Climate Ready Great Lakes

NOAA

U.S. National Oceanic and Atmospheric Administration

U.S. Department of Commerce

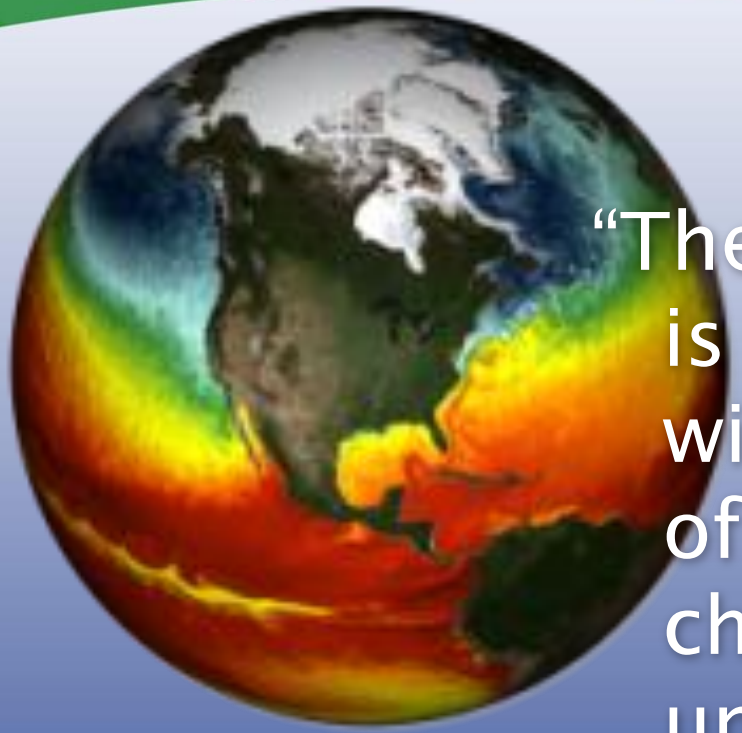
Sea Grant

Great Lakes Network

Module 1:
What am I adapting to?

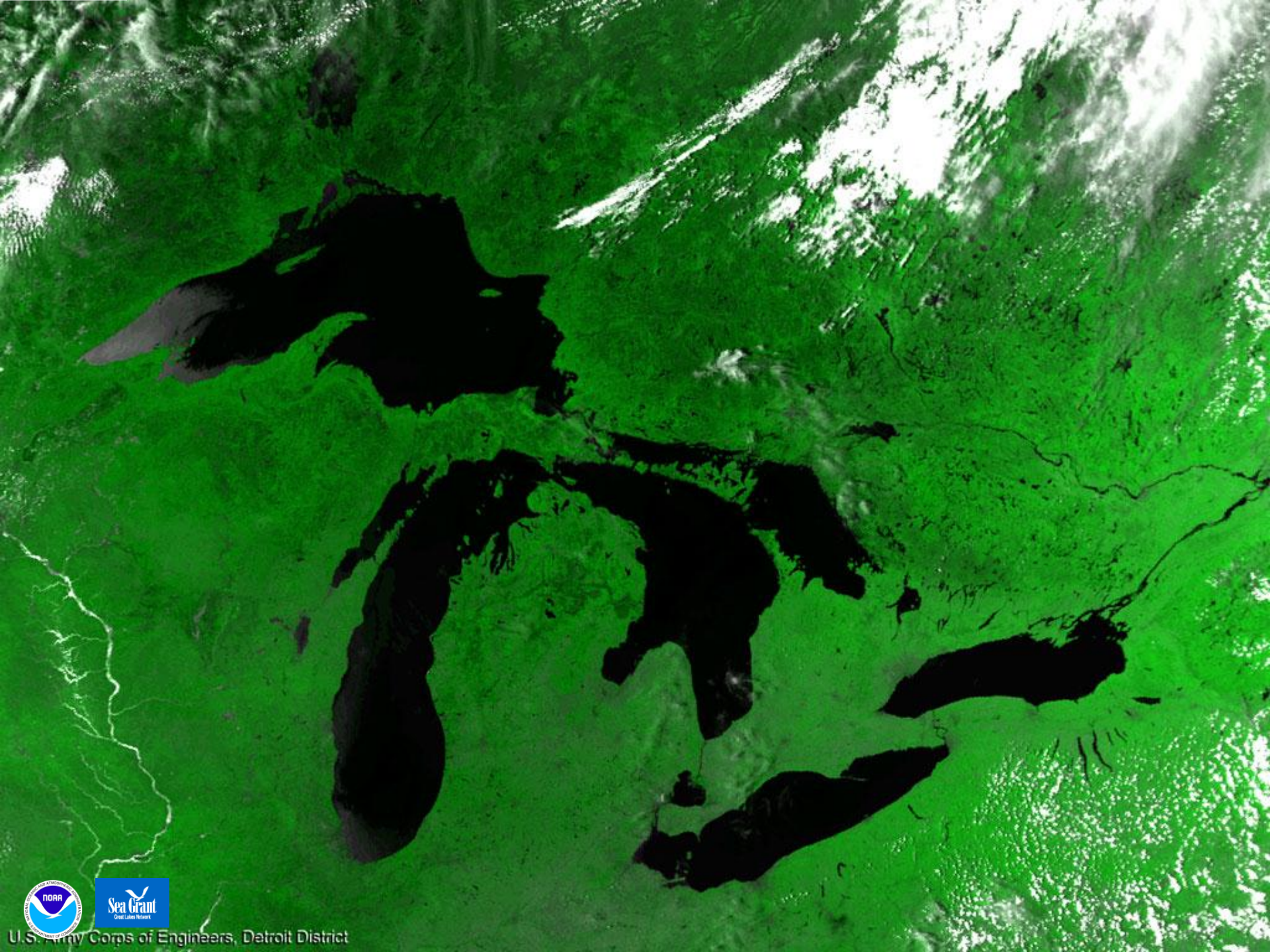
Understanding the Impacts of Climate Change in the Great Lakes

Climate Ready Great Lakes



"The climate challenge before us is real. Climate change impacts will touch nearly every aspect of our lives. Meeting the challenge requires an unprecedented need for climate information and services."

-Dr. Jane Lubchenco


NOAA
Sea Grant
Great Lakes Network
U.S. Army Corps of Engineers, Detroit District

Presentation Objectives

- To provide information on climate change in the Great Lakes, based on peer-reviewed science.
- To provide examples of ways that communities are preparing for a changing climate.

This training should help you to…

- Understand that climate change is a relevant issue for planning professionals.
- Understand that there will be similarities and differences between climate change impacts observed at regional (Great Lakes) and global scales.
- Identify **at least** one climate change impact specific to the Great Lakes that will affect issues within your profession.

Climate Ready Great Lakes

Part 1: Fundamentals of Climate Change

Climate Science

Observed and Projected Global Changes

Climate Change in the Great Lakes Region

Climate Ready Great Lakes

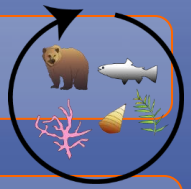
Part 2: Climate Change Impacts in the Great Lakes

Lake Levels

Ice Cover

Severe Weather

Ecosystem Changes



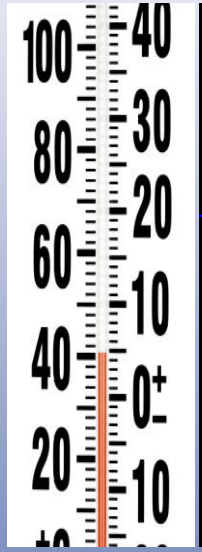
Human Health & Economy

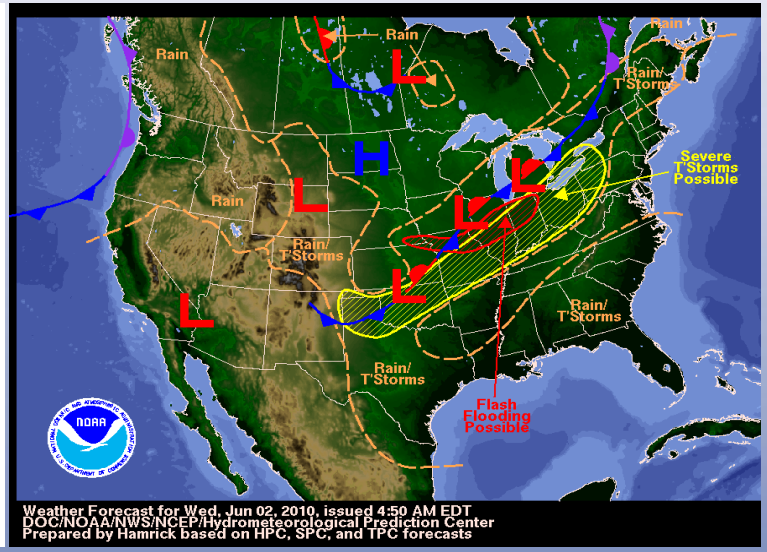
Part 1:
Climate Science

Weather and Climate

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

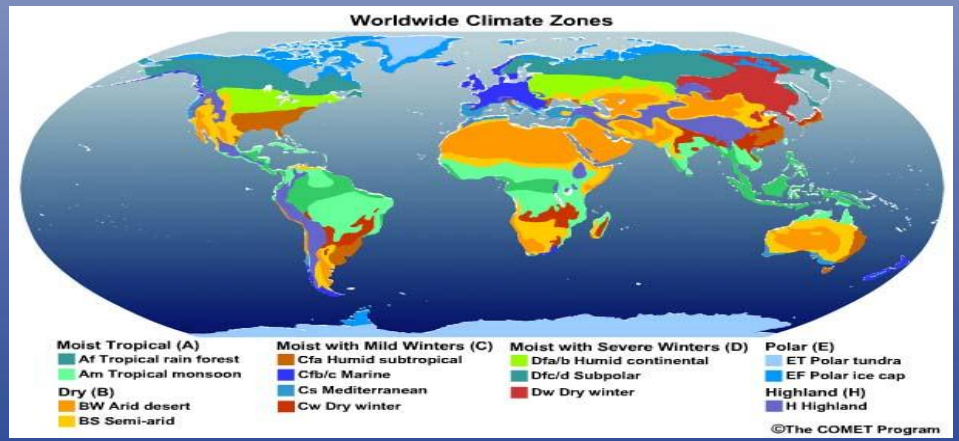
WEATHER





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

CLIMATE



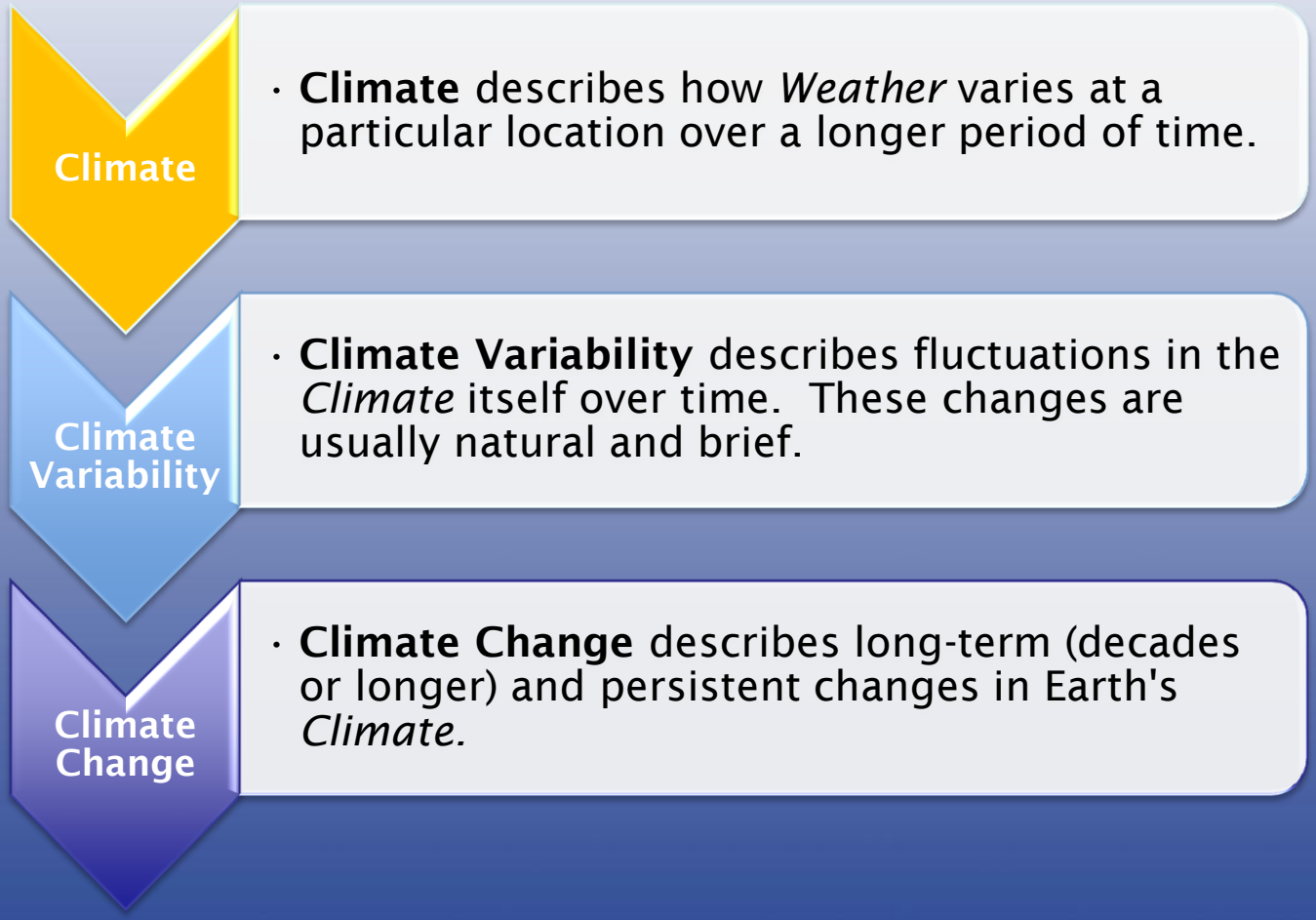
Weather and Climate

Or… put another way…

Meteorologists are most interested in the prediction of short-term, day-to-day weather.

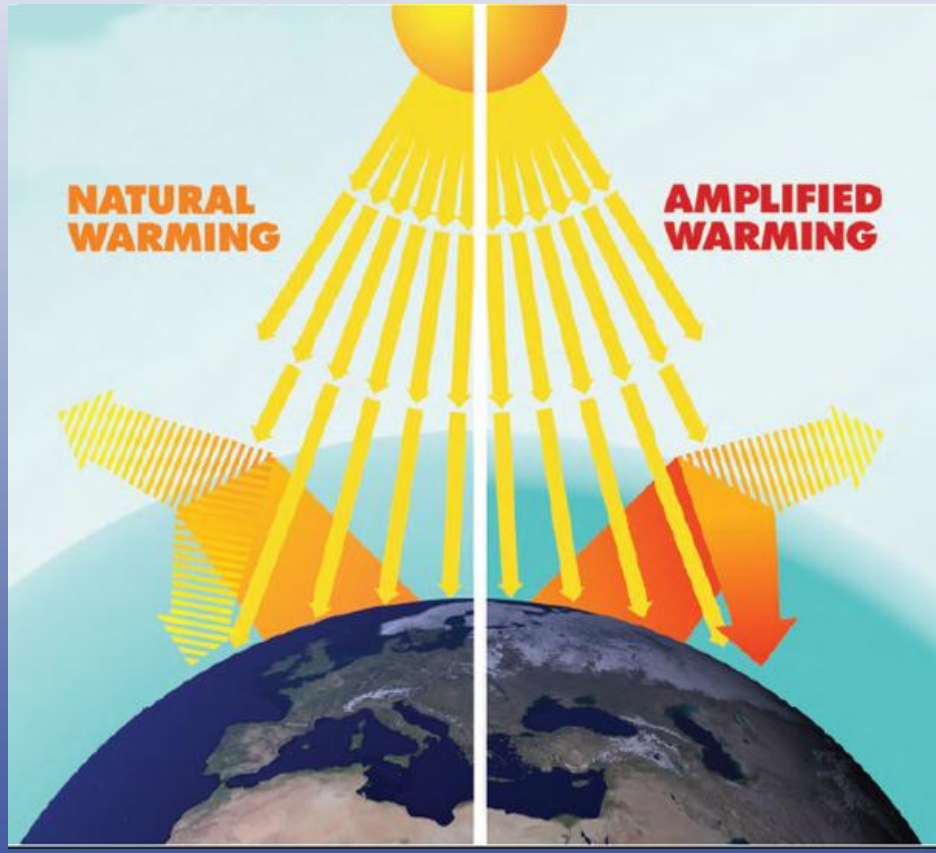
Climatologists are most interested in long- term trends of "*average*" weather and frequencies of extreme weather.

Climate Change: The Fundamentals



Global Climate Change: The Science

- ***The Greenhouse Effect*** is a vital process that helps Earth retain an appropriate amount of heat from the sun.
- Greenhouse gases (such as carbon dioxide and water vapor) absorb heat and then re-emit heat back to the Earth's surface (like a blanket).
- As we increase greenhouse gases in the atmosphere, more heat is retained—resulting in an overall warming pattern.

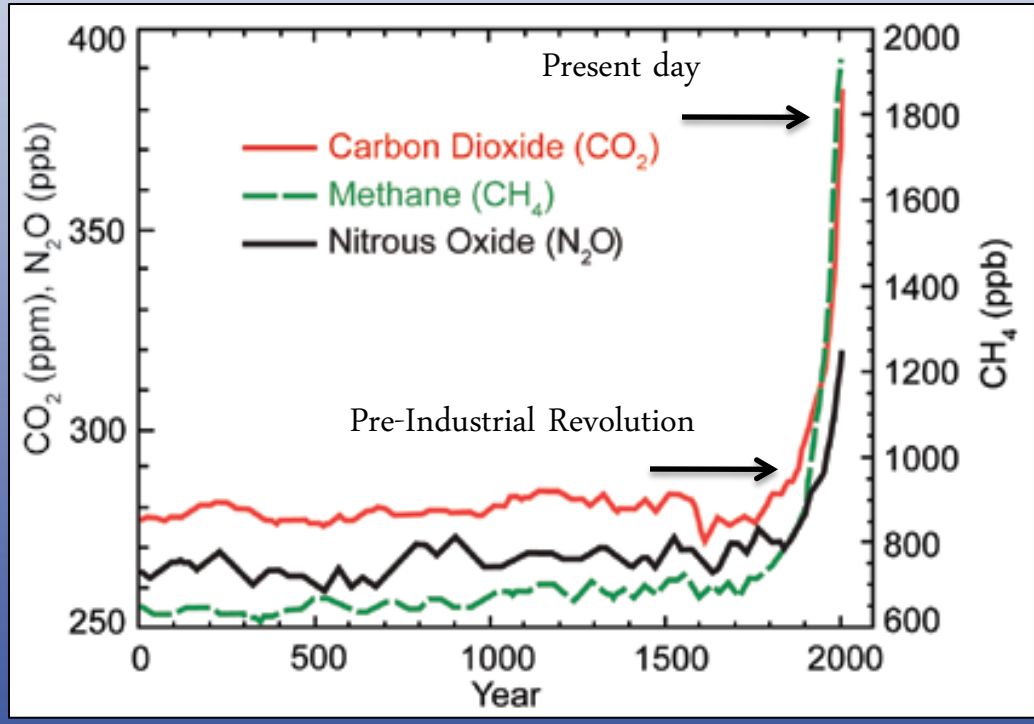


Part 1: Observed and Projected Global Changes

Global Climate Change: The Observations

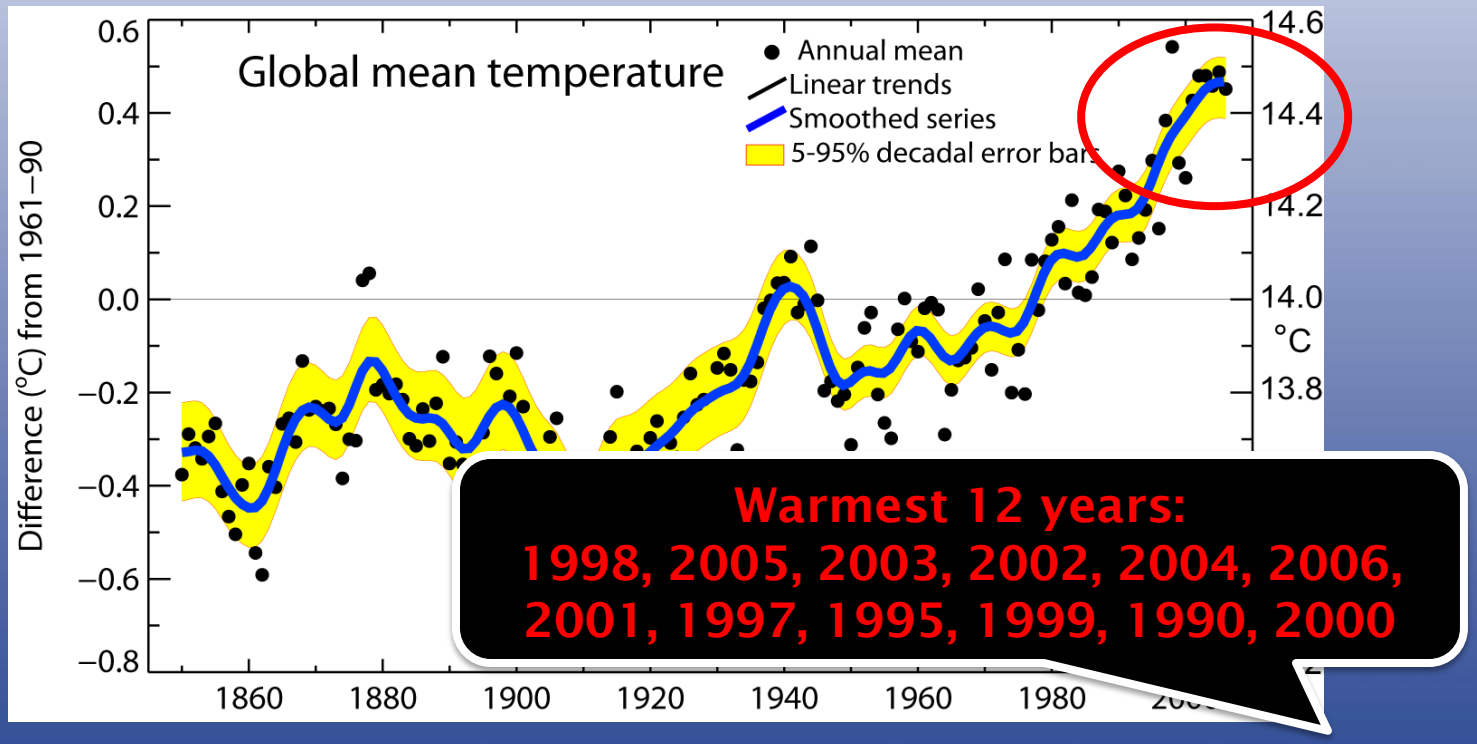
Carbon dioxide in the atmosphere is increasing:

- A rise from ~ **280 ppm** (prior to the Industrial Revolution) to nearly **380 ppm** today.
- A **35% increase** in atmospheric CO_2 in the last 150 years.



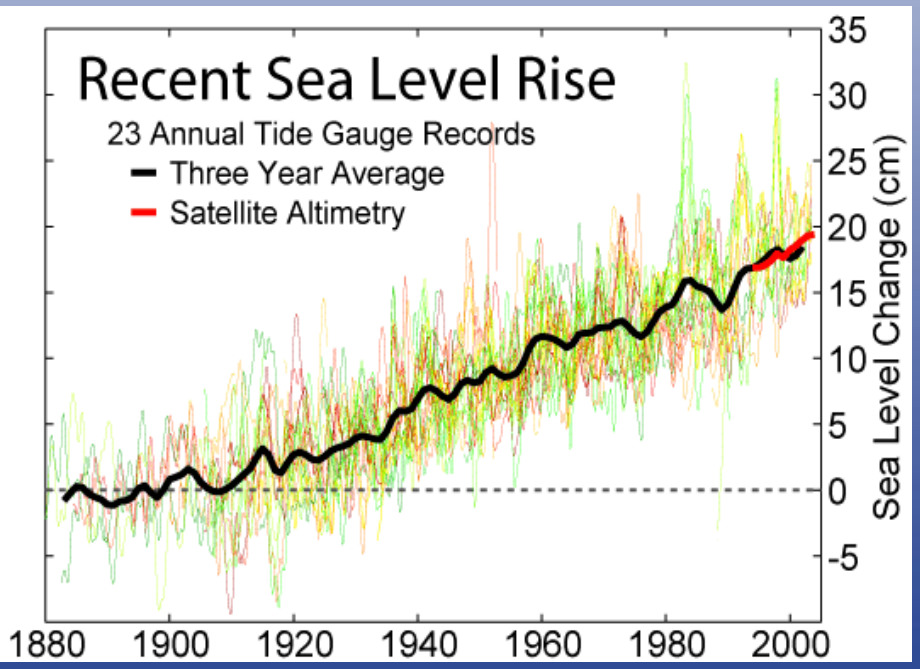
Global Climate Change: The Observations

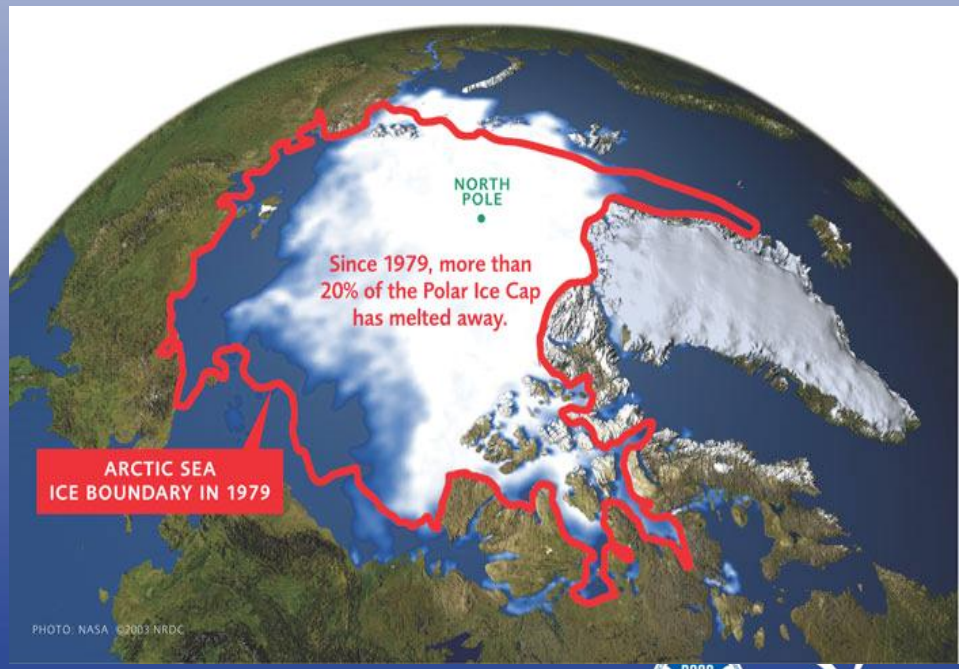
There has been a significant increase in globally-averaged surface temperatures over the last century.



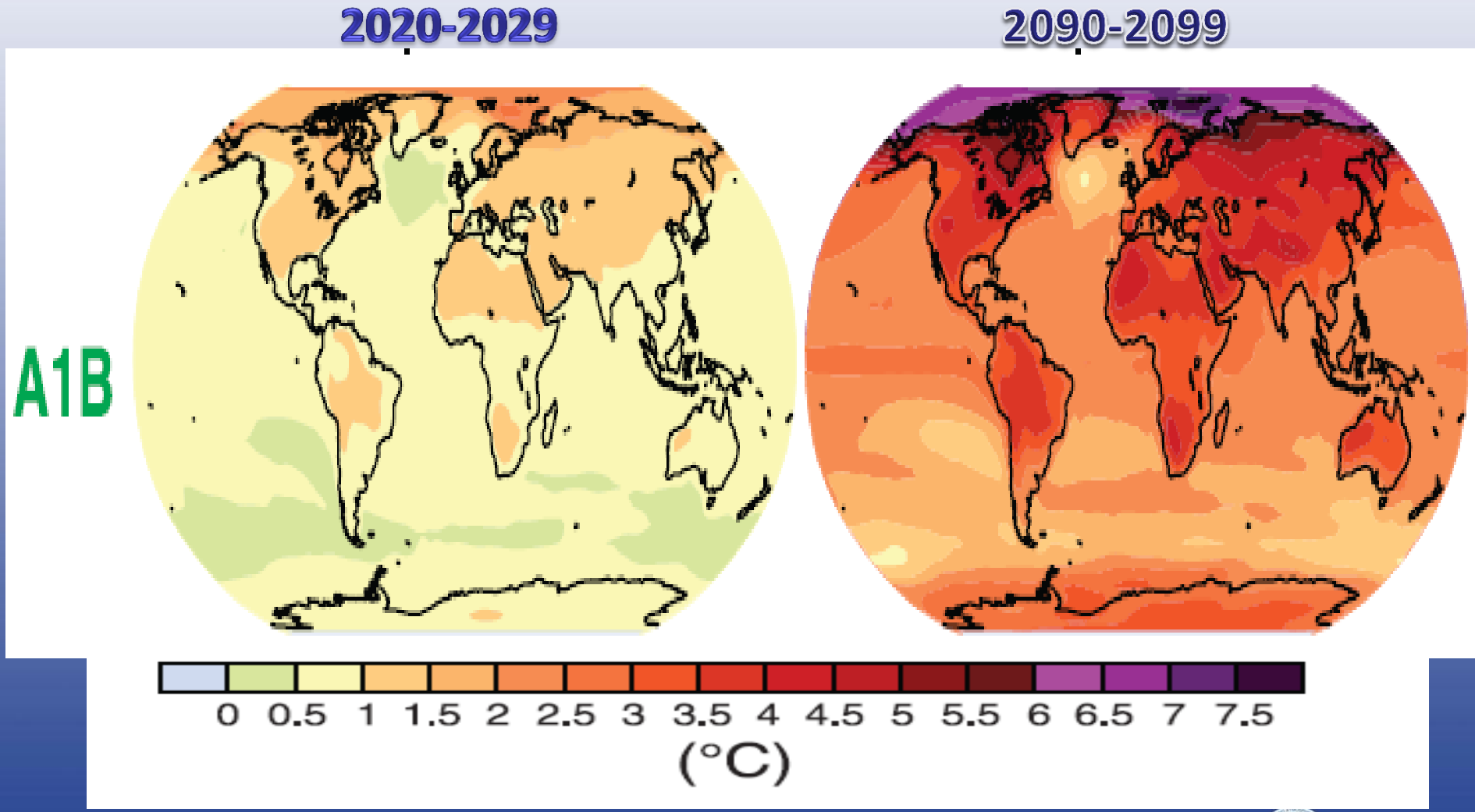
Global Climate Change: The Observations

- Global sea level has risen 4-8 inches over the past century.
- Arctic sea ice has decreased nearly 10% (in its areal extent) each decade between 1973 and 2007.
- Climatologists have observed increases in northern latitude precipitation and decreases in southern/subtropical regions.

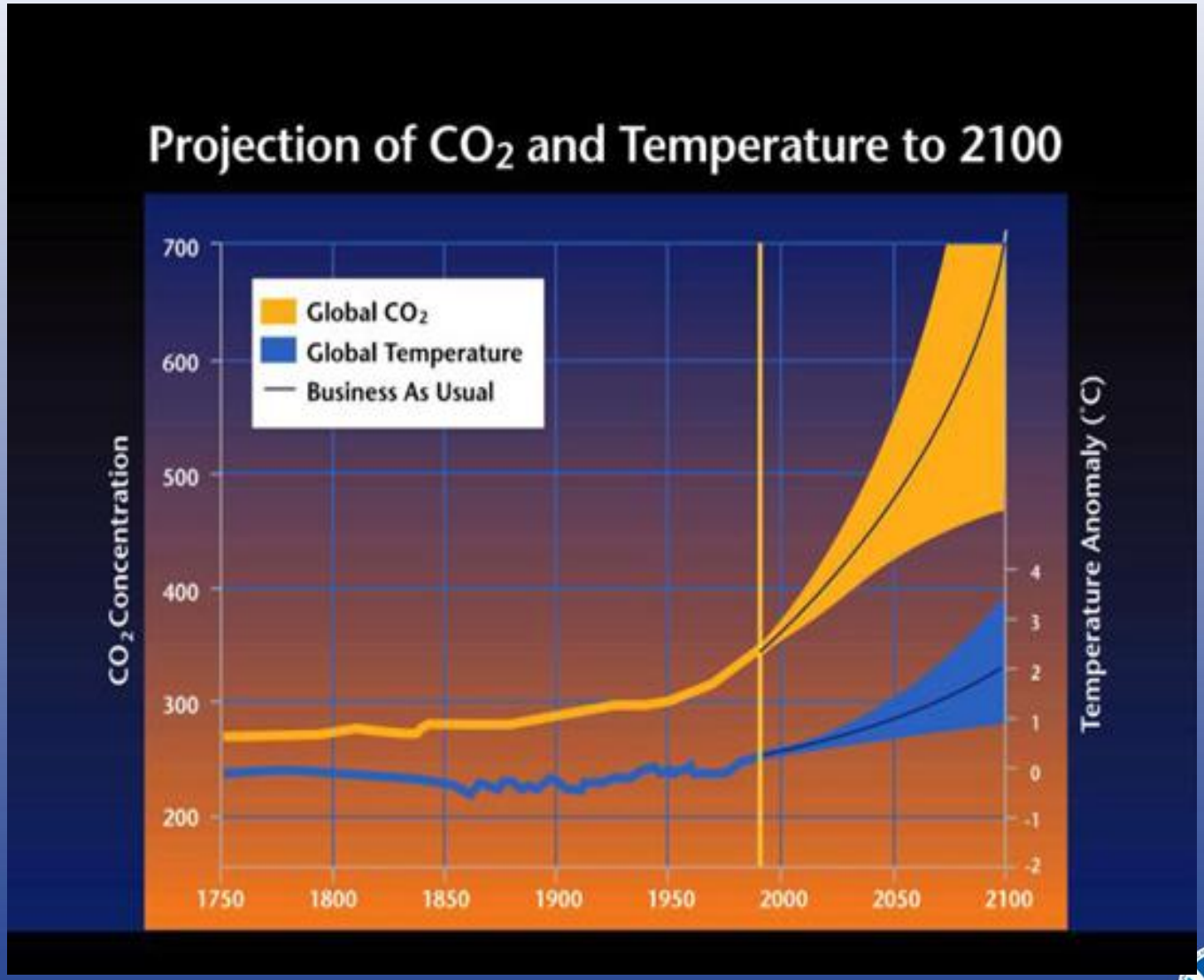




Global Climate Change: The Projections

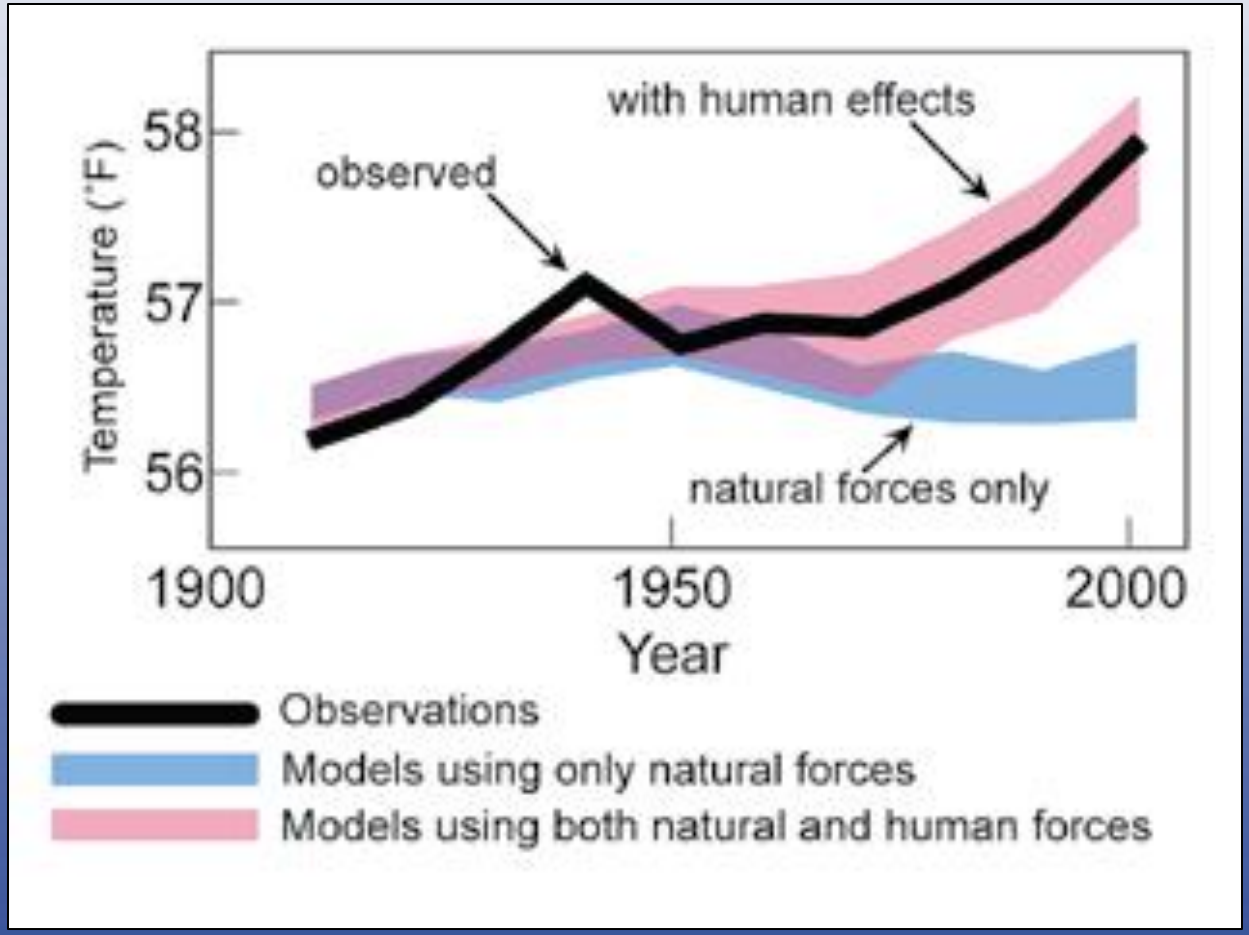


Global Climate Change: The Projections



A Valuable Tool: Climate Models

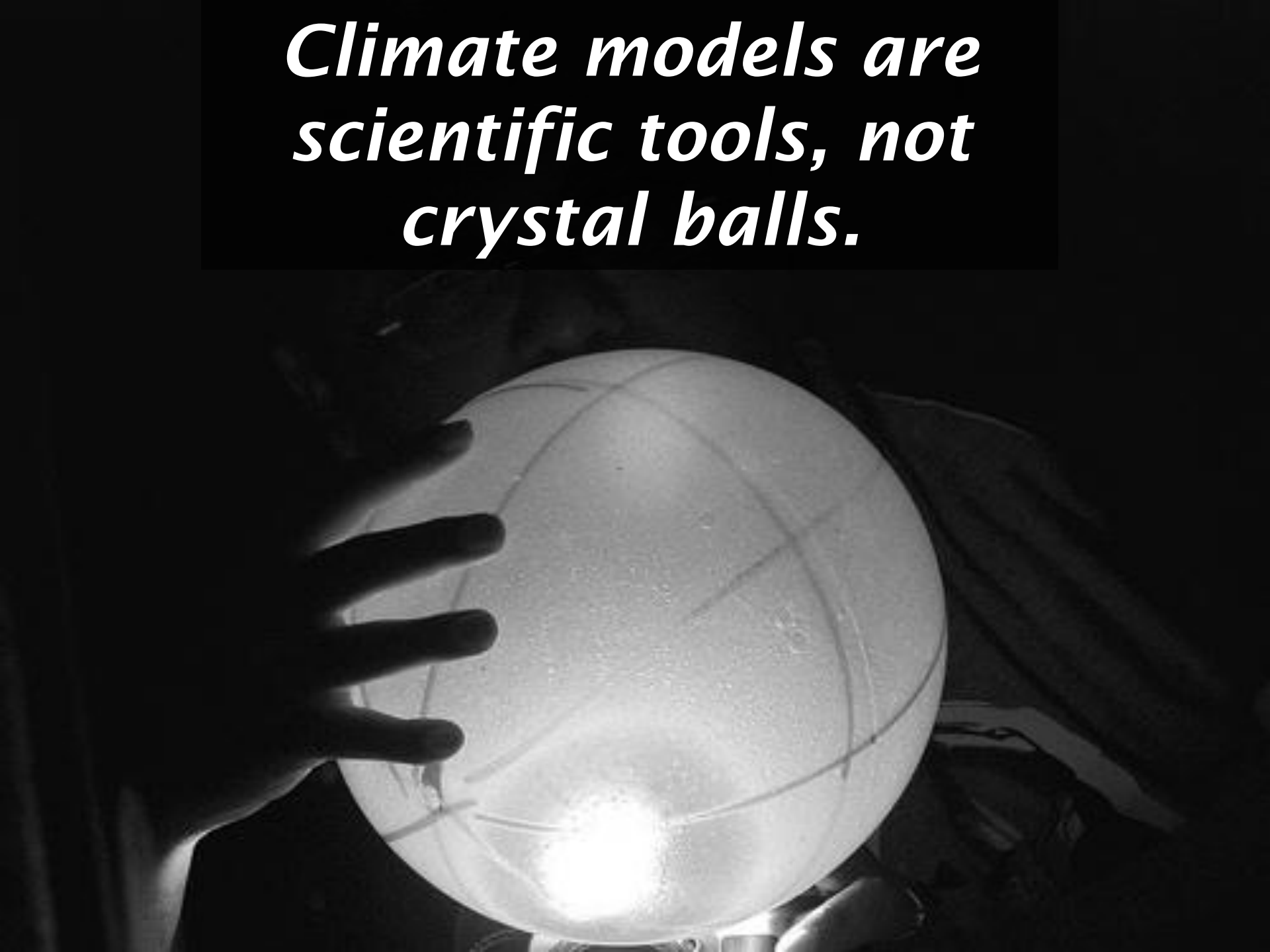
Climate models give additional clues concerning how human forces contribute to climate change.



Climate Models

- Computer models are essential for understanding the complexities of climate change.
- Confidence in the ability of models to project future climate is growing.

Climate models are scientific tools, not crystal balls.

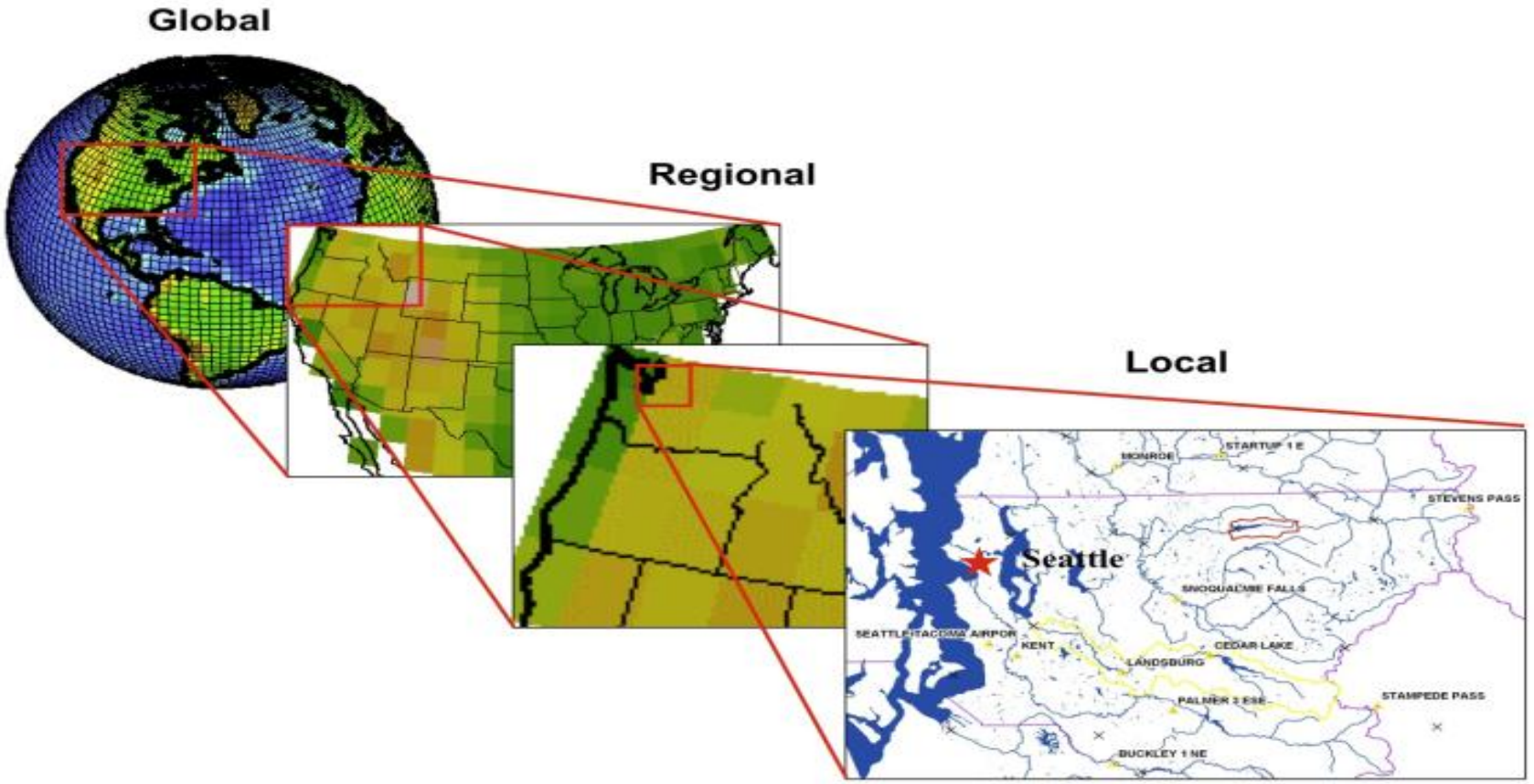


Downscaling: Climate Change at a Regional Level

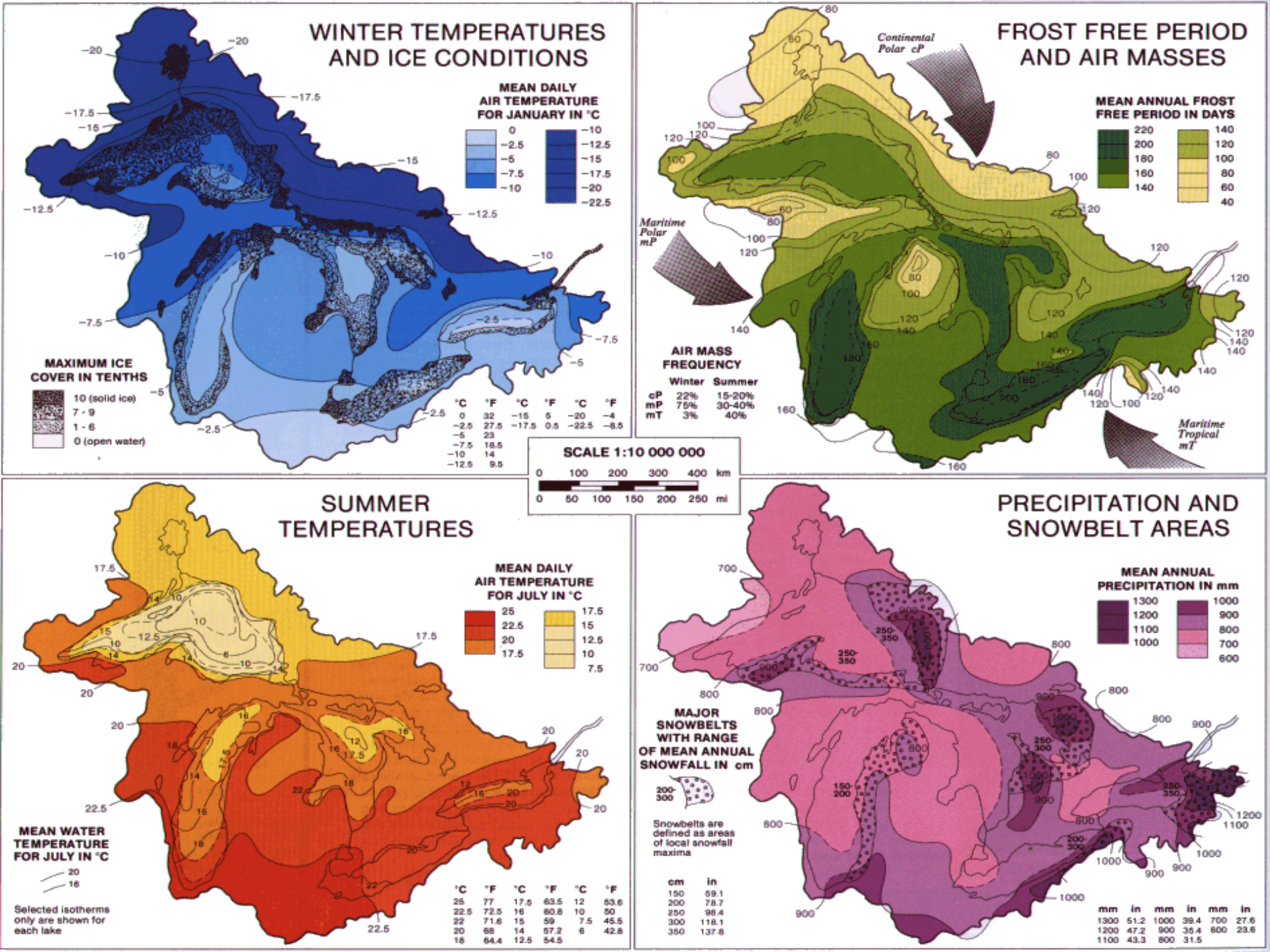
- Climate change is global in its nature; however, its precise impacts will undoubtedly vary on a regional level—and the Great Lakes region is no exception.

- Downscaling allows researchers to capture unique aspects of climate change in the Great Lakes region, while also providing a general picture of its impacts.

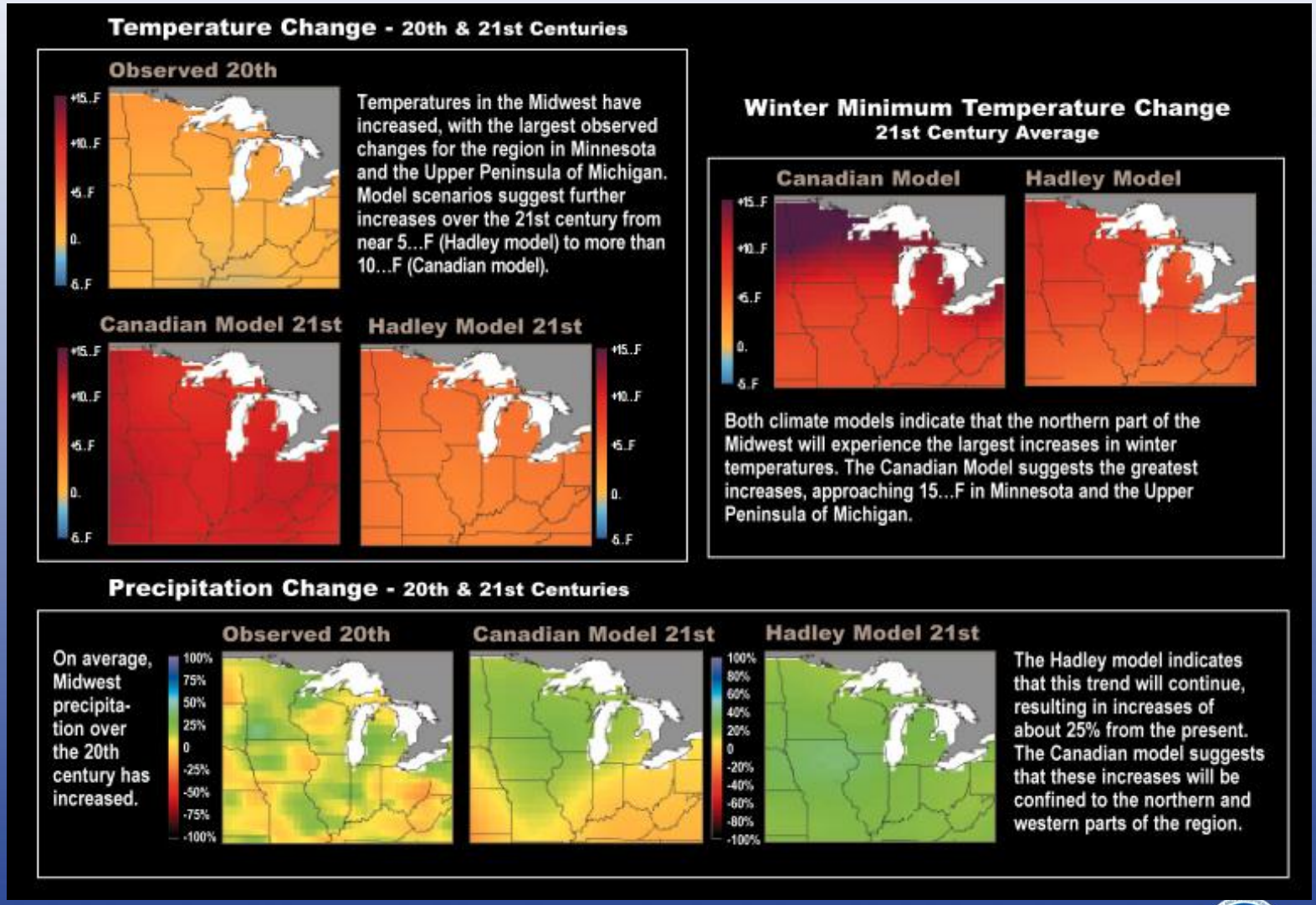
Downscaling: Climate Change at a Regional Level



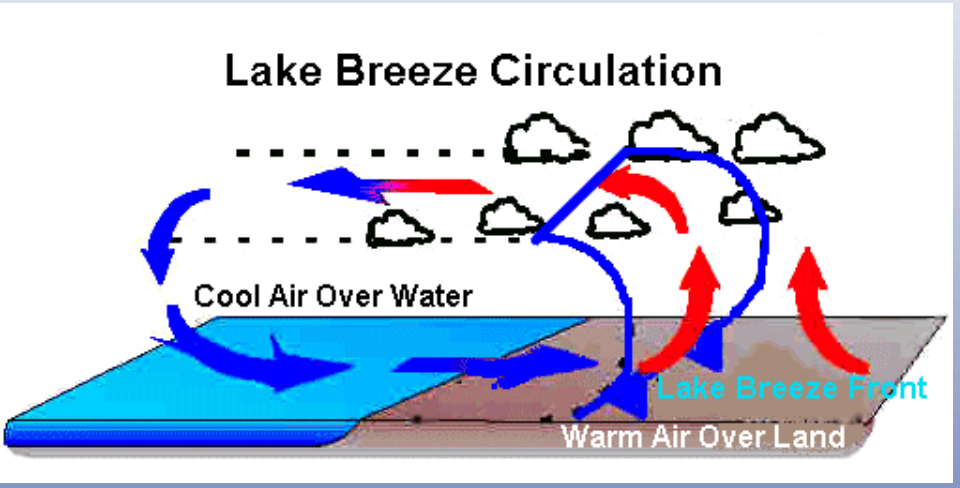
Part 1: Climate Change in the Great Lakes

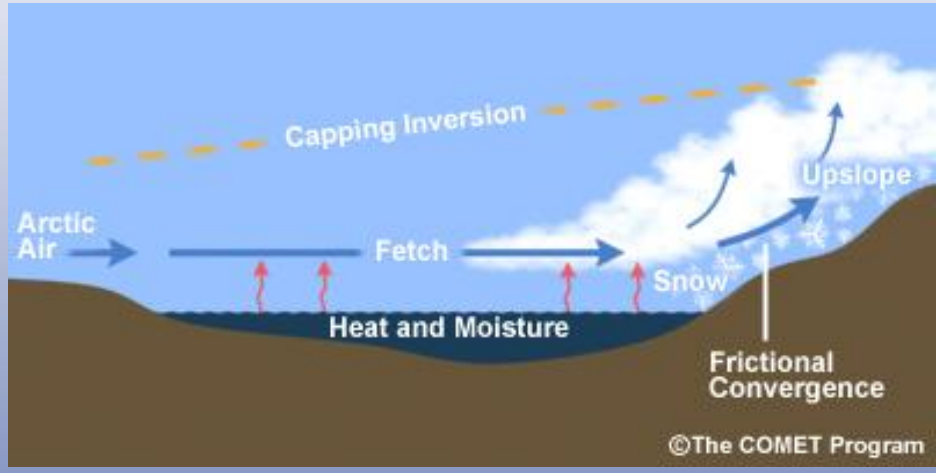

WINTER TEMPERATURES AND ICE CONDITIONS
MEAN DAILY AIR TEMPERATURE FOR JANUARY IN °C
0
−2.5
−5
−7.5
−10
−10
−12.5
−15
−17.5
−20
−22.5
MAXIMUM ICE COVER IN TENTHS
10 (solid ice)
7 - 9
1 - 6
0 (open water)
°C °F °C °F °C °F
0 32 −15 5 −20 −4
−2.5 27.5 −17.5 0.5 −22.5 −8.5
−5 23
−7.5 18.5
−10 14
−12.5 9.5
FROST FREE PERIOD AND AIR MASSES
Continental Polar cP
Maritime Polar mP
Maritime Tropical mT
MEAN ANNUAL FROST FREE PERIOD IN DAYS
220
200
180
160
140
140
120
100
80
60
40
AIR MASS FREQUENCY
Winter Summer
cP 22% 15-20%
mP 75% 30-40%
mT 3% 40%
SCALE 1:10 000 000
0 100 200 300 400 km
0 50 100 150 200 250 mi
SUMMER TEMPERATURES
MEAN DAILY AIR TEMPERATURE FOR JULY IN °C
25
22.5
20
17.5
17.5
15
12.5
10
7.5
MEAN WATER TEMPERATURE FOR JULY IN °C
20
16
Selected isotherms only are shown for each lake
°C °F °C °F °C °F
25 77 17.5 63.5 12 53.6
22.5 72.5 16 60.8 10 50
22 71.6 15 59 7.5 45.5
20 68 14 57.2 6 42.8
18 64.4 12.5 54.5
PRECIPITATION AND SNOWBELT AREAS
MEAN ANNUAL PRECIPITATION IN mm
1300
1200
1100
1000
1000
900
800
700
600
MAJOR SNOWBELTS WITH RANGE OF MEAN ANNUAL SNOWFALL IN cm
200-300
Snowbelts are defined as areas of local snowfall maxima
cm in
150 59.1
200 78.7
250 98.4
300 118.1
350 137.8
mm in mm in mm in
1300 51.2 1000 39.4 700 27.6
1200 47.2 900 35.4 600 23.6
1100 43.3 800 31.5

Climate Change in the Great Lakes Region: Projected Changes in Climate



The Impact of the Great Lakes on Regional Climate Change





In summer, lake breeze circulation keeps shoreline areas cooler (as compared to surrounding inland areas).

Lake-effect precipitation may become increasingly common in late fall and winter (as cool wintertime air flows over warm lake waters).

Projected Changes in Great Lakes Weather

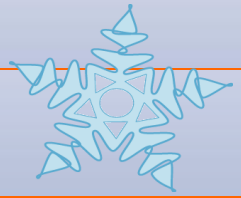
The following changes are ***likely*** over the next century:

- Number of days with low temperatures below 0ºF will drop by 50% or more
- Number of days with high temperatures above 90ºF will more than double
- Largest increases occur over western portions of the Great Lakes region
- Extreme or heavy rainstorms become 50-100% more frequent

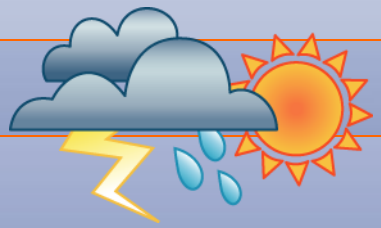
Part 2: Climate Change Impacts in the Great Lakes Region

CLIMATE CHANGE IMPACTS

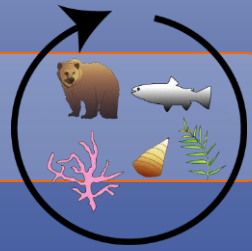
Lake Levels



Ice Cover



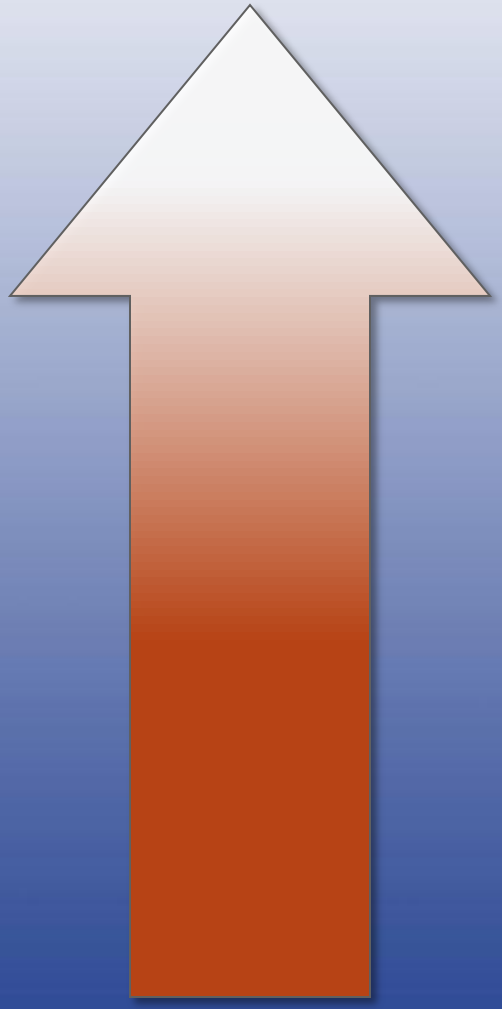
Severe Weather



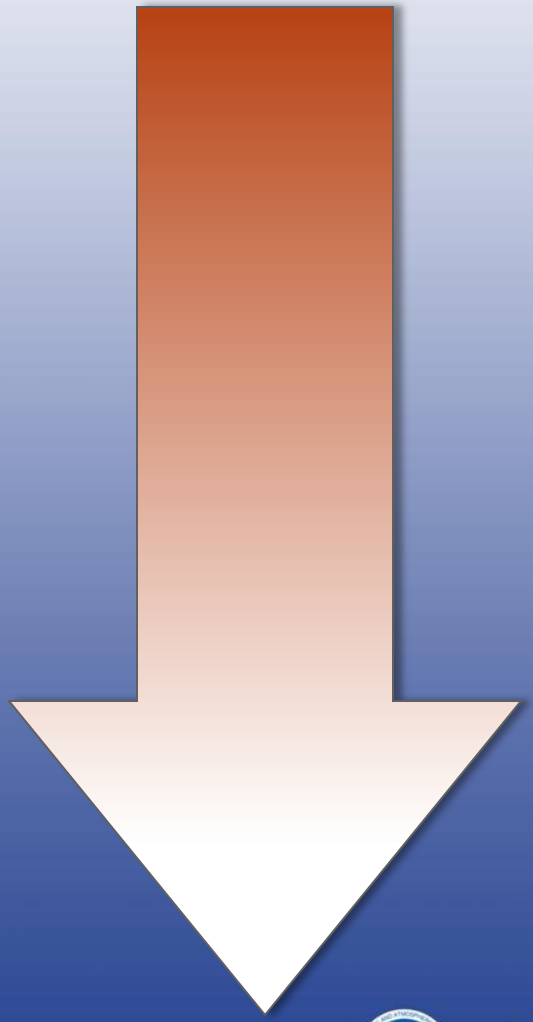
Ecosystem Changes

Human Health and Economy

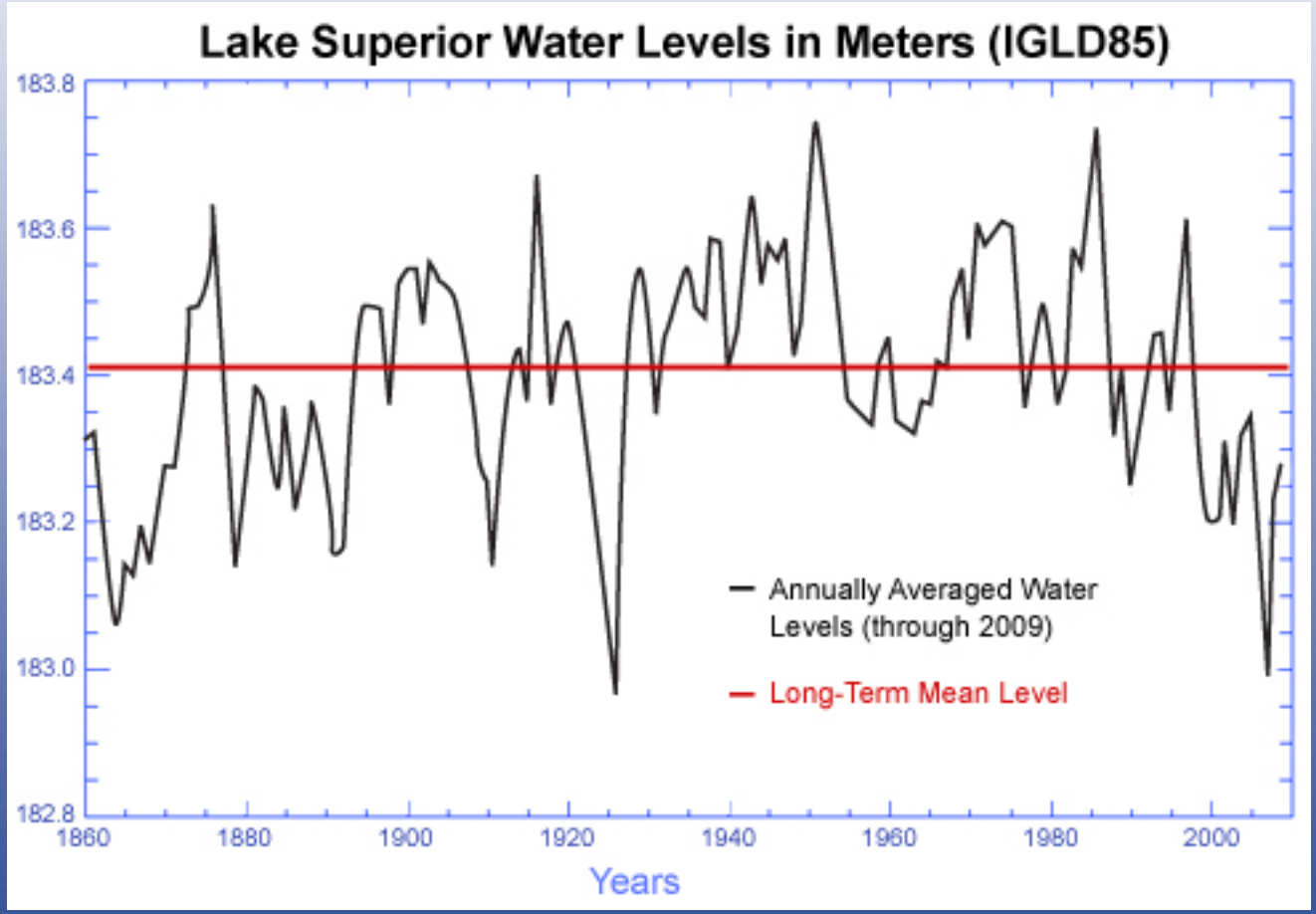
Lake Levels



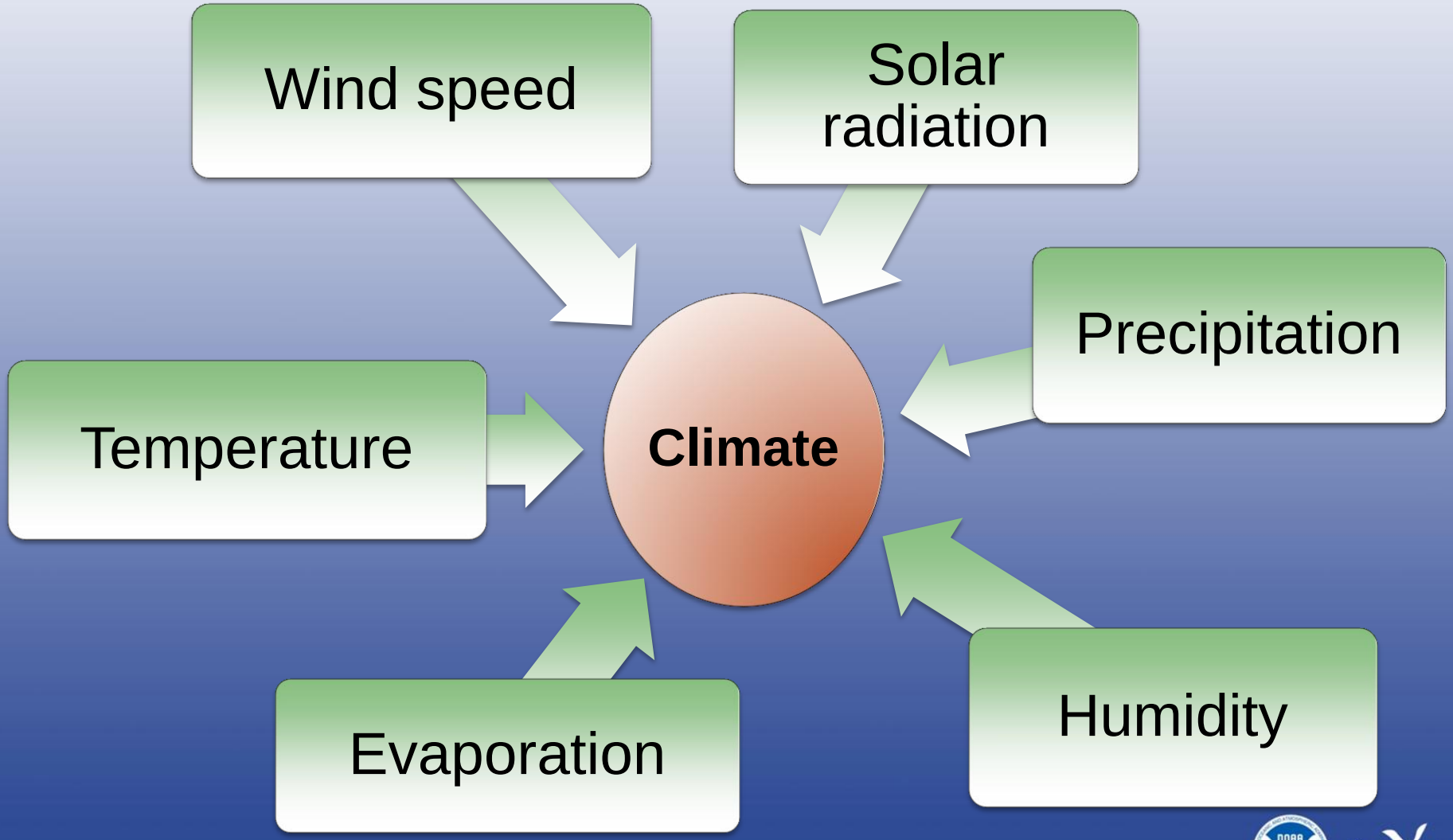
OR

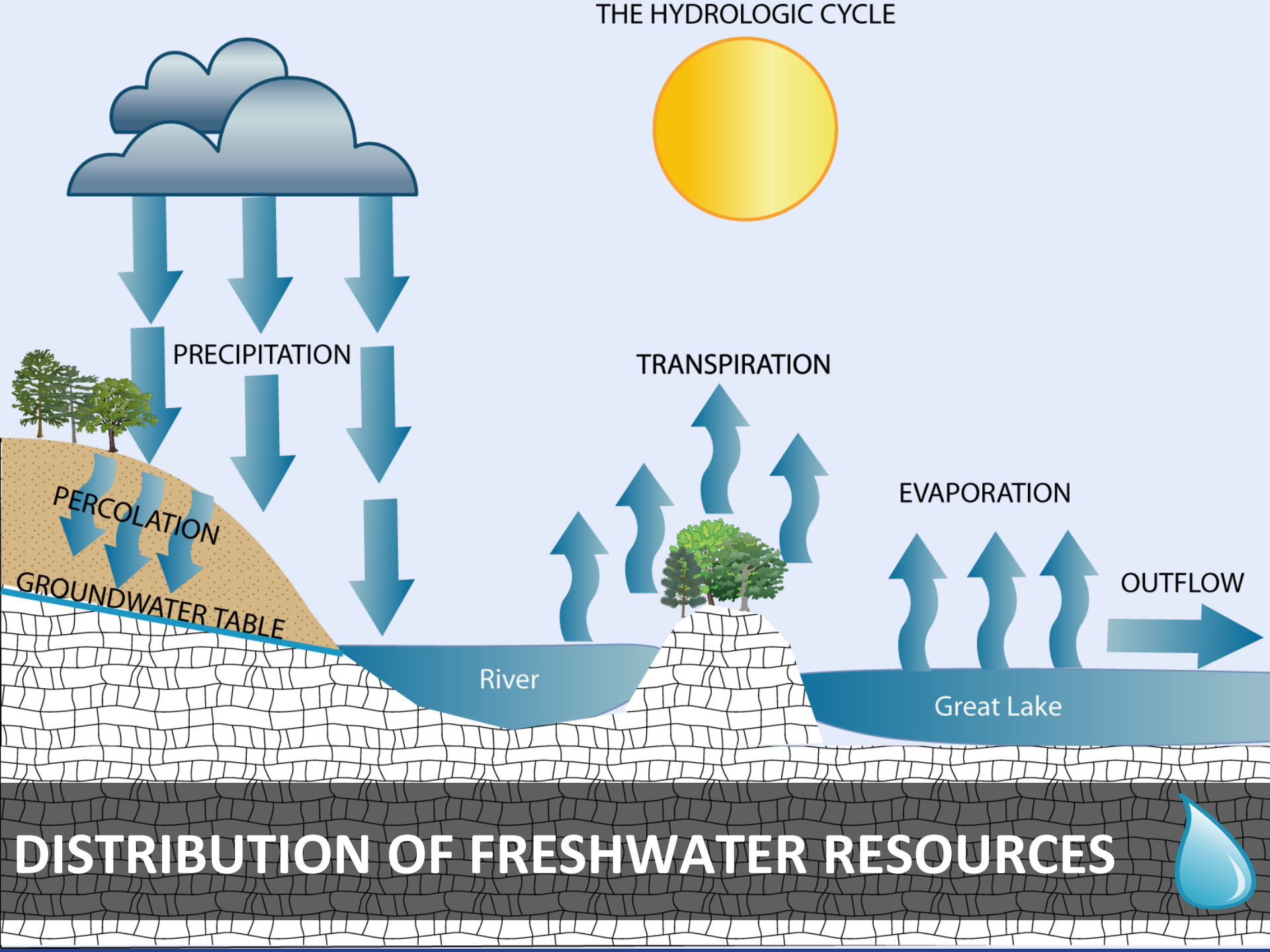


Great Lakes Water Level Variability



What are the climate variables for lake levels?




THE HYDROLOGIC CYCLE
PRECIPITATION
TRANSPIRATION
EVAPORATION
OUTFLOW
PERCOLATION
GROUNDWATER TABLE
River
Great Lake
DISTRIBUTION OF FRESHWATER RESOURCES

Impact on Shipping and Shoreline Infrastructure

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

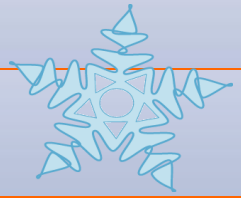
Fluctuating lake levels will impact shoreline infrastructure and harbors (recreational and commercial).

Lake Levels Summary

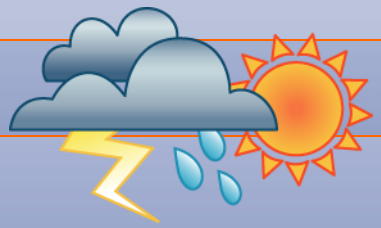
- There is a range of predicted lake levels, but the likely overall trend is downward.
- Natural variation in lake levels already occurs, but it will be amplified by climate change.
- Lake levels are affected by environmental factors (e.g., solar radiation, precipitation, humidity, evaporation, temperature, and wind speed).
- Shifting lake levels will impact shoreline infrastructure and shipping.

CLIMATE CHANGE IMPACTS

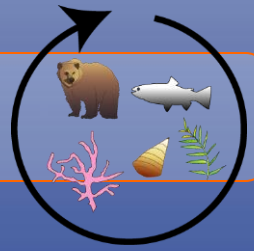
Lake Levels



Ice Cover



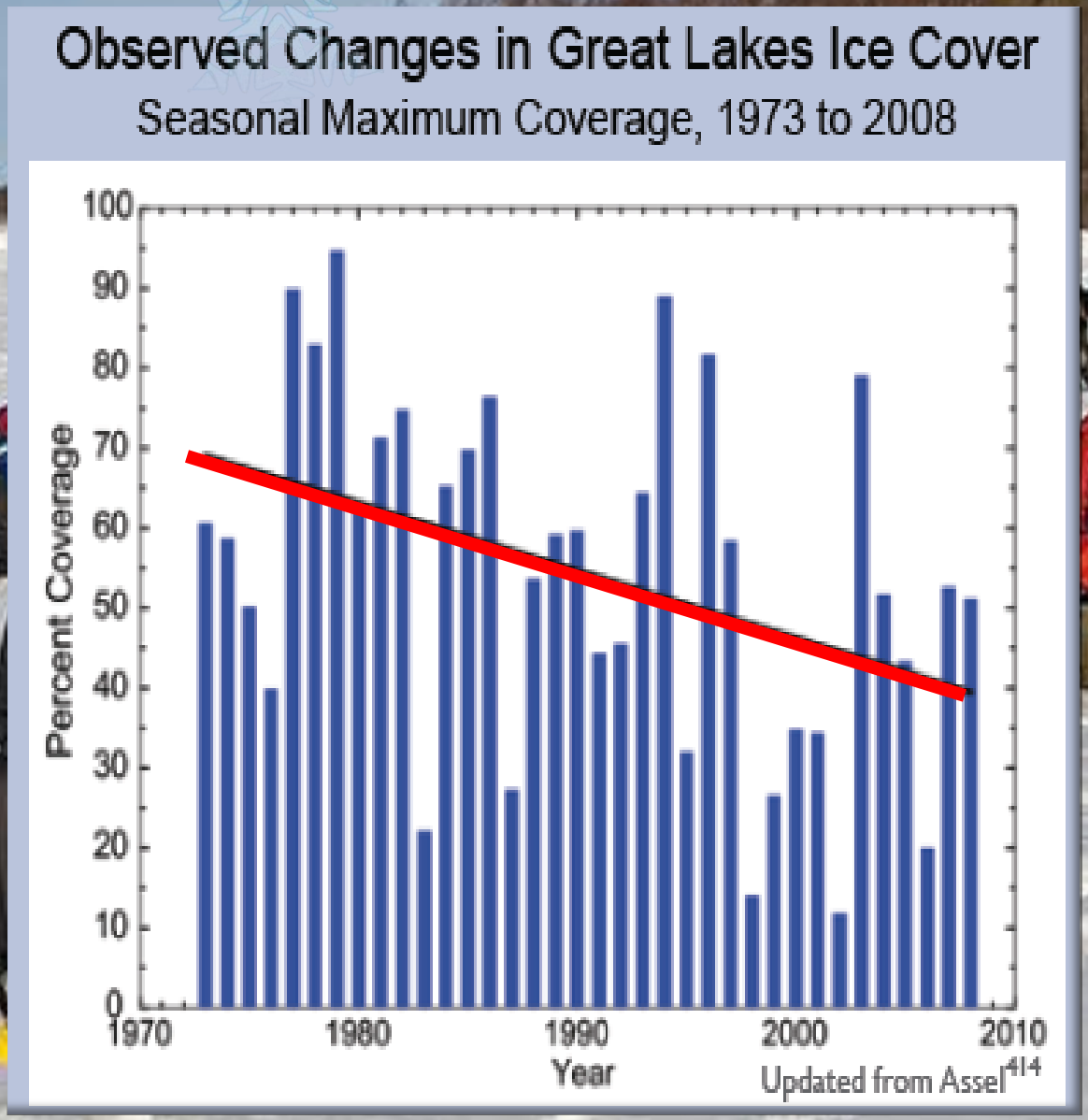
Severe Weather



Ecosystem Changes

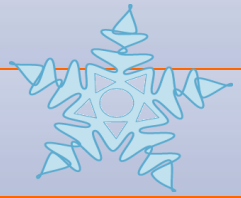
Human Systems

Ice

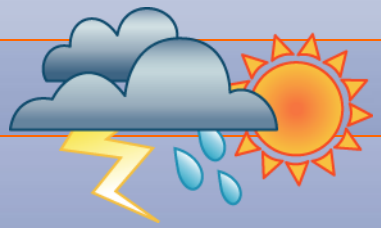

Observed Changes in Great Lakes Ice Cover
Seasonal Maximum Coverage, 1973 to 2008
Percent Coverage
100
90
80
70
60
50
40
30
20
10
0
1970
1980
1990
2000
2010
Year
Updated from Assel[4|4]

CLIMATE CHANGE IMPACTS

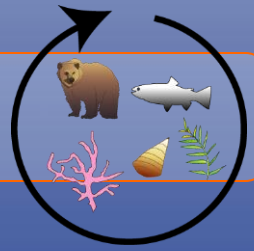
Lake Levels



Ice Cover



Severe Weather



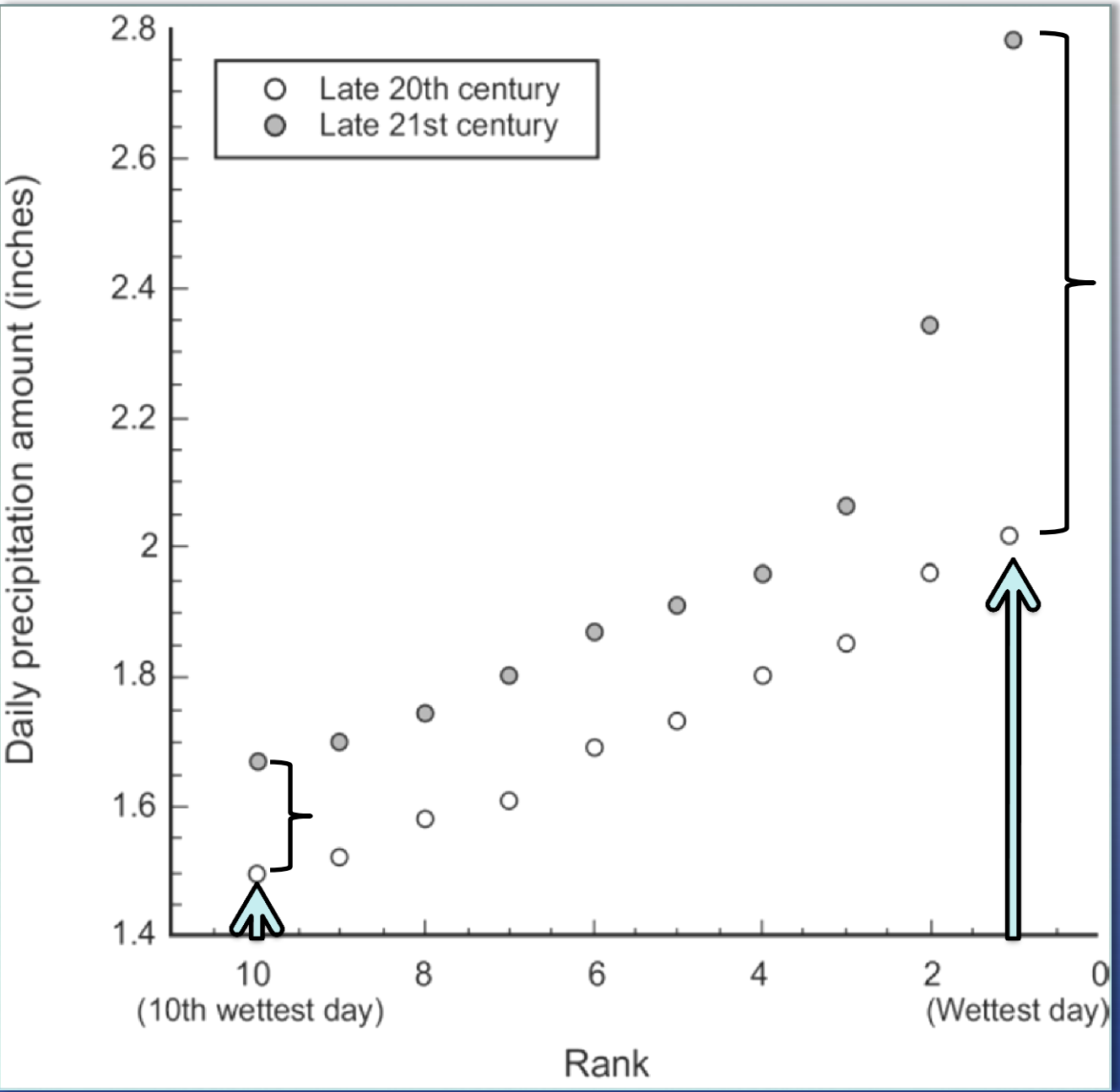
Ecosystem Changes

Human Health and Economy

Severe Weather

- Relationship between climate change and local-scale weather is complex, which limits long-range predictability of predominant weather patterns.

- However, we can make some generalized projections. For example, climate change will likely result in more extreme weather events (such as floods and droughts).



Frequency of heavy rain/flood events could increase (for late winter to early summer)

Severe Weather: Flooding

More Frequent

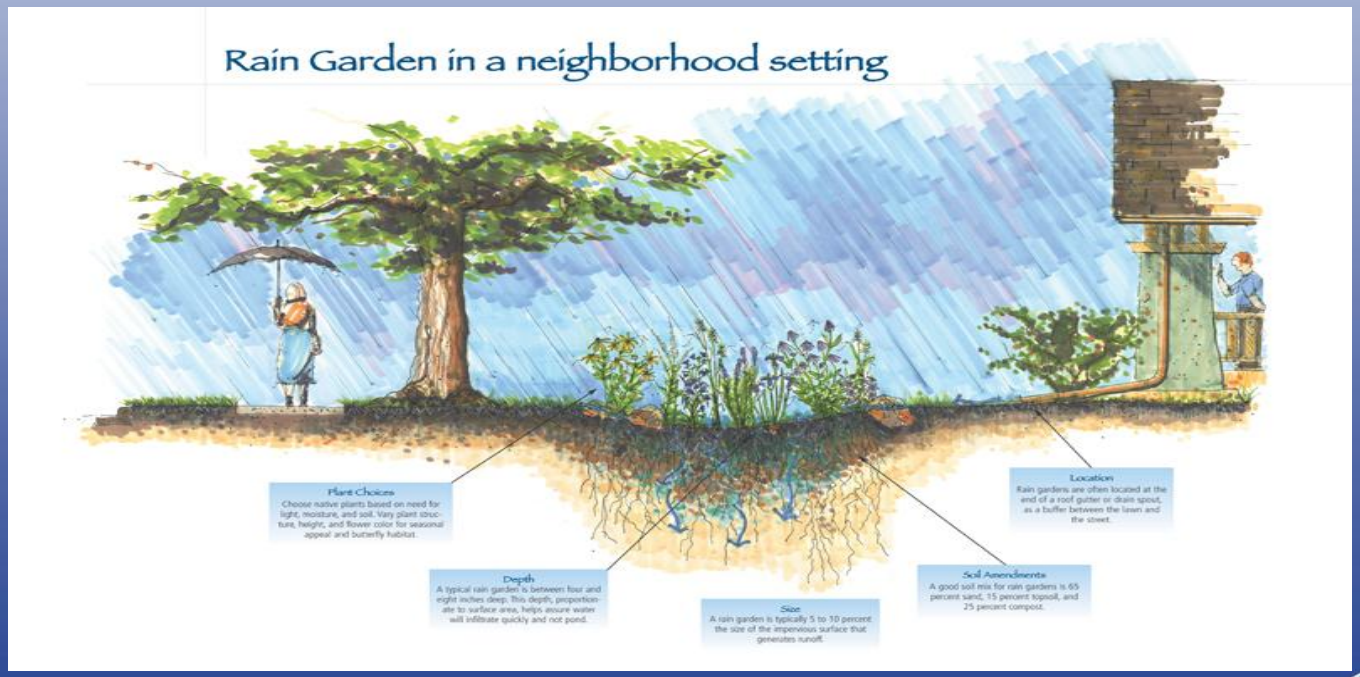
More Severe

More Damaging

Milwaukee, Wisconsin
Summer 2010

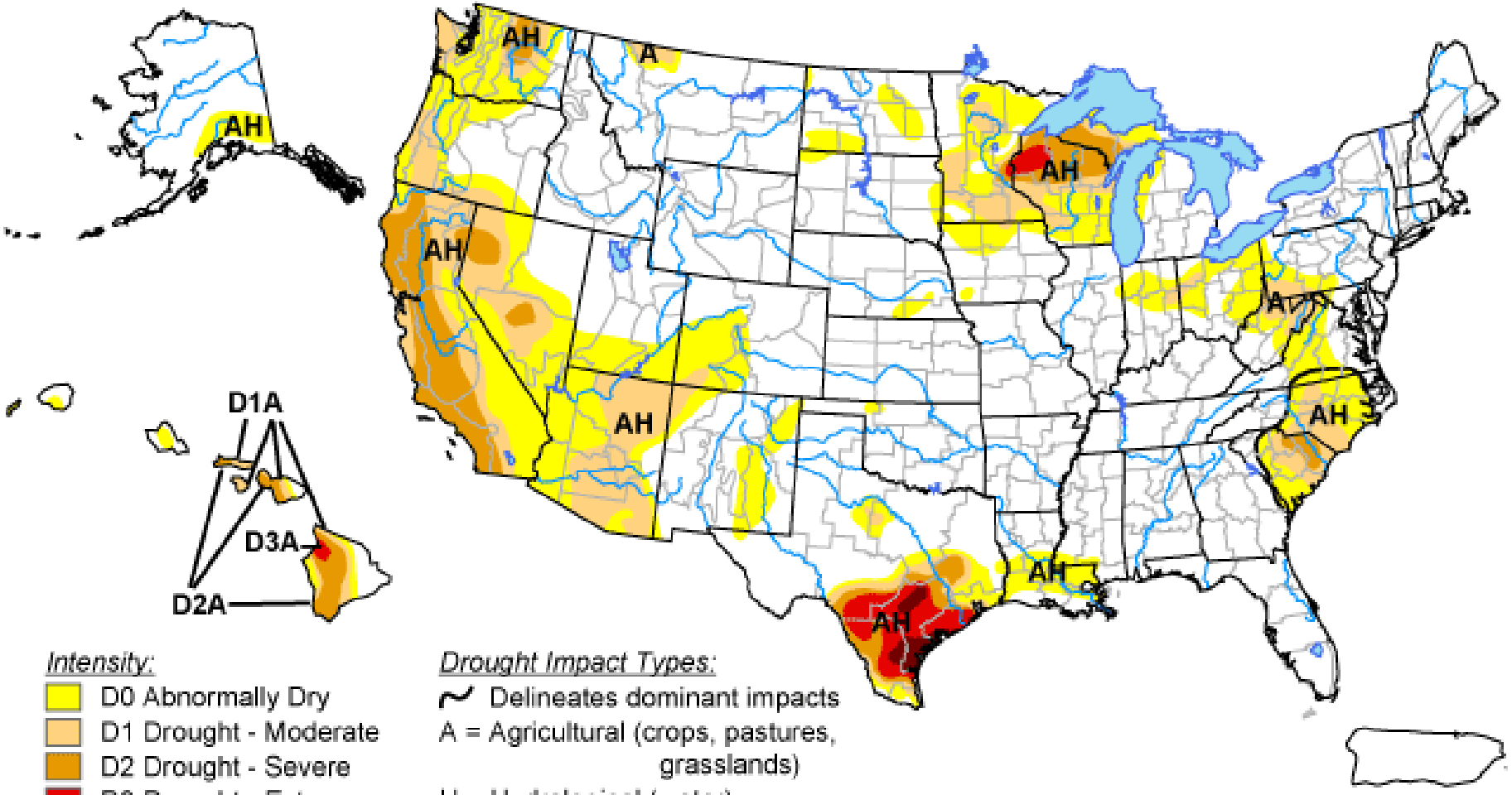
Case Study: Milwaukee, WI

- Public/private partnership to promote green infrastructure.
- Comprehensive watershed management approach that helps address cross-jurisdictional issues.
- Projects include a land acquisition program, promoting downspout disconnection, and installing rain gardens.



U.S. Drought Monitor

September 22, 2009
Valid 8 a.m. EDT



Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:
- Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

USDA National Drought Mitigation Center

Released Thursday, September 24, 2009

Author: David Miskus, JAWF/CPC/NOAA

www.drought.gov

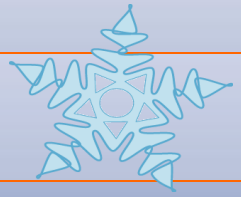
Severe Weather Summary

- Likely increase of heavy precipitation events
  - More severe
  - More frequent
  - More damaging

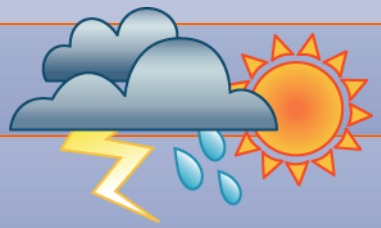
- Likely increase of drought due to warmer temperatures between rain events

CLIMATE CHANGE IMPACTS

Lake Levels

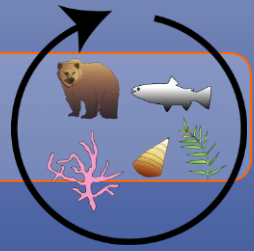


Ice Cover



Severe Weather

Ecosystem Changes



Human Health and Economy

Lake Stratification

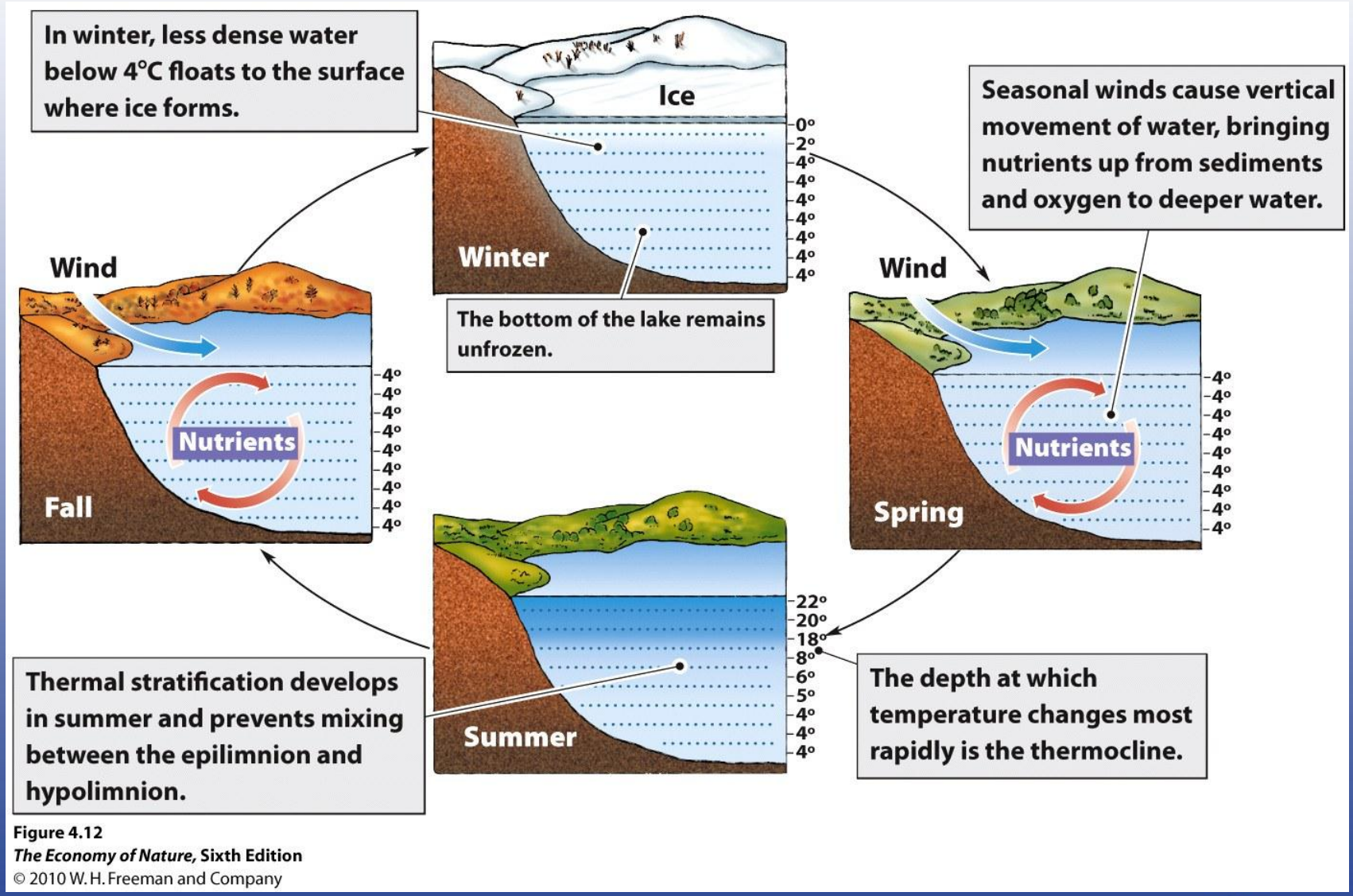
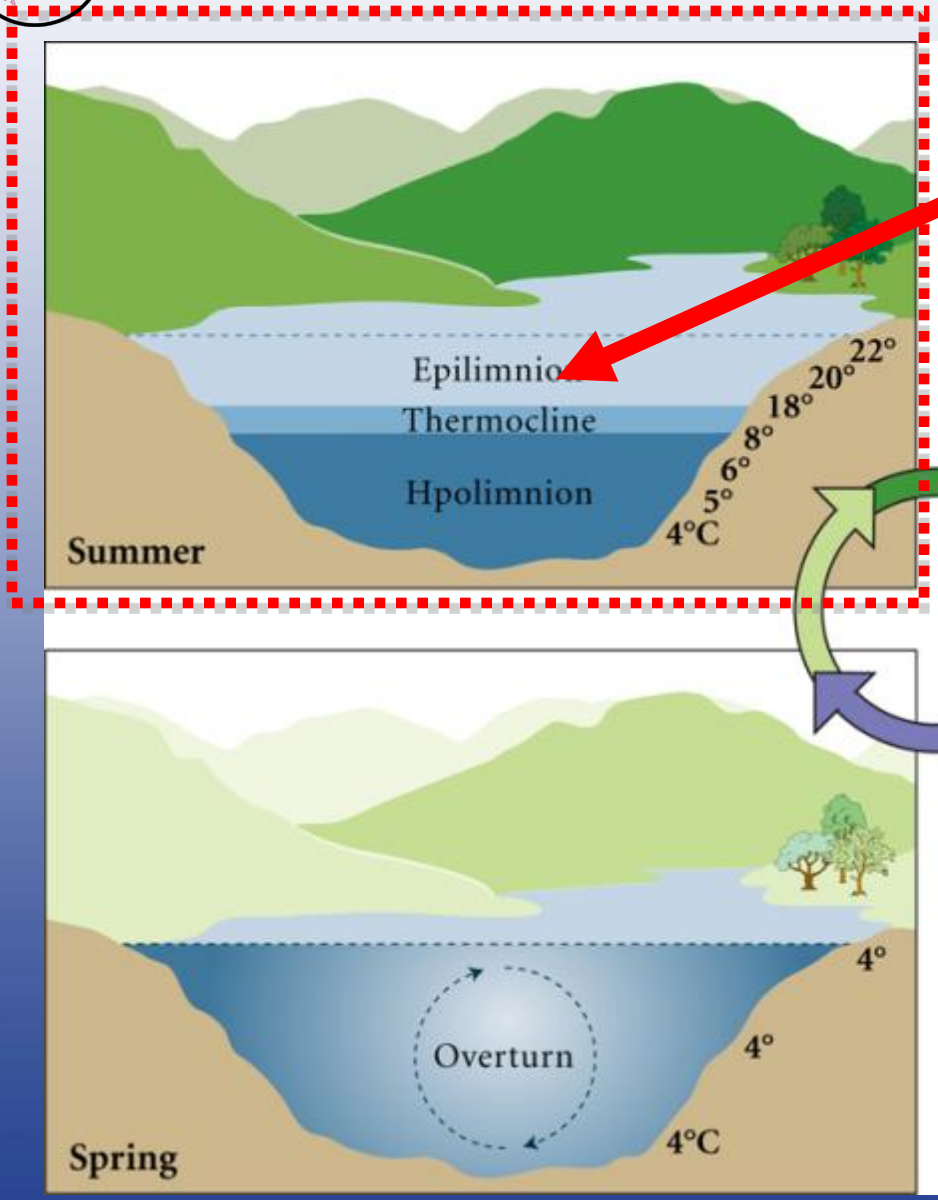


Figure 4.12
***The Economy of Nature*, Sixth Edition**

Increased Duration of Thermal Stratification



Currently 135 Days in Lake Michigan

In the future, up to 225 days in Lake Michigan


Habitat Shifts
Species Shifts
Food Webs

Habitat Shift and Expansion

Minnesota

Wisconsin

Michigan

New

Iowa

Ohio

Pennsylvania

Indiana

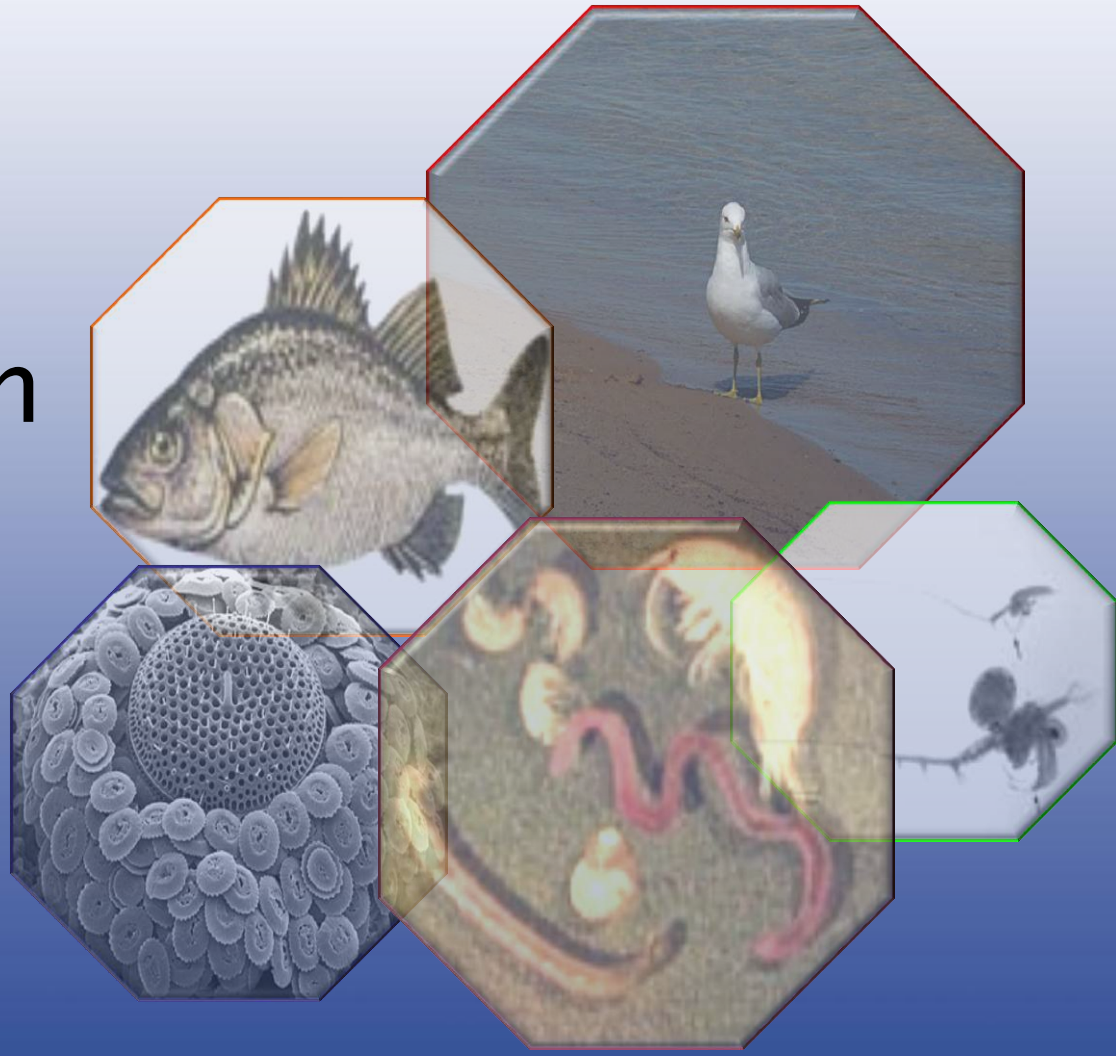
Maryland

West Virginia

Missouri

Food Webs May Change

- Zooplankton
- Phytoplankton
- Fish
- Birds



Case Study: Conservation Resource Alliance

Public/private partnership working to protect regional watersheds through:

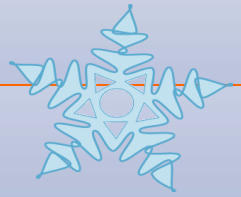
- Wild Link, which encourages private landowners to help preserve connective corridors for wildlife
- River Care, which restores stream habitat

Ecosystem Changes Summary

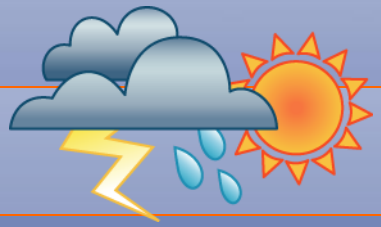
- Lake stratification changes due to warming temperatures will affect the biogeochemistry and ecology of lakes.
- Plant and animal habitats will shift to the north.
- Food webs may change due to shifting species habitats.

CLIMATE CHANGE IMPACTS

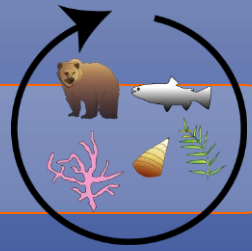
Lake Levels



Ice Cover



Severe Weather

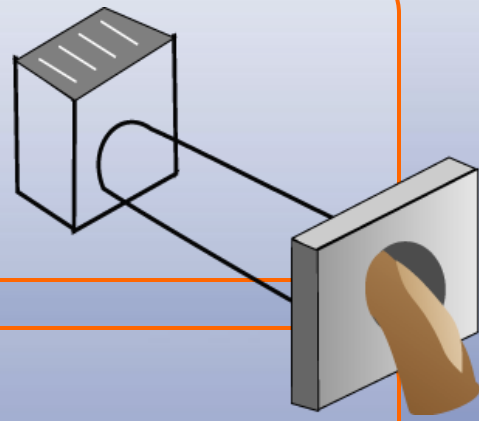


Ecosystem Changes

Human Health and Economy

Human Health Concerns

Heat Waves



Water and Air Quality

Agriculture

Chicago Tribune, July 13, 1995

The 1995 Chicago heat wave: Record temperatures and humidity result in a deadly weekend

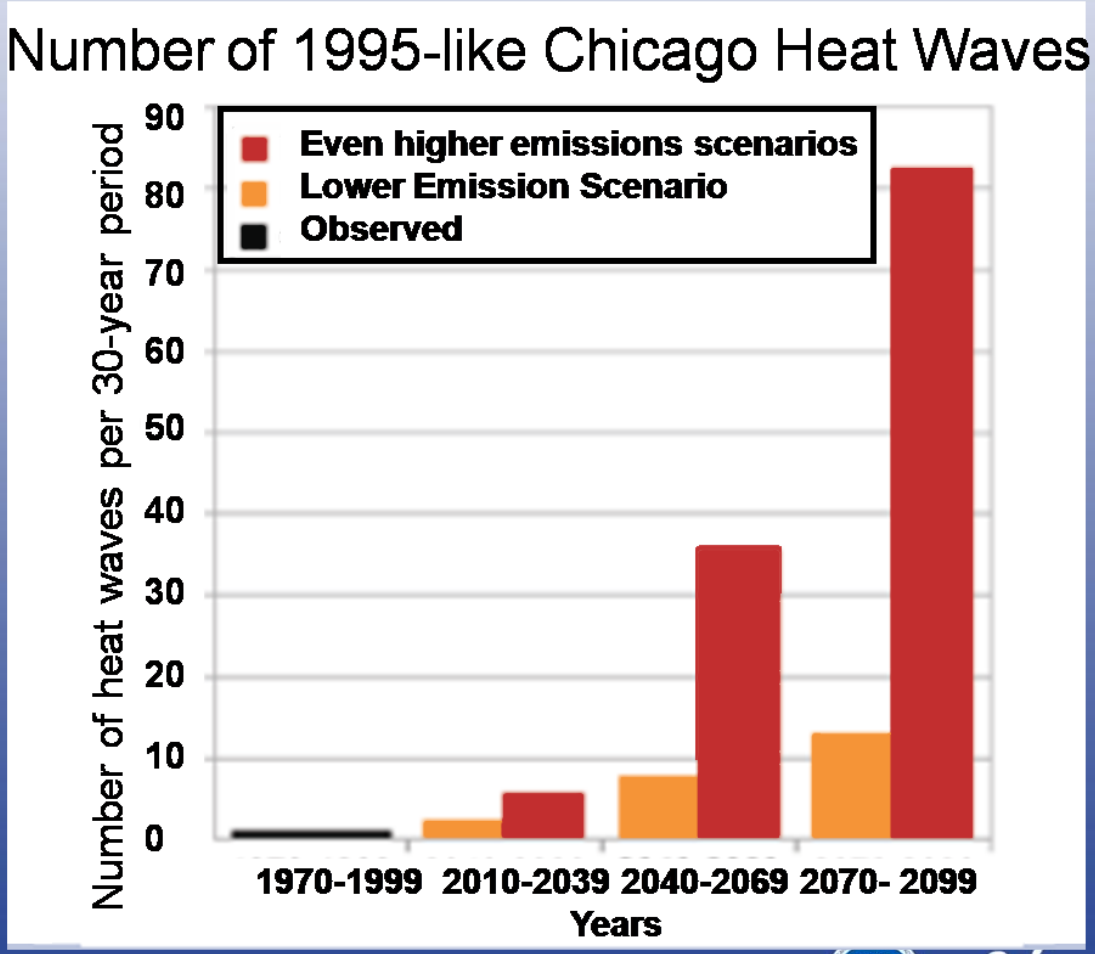
The elderly were especially susceptible to the hot weather of the 1995 heat wave. This 101-year-old woman was overcome by heat later in the summer when an electrical fire knocked out the power in her apartment building. (Tribune photo by Walter Kale)

Heat Waves in Cities

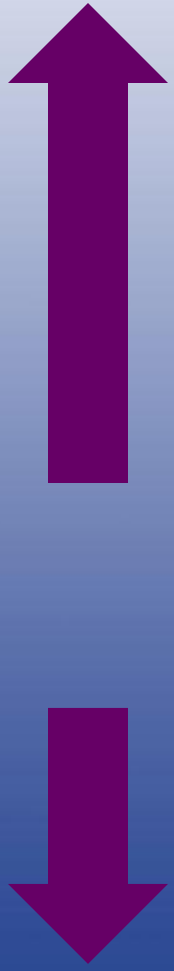
More Frequent

More Severe

Longer Lasting



Air Quality in a Changing Climate



Air Temperature

+

Air Stagnancy

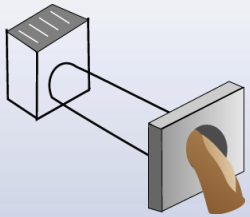
+

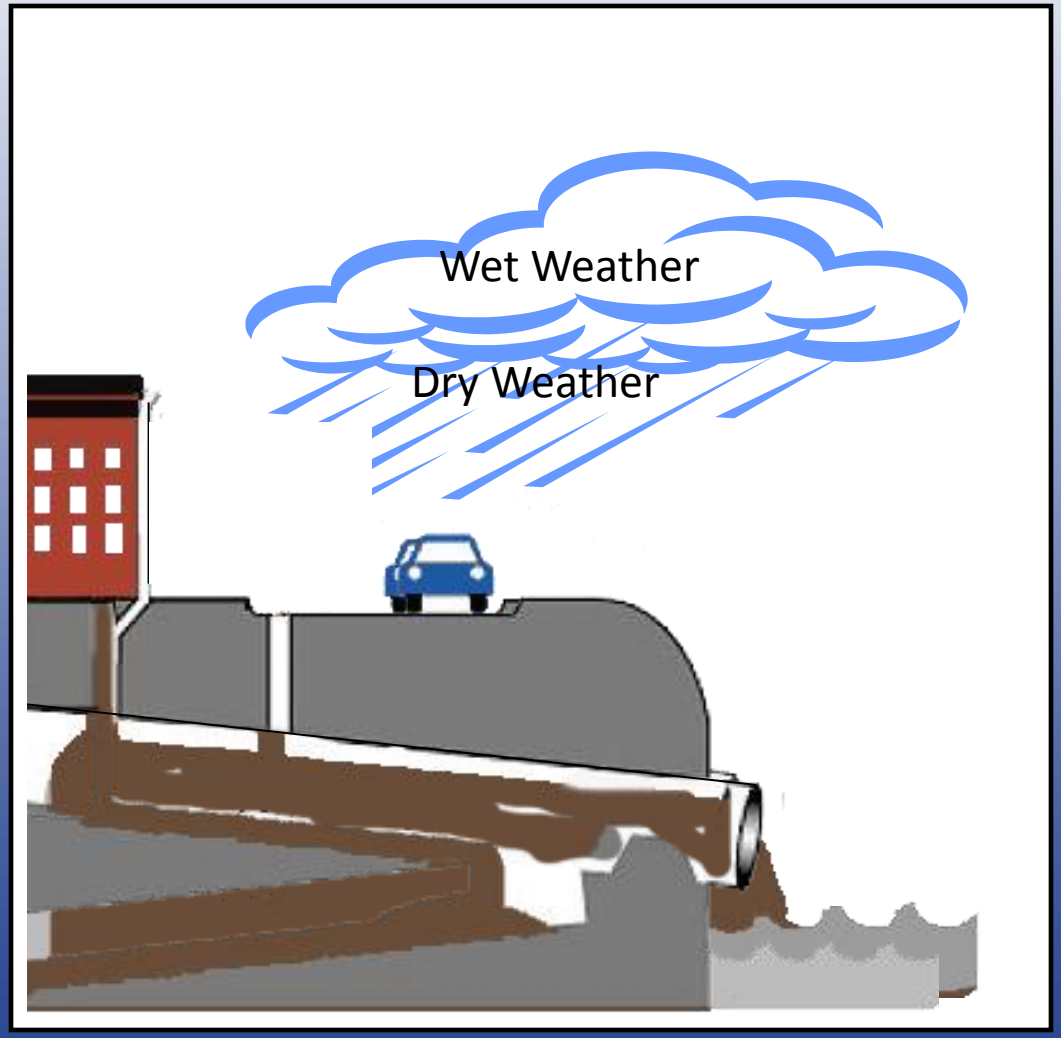
Emissions

=

Air Quality

Combined Sewer Overflows





Combined sewer overflows cause:

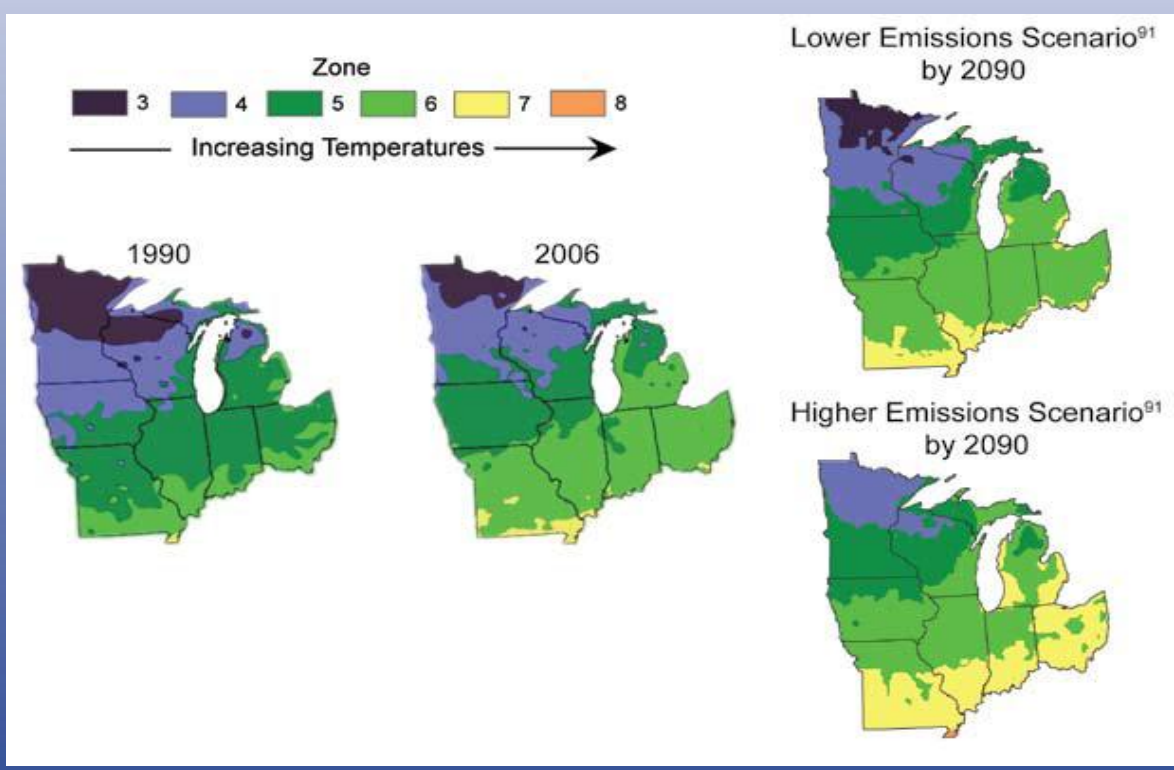
- Water quality problems
- Beach closures
- Human health risks

Agriculture Impacts

Changes in crop distribution:

About every 30 years, plant winter hardiness zones are likely to shift 0.5–1 zone.

Observed and Projected Changes in Plant Hardiness Zones



Agriculture

More growth potential

For Crops AND Pests

Impacts on Business

- 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

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 Ready Great Lakes

So now we know…

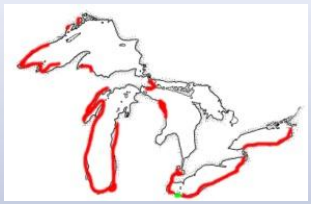
- Climate change uniquely impacts the Great Lakes

- Climate change in the Great Lakes affects:
  - ❑ Lake levels
  - ❑ Ice cover
  - ❑ Severe weather
  - ❑ Ecosystems
  - ❑ Human health

So… how might climate change affect YOUR community???

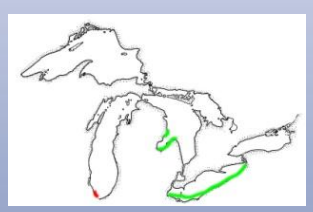
Extra Slides

Range Expansion Species To Date



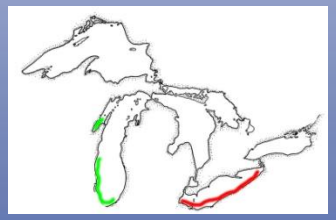
Native to Lake Erie, expanding northward

Rusty crayfish



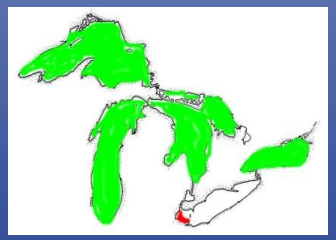
Native to Lake Erie and Huron, invading Lake Michigan

River darter



Native to Lake Michigan, invading Lake Erie

Bullhead minnow



Native in Lakes Superior, Michigan, Huron, and Ontario; Introduced Lake Erie and Lake St. Clair

Brook trout

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).

Dealing with Uncertainty

This is IPCC's likelihood scale. When IPCC declares a ***likely*** impact of GCC, it indicates a 66% or greater chance of occurrence.

Table 4. Likelihood Scale.

Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability
Likely	> 66% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability