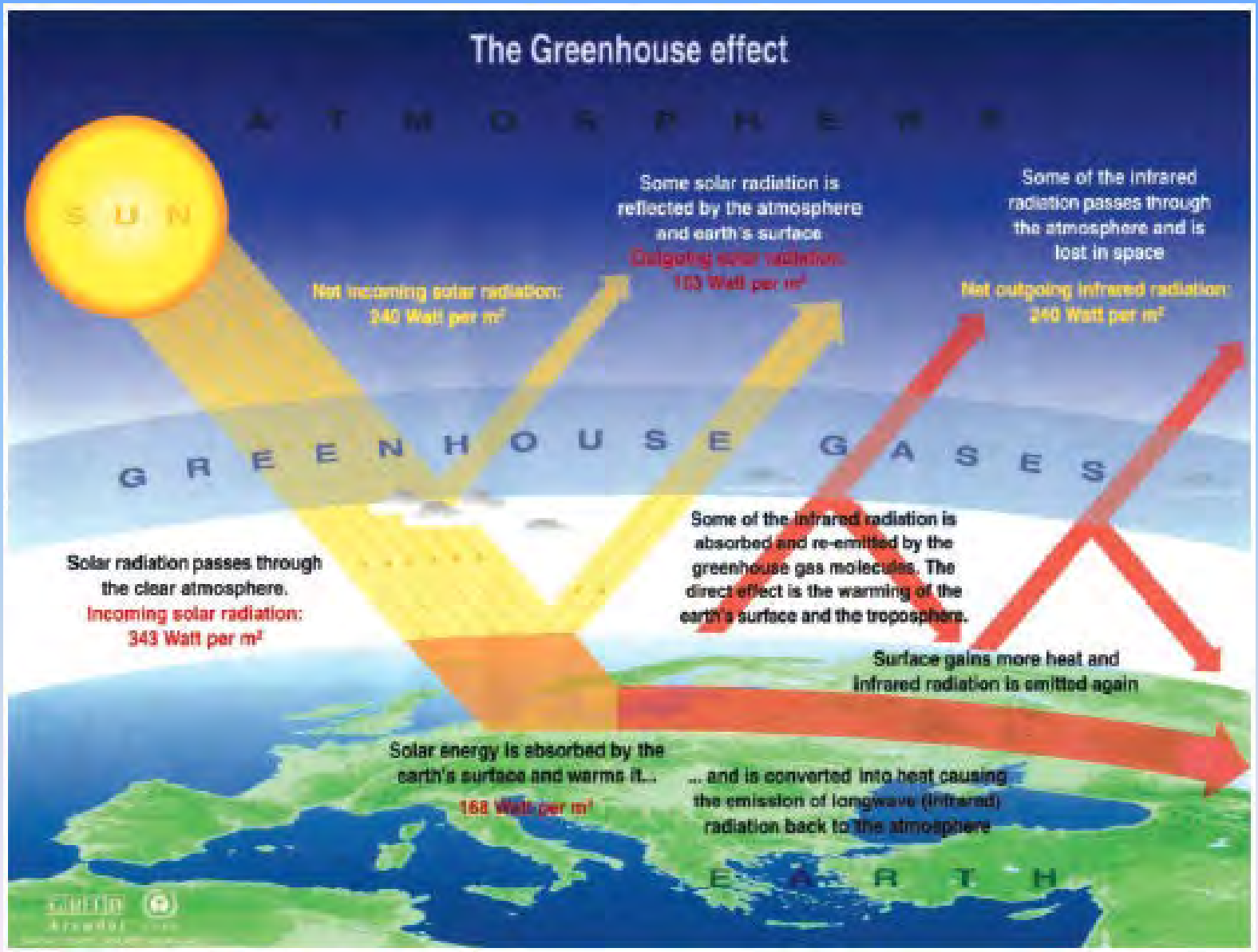
Climate Change and Great Lakes

Dr. Alan Steinman
Annis Water Resources Institute
Grand Valley State University

Outline

- Background information on climate change
- Great Lakes and climate change
- Solutions?

The Greenhouse Effect



Climate Change Background

Greenhouse gases in our atmosphere:

- water vapor
- carbon dioxide
- methane
- also ozone, nitrous oxide, and halocarbons

Climate Change Background

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The Earth is Warming

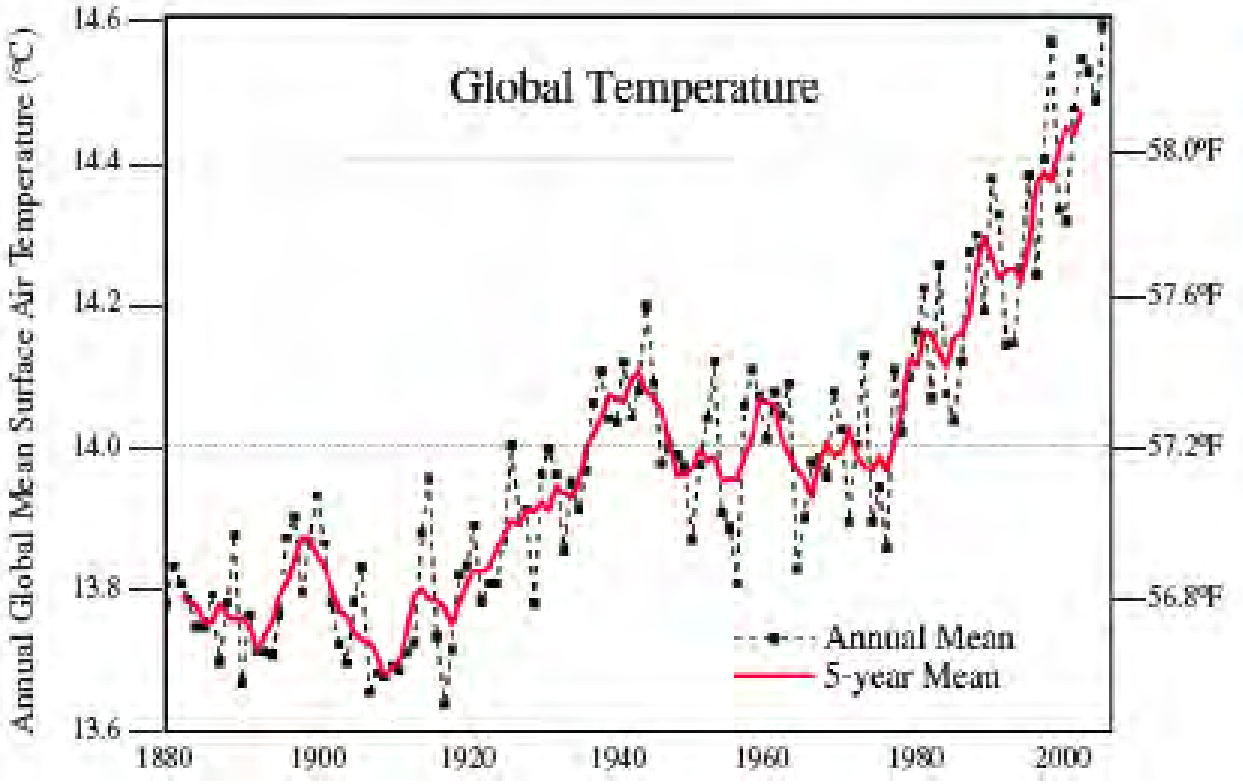


Figure 2. Global annual-mean surface air temperature derived from measurements at meteorological stations has increased by 1.4° F (0.7°C) since the early 20th century, with about 0.9°F (0.5°C) of the increase occurring since 1978. Figure courtesy of Goddard Institute for Space Studies.

- the Earth's atmosphere is warming—surface temps have risen ~1.4°F since the early 20th century

Muir Glacier, SE Alaska

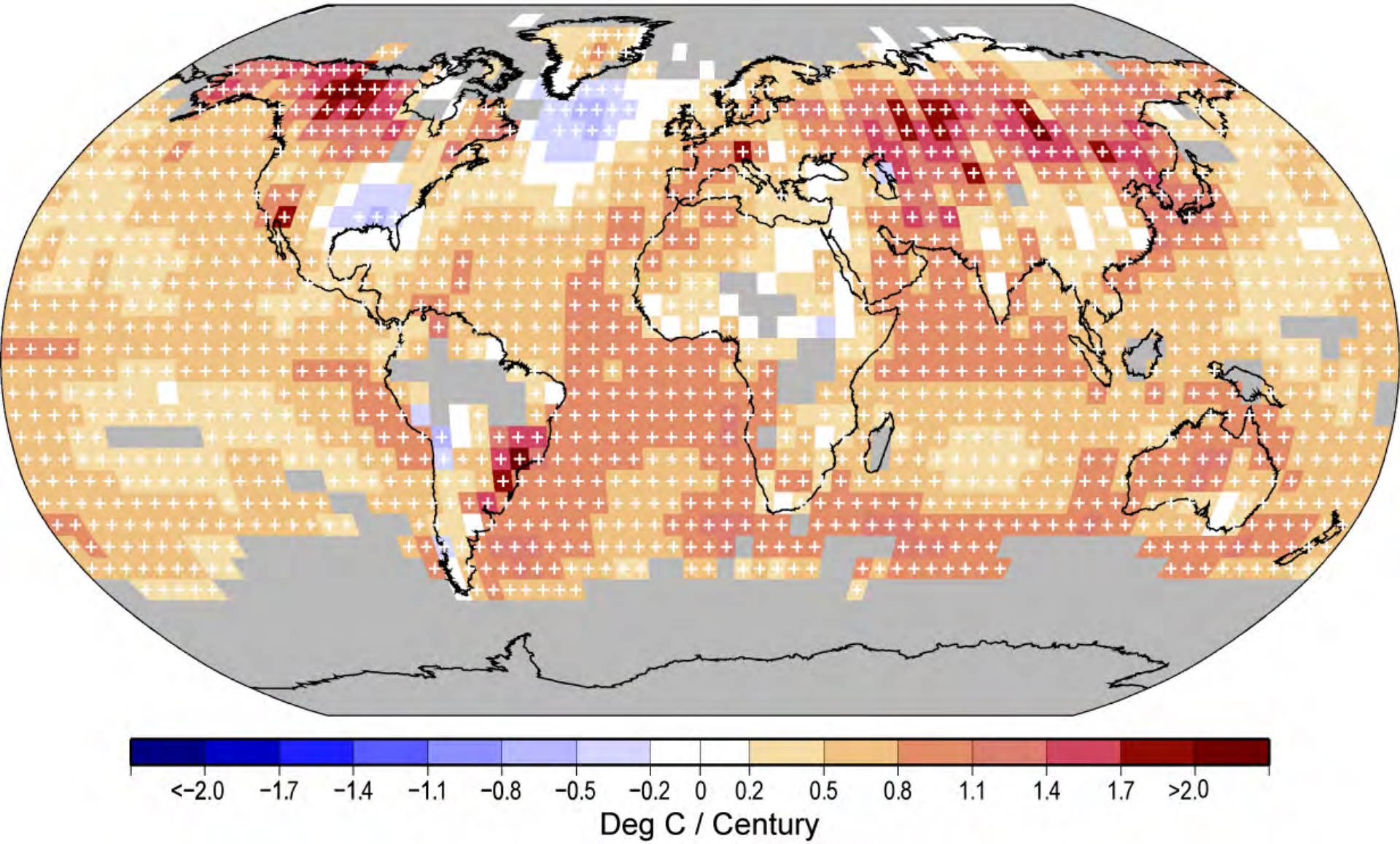
August, 1941

August, 2003

Temperature Trends

http://www.youtube.com/watch?v=lV8PI4R5nI4&feature=youtube_gdata

Change in Annual Average Temperature: 1901-2005

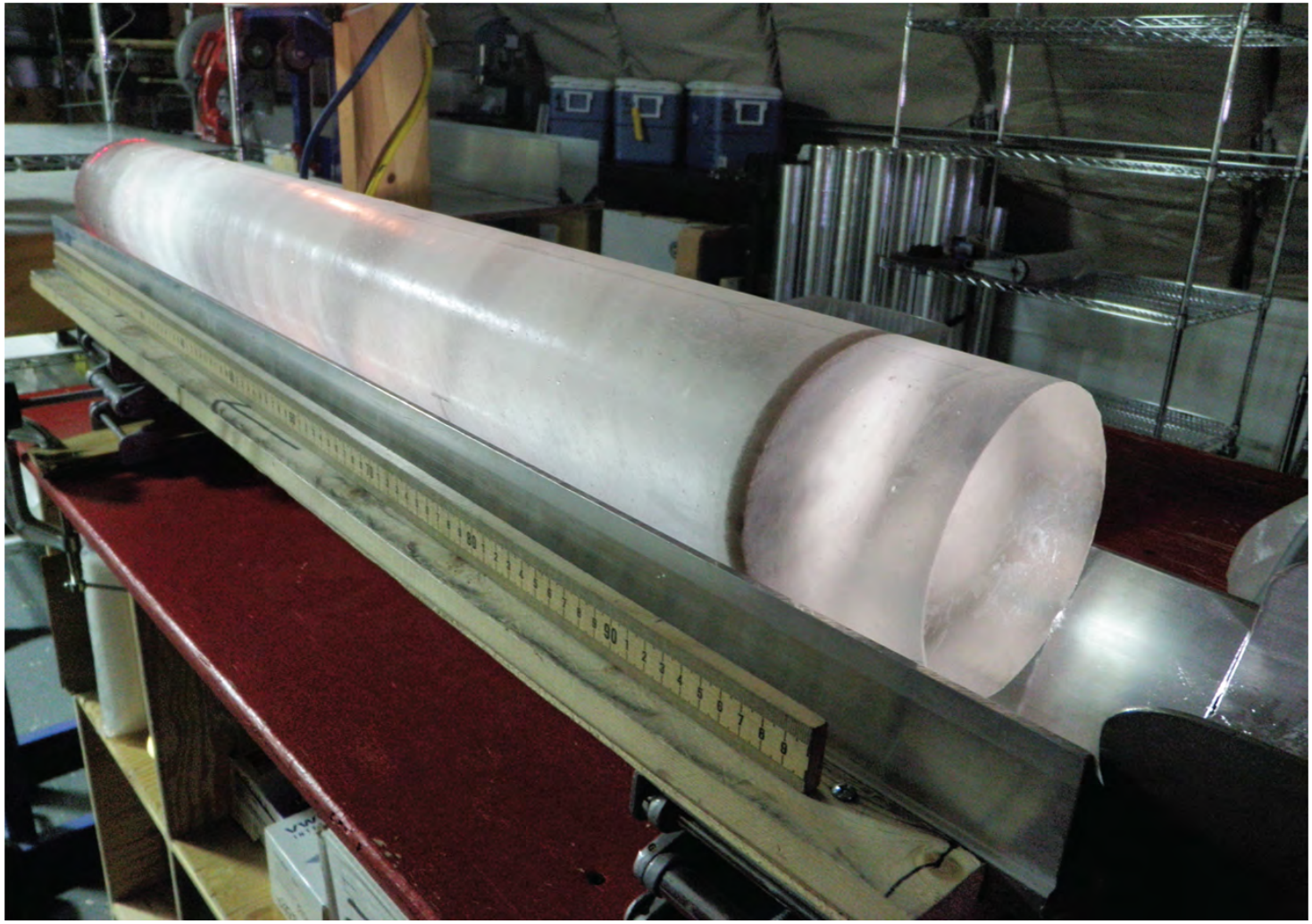


Climate Change Background

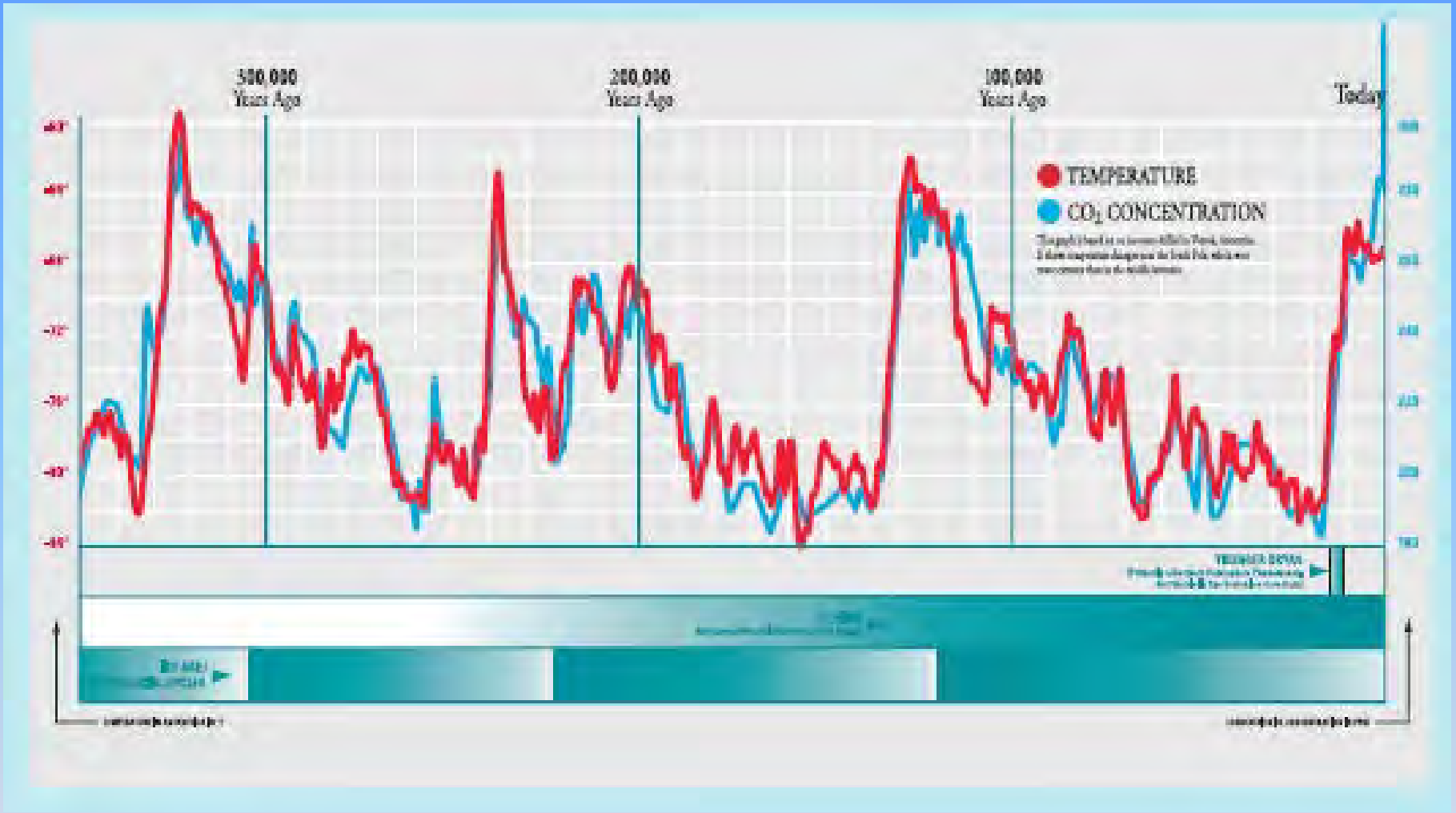
- Earth's climate is constantly changing

- So, how much of the observed warming is due to human activities and how much is due to the natural variability in the climate?

Ice core from the West Antarctic Ice Sheet Divide.The dark band is a layer of volcanic ash that settled on the ice sheet ~21,000 years ago.



L Skinner Science 2012;337:917-919



Temperature and Carbon Dioxide levels from Antarctic ice core

Source: National Academy of Sciences

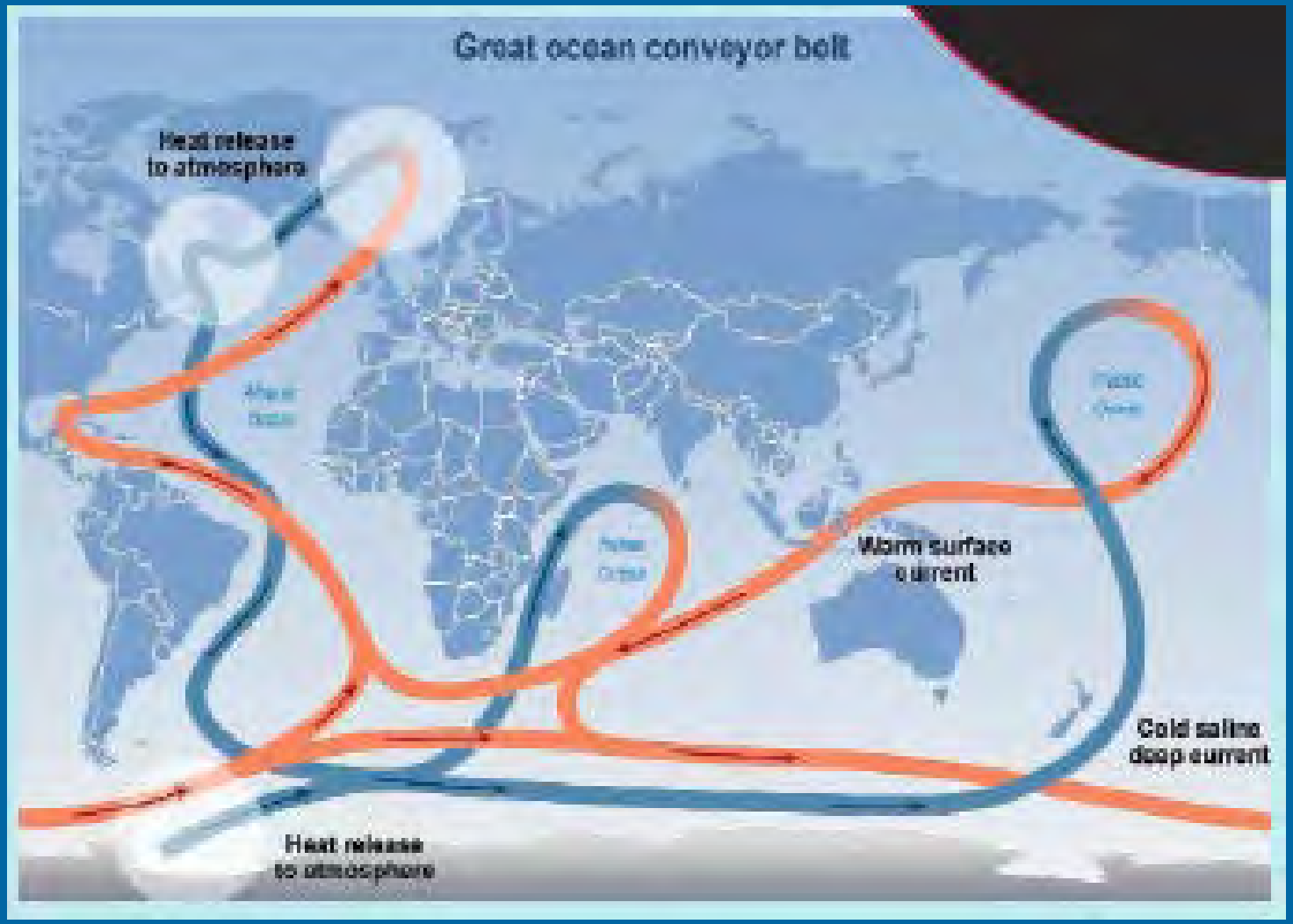
Climate Change Measurements

- Over past 750,000 years, Earth has been thru 8 glacial/interglacial cycles:

  - Ice Age: CO_2 ~ 210 ppm
  - Interglacial: CO_2 ~ 260-280 ppm
  - Temp changes were 5-8°C

Climate Change Uncertainties

1) Ocean circulation impacts:
   - Will melting ice caps “freshen” the water and disrupt ocean circulation?

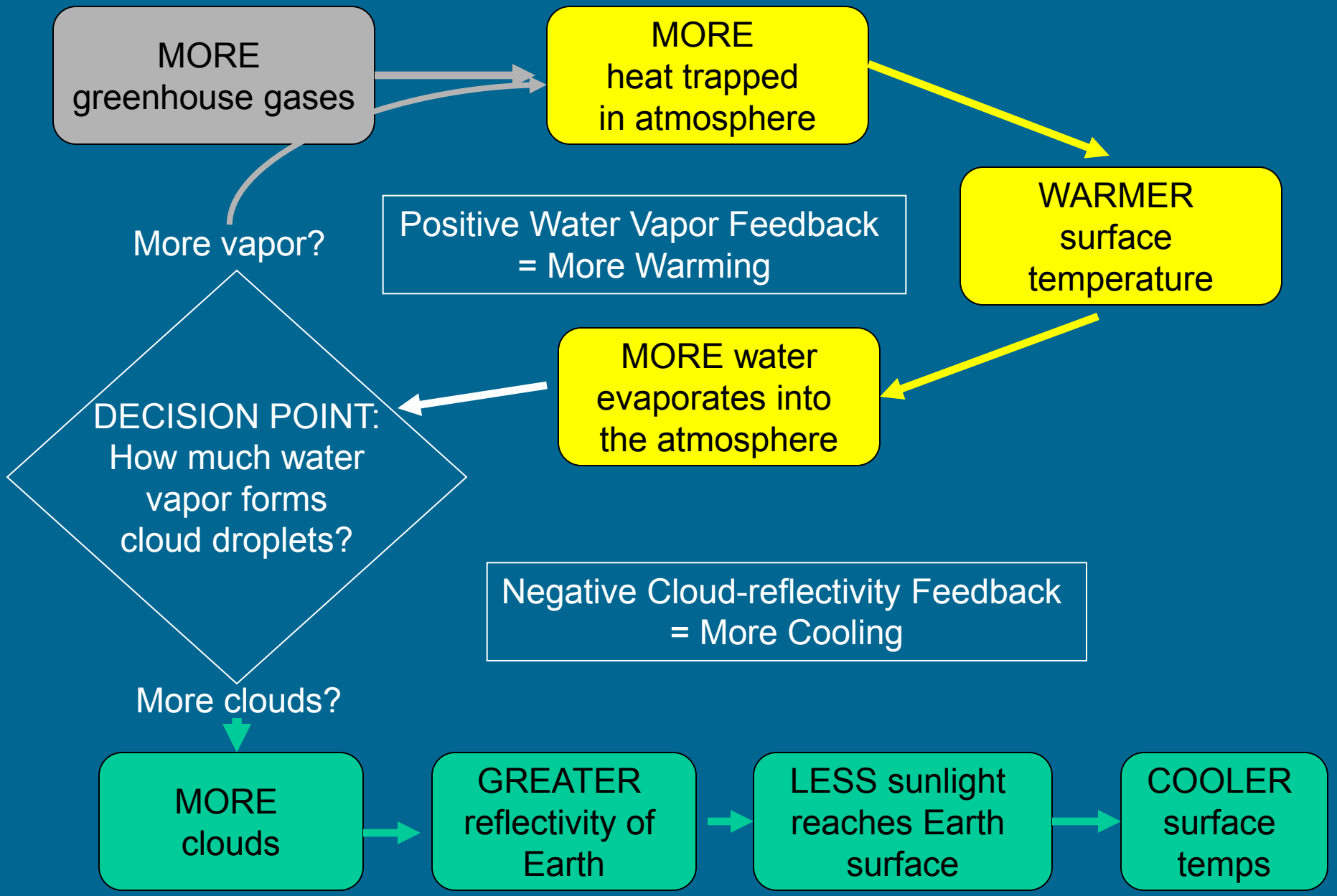


- Orange: Warmer, saline water on surface
- Blue: Cooler water, becomes denser, sinks, and moves south

Climate Change Uncertainties

2) Climate Feedbacks
   - can either amplify or dampen the climate response to radiative force

Feedback Loops

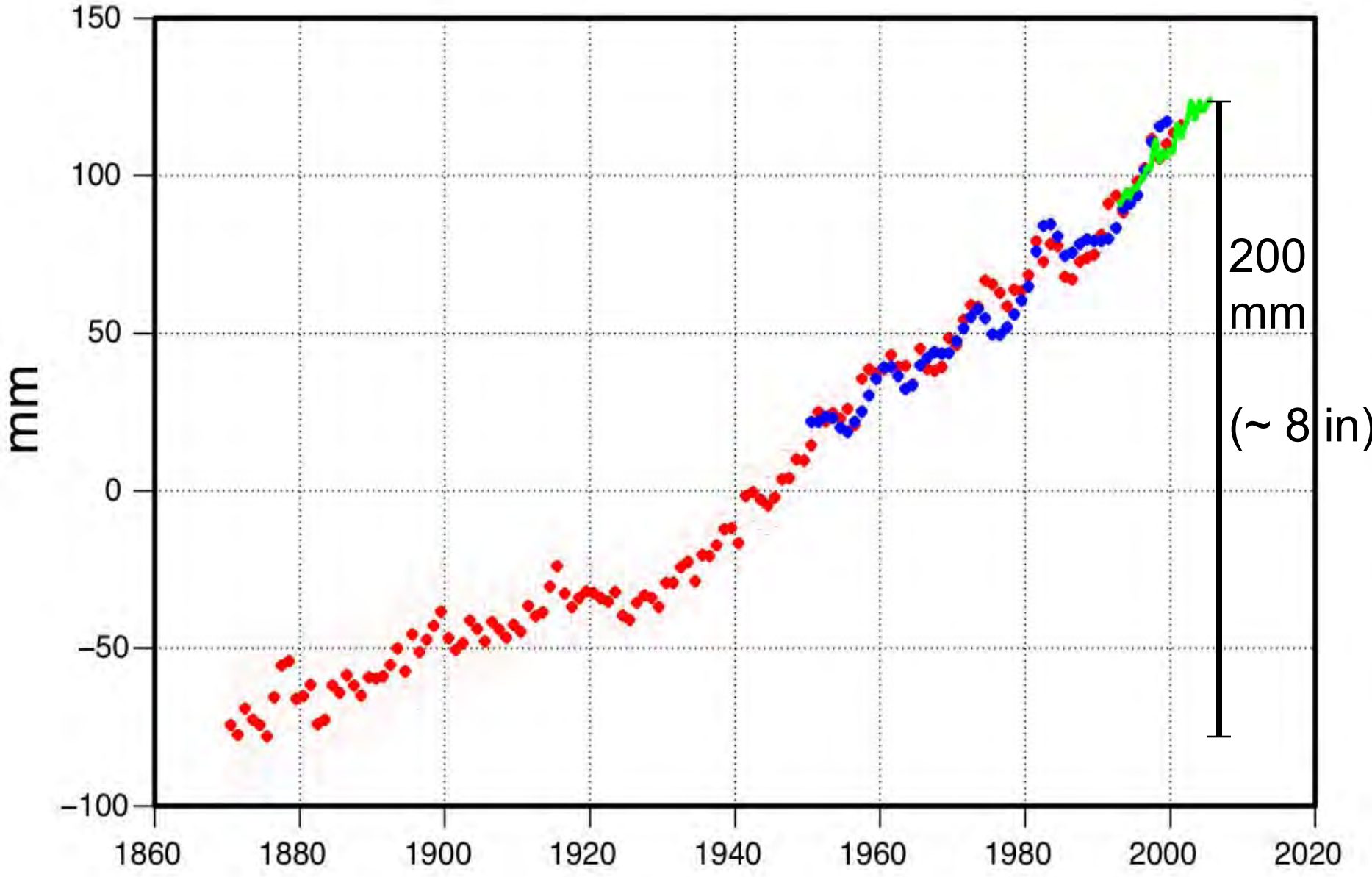


Climate Change Uncertainties

3) Climate change impacts will be uneven

- will be “winners” and “losers”

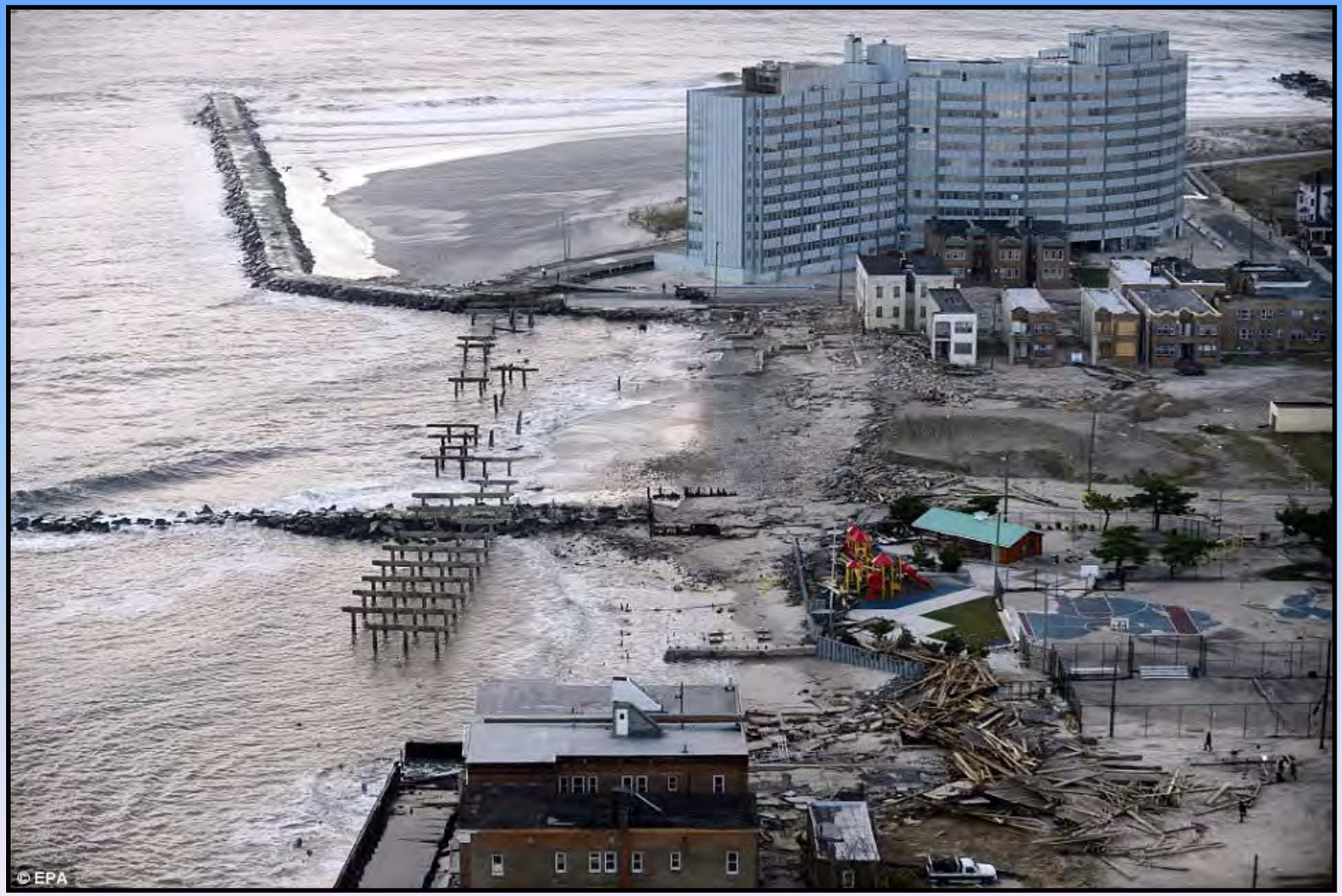
Globally Averaged Sea-level Rise: 1860 - Present



Sea Level Rise: Consequences

- Inundate low-lying wetlands and dry lands; erode beaches; and increase salinity of marshes, estuaries, & aquifers
- Loss of buffering against storms and floods
- Property losses
- Infrastructure damage

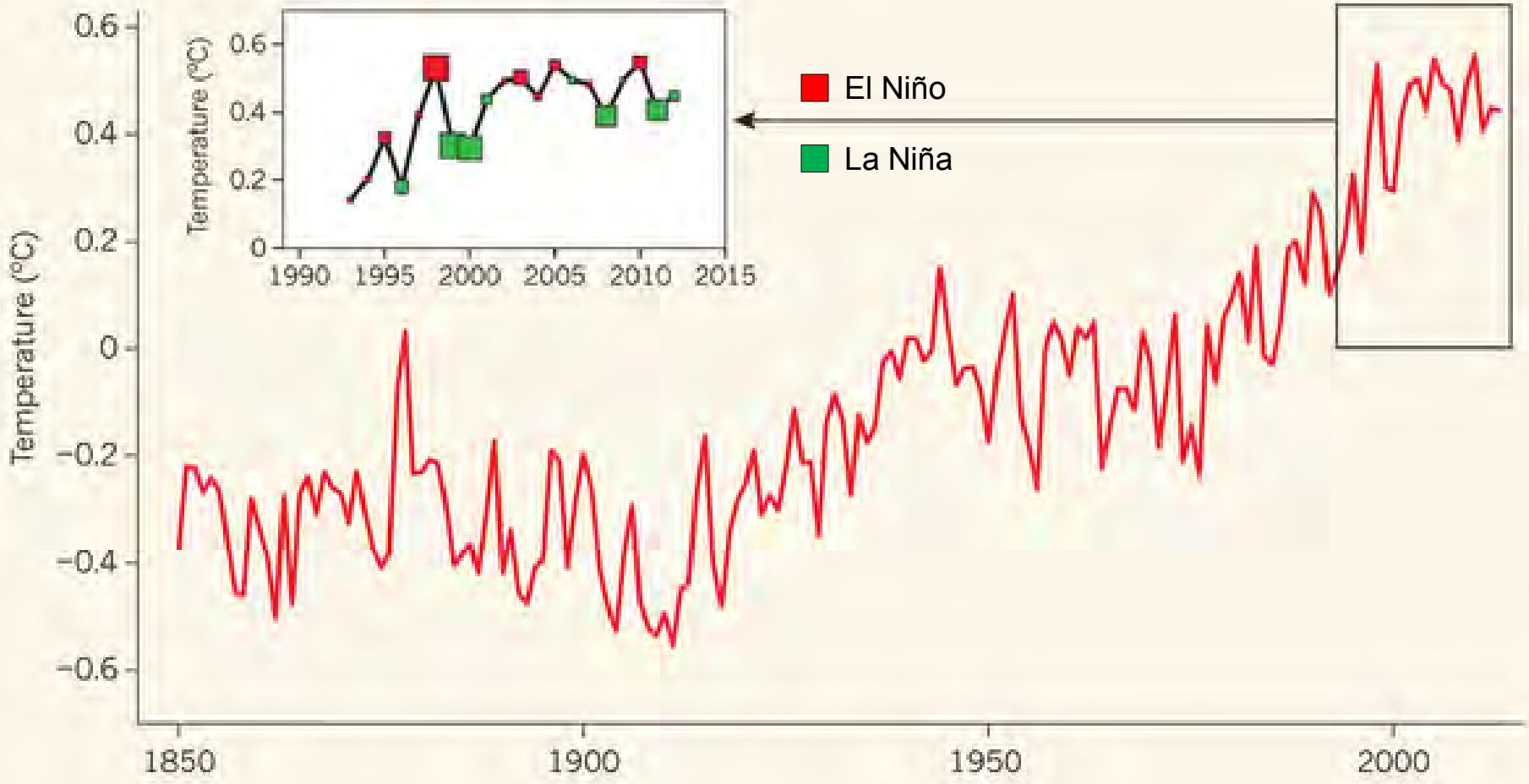
Sea Level Rise: Consequences



Climate Change Uncertainties

4) Recent temperature stasis

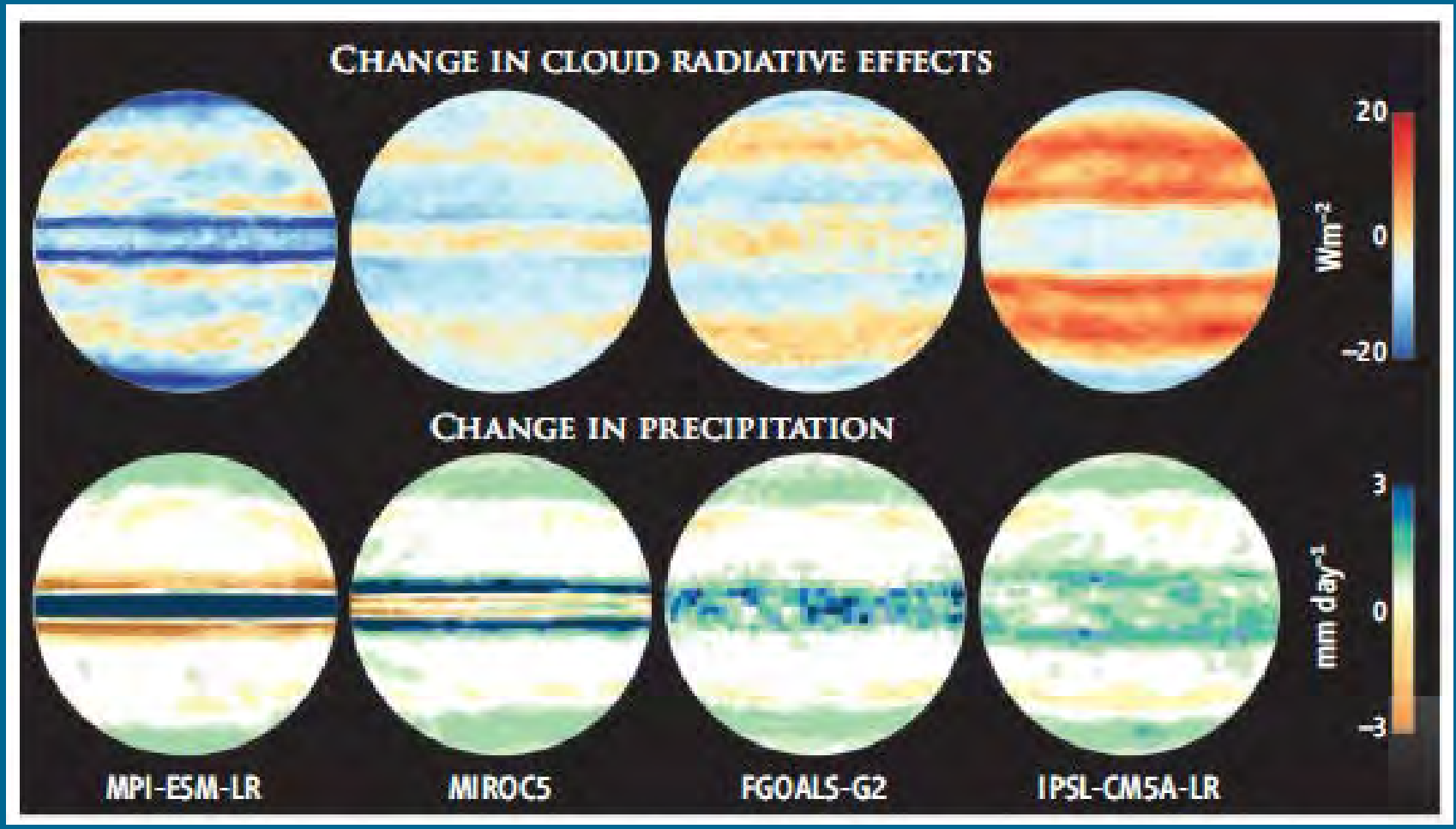
Climate Change Uncertainties



Climate Change Uncertainties

5) General Circulation Model Outputs

Climate Change Uncertainties



Source: Science 2013 Vol. 340

IPCC Principal Findings*

1) Warming of the atmosphere and ocean system is unequivocal.

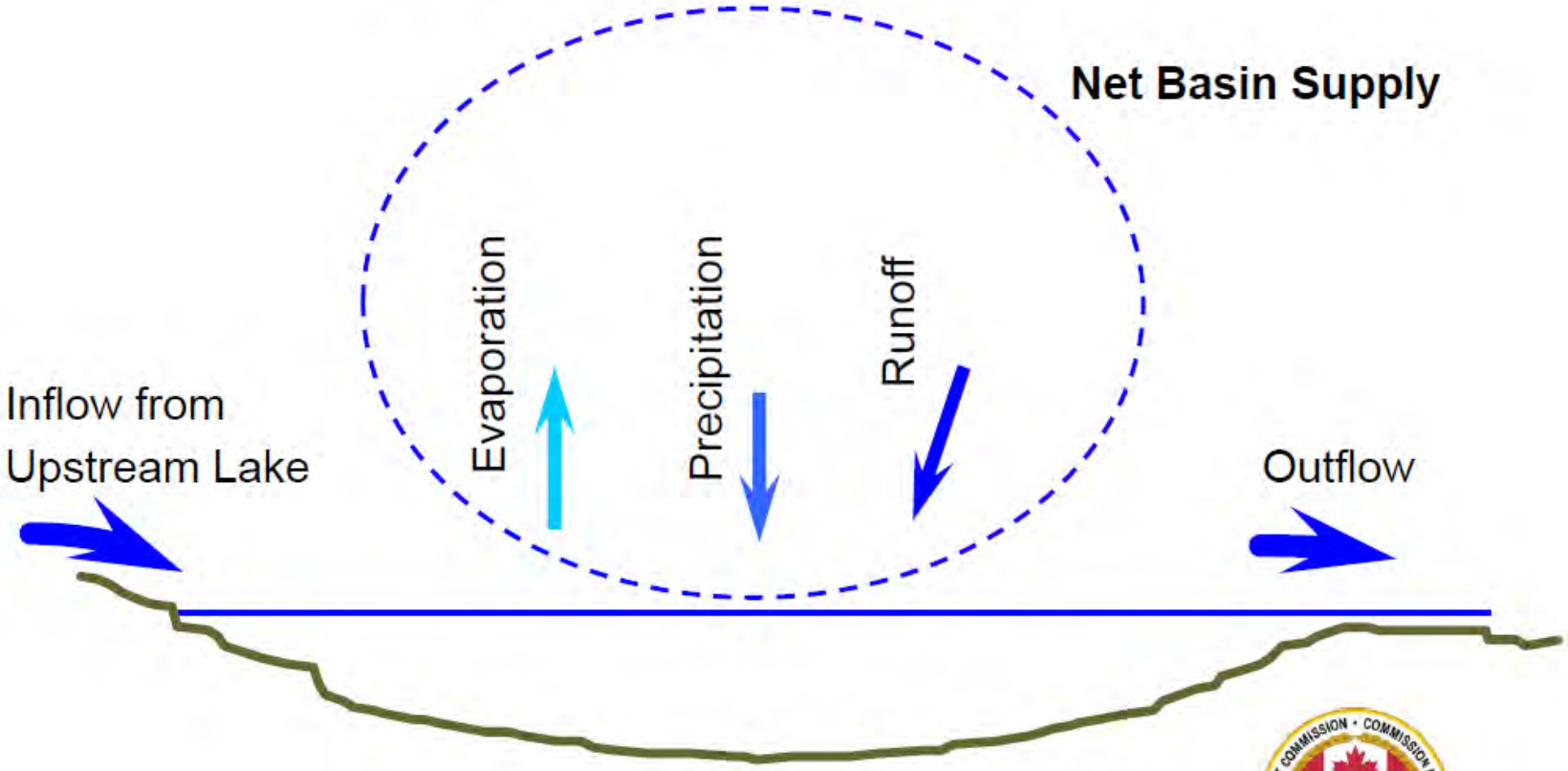
2) It is extremely likely that human influence has been the dominant cause of observed warming since 1950, with the level of confidence having increased since the fourth report

*Intergovernmental Panel on Climate Change (IPCC). 2013. Fifth Assessment Report

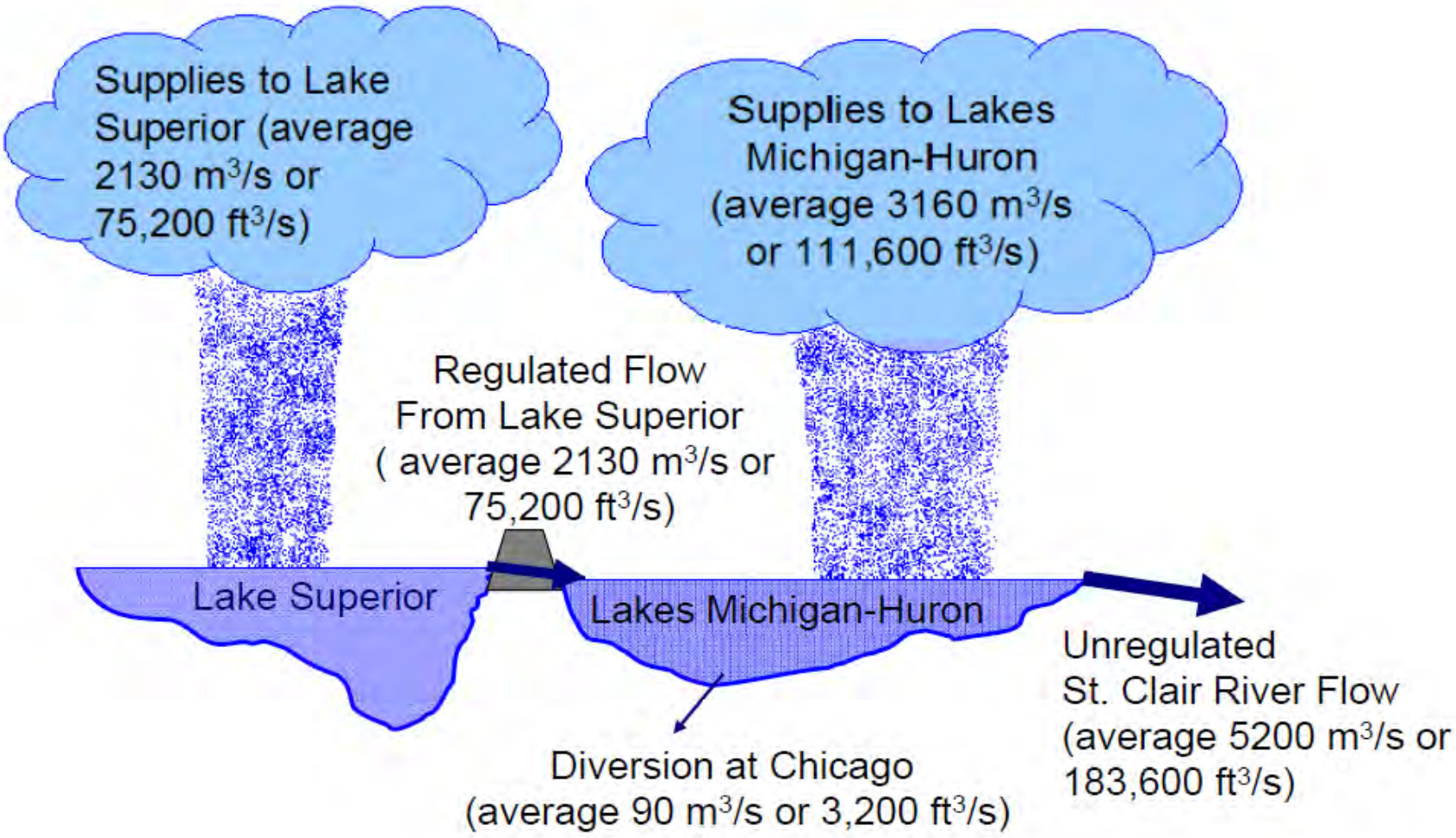
Great Lakes

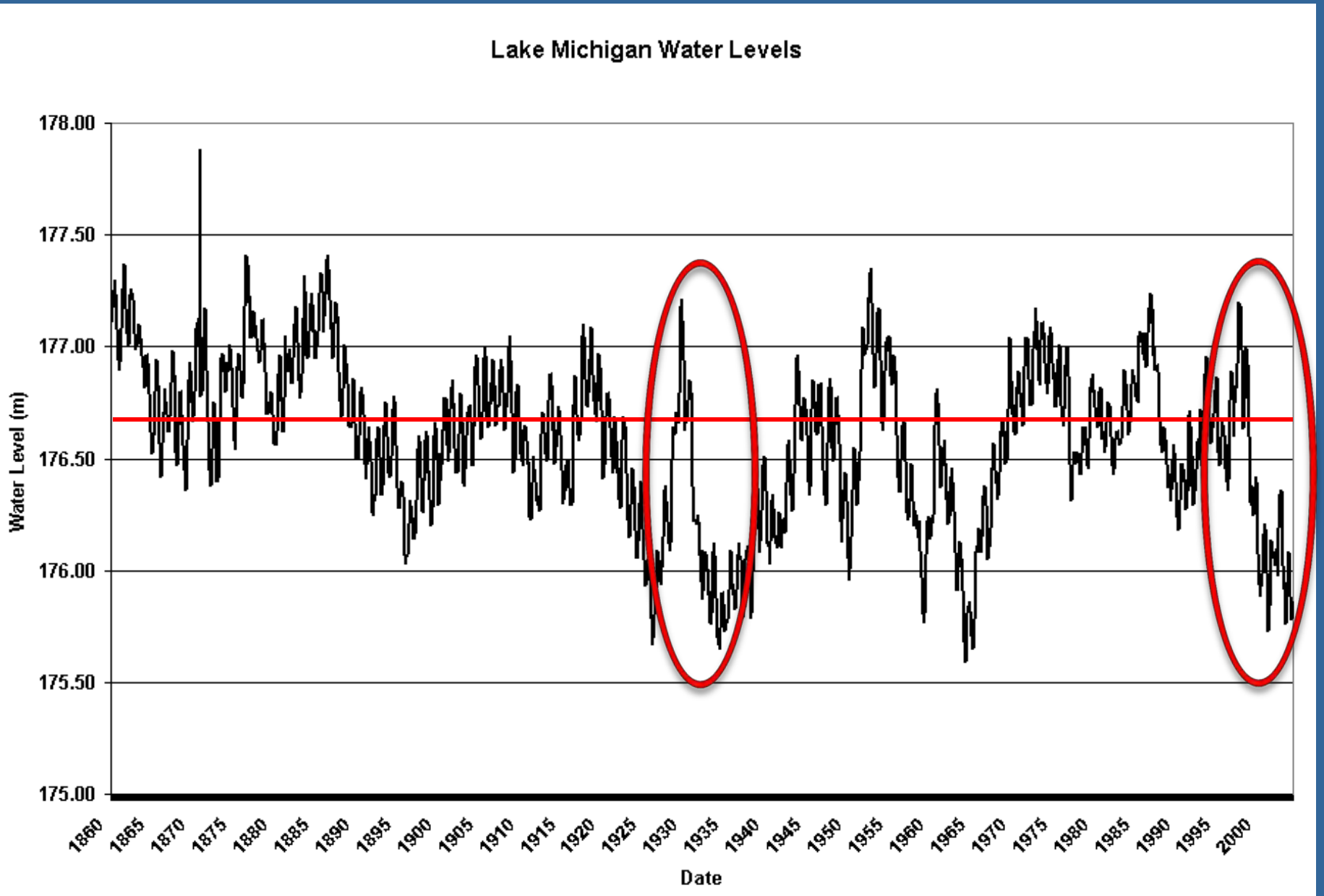
Great Lakes Water Supplies

(Factors Affecting Water Levels)



International Upper Great Lakes Study


Supplies to Lake Superior (average 2130 m3/s or 75,200 ft3/s)
Supplies to Lakes Michigan-Huron (average 3160 m3/s or 111,600 ft3/s)
Regulated Flow From Lake Superior (average 2130 m3/s or 75,200 ft3/s)
Lake Superior
Lakes Michigan-Huron
Unregulated St. Clair River Flow (average 5200 m3/s or 183,600 ft3/s)
Diversion at Chicago (average 90 m3/s or 3,200 ft3/s)


Lake Michigan Water Levels
178.00
177.50
177.00
176.50
176.00
175.50
175.00
Water Level (m)
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
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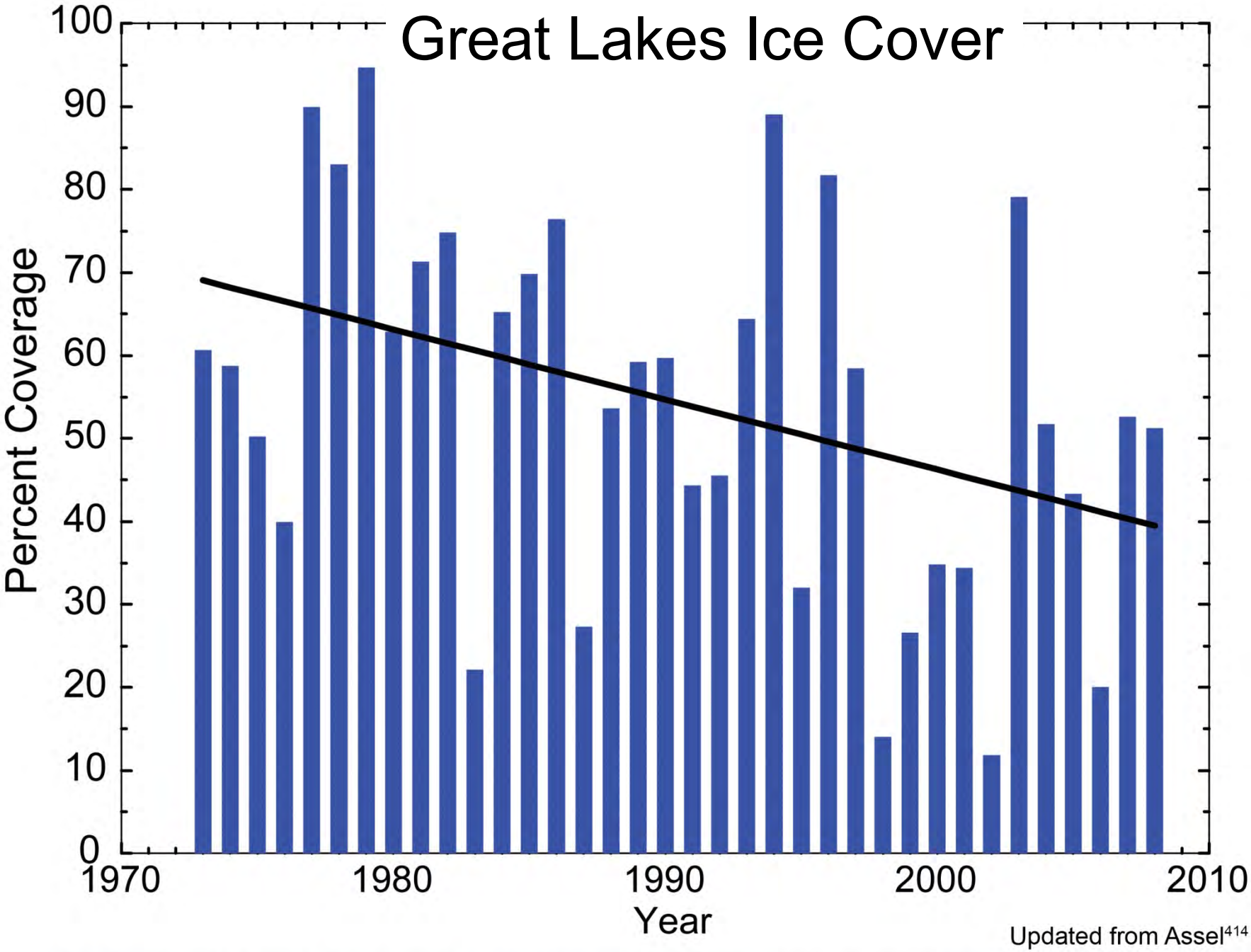
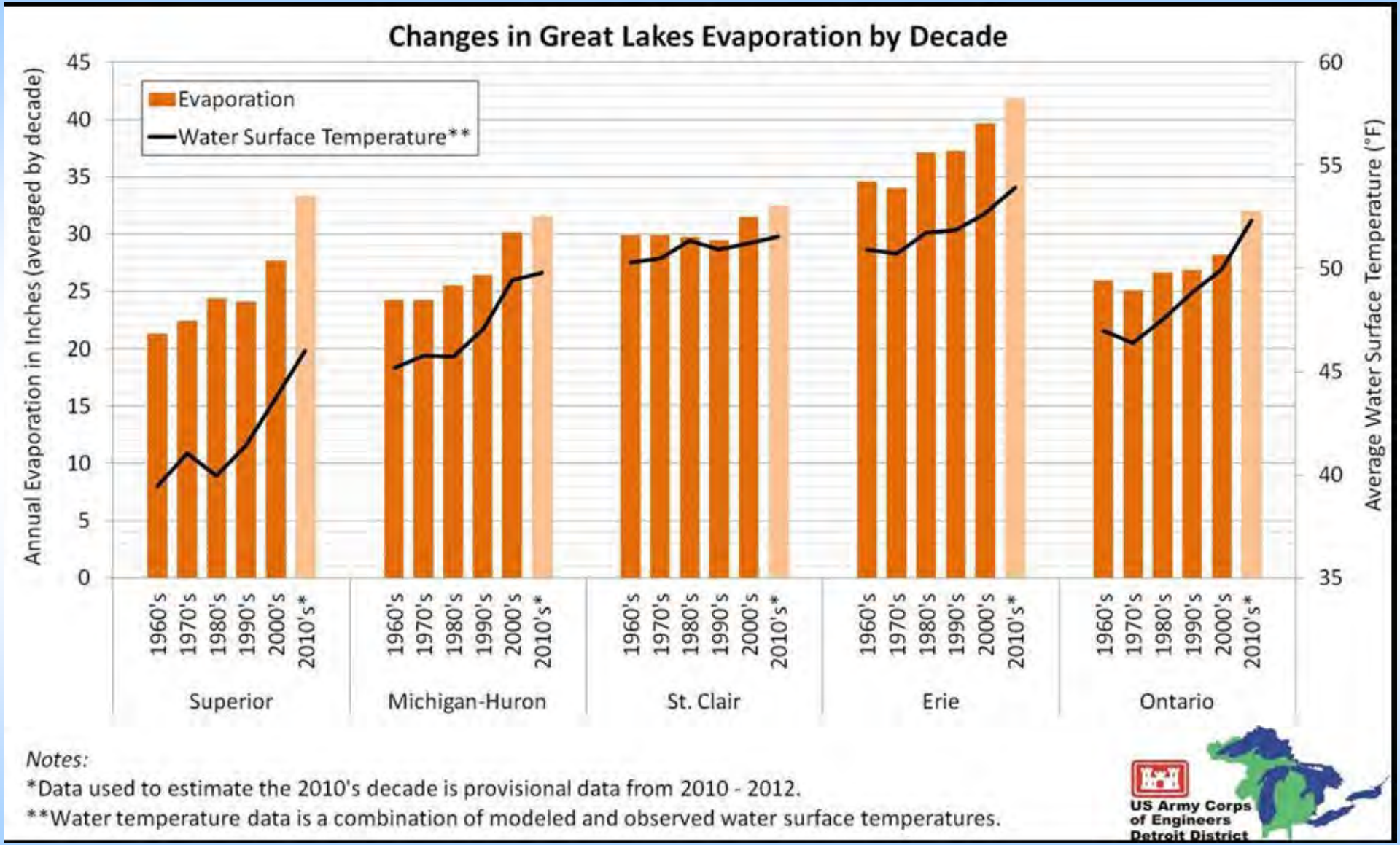
2000
Date

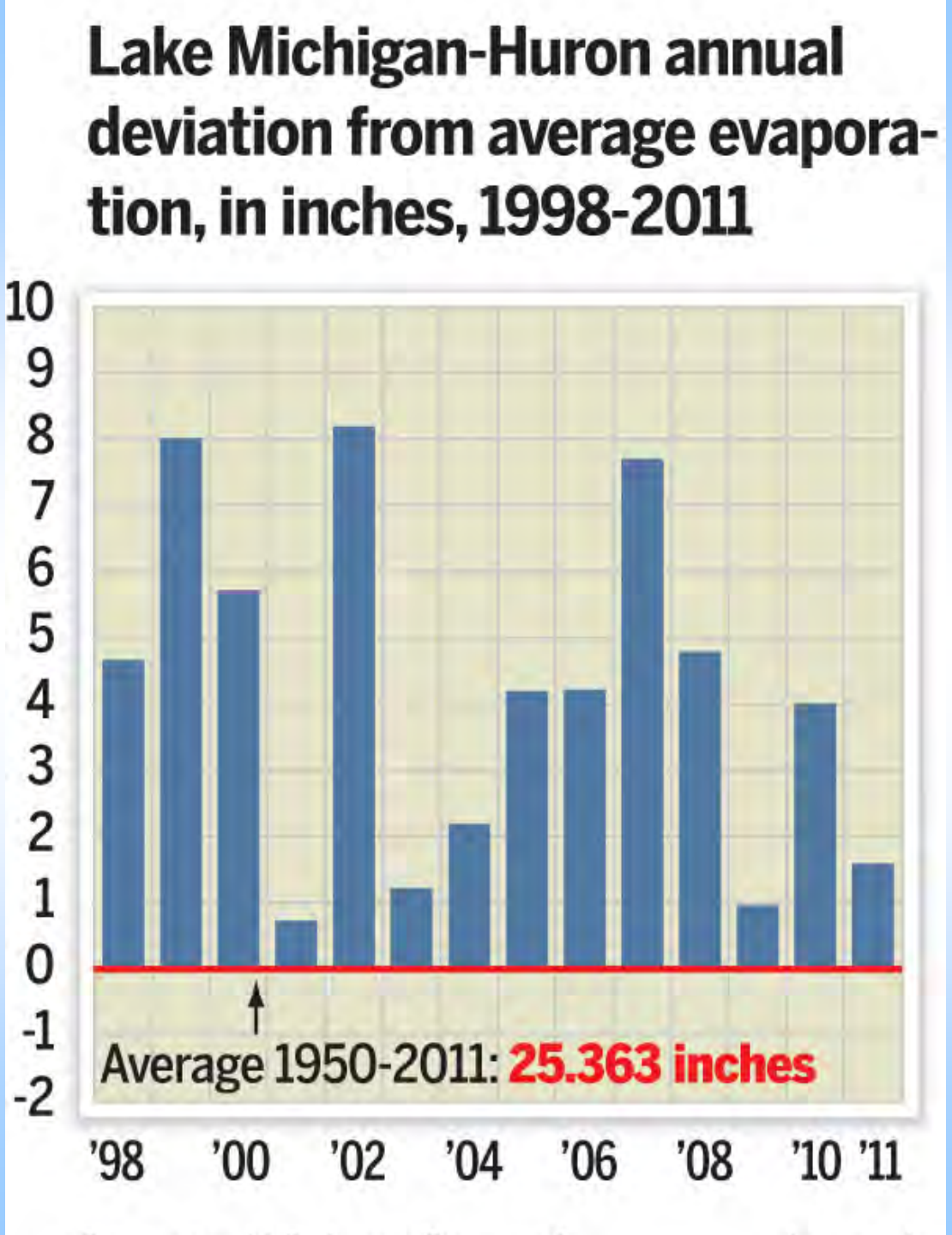
Great Lakes Ice Cover



Updated from Assel[414]

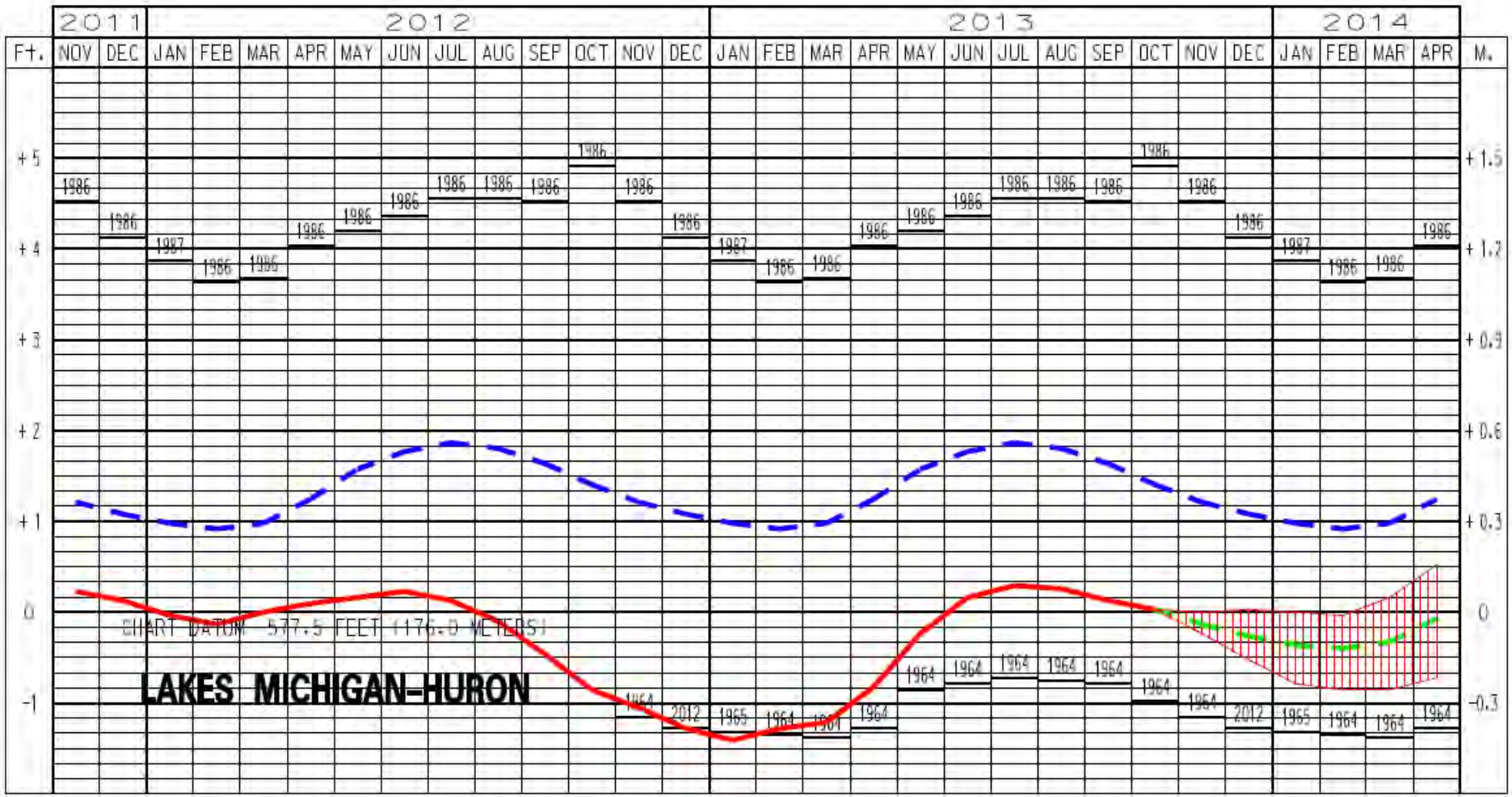


Data Source: US Army Corps of Engineers



Data: Army Corps of Engineers

Graphic: Milwaukee Journal-Sentinel



Data Source: US Army Corps of Engineers

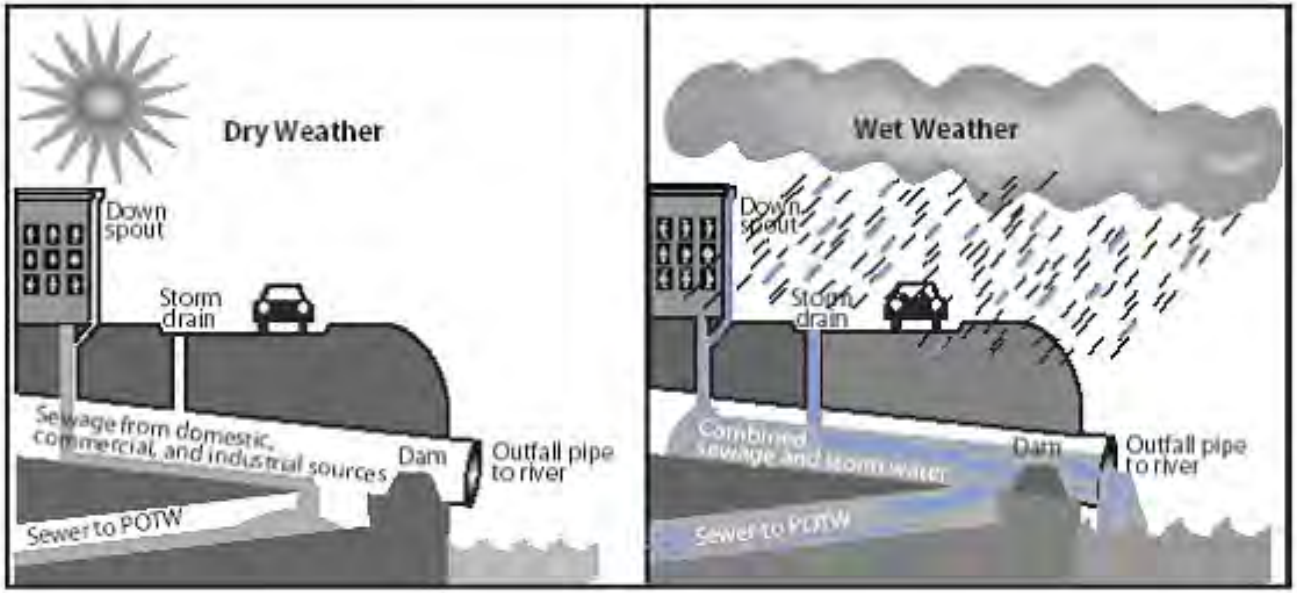
What Might the Future Hold?

Predictions

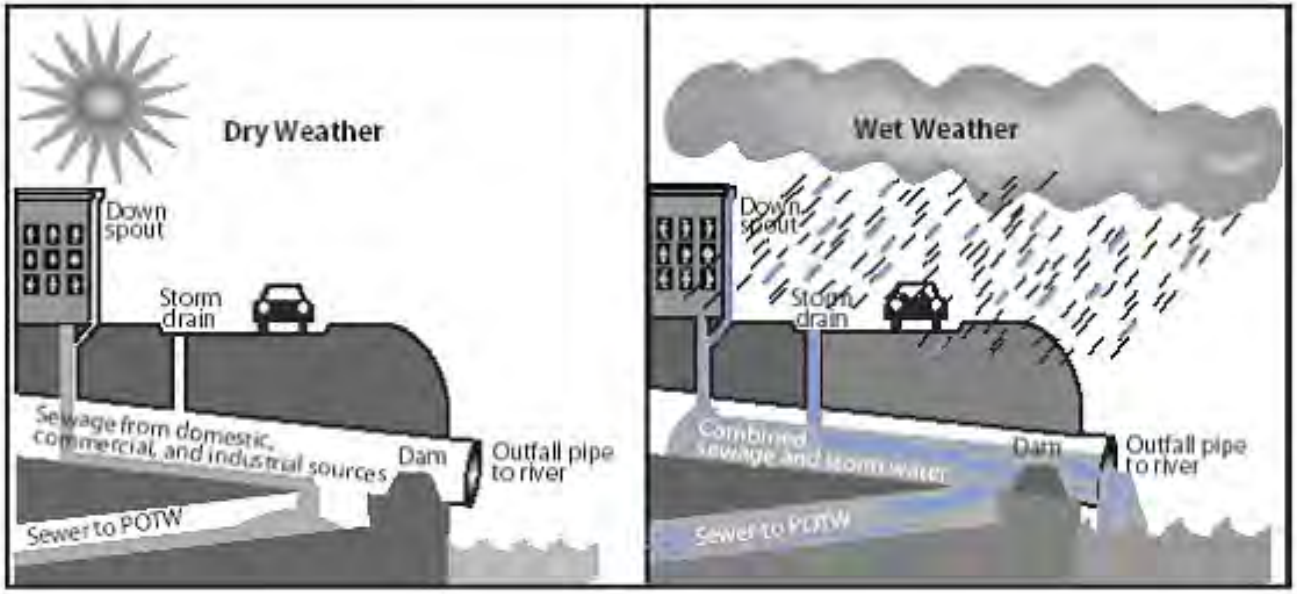
- Precipitation:
  - annual average ppt'n slight increase/decline
  - frequency of extreme events will increase
    - Stormwater runoff
    - Stronger lake stratification

Predictions

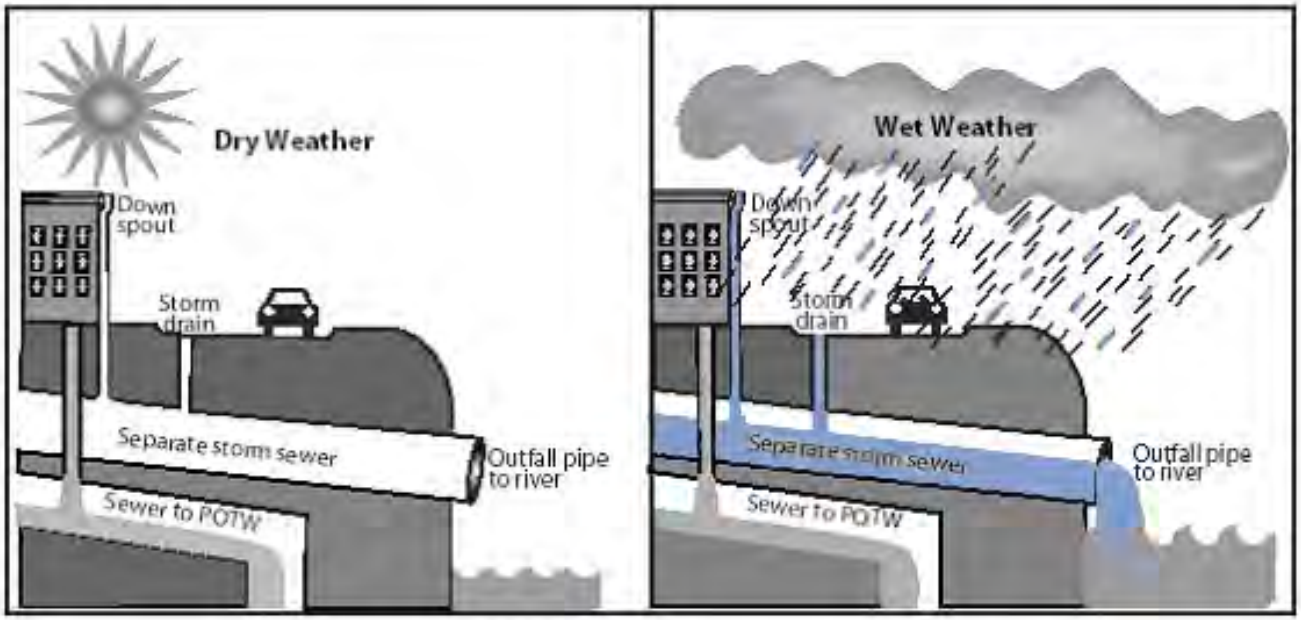
- Precipitation events in Great Lakes region >2-2.5 inches → stormwater contaminants (McLellan et al. 2007)
- Frequency of events exceeding 2-2.5 inch threshold will increase by 50 to 120% by end of 21st Century (Patz et al. 2008)



Combined sewer system



Combined sewer system



Separate sewer system

Infrastructure Problems

In addition to bacteria, more than 120 intestinal viruses and a variety of parasites may be found in CSO sewage.

- Grand Rapids: dumped 1.7 million gallons of combined sewage into the Grand in 2010, down from ~200 million gal in 2004, and << ~337 million gal discharged from Lansing.

Stormwater Impacts

1) Flashier hydrograph
2) More erosion/sediment
3) Less recharge
4) More nutrients/toxics
5) Degraded biota
6) Cost of infrastructure

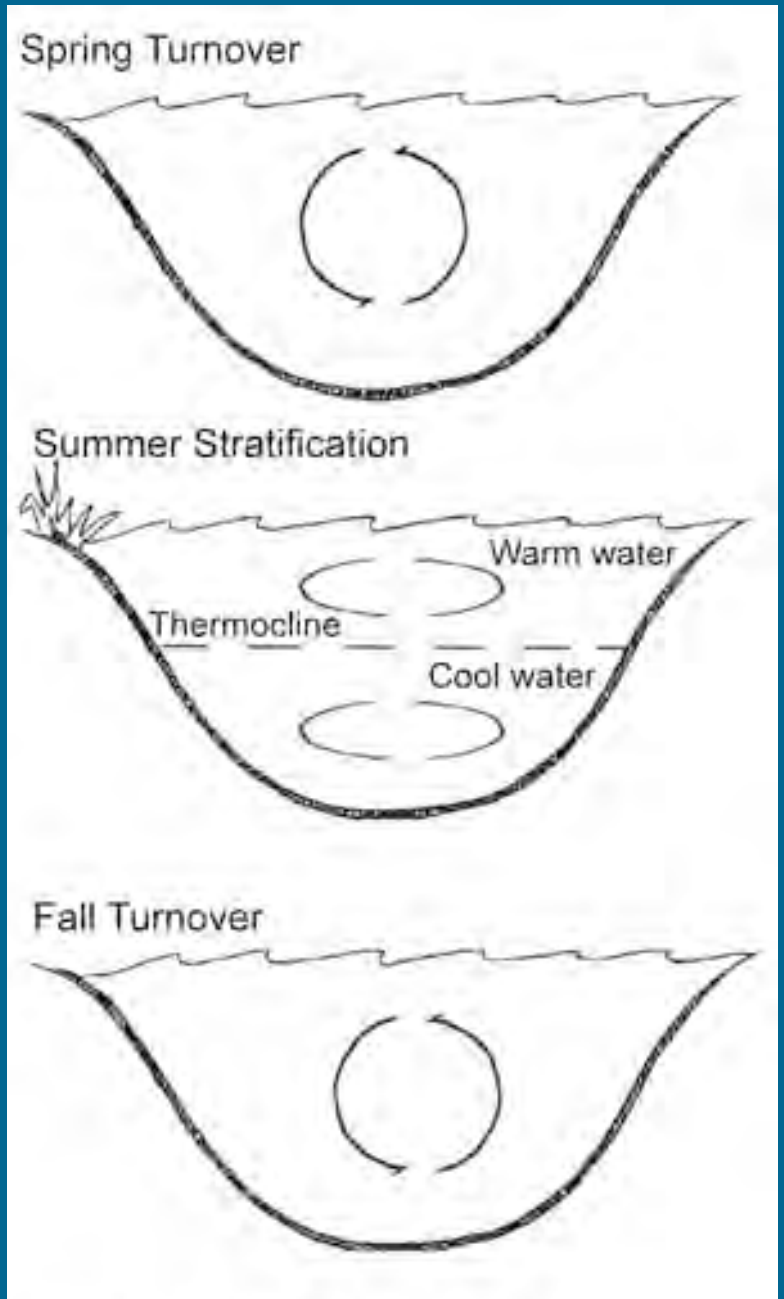
Urban Stream Syndrome

Photo Credit: WOOD TV

Climate Change Predictions: Michigan

Confronting Climate Change in the Great Lakes Region
www.ucsusa.org/greatlakes

- Air Temperatures by 2100:
  - winter temps predicted to be 6-10°F higher
  - summer temps predicted to be 7-13°F higher

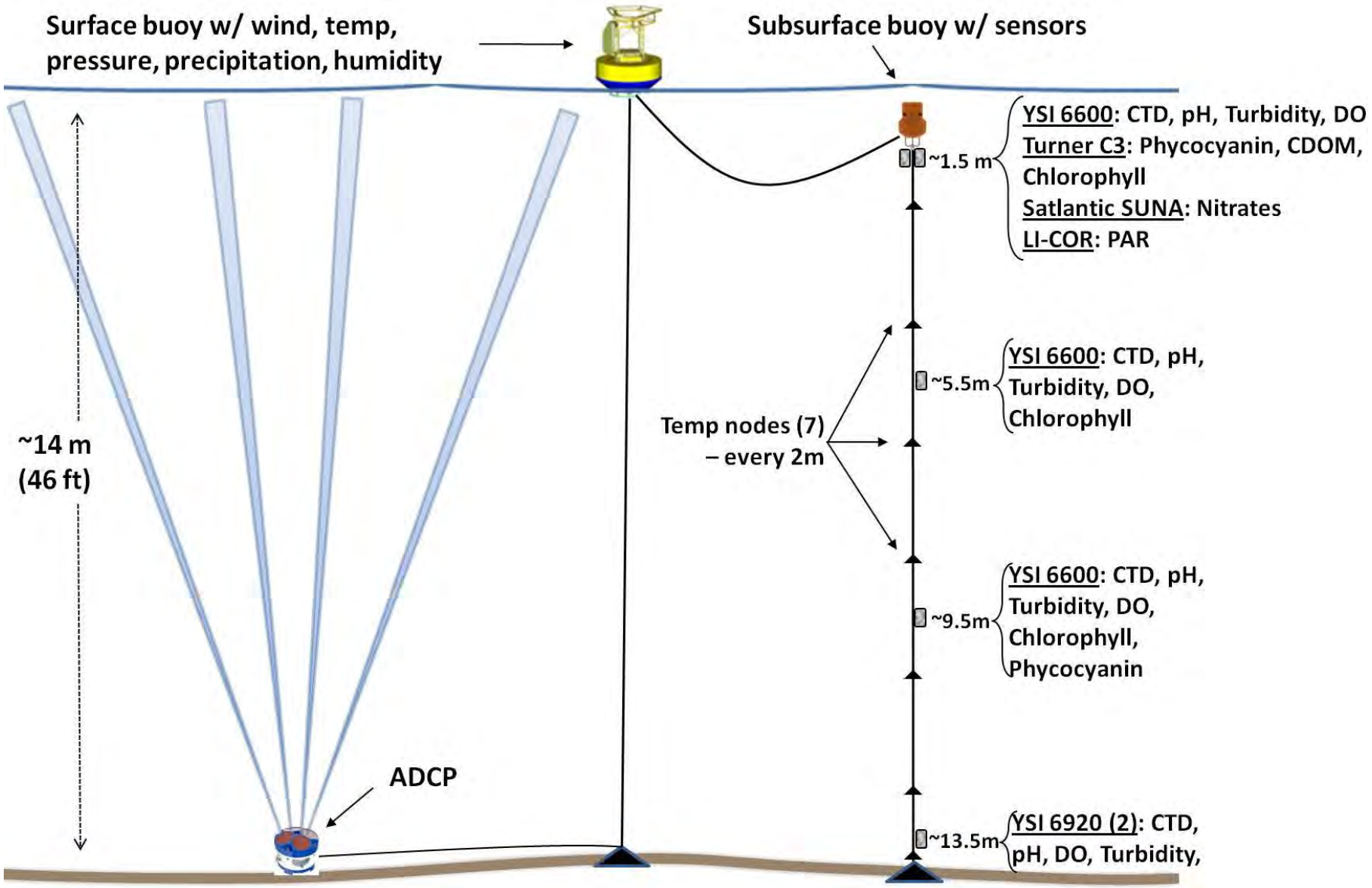


Lakes

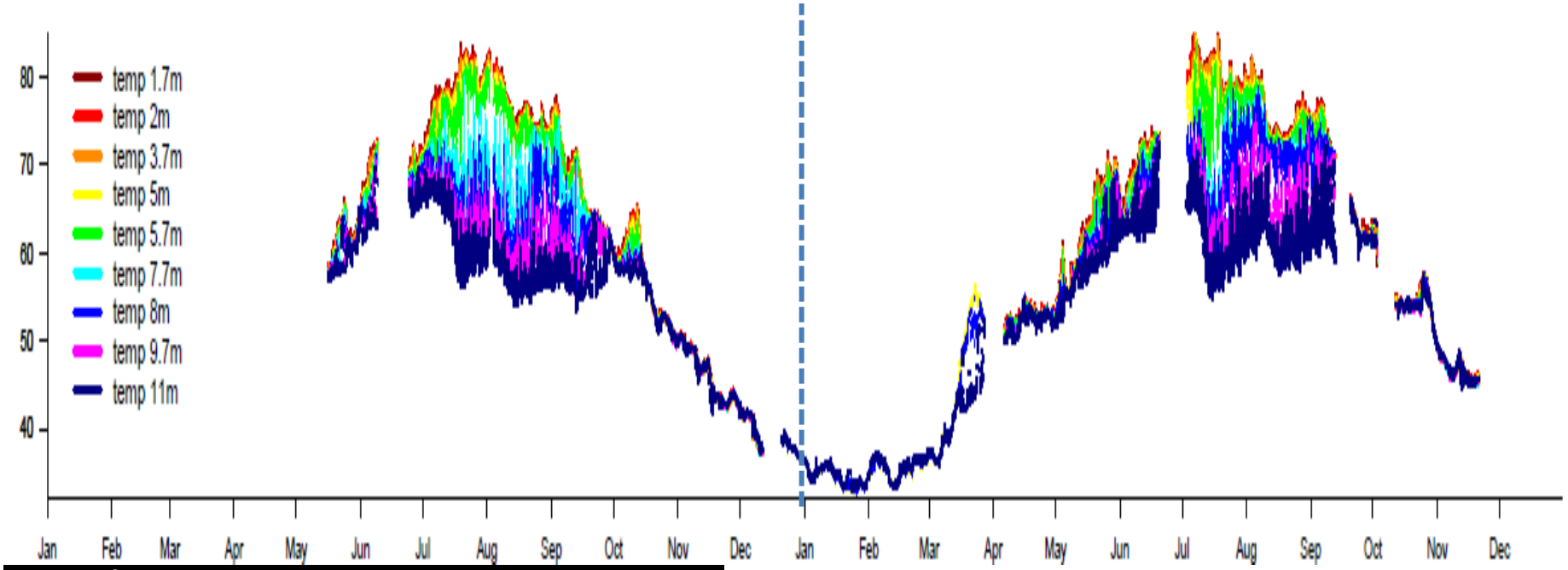
- Duration and strength of summer stratification will increase, adding to risk of oxygen depletion

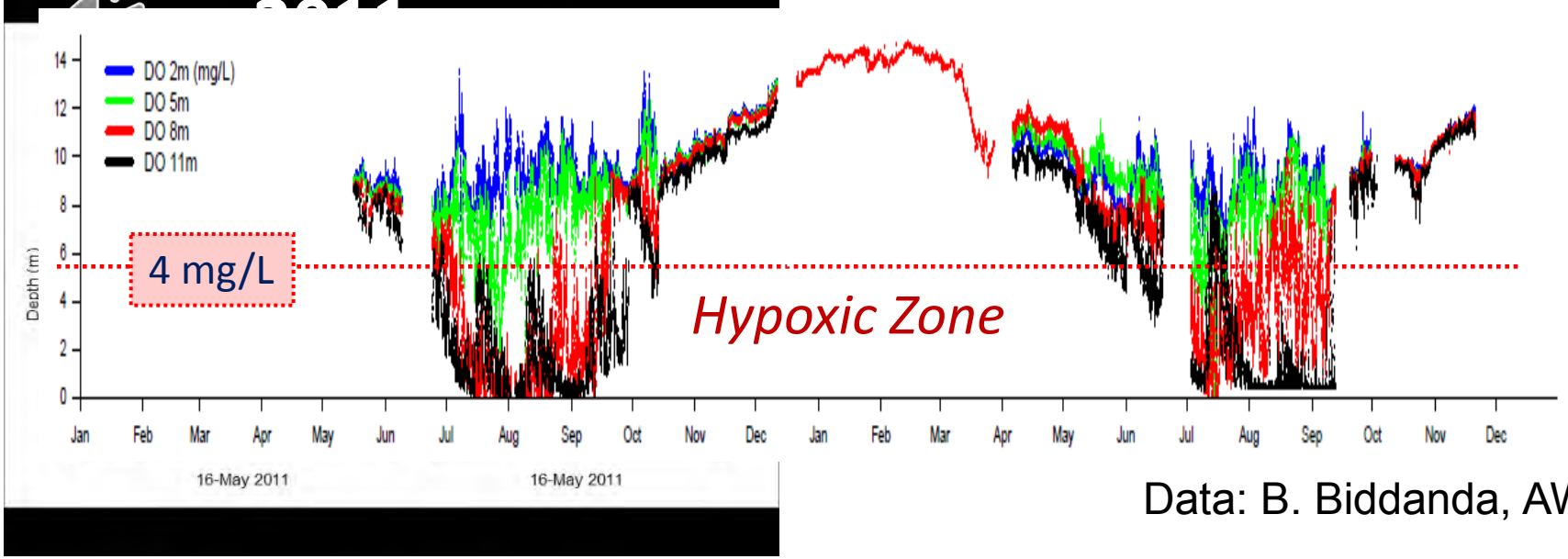

GVSU Research

Lake Observatory Components



Tracking Water Column Temperature & DO in Muskegon Lake 2011 through 2012





Data: B. Biddanda, AWRI

Harmful Algal Blooms (HABs)

Microcystin is the most common cyanotoxin produced by HABs → hepatoxin and tumor promotor.

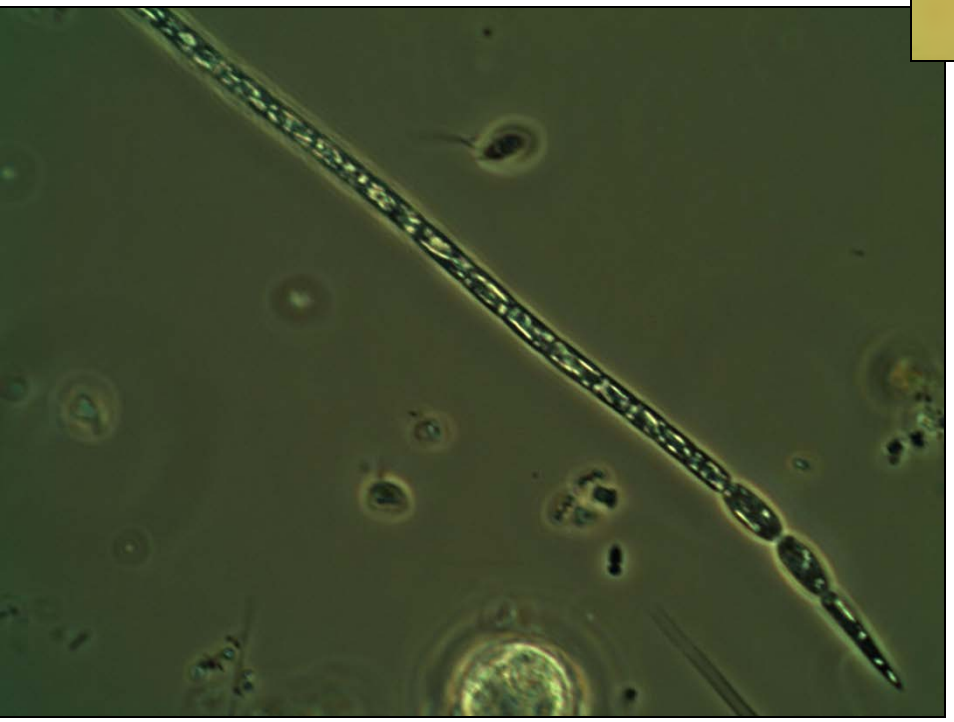
WHO standards:

- drinking water: 1 µg/L
- recreational: 20 µg/L

Harmful Algal Blooms (HABs)

Microcystin Concentrations		
Location	Date	Concentration (µg/L)
Mona Lake (bloom)	July, 2007	~350
Lake Erie (bloom)	October, 2011	~4,200

Cylindrospermopsis



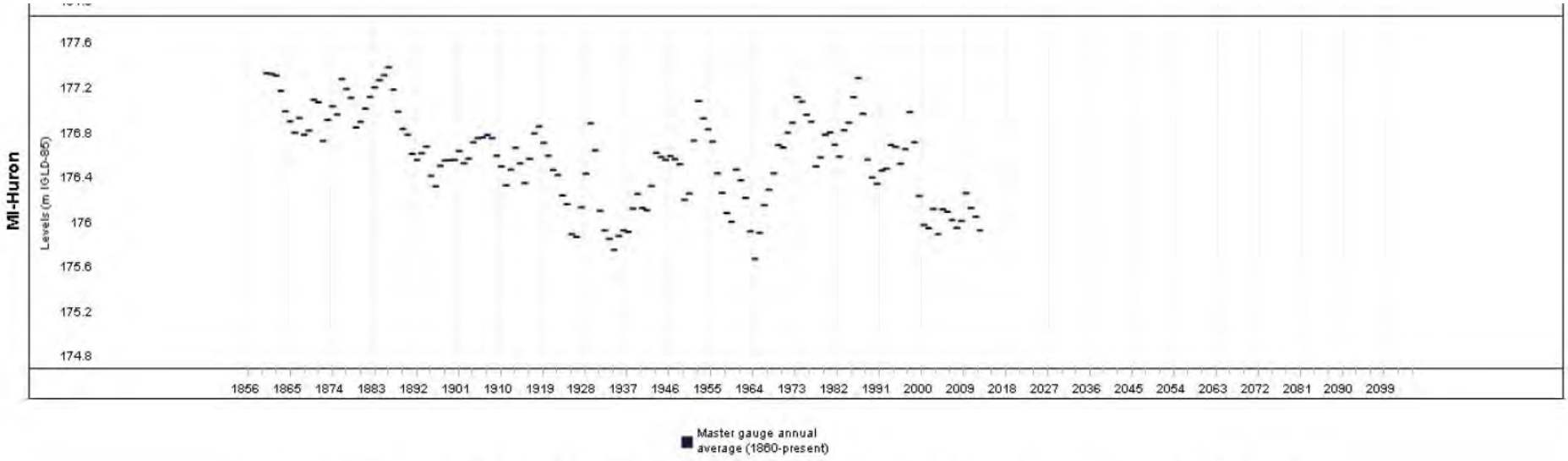
Hong et al. (2006) J. Great Lakes Research
Gillett and Steinman (2011) J. Great Lakes Research

Recreation and Tourism

- Valued at over $10 billion per year in MI
- Millions of anglers affected by shifts in fish ranges, loss of habitat, and changes in their preferred catch
- Loss of habitat or food resources for migratory songbirds, shorebirds, and waterfowl will affects MI's multi-million dollar birdwatching and hunting industries
- Winter recreation activities will be hard-hit
- Summer recreation activities will increase, unless temps are too high or insect-borne diseases increase

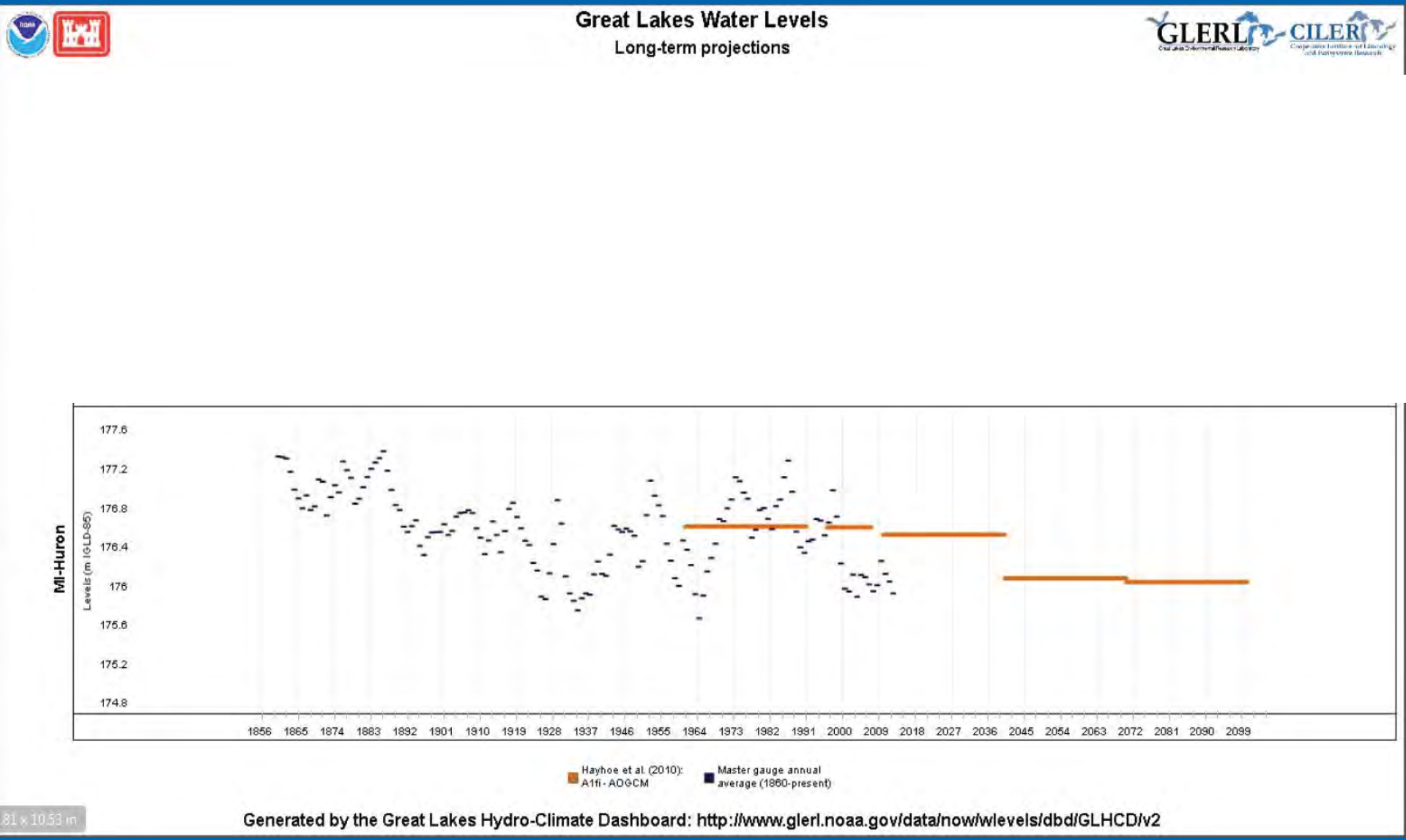
Great Lakes Water Levels

Long-term projections

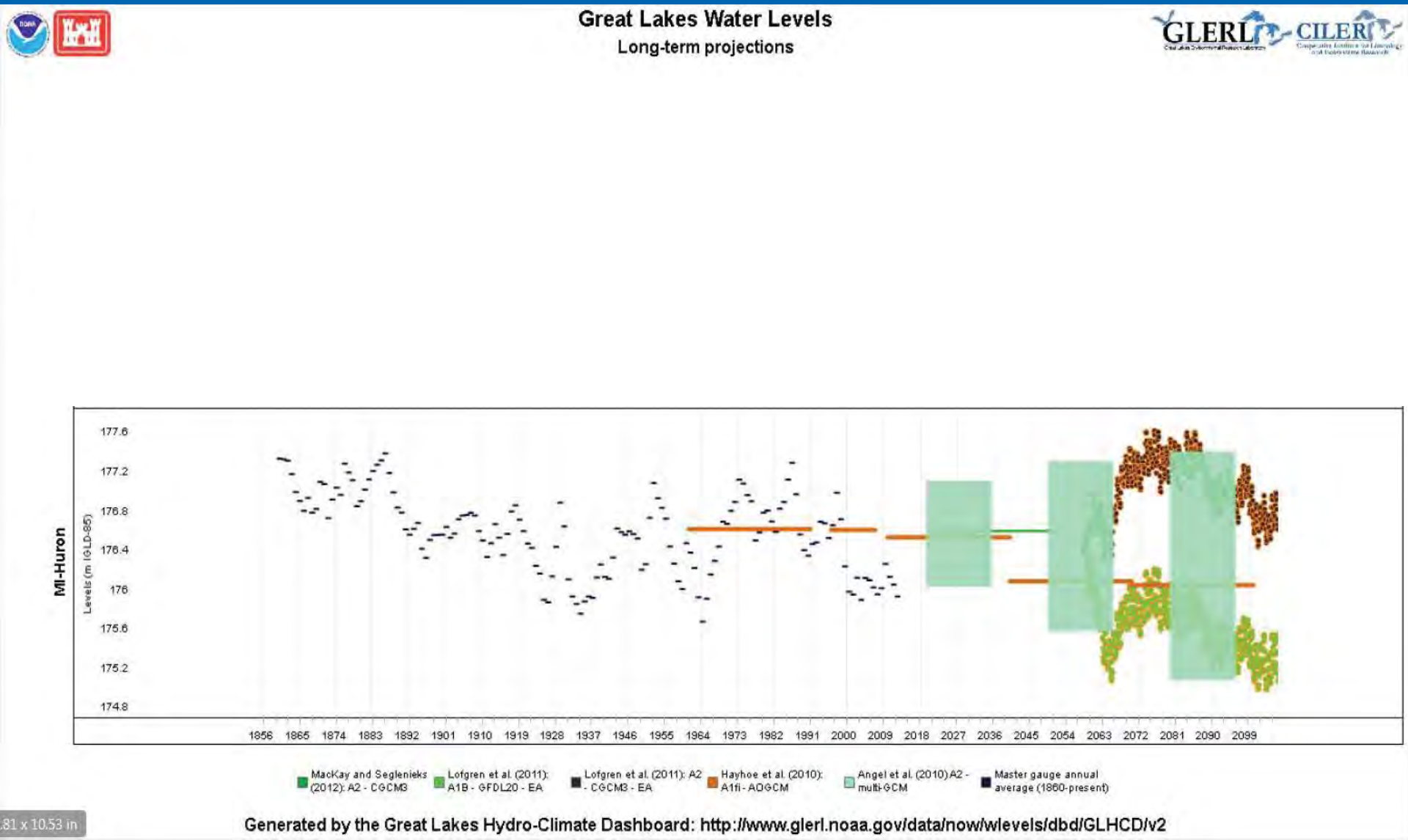


Generated by the Great Lakes Hydro-Climate Dashboard: http://www.glerl.noaa.gov/data/now/wlevels/dbd/GLHCD/v2

Gronewold et al. 2013



Gronewold et al. 2013



Gronewold et al. 2013

Potential Impacts: Economic

1) Increased need for dredging

2) Light-loading of freighters → additional costs to consumers

3) Tourism may be affected

Potential Impacts: Environmental

4) Coastal wetland habitat (fish, birds, vegetation)

5) Increased stormwater runoff → additional algal blooms

Societal Actions

1) Mitigation: options for limiting climate change → geoengineering

- reducing emissions
- removing gases from the atmosphere

2) Adaptation: changes made to better respond to present or future climatic conditions

- growing different crops
- changes in zoning/building codes

Climate Change Solutions: geoengineering

- Engineered solutions to alter Earth's climate to counteract global warming

1) aerosols to mimic the cooling effect of volcanoes
    - inject sulfur dioxide into the stratosphere
2) space shades or sea clouds
3) inject CO_2 into deep geologic strata
4) fertilize oceans with iron

Turbine=fitted vessels to spray mist to whiten clouds

Climate Change Solutions: Individual

- Save Electricity
  - turn off TV, lights, computer when done
- Study and discuss the issue with others
- Bike, bus and walk
- Plant trees
  - they absorb carbon dioxide

Climate Change Solutions: Individual

- Recycle - helps save natural resources
- Buy low-energy appliances (Energy Star®)
- Use solar power if possible
- Use hybrid or gas-efficient automobiles
- Vote wisely
  - Current US House appropriations committee cuts climate change funding by 29% in 2013

Summary

1) Global warming is unequivocal and primarily human-induced

2) Climate change will stress water resources

3) Climate change will interact with many social and environmental stresses

4) Future climate change and its impacts depend on choices made today