

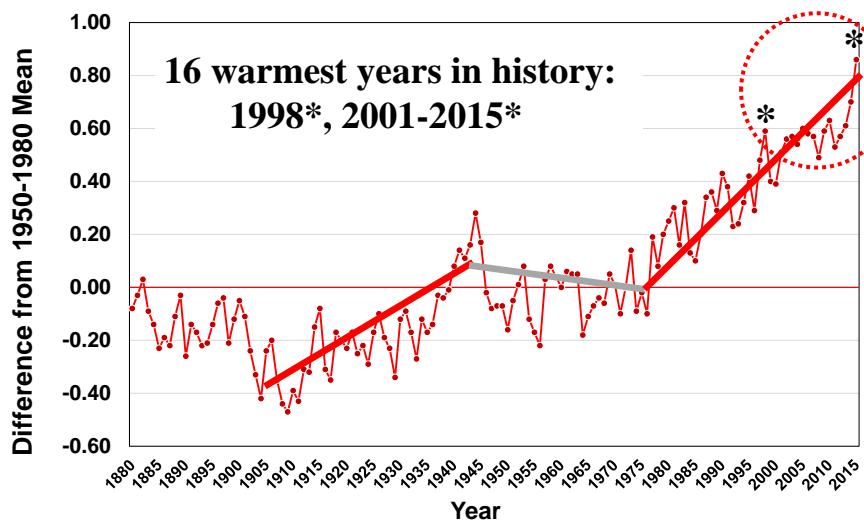
Effects of Climate Change on the Great Lakes Region



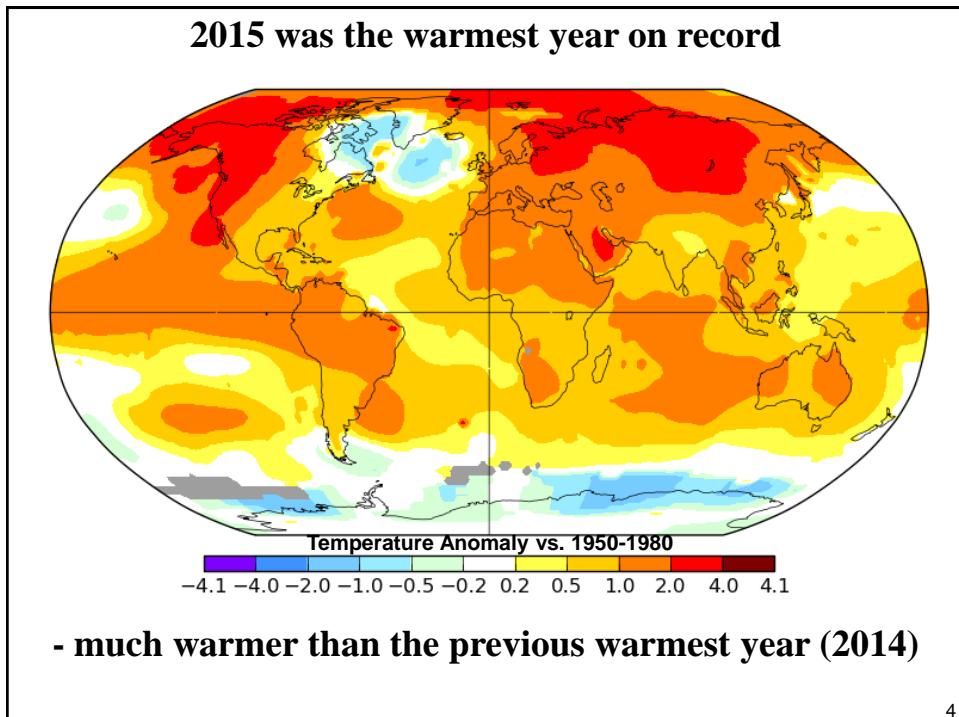
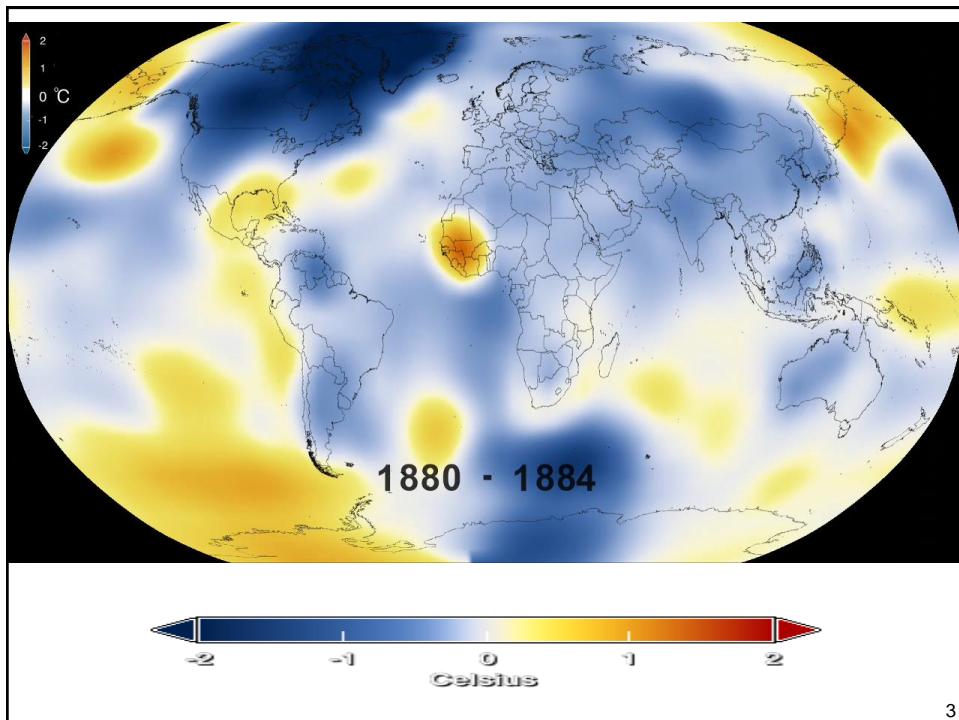
Dr. David Karowe
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Western Michigan University
Kalamazoo, MI
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1

Since 1900, Earth has warmed ~ 0.9° C

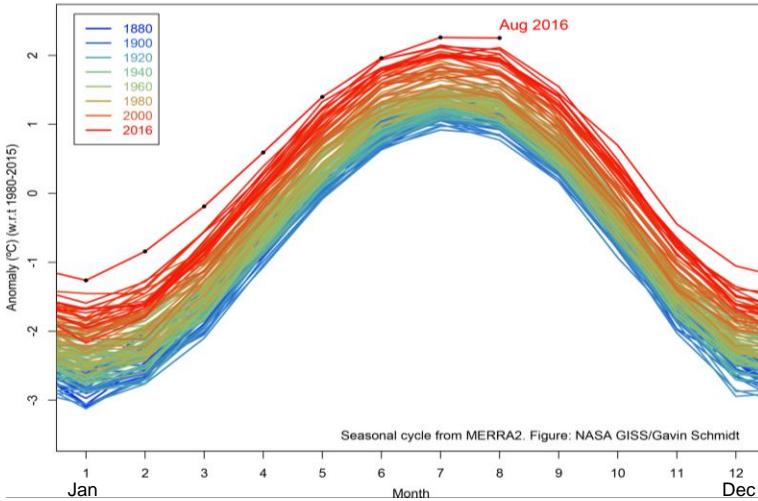


2



So far, 2016 is much warmer than 2015

- every month this year has set a new record

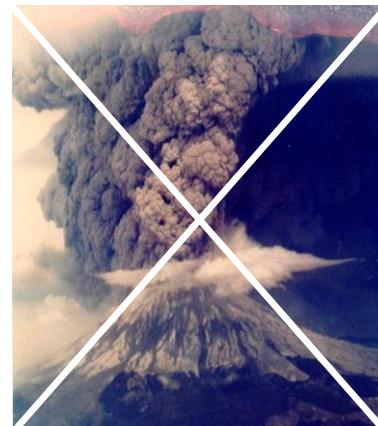
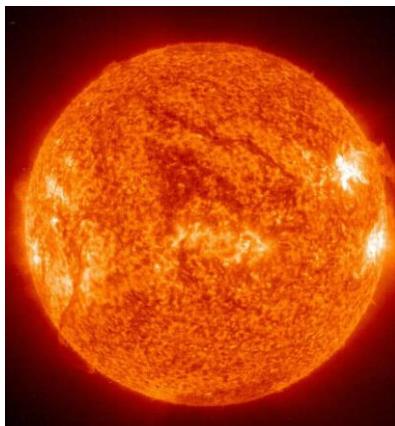


- July and August 2016 are the warmest months ever recorded

5

**How do we know that current climate change is
not due to “natural factors”?**

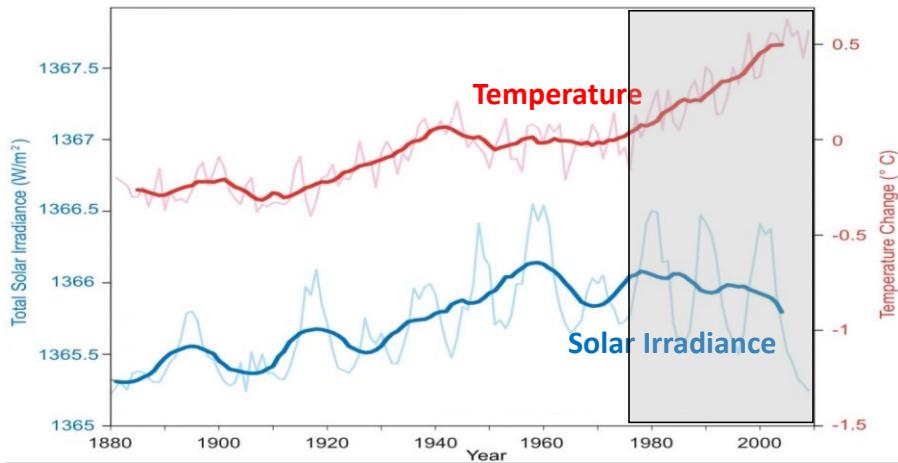
Until ~1900, all climate change was due to natural factors



Have we been getting more energy from the sun?

6

**Since 1975, while Earth has been warming fastest,
solar irradiance has been decreasing**



**Since 1900, sun and volcanoes together (“natural factors”)
would have caused a slight cooling of Earth**

7

**In two major ways, current warming is very
different than any known warming in the past**

1. It's at least 10 times faster
2. Unlike all past climate change, it's happening
while solar input is decreasing

8

Best estimate: at least 95% of current warming is due to human activities

Greenhouse gas emissions (CO₂)



Deforestation



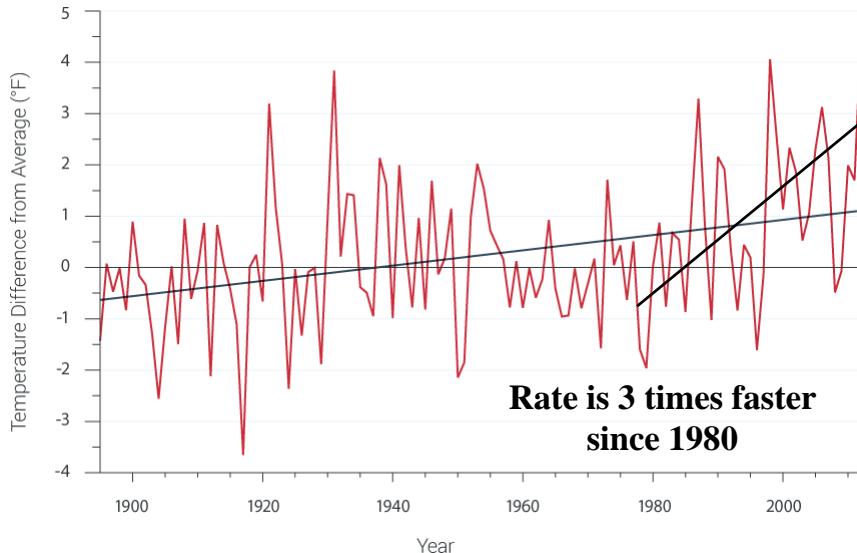
9

How has climate been changing in the Great Lakes Region?



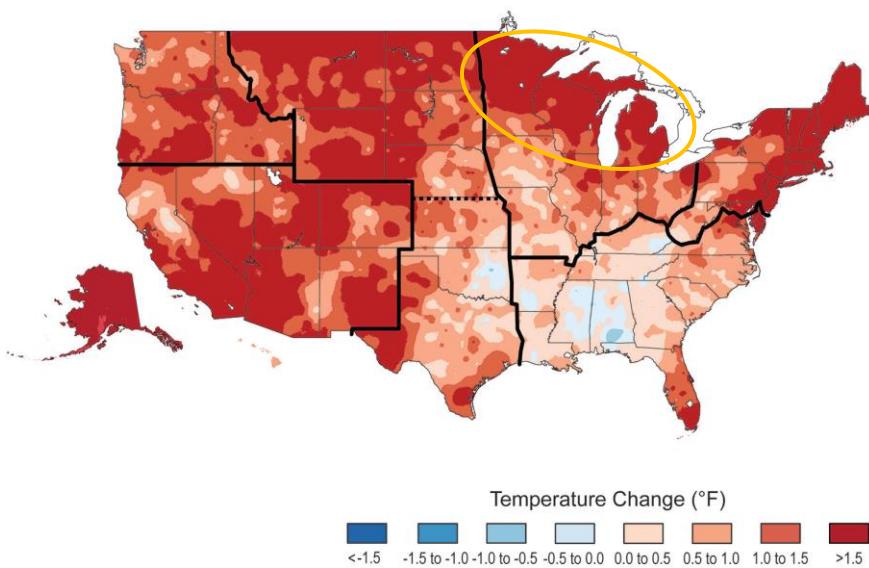
10

Since 1900, the Great Lakes Region (GLR) has warmed by ~ 0.9° C



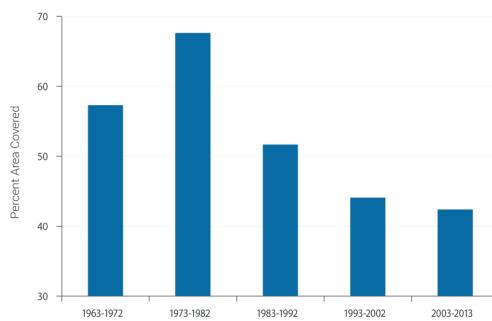
11

Over the past 25 years, the northern GLR has been warming faster than most of the U.S.



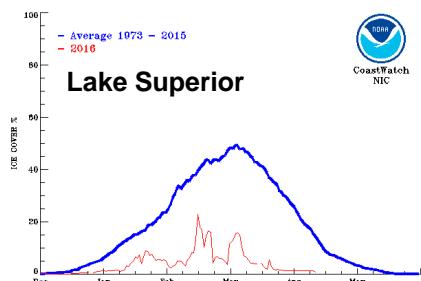
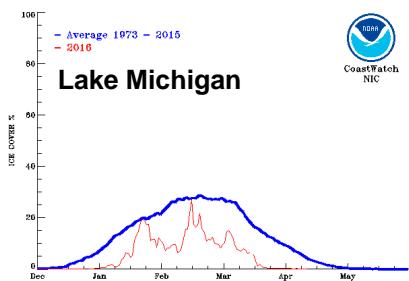
12

Warming has caused a decrease in ice cover



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Ice cover was particularly low this year

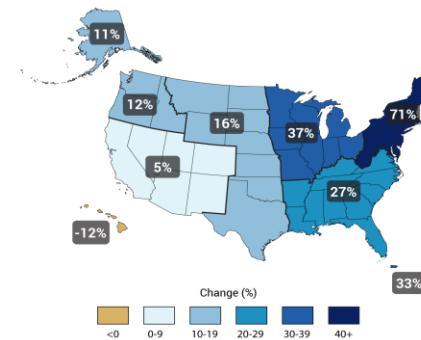


14

Over the 50 years, there has been a big increase in extreme precipitation events in the GLR



Observed Change in Very Heavy Precipitation Since 1958



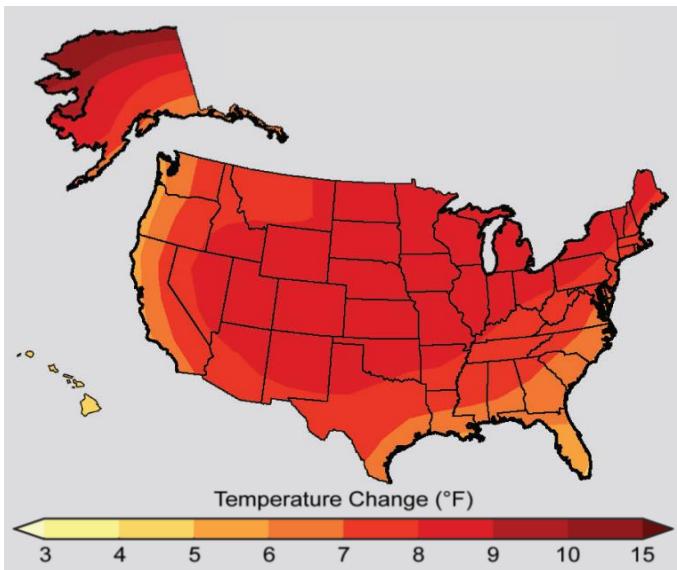
15

How will future climate change affect the Great Lakes Region?



16

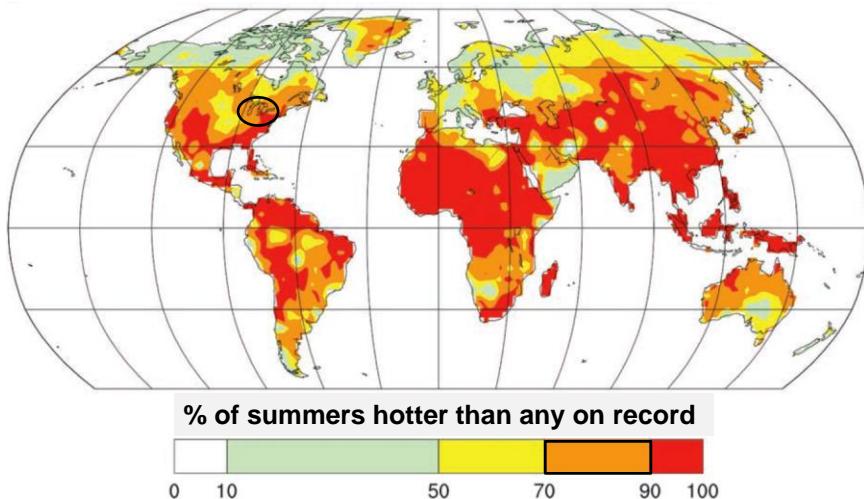
**By 2100, most of the GLR is predicted to warm by
8-12° F**



- warming will be greater in summer than in winter

17

By 2100, most summers will be hotter than any the region has experienced to date



18

For many GLR cities, the number of Chicago 1995-like heat waves is predicted to increase dramatically

- responsible for ~ 700 deaths in 1995

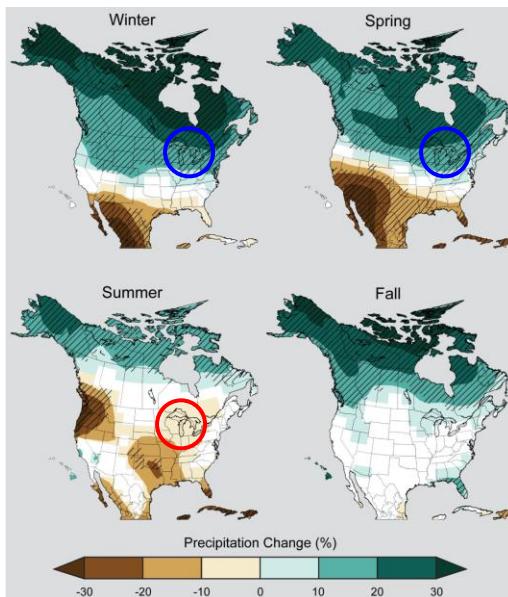


Number of Chicago 1995-like heat waves per decade

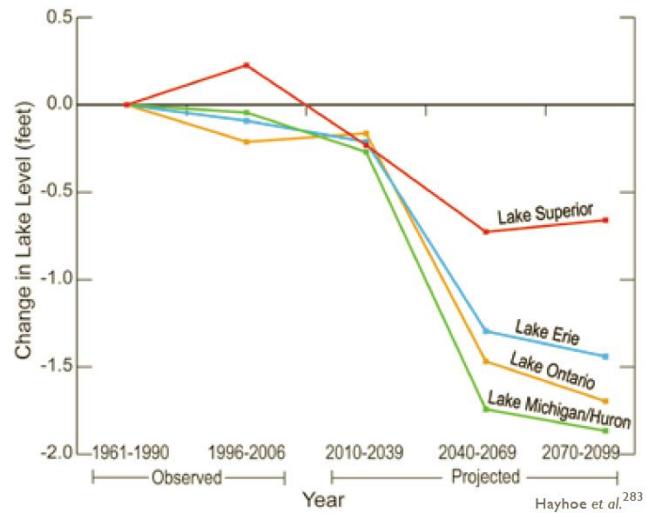
City	1961-1990	2070-2099
CHICAGO	0.11	4.22 → 27.44
CINCINNATI	0.11	1.44
CLEVELAND	0.00	0.33 → 11.11
DES MOINES	0.56	4.33
DETROIT	0.11	1.44 → 19.33
INDIANAPOLIS	0.22	2.11
MILWAUKEE	0.00	0.78
MINNEAPOLIS	0.11	1.89
ST LOUIS	1.33	11.11
		4°

- could cause 1,900 additional deaths per year in Chicago and 1,400 “ “ “ “ “ in Detroit¹⁹

For most of the region, more precipitation is predicted in winter and spring, but less in summer



Great Lakes water levels are predicted to drop by 1-2 feet by 2100



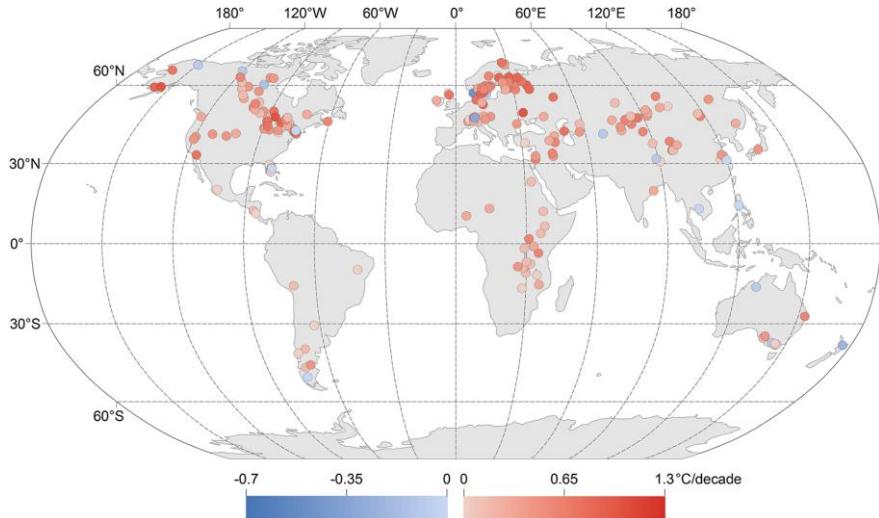
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Climate change is likely to strongly impact aquatic ecosystems in the GLR



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Lakes in the GLR are already warming relatively quickly



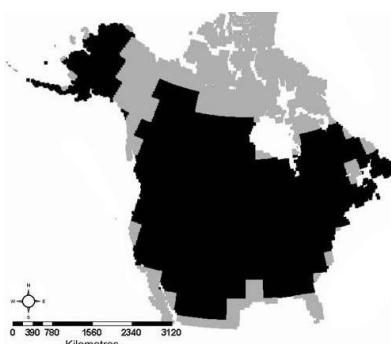
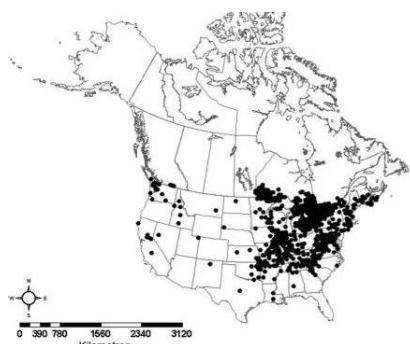
Because our lakes are:

- seasonally ice covered
- in an area with decreasing summer cloud cover

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Warming is predicted to cause habitat gain for warm-water species, but loss for cold-and cool-water species

e.g. huge increase in suitable habitat for smallmouth bass (warm-water) throughout the GLR



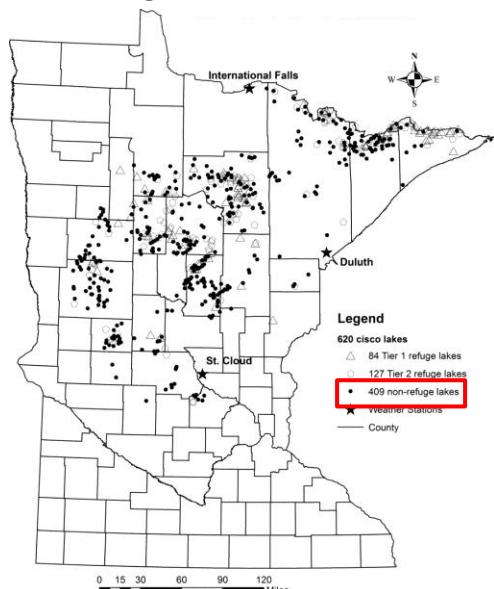
24

But a large decrease for cisco (cold-water)

e.g. in Minnesota



- 66% of currently inhabited lakes are predicted to become unsuitable by 2100



25

other “climate winners”



carp



bluegill



catfish



white perch

other “climate losers”



lake trout



rainbow trout



whitefish

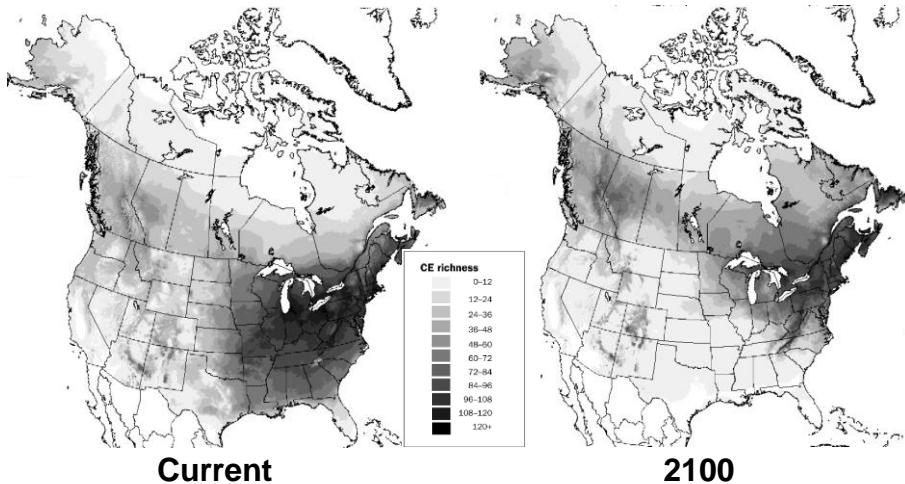


chinook salmon

26

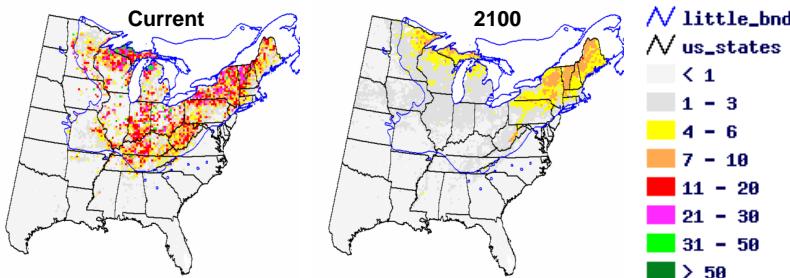
Terrestrial ecosystems will also be adversely affected

The number of tree species is predicted to decline substantially throughout most of the GLR



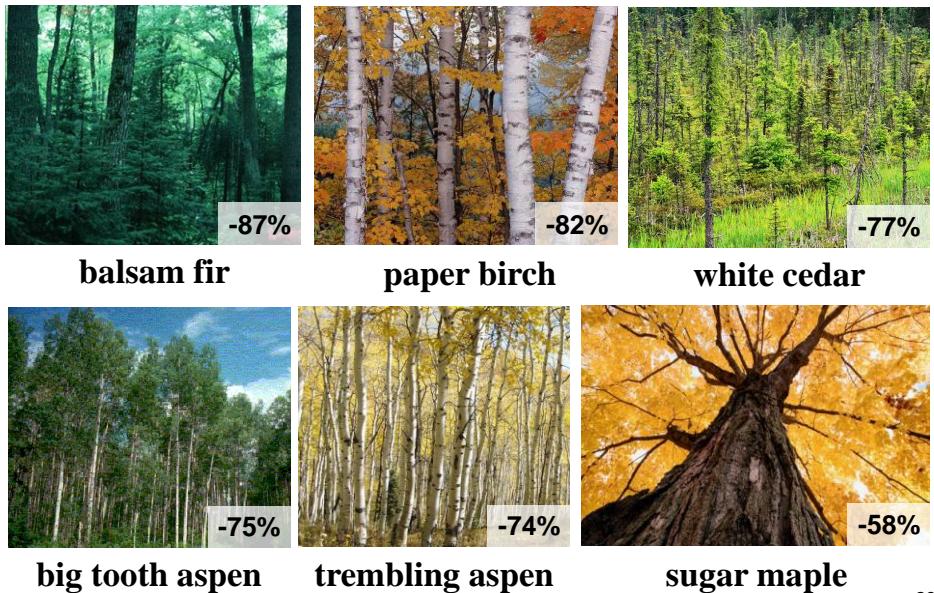
27

e.g. sugar maple is predicted to decline by more than 80%



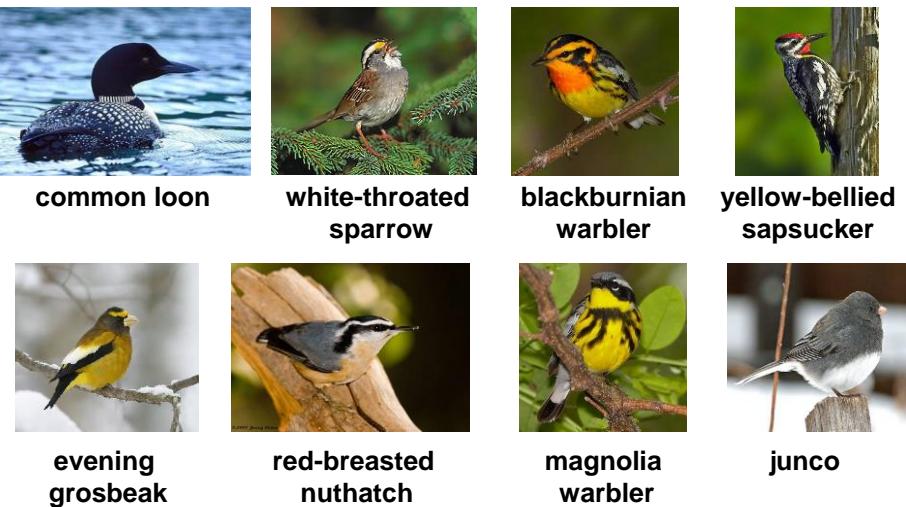
28

**In Michigan, 8 of the 15 most abundant tree species
are predicted to decline by at least 50%**



29

36 Michigan bird species predicted to decline by 75-100%



30

Several rare and/or southern tree species are predicted to increase in Michigan



eastern red cedar



hackberry



black walnut



silver maple



boxelder



eastern cottonwood

31

And 15 new bird species are predicted to arrive



**northern
bobwhite**



**yellow-billed
cuckoo**



**little blue
heron**



cattle egret



**Mississippi
kite**



**scissor-tailed
flycatcher**



**painted
bunting**

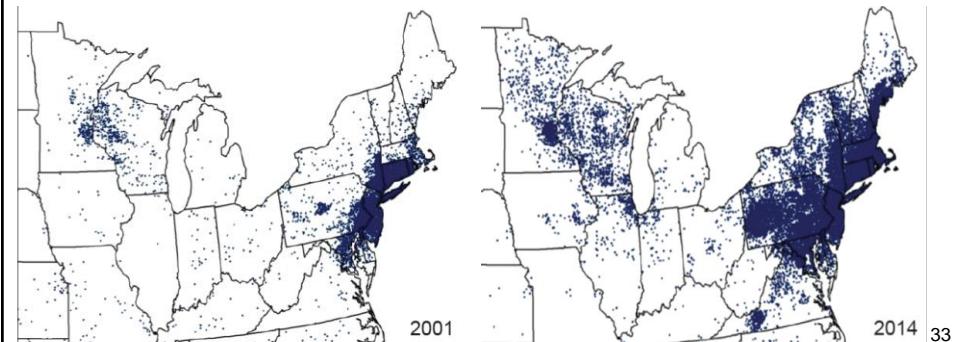


**summer
tanager**

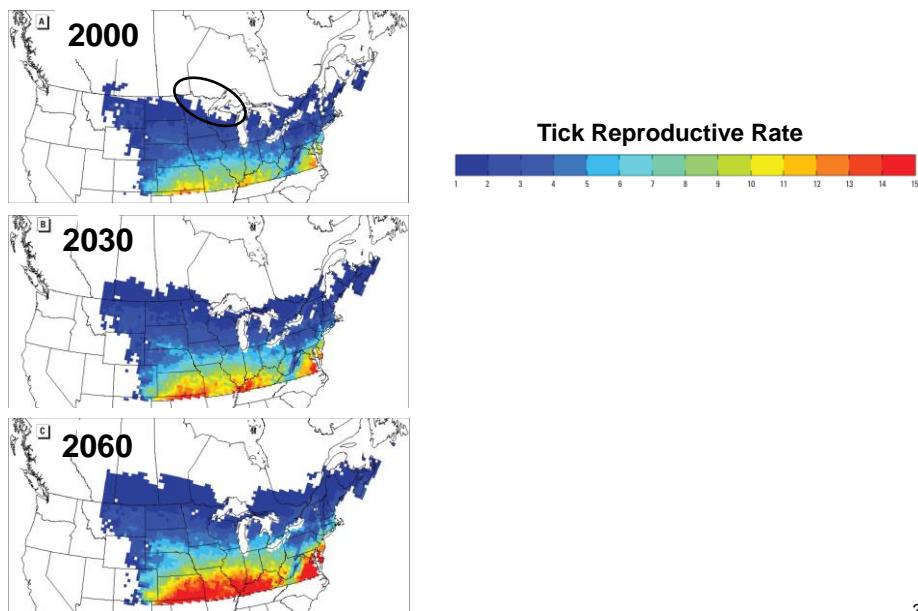
32

Climate change is likely to increase the incidence of vector-borne diseases in the GLR

e.g. Lyme disease is already increasing



Future climate change is likely to further increase the spread of Lyme disease in the Great Lakes Region



Most of the GLR will be at risk of at least moderate biome change

Moderate change
e.g. temperate evergreen forest to temperate mixed forest



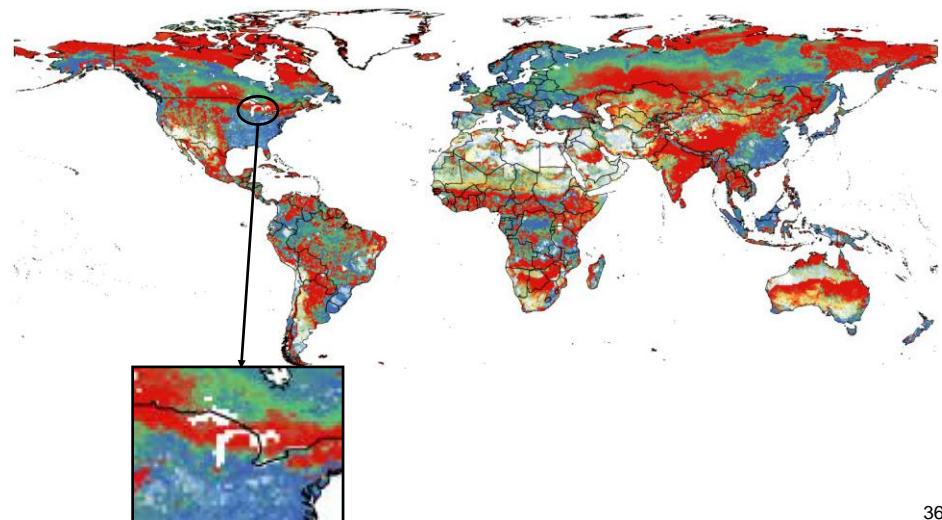
Major change
e.g. tropical forest to savanna



35

Most of the GLR will be at risk of at least moderate biome change

■ Major change ■ Major/Moderate change ■ Moderate change



36

But the future depends on our choices



37

This December in Paris, 195 countries agreed to limit global warming to 2° C



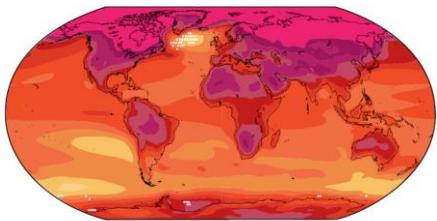
The Paris Agreement enters into force when signed by
≥ 55 countries responsible for ≥ 55% of global emissions

This happened on October 4!

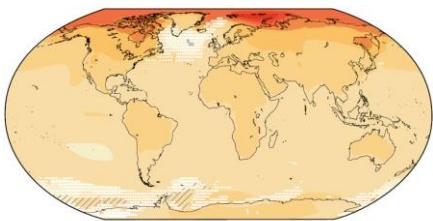
38

How would the Paris Agreement alter the future of the Great Lakes Region?

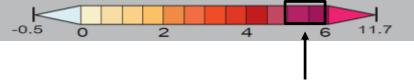
4° warming



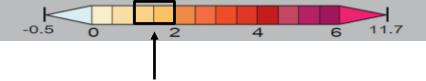
2° warming



Projected Temperature Change

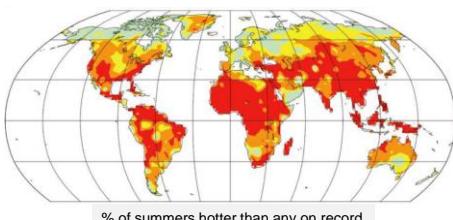


Projected Temperature Change



Many fewer summers in the GLR would be hotter than the current record hot summer

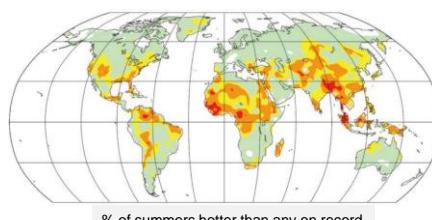
4° warming



% of summers hotter than any on record

0 10 50 70 90 100

2° warming



% of summers hotter than any on record

0 10 50 70 90 100

For many GLR cities, the number of Chicago 1995-like heat waves would decrease dramatically



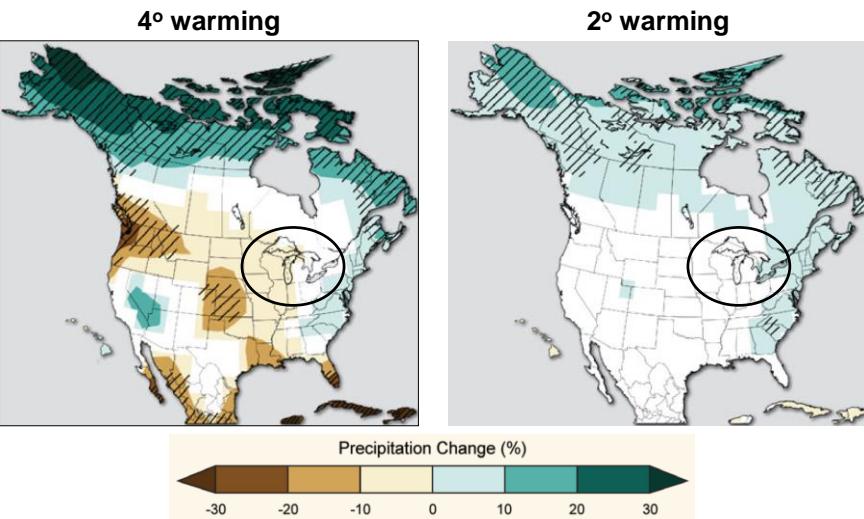
Number of Chicago 1995-like heat waves per decade

City	1961-1990	2070-2099	
		2°	4°
CHICAGO	0.11	4.22	27.44
CINCINNATI	0.11	1.44	21.44
CLEVELAND	0.00	0.33	11.11
DES MOINES	0.56	4.33	34.44
DETROIT	0.11	1.44	19.33
INDIANAPOLIS	0.22	2.11	24.56
MILWAUKEE	0.00	0.78	12.67
MINNEAPOLIS	0.11	1.89	19.67
ST LOUIS	1.33	11.11	59.89

- could prevent 1,600 deaths per year in Chicago and 1,300 “ “ “ in Detroit

41

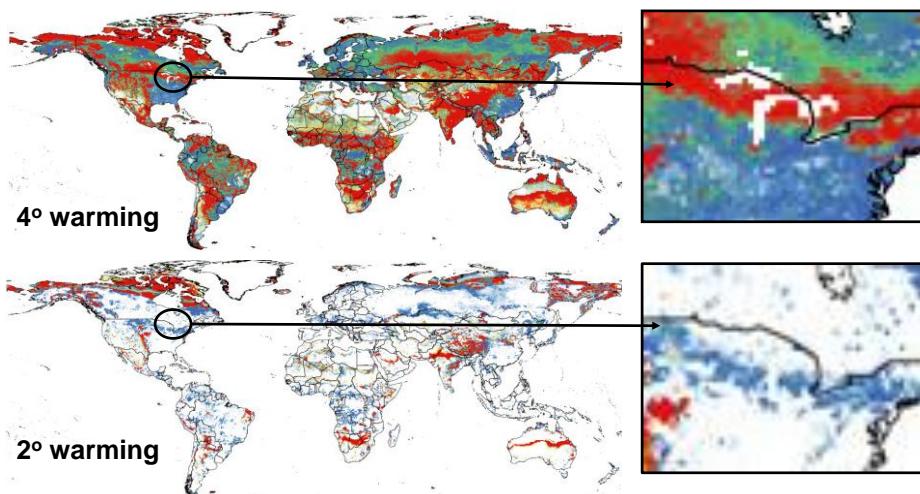
Limiting warming to 2° C would prevent a decrease in GLR summer rainfall



42

Limiting warming to 2° would greatly reduce the GLR area at risk of at least moderate biome change

■ Major change ■ Major/Moderate change ■ Moderate change



43

How do we limit warming to 2° C?

1. Starting today, choose to use less fossil fuel energy
- practice energy efficiency and conservation



- however, by itself, only delays the outcome

44

2. In the next 25 years, choose to replace fossil fuels with smarter energy choices

Target: 80% of energy from smarter sources by 2040

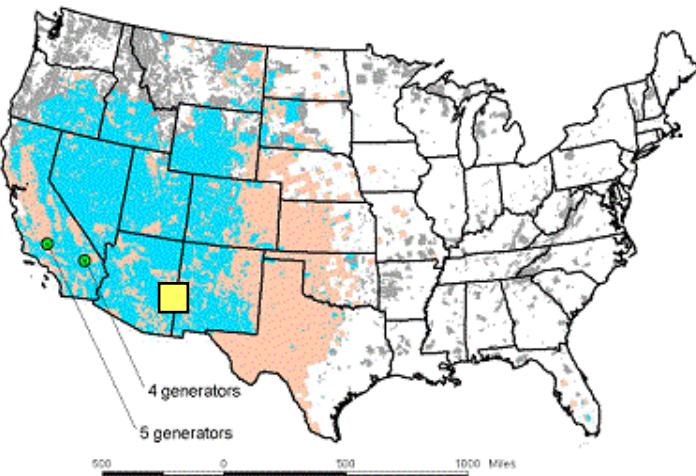


Potential: 100 times
total global energy use

Potential: 40 times
total global energy use

45

A solar array 100 x 100 miles could provide all of U.S. electricity needs today



- excess heat captured during the day could be stored and used to produce electricity at night

46

The 9 highest CO₂-emitting countries could produce 3-183 times their current energy use with wind alone



47

3. At all times, choose to continue educating yourself and others



48

4. Starting today, choose to demand that all of our policymakers support smarter energy choices

Which one is not like the others?



What's the single most important thing we can do?



Which of these has the largest effect on our probability of limiting warming to 2°?

- a. Range of available technologies (especially carbon capture and storage)
- b. Future energy demand (high, medium, low)
- c. Year in which political action starts

Chance of reaching 2° target with \$40/ton carbon tax

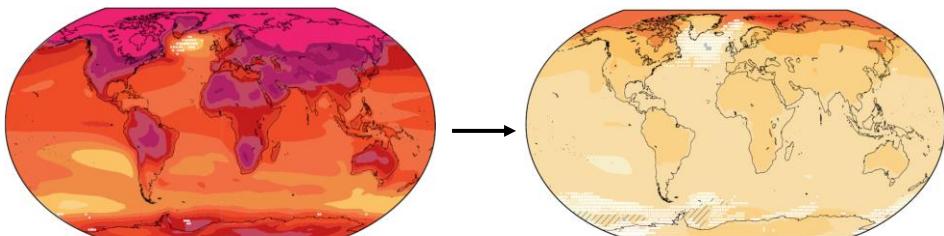
Immediate action: 67%

Delayed to 2020: 55%

Delayed to 2030: 20%

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Bottom line: The Great Lakes Region, like the rest of the planet, would benefit tremendously from limiting warming to 2° C. It's still an achievable target, and is worth fighting for.



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The future depends on our choices



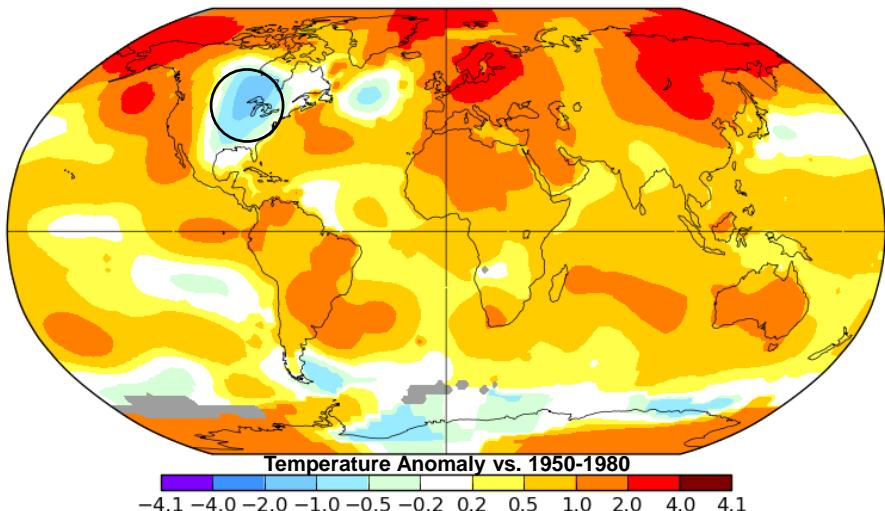
Thank you for listening

53

The following slides were not included in the presentation (due to time constraints), but might also be of interest.

54

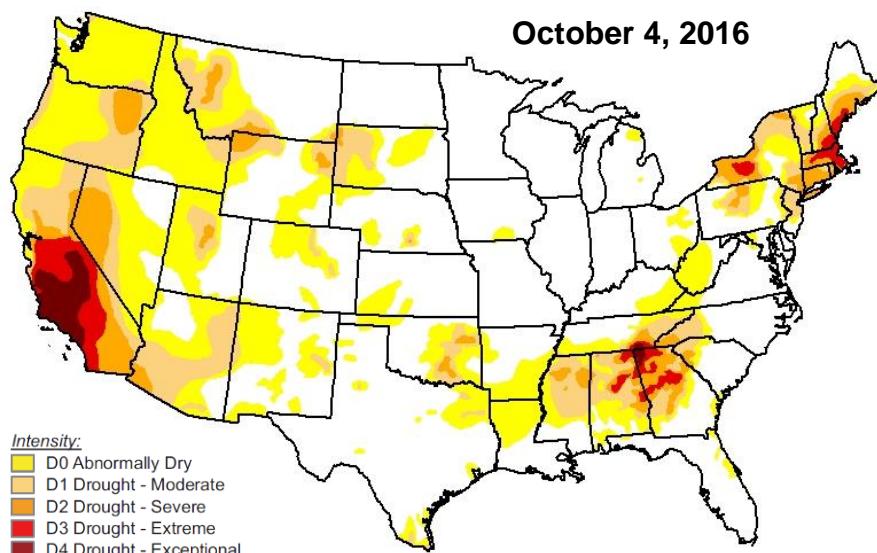
2014 was the 2nd warmest year on record



- but not in the Great Lakes Region

55

Since 2011, much of the U.S. has been in severe drought



44% of the U.S. is still in drought

56

Is there any debate among scientists about whether humans are the primary cause of global warming?

“Most of the global warming in recent decades can be attributed to human activities.”

Scientific organizations endorsing this statement:

United States:

National Academy of Sciences

American Medical Association

American Association for the Advancement of Science

American Meteorological Society

American Institute of Biological Sciences

American Chemical Society

American Geophysical Union

American Institute of Physics

57

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

Geological Society of America

American Academy of Paediatrics

American College of Preventive Medicine

American Public Health Association

Environmental Protection Agency

National Center for Atmospheric Research

University Corporation for Atmospheric Research

Ecological Society of America

American Society of Agronomy

American Society of Plant Biologists

Association of Ecosystem Research Centers

Botanical Society of America

Crop Science Society of America

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American Statistical Association
Organization of Biological Field Stations
American Physical Society
Society for Industrial and Applied Mathematics
Society of Systematic Biologists
Soil Science Society of America
Federation of American Scientists
National Research Council
National Association of Geoscience Teachers
American Quaternary Association
American Association of Wildlife Veterinarians
American Society for Microbiology
Society of American Foresters
American Astronomical Society
Natural Science Collections Alliance

59

Europe:

European Academy of Sciences and Arts
European Science Foundation
European Geosciences Union
European Physical Society
European Federation of Geologists
Norwegian Academy of Science and Letters
Royal Society of the United Kingdom
Academie des Sciences (France)
Deutsche Akademie der Naturforscher (Germany)
Accademia dei Lincei (Italy)
Royal Irish Academy
Royal Swedish Academy of Sciences
Royal Academy of Belgium for Sciences and the Arts
Royal Meteorological Society
British Antarctic Survey

60

Other countries (≥ 35):

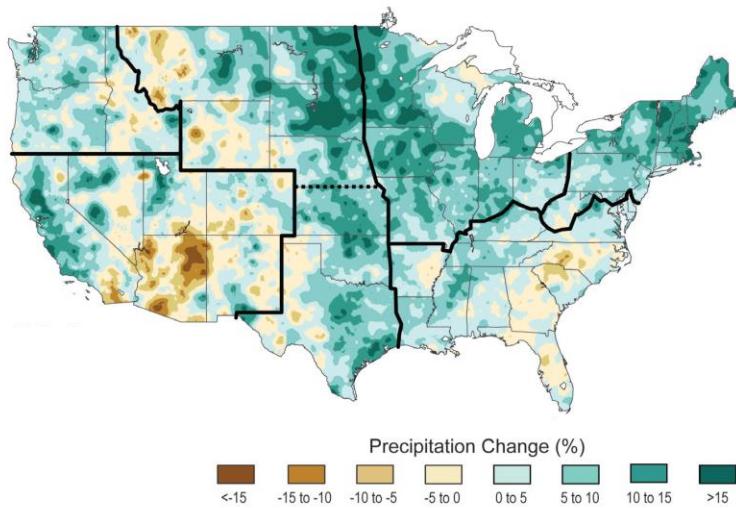
Chinese Academy of Sciences
Science Council of Japan
Russian Academy of Sciences
Indian National Science Academy
Royal Society of New Zealand
Australian Academy of Sciences
Australian Medical Association
Polish Academy of Sciences
Academia Brasiliera de Ciencias (Brazil)
Royal Society of Canada
African Academy of Sciences
Caribbean Academy of Sciences
Academy of Sciences of Malaysia
Indonesian Academy of Sciences
Academy of Science of South Africa

61

Scientific organizations holding a dissenting opinion:**In 2007:****American Institute of Petroleum Geologists****Since 2008:****None**

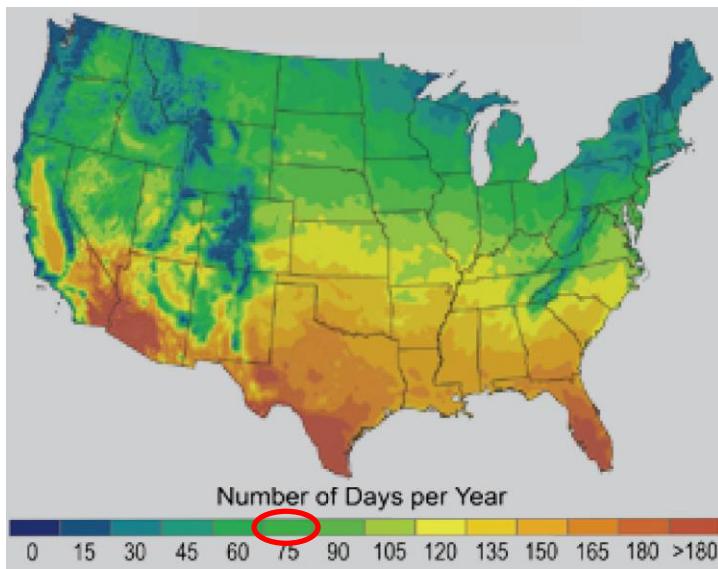
62

Over the past 25 years, total precipitation has increased in the GLR

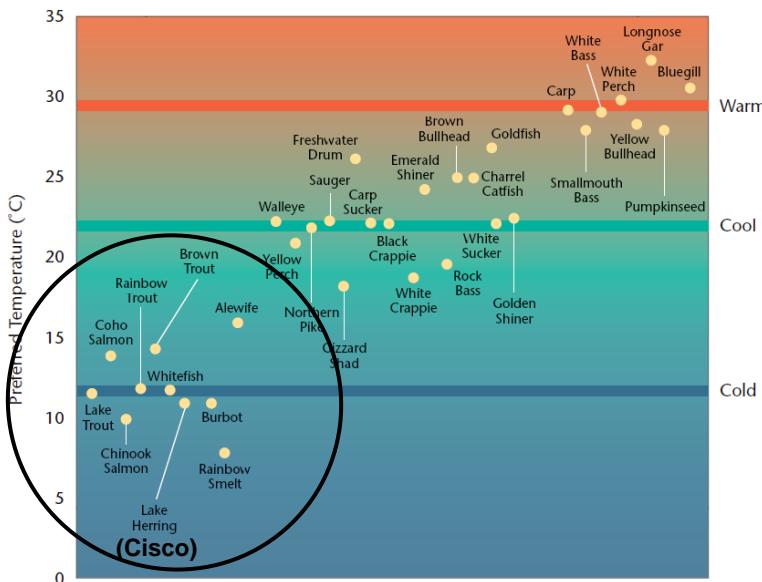


63

With 4° warming, much of the GLR is predicted to have ~75 days over 90° F each year

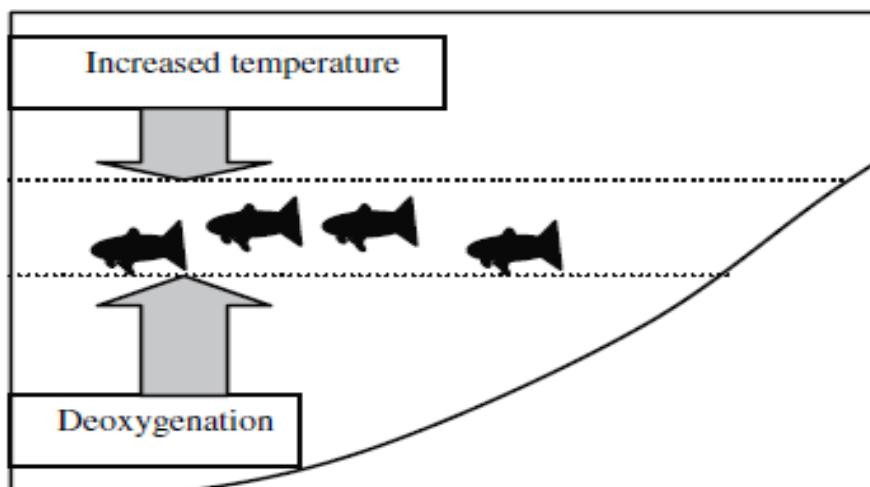


Therefore, cold- and cool-water species are very likely to be “climate losers”



65

Changes in both temperature and stratification reduce habitat for cool- and cold-water fish

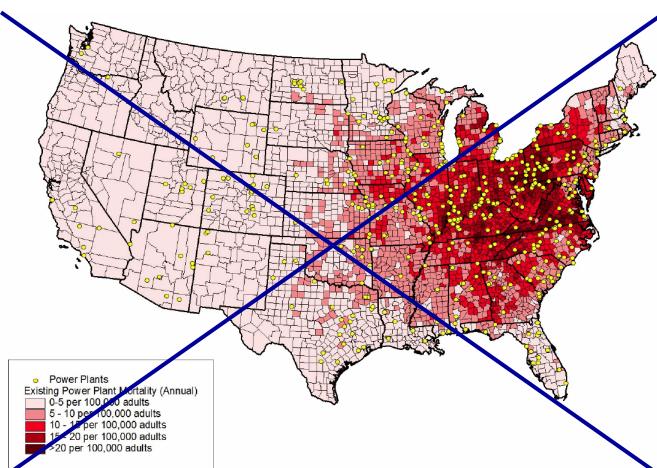


Lower lake levels would increase shipping costs by up to 25%



67

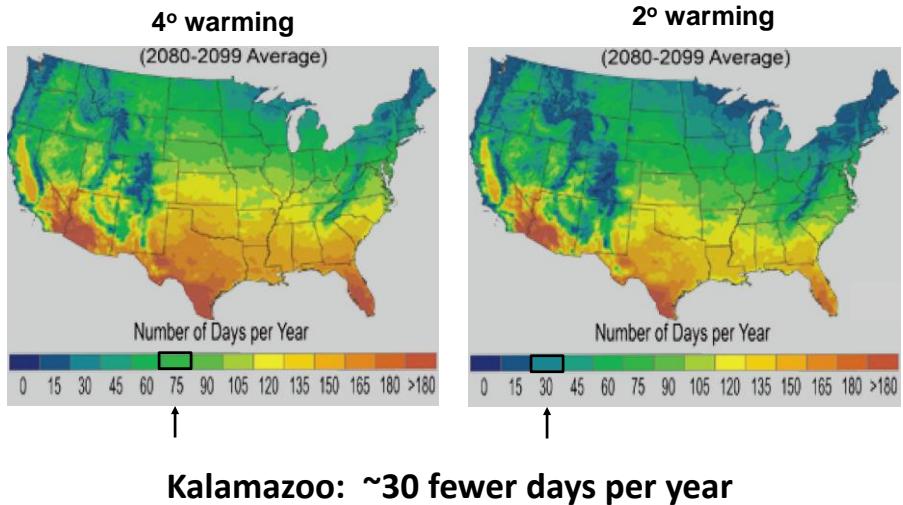
Eliminating coal power would prevent 20,000 heart attacks and 13,000 deaths per year in the U.S.



- annual health cost savings of over \$100 billion

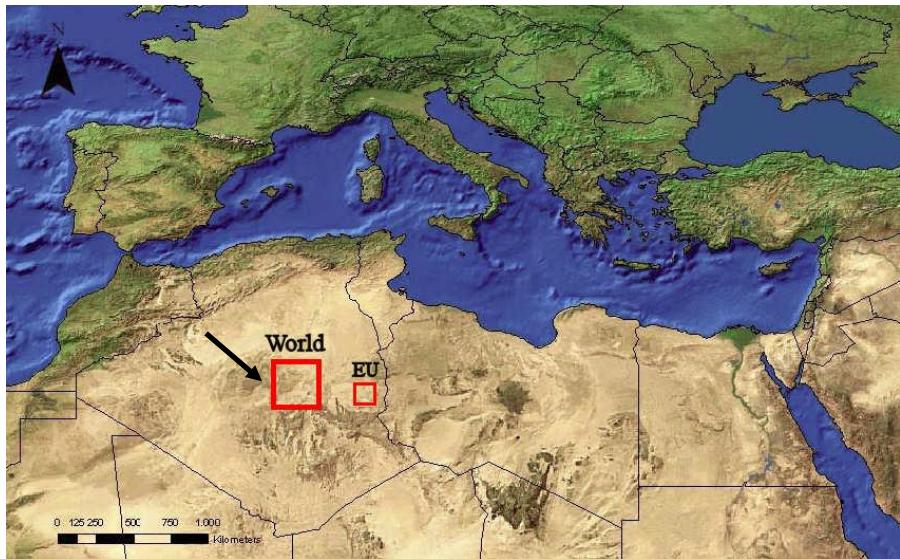
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Limiting warming to 2° C would dramatically decrease the number of days over 90° F each year



69

A small portion of the Sahara desert could supply all of the world's electricity



70