC) is a scientific intergovernmental body tasked with reviewing and assessing the most recent scientific technical and socioeconomic information produced worldwide relevant to the understanding of climate change. One primary activity of IPCC is regularly publishing special reports or assessments of climate change and its impacts. In their reports, IPCC uses a likelihood scale to describe the probability of occurrence for an event.

When IPCC declares a likely impact of global climate change (GCC), it is indicating a 66% or greater chance of occurrence.

It is important to remember that uncertainty is a crucial part of any form of scientific research—and climate research is no exception. No matter how elaborate our models are (or how convincing our observations seem), a degree of uncertainty always exists. Global Climate Models also help us understand and quantify degrees of uncertainty associated with climate change forecasts. Climate change uncertainties include questions regarding the degree of future greenhouse gas emissions, solar output, and variations in ocean circulation patterns.

Image citations:
National Aeronautics and Space Administration (NASA). http://climate.nasa.gov/uncertainties/