Confronting our Emerging Global Climate Crisis in Northern Michigan

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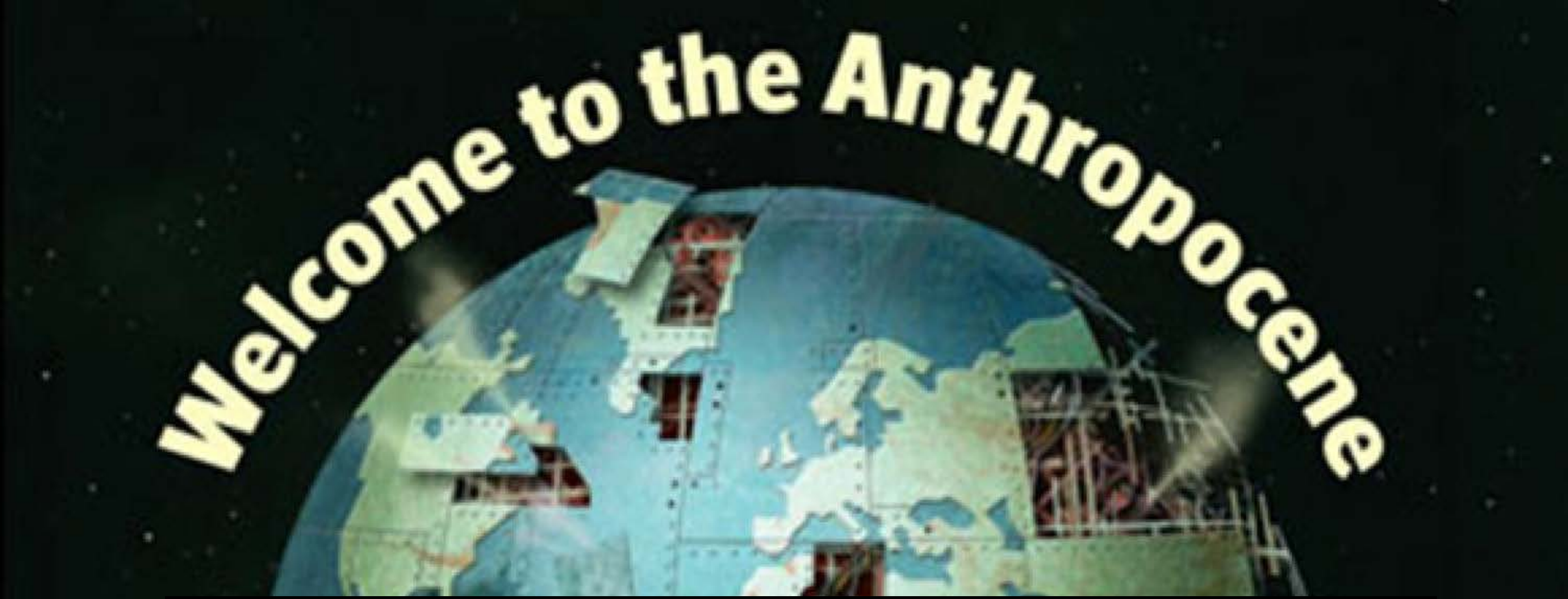
June 6, 2019



- The **Anthropocene** defines Earth's most recent geologic time period as being human-influenced, or *anthropogenic*.
- This epoch is named because of overwhelming evidence that atmospheric, geologic, hydrologic, biospheric and other earth system processes are now altered by humans.

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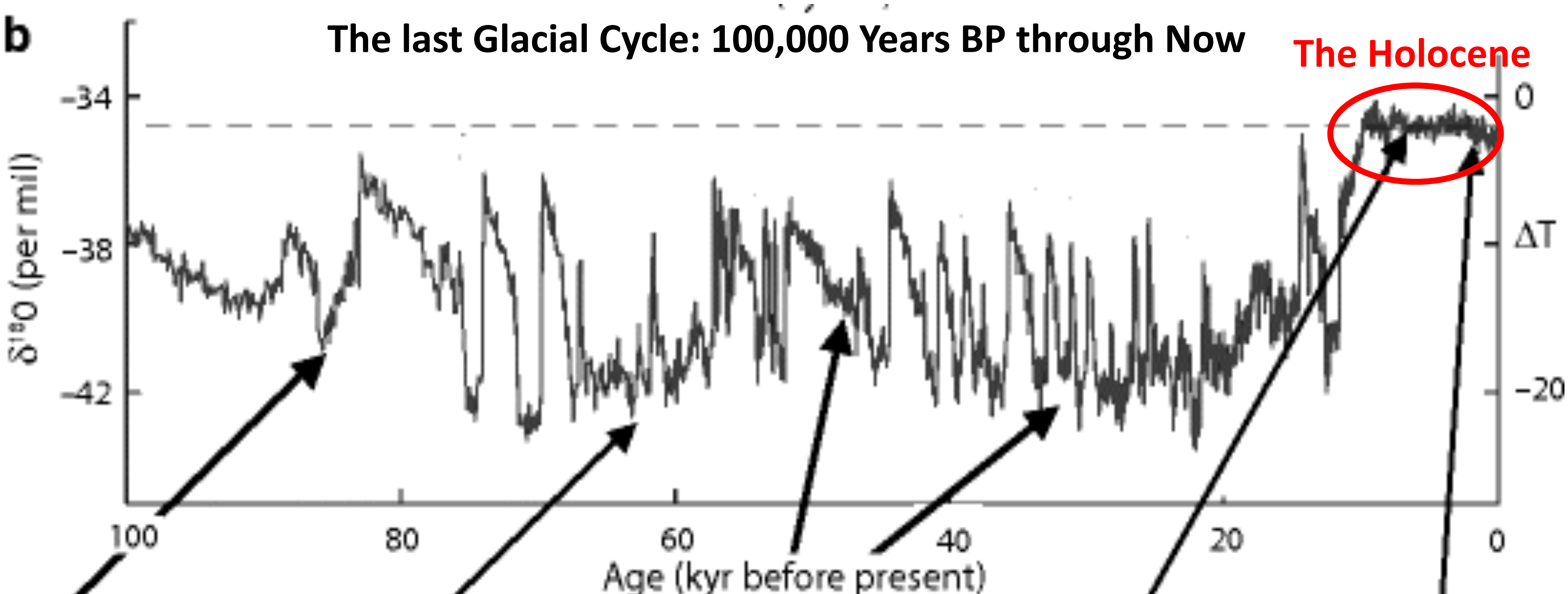
Atmospheric Chemistry & Global Temperatures



Migration of *Homo sapiens* (fully modern humans) out of Africa

Fully modern humans arrive in Australia

Migrations of of fully modern humans from South Asia to Europe

Beginning of agriculture and settled cities

Greek & Roman empires

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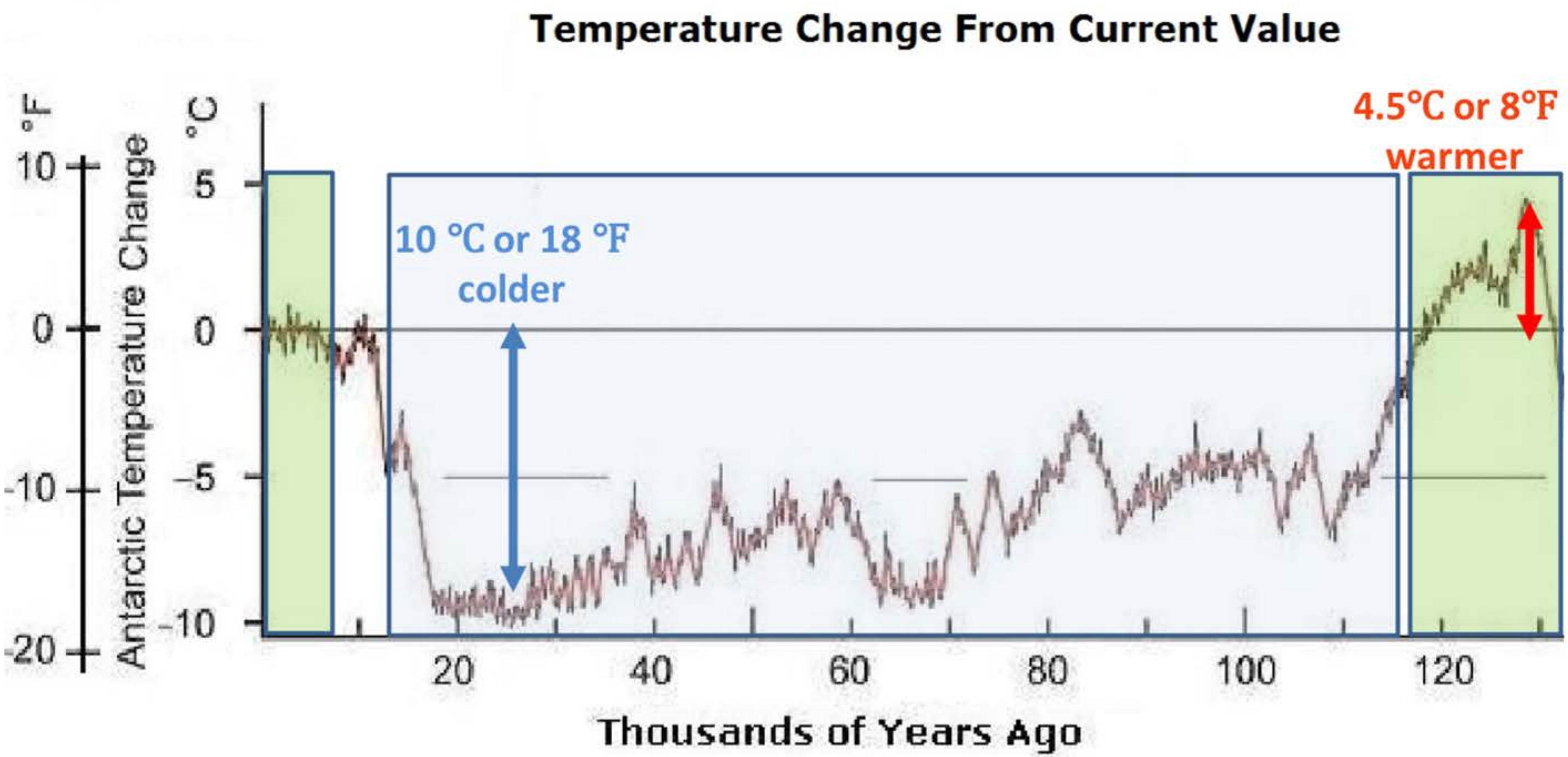
Modified from Young & Steffen, 2009

Earth's temperature change though the last glacial cycle



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Basic data: NOAA

Human-Caused Climate Change: our "Road Map"

Decision Making: Evidence- or Belief-based?

1) Climate Observations
2) Physical Processes
3) Atmospheric Chemistry
4) Global Carbon Cycle
5) Climate Impacts (Global & Regional)
6) Solutions

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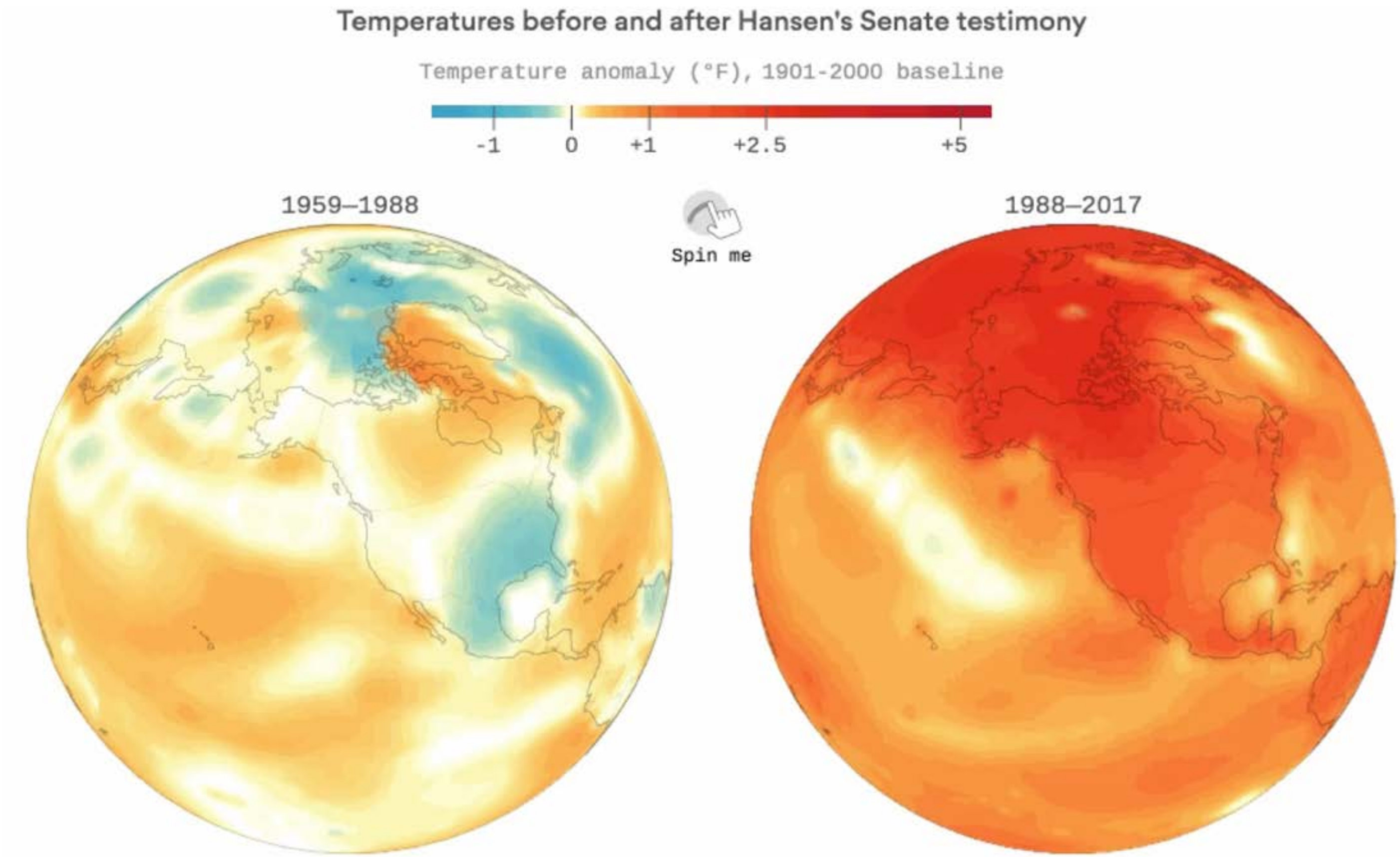
A 31-year alarm on the reality of climate change

Three decades have passed since then-NASA scientist James Hansen testified before the Senate Energy committee and alerted the country to the arrival of global warming.

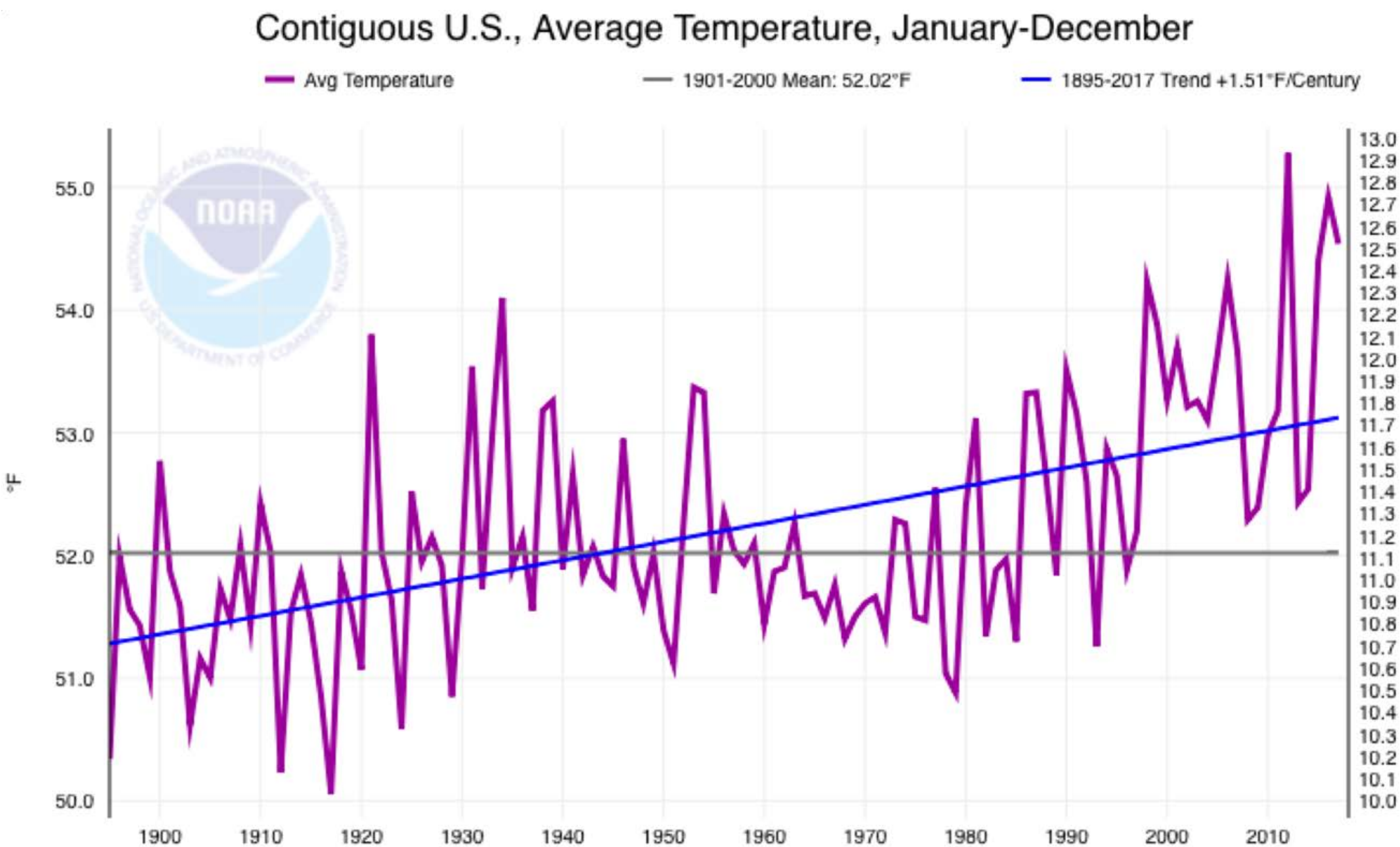


On June 23, 1988, in the midst of a heat wave, NASA climate scientist James Hansen issued a stark warning to the Senate energy committee: Human-caused global warming was already detectable, and would grow far worse with time.

Why does it matter?

Hansen was right. The predictions of the world's leading climate scientists have come true, with serious consequences for the planet.

- **Since 1988,** the Lower 48 states have warmed at a rate of 5.2 degrees Fahrenheit per century, and the globe has warmed at a rate of 3.2 degrees Fahrenheit per century (source: NOAA)



https://www.climate.gov/news-features/blogs/beyond-data/mapping-us-climate-trends

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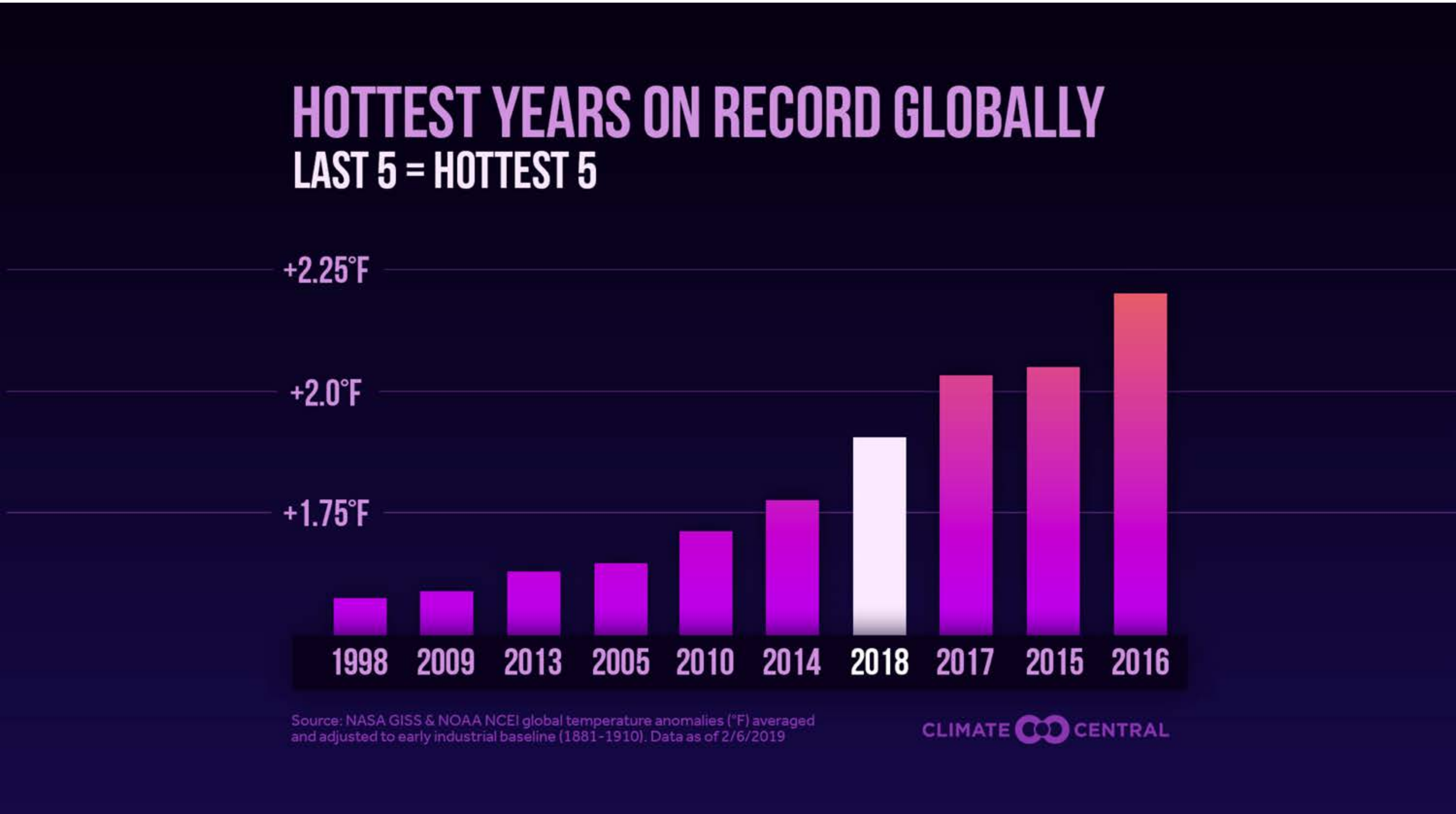
Why does it matter?

- **The <u>five warmest years</u>** on record have all occurred in the 2010s.



http://www.climatecentral.org/gallery/graphics/the-10-hottest-global-years-on-record

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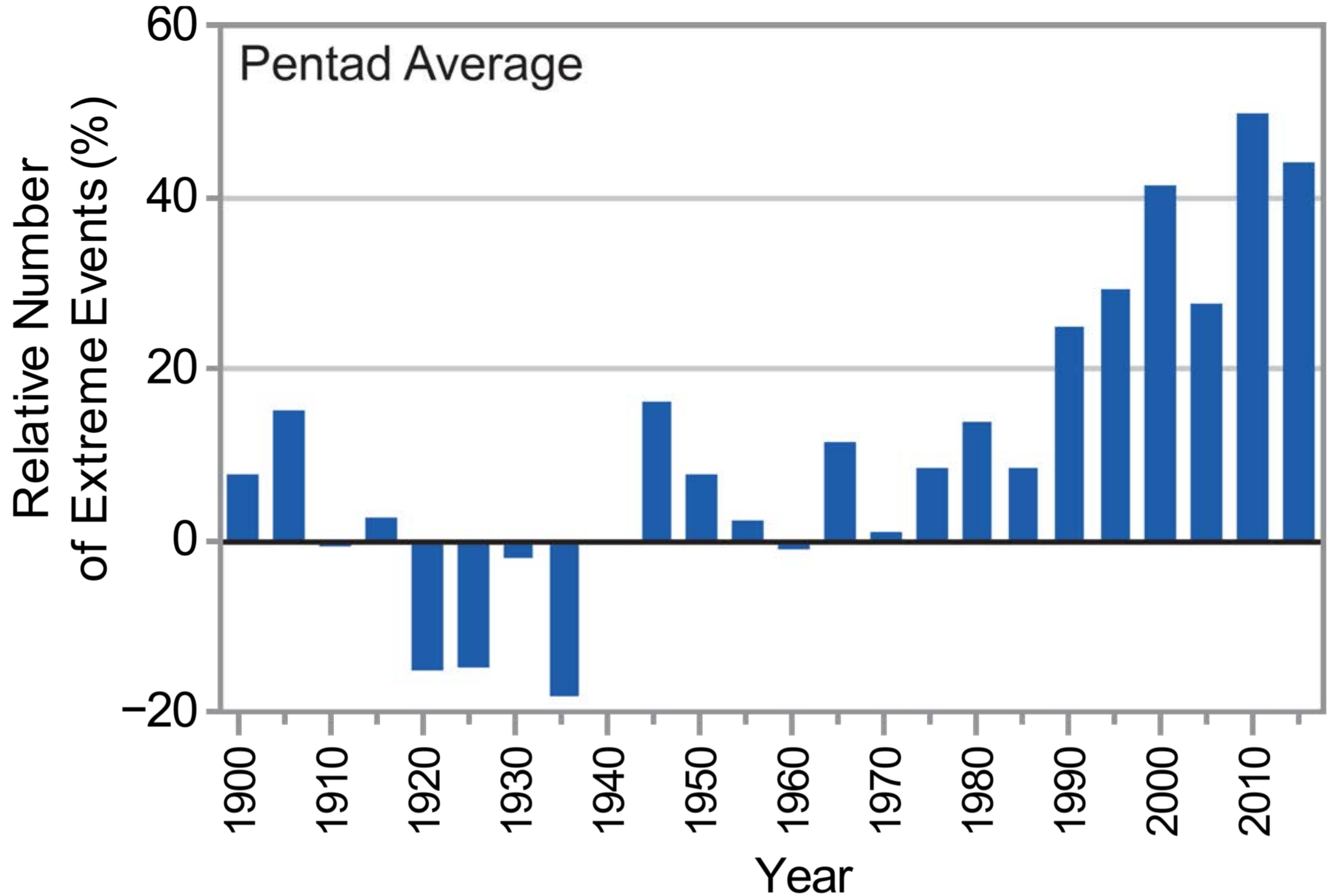
Why does it matter?

- **Precipitation** is now falling in more intense bursts.



Increases in extreme precipitation events (severe storms) in the contiguous U.S. through 2016. Graph shows the percentage increase in 2-day extreme events "normally" occurring only once every 5 years (during the 1896 to 2015 reference period).

From US Global Change, Fourth National Climate Assessment, https://science2017.globalchange.gov/chapter/7

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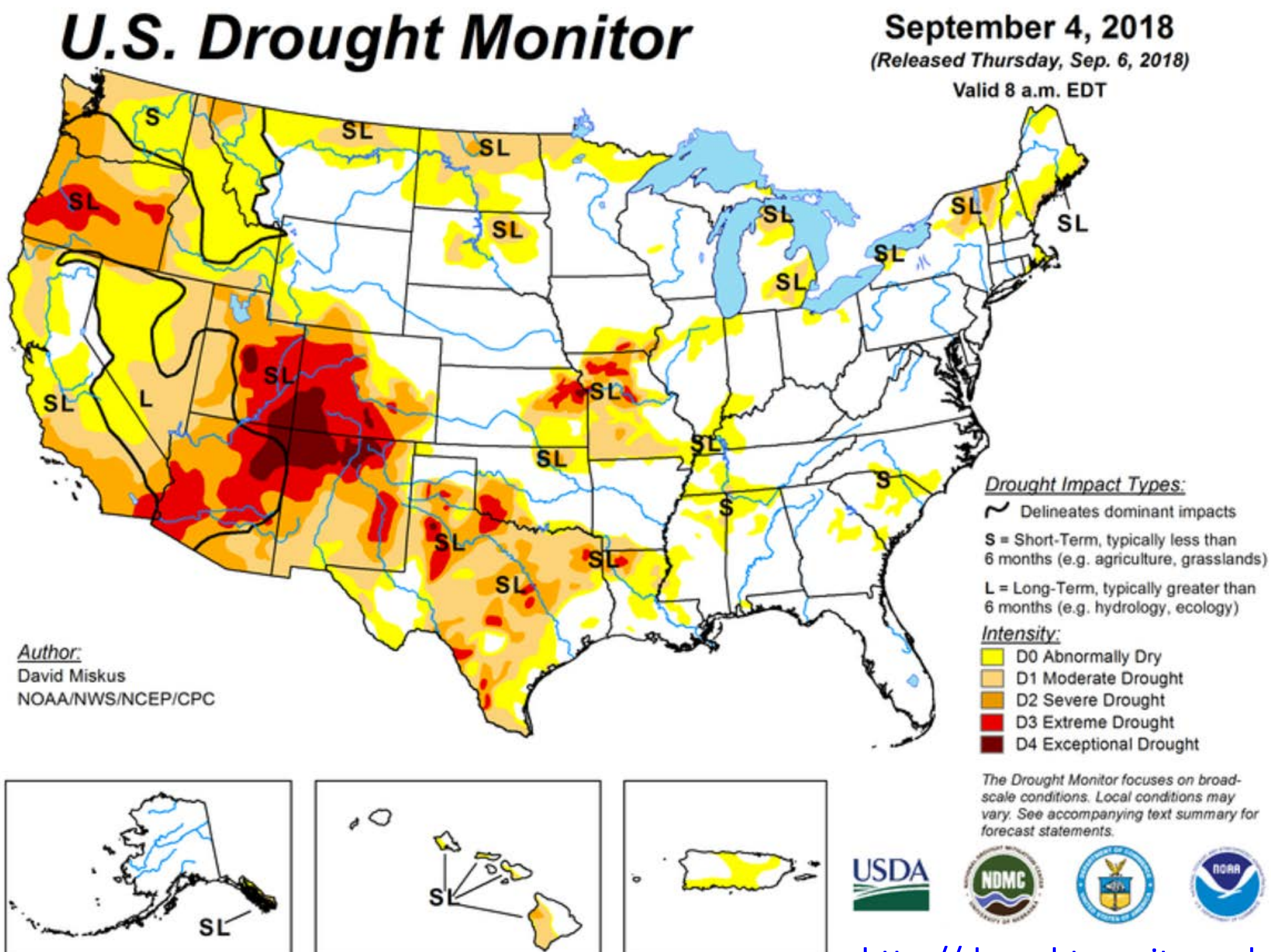
Why does it matter?

- Heat waves and droughts are more frequent and severe.



http://droughtmonitor.unl.edu

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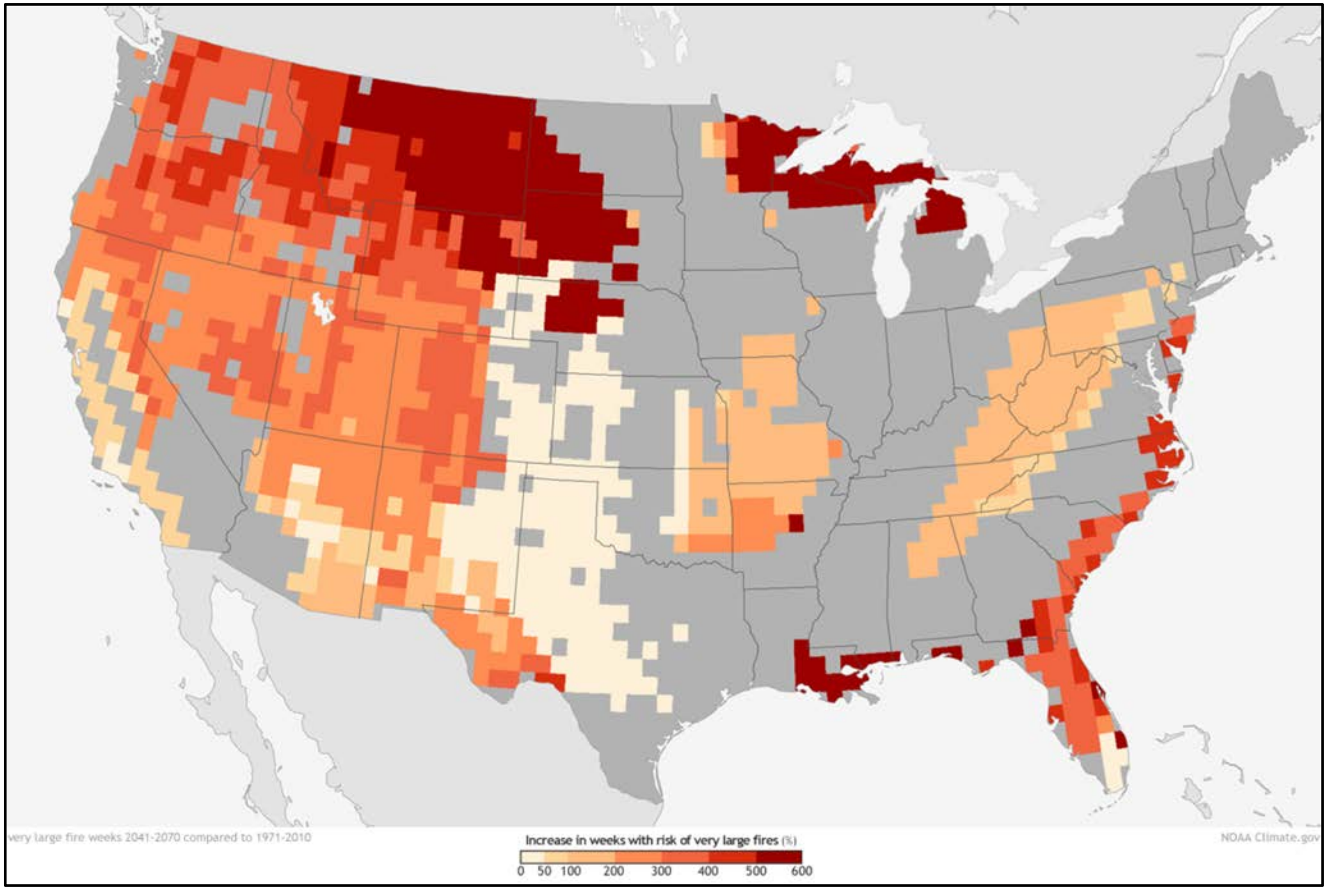
Why does it matter?

- **Wildfires** are getting more destructive amid hotter, drier summers, and earlier snowmelt in the spring.
- Climate change is expected to both intensify fire-friendly weather conditions, as well as lengthen the season during which very large fires tend to spread.



Projected increase in numbers of “very large fire weeks”—weeks in which conditions are favorable to the occurrence of very large fires—by mid-century (2041-2070) compared to the recent past (1971-2000).

From [*https://www.climate.gov/news-features/featured-images/risk-very-large-fires-could-increase-sixfold-mid-century-us*](https://www.climate.gov/news-features/featured-images/risk-very-large-fires-could-increase-sixfold-mid-century-us)

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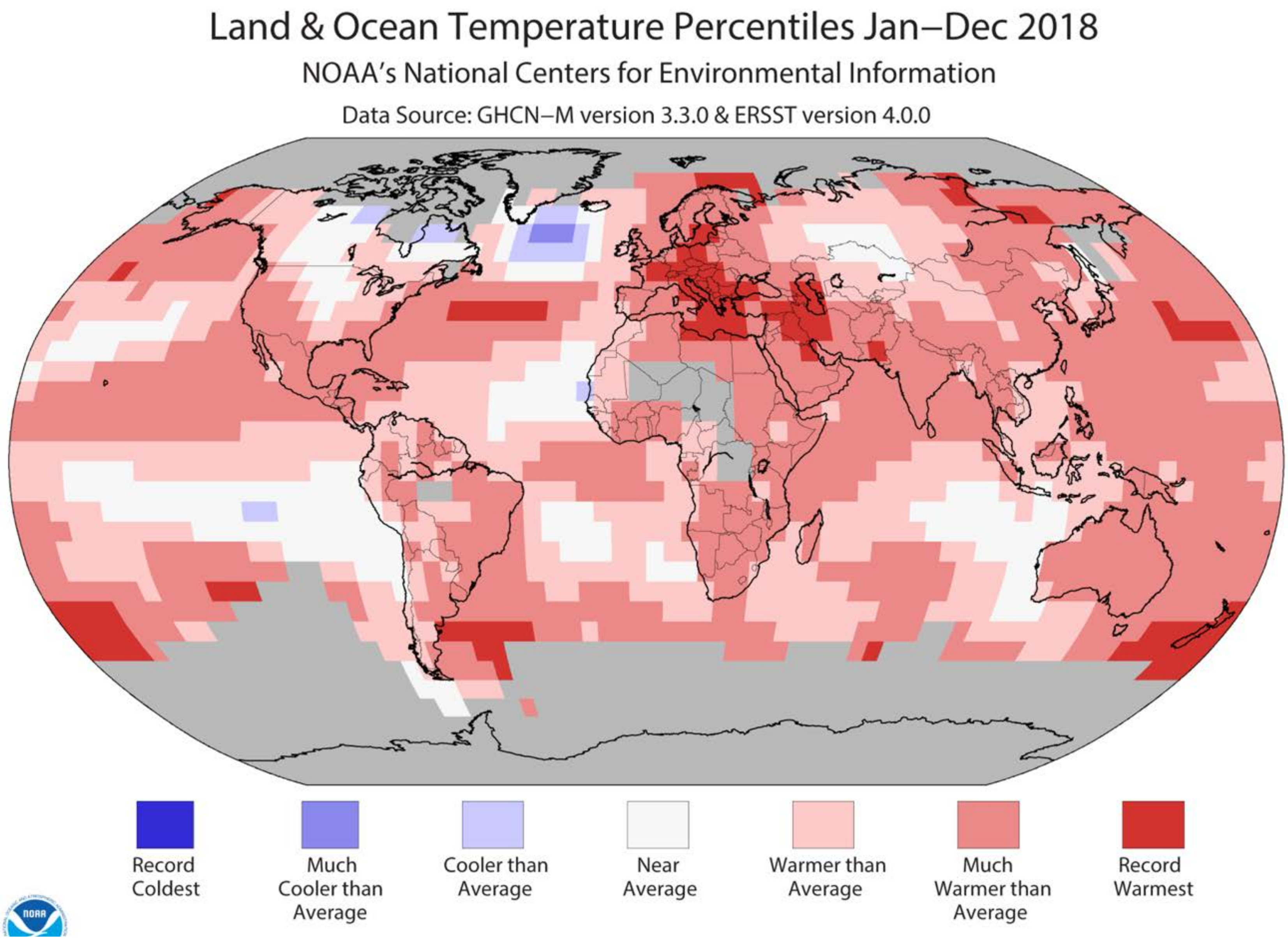
Climate Observations



https://www.ncei.noaa.gov/news/global-climate-201812

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Climate

Global Highlights REAL DATA

https://www.ncei.noaa.gov/news/global-climate-201812 as of June 5, 2019

- The 2018 average temperature across global land and ocean surfaces was 1.42°F (0.79°C) above the 20th century average of 57.0°F (13.9°C).
- This was the 4th highest among all years in the 1880–2018 record, behind 2016 (highest), 2015 (2nd highest), and 2017 (3rd highest).
- Nine of the top 10 warmest years in the 138 year record have occurred in the 21st century.

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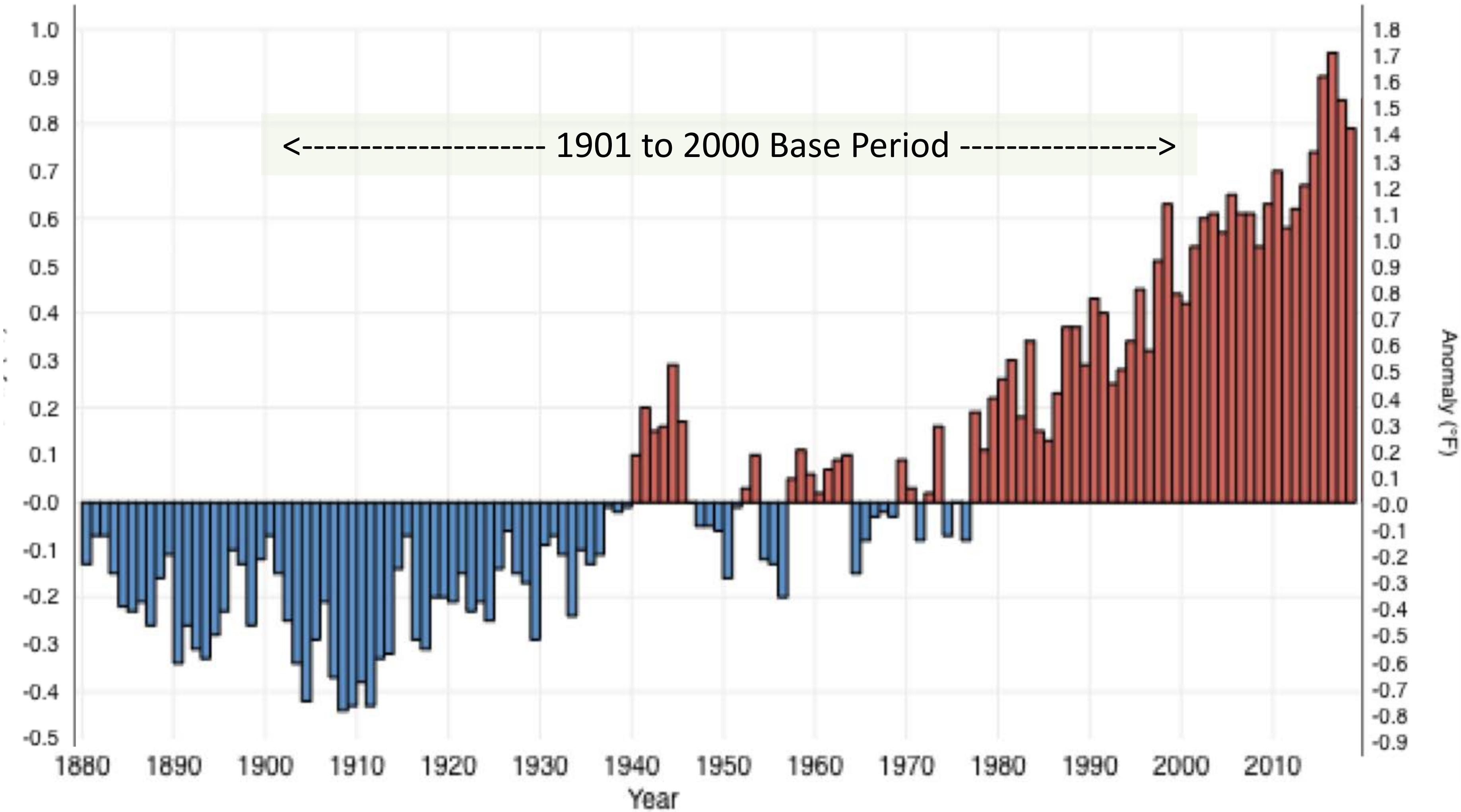
Earth's Surface Temperatures: 138-Year Trend



https://www.ncdc.noaa.gov/cag/global/time-series/globe/land_ocean/ytd/12/1880-2017

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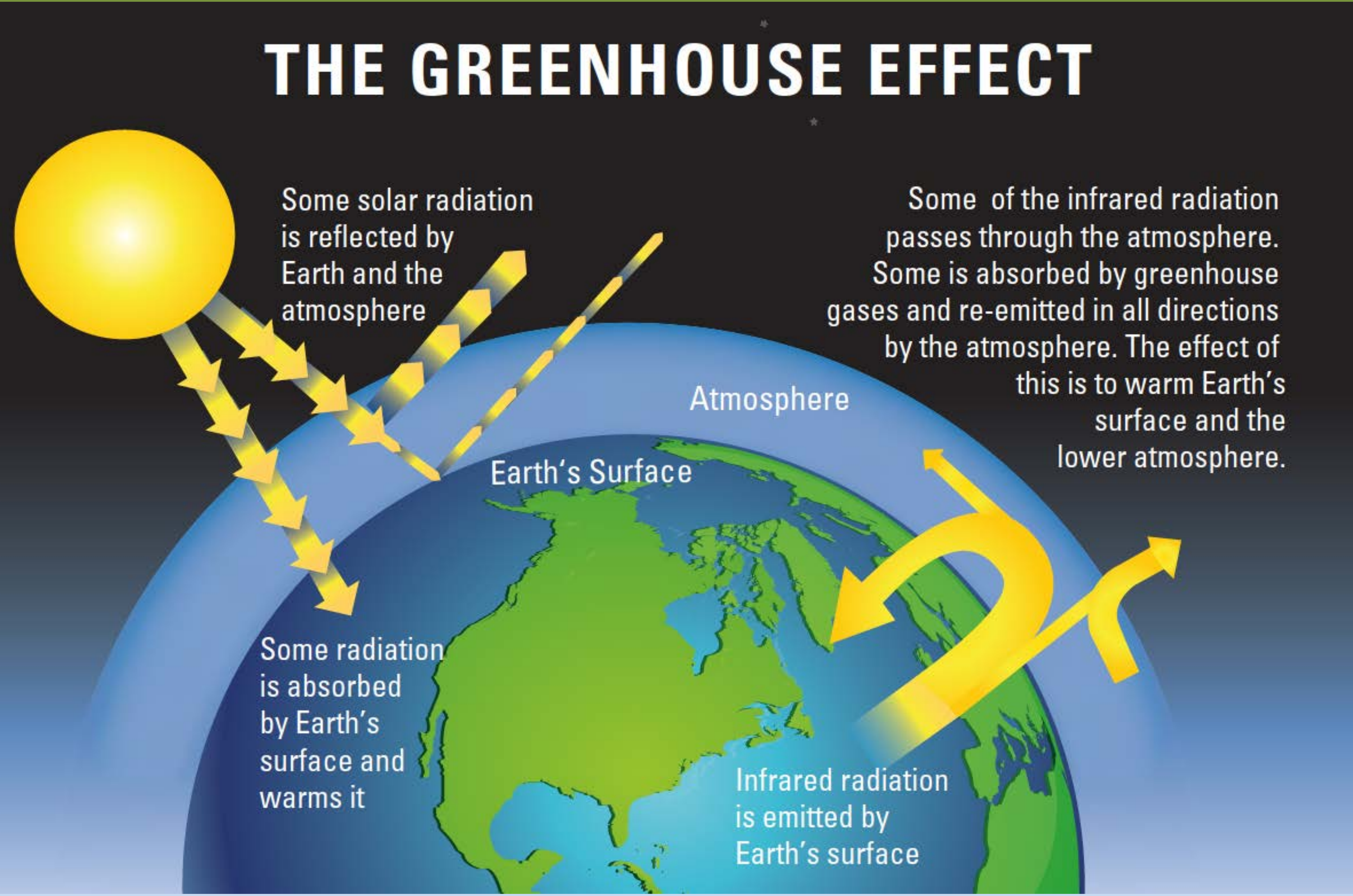
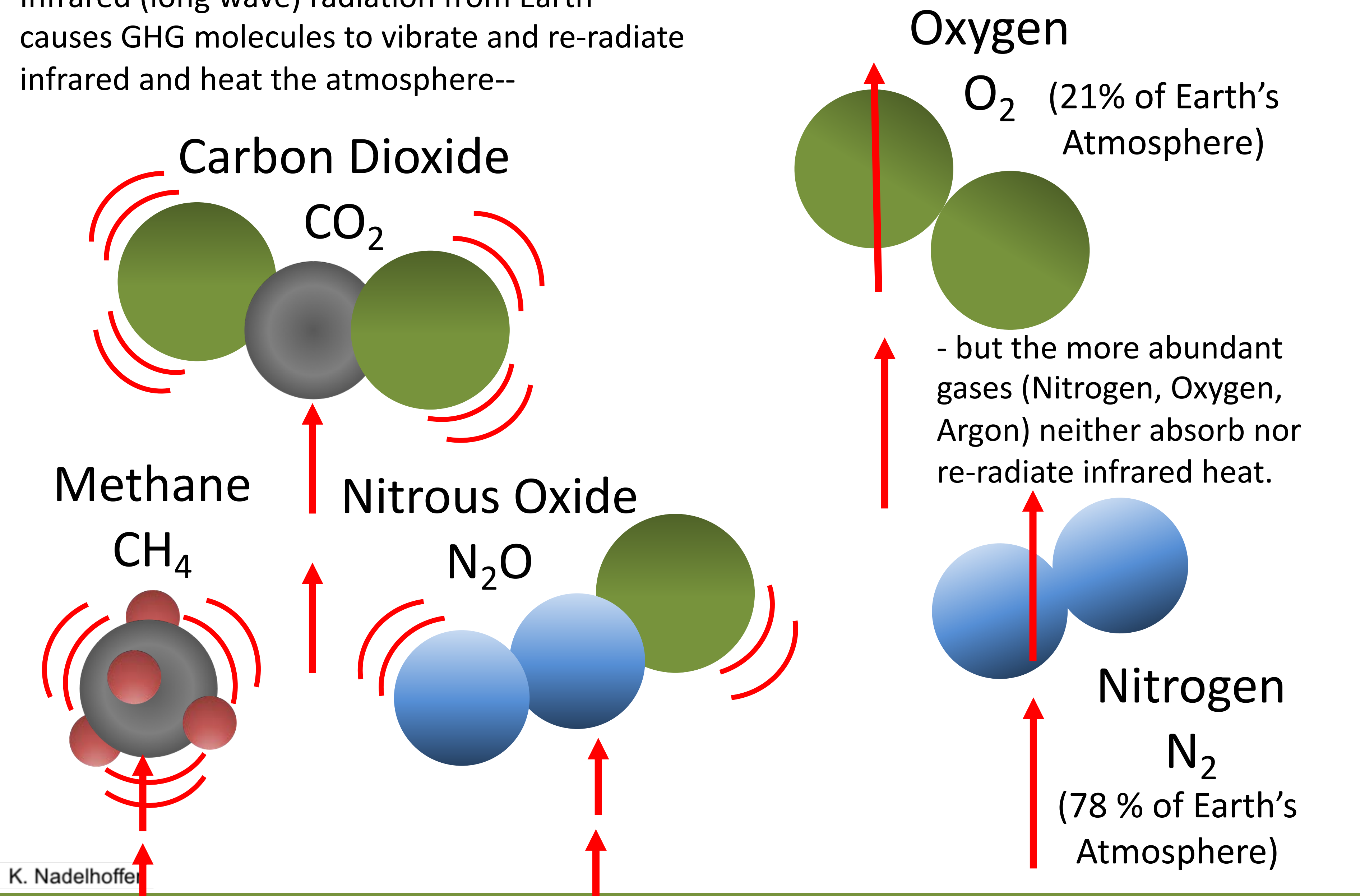
Physics


THE GREENHOUSE EFFECT
Some solar radiation is reflected by Earth and the atmosphere
Some of the infrared radiation passes through the atmosphere. Some is absorbed by greenhouse gases and re-emitted in all directions by the atmosphere. The effect of this is to warm Earth's surface and the lower atmosphere.
Atmosphere
Earth's Surface
Some radiation is absorbed by Earth's surface and warms it
Infrared radiation is emitted by Earth's surface

Greenhouse gas (GHG) molecules re-radiate infrared (heat) energy

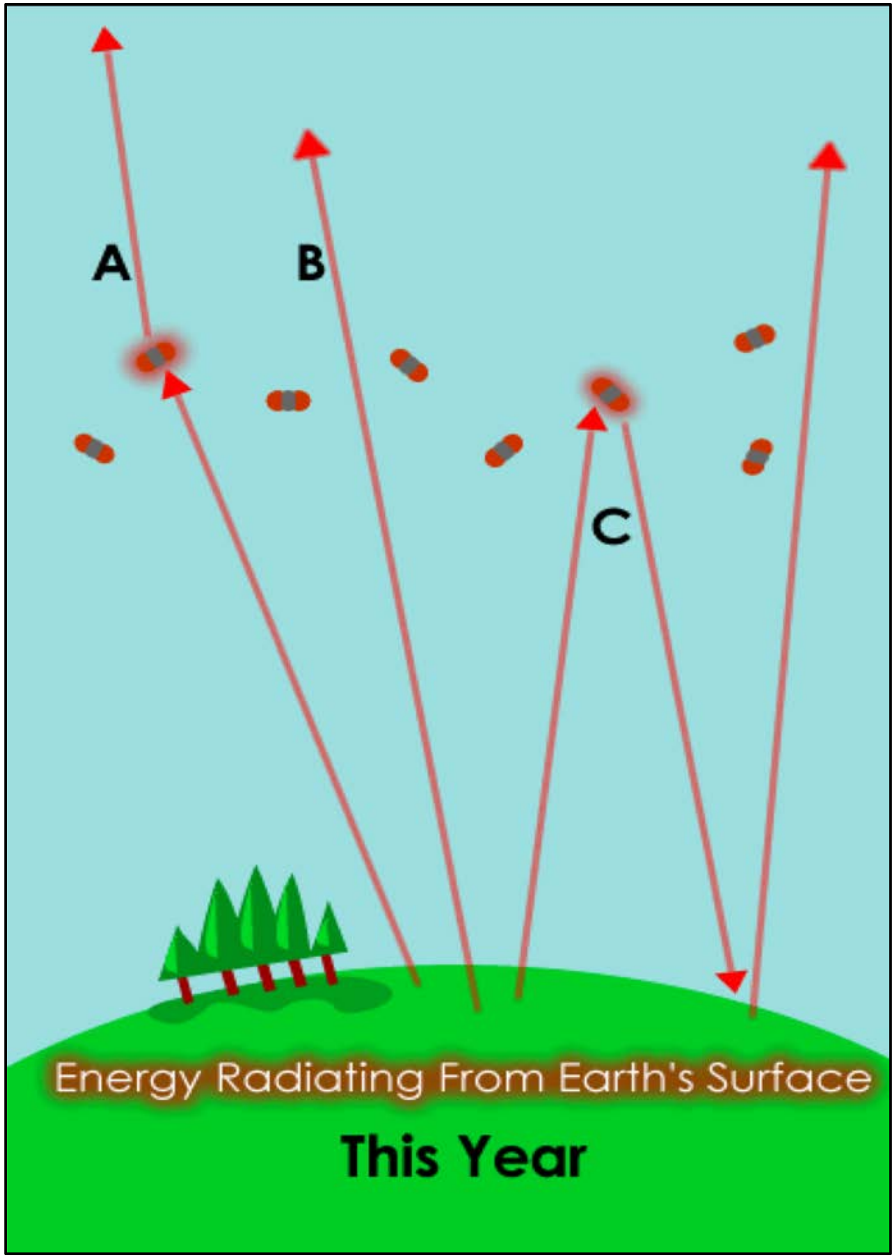
Infrared (long wave) radiation from Earth causes GHG molecules to vibrate and re-radiate infrared and heat the atmosphere--

- but the more abundant gases (Nitrogen, Oxygen, Argon) neither absorb nor re-radiate infrared heat.



Greenhouse gases re-radiate infrared (heat) energy

- *The Earth's surface absorbs short-wave radiation and re-radiates long-wave (infrared) radiation into the atmosphere.*
- *Some Infrared radiation (heat) is absorbed by greenhouse gases like carbon dioxide and then emitted to space (A).*
- *Some heat makes its way to space directly (B).*
- *Some heat is absorbed by greenhouse gases and is then re-radiated back towards the Earth's surface (C).*



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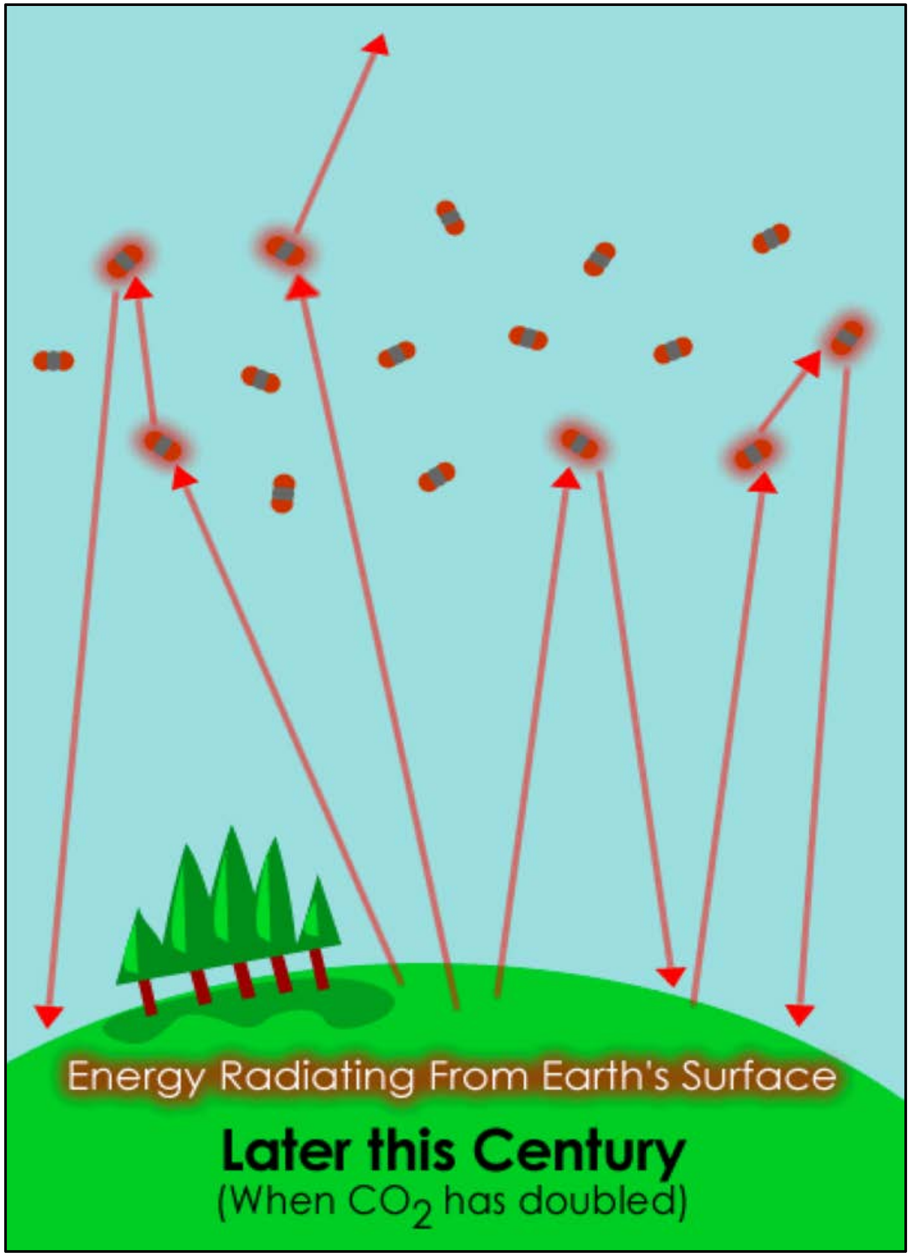
Greenhouse gases re-radiate infrared (heat) energy

With continuing increases of carbon dioxide and other greenhouse gases, more heat will be trapped in the atmosphere and Earth's temperature will continue to rise.



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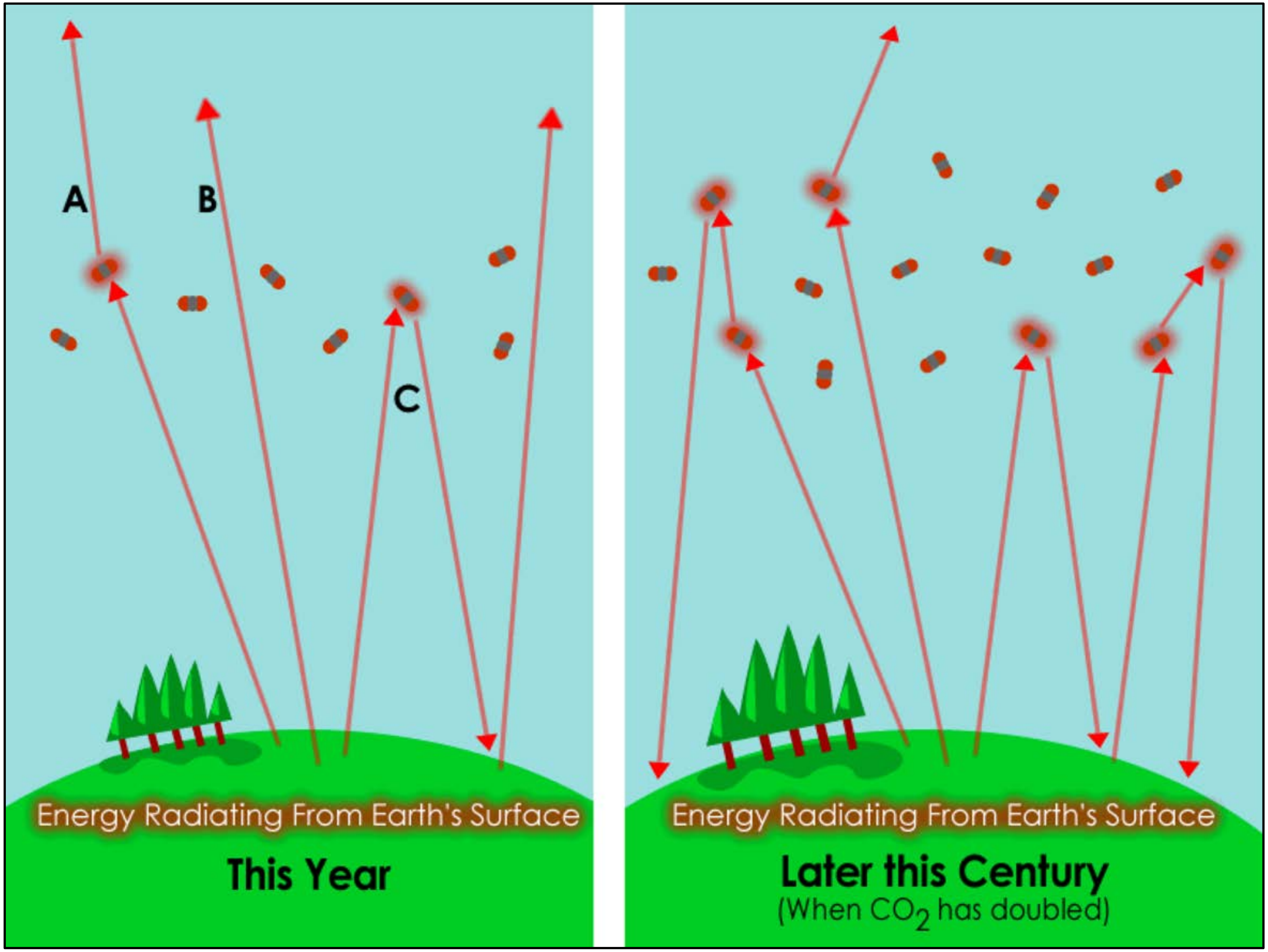
Greenhouse gases re-radiate infrared (heat) energy



(Image: Lisa Gardiner/Windows to the Universe)
https://scied.ucar.edu/longcontent/greenhouse-effect

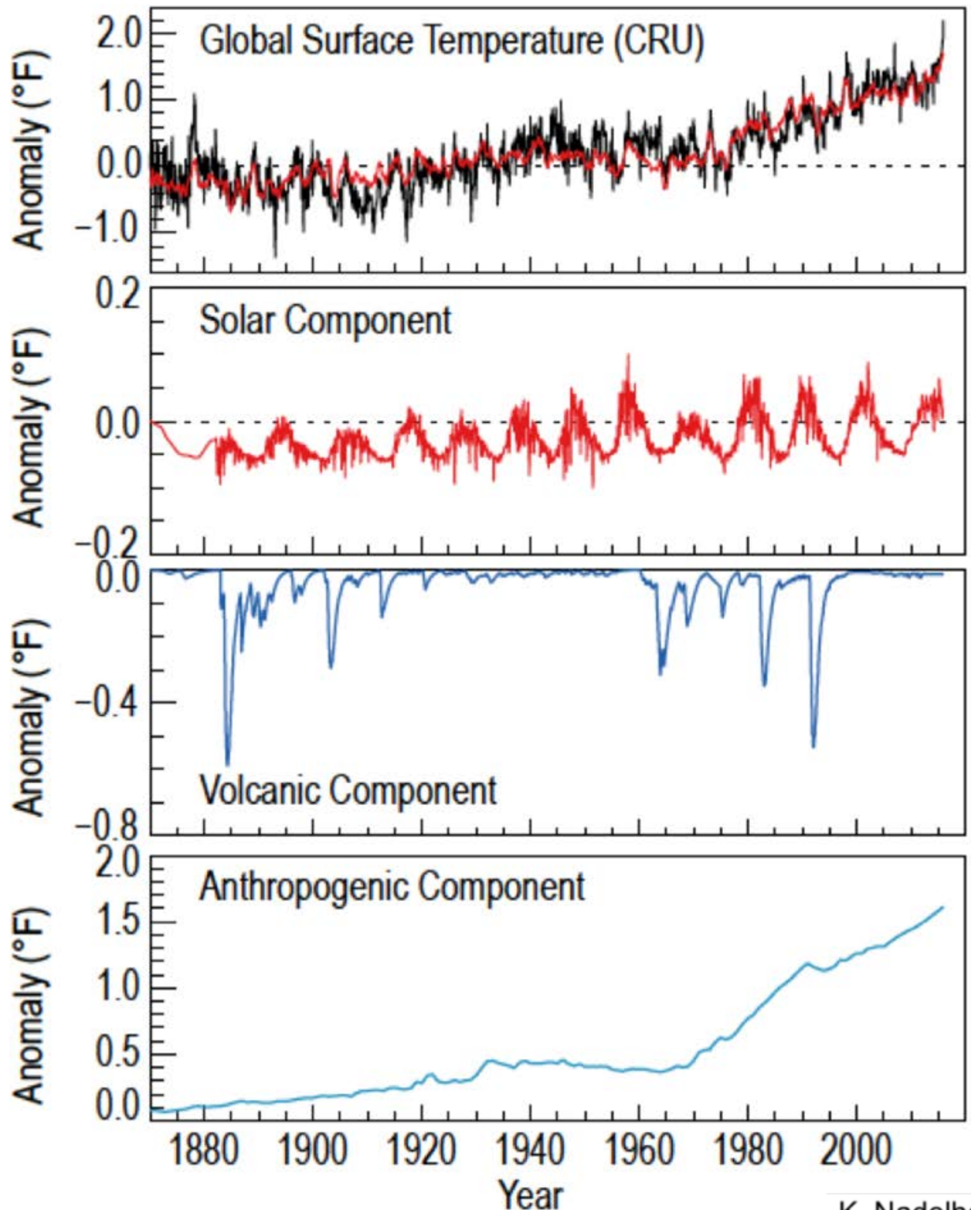
Physics

Estimates of the contributions of several forcing factors and internal variability to global mean temperature change since 1870.

The top panel shows global temperature anomalies (°F) from the observations in black with the multiple linear regression result in red (1901–1960 base period).

The lower 3 panels show estimated contributions to global mean temperature anomalies from solar variability; volcanic eruptions; and anthropogenic forcing.

The anthropogenic contribution includes a warming component from greenhouse gases concentrationsn and a cooling component from anthropogenic aerosols



From **USGCRP**, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Vol I . Figure 3.3*
https://science2017.globalchange.gov/

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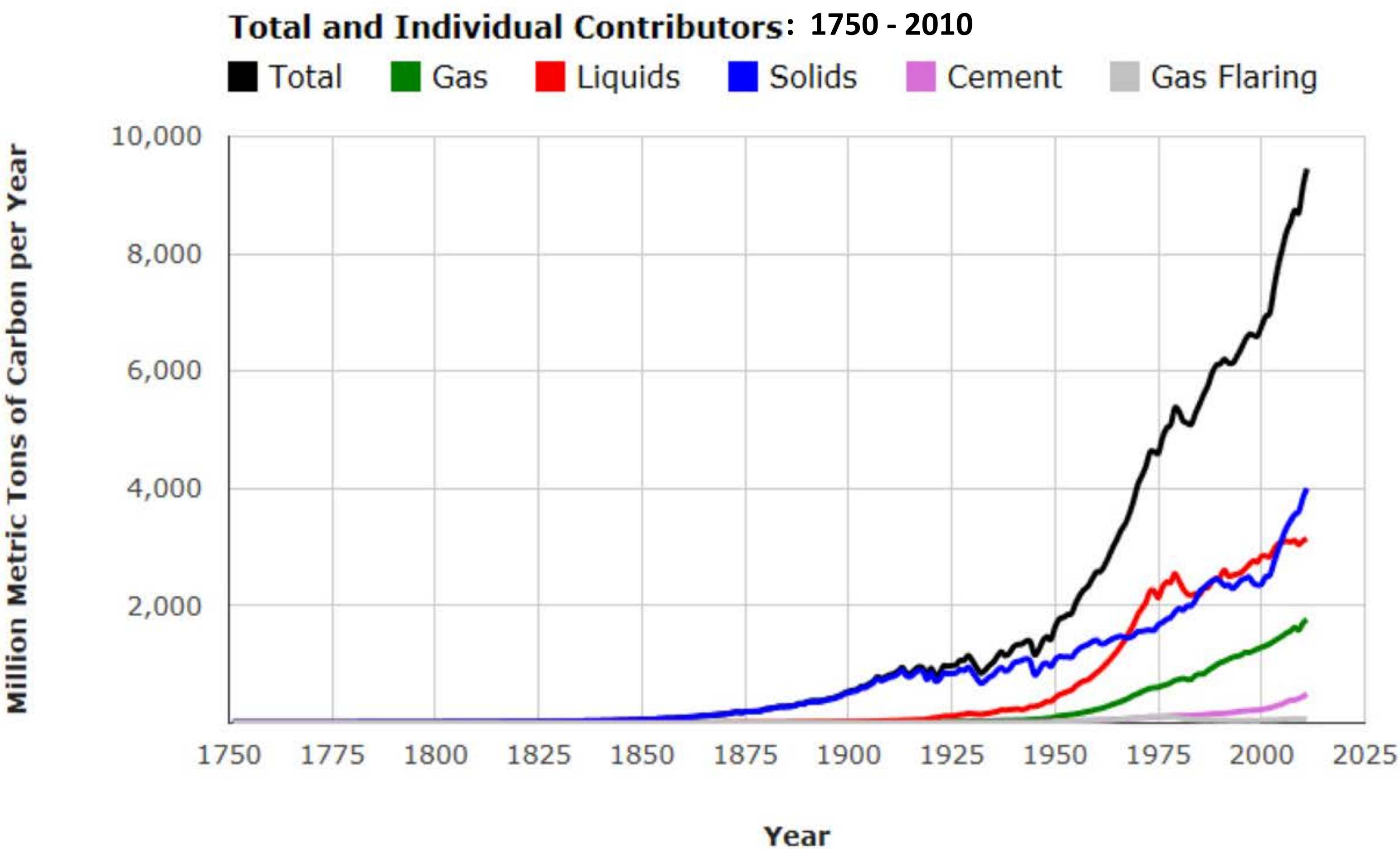
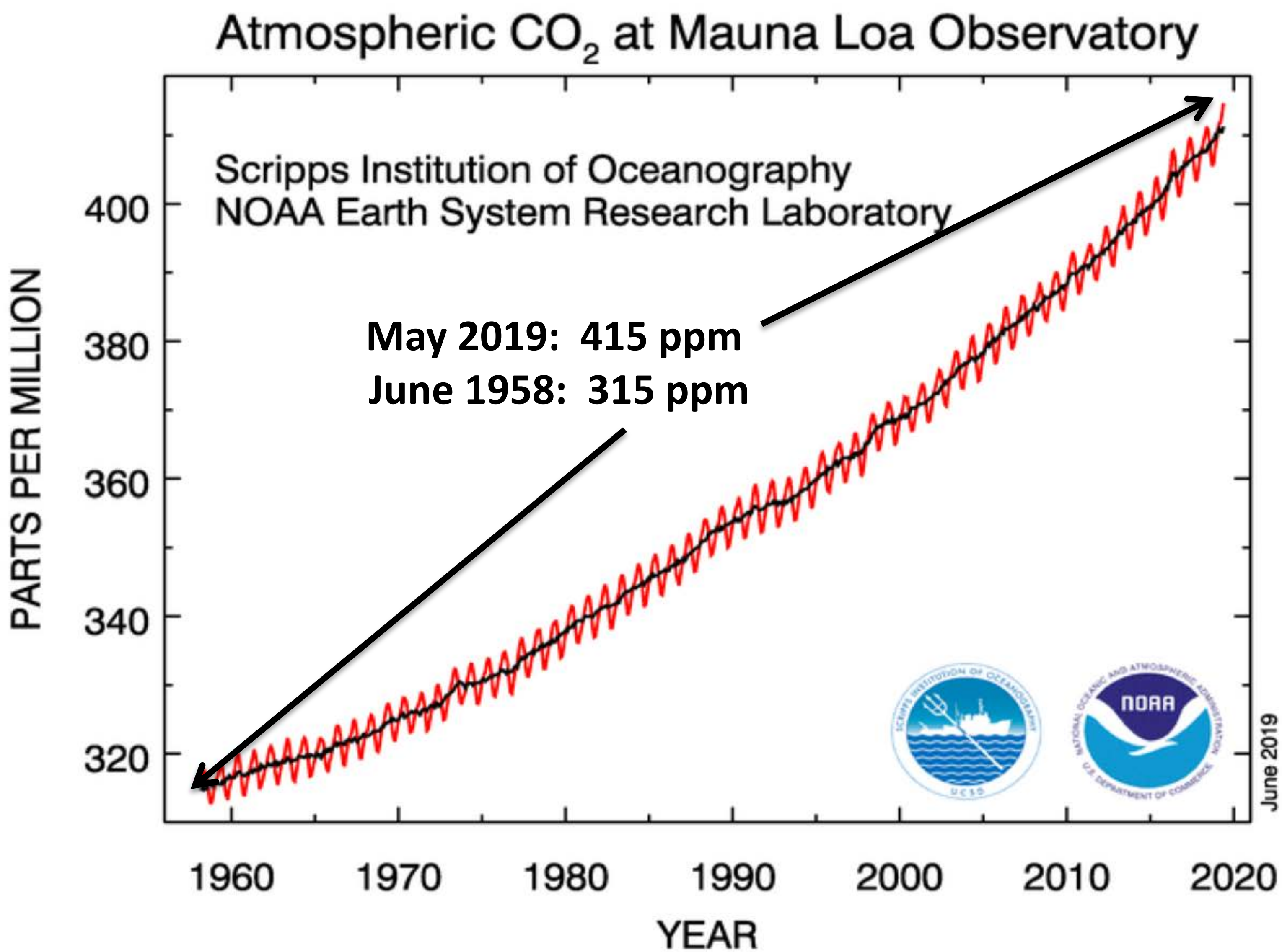
Emissions



Source: Boden, T.A., G. Marland, and R. J. Andres. 2015. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi: 10.3334/CDIAC/00001_V2015.

From http://cdiac.ornl.gov/images/global_fossil_carbon_emissions_google_chart.jpg

Chemistry: Atmospheric CO_2



May 2019: 415 ppm
June 1958: 315 ppm

http://www.esrl.noaa.gov/gmd/ccgg/trends/

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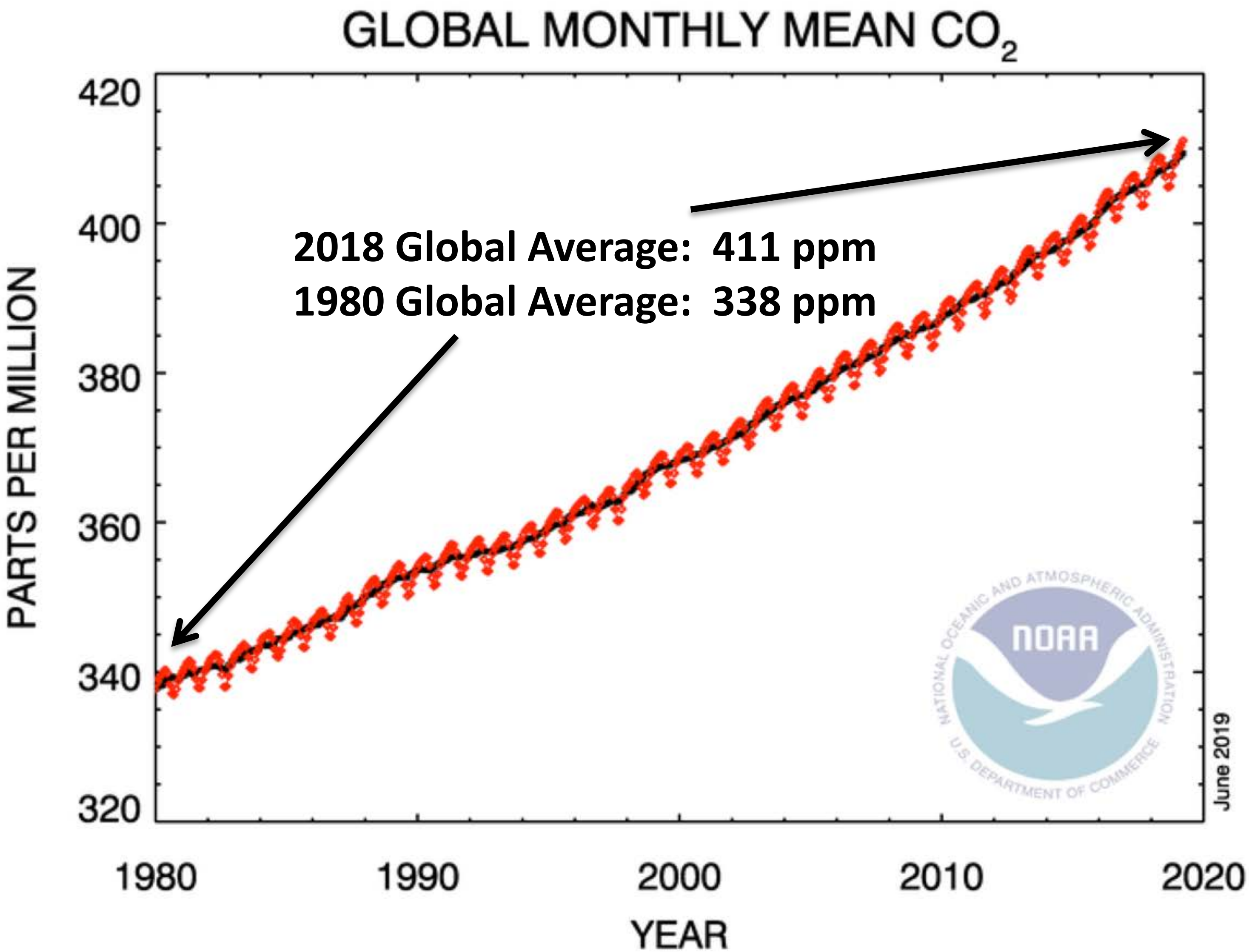
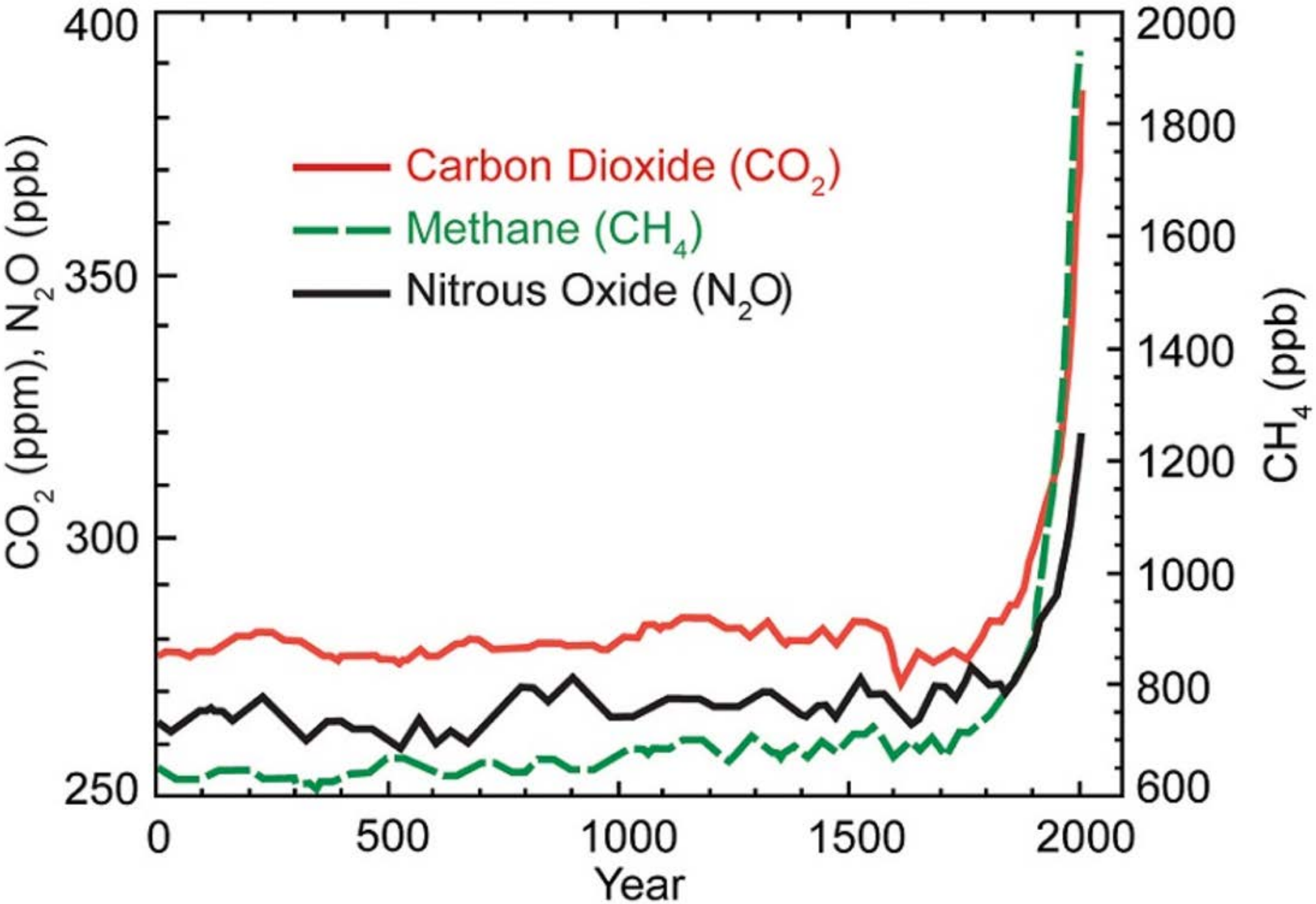
Chemistry: Atmospheric CO_2



K. Nadelhoffer https://www.esrl.noaa.gov/gmd/ccgg/trends/global.html. as of June 5, 2019

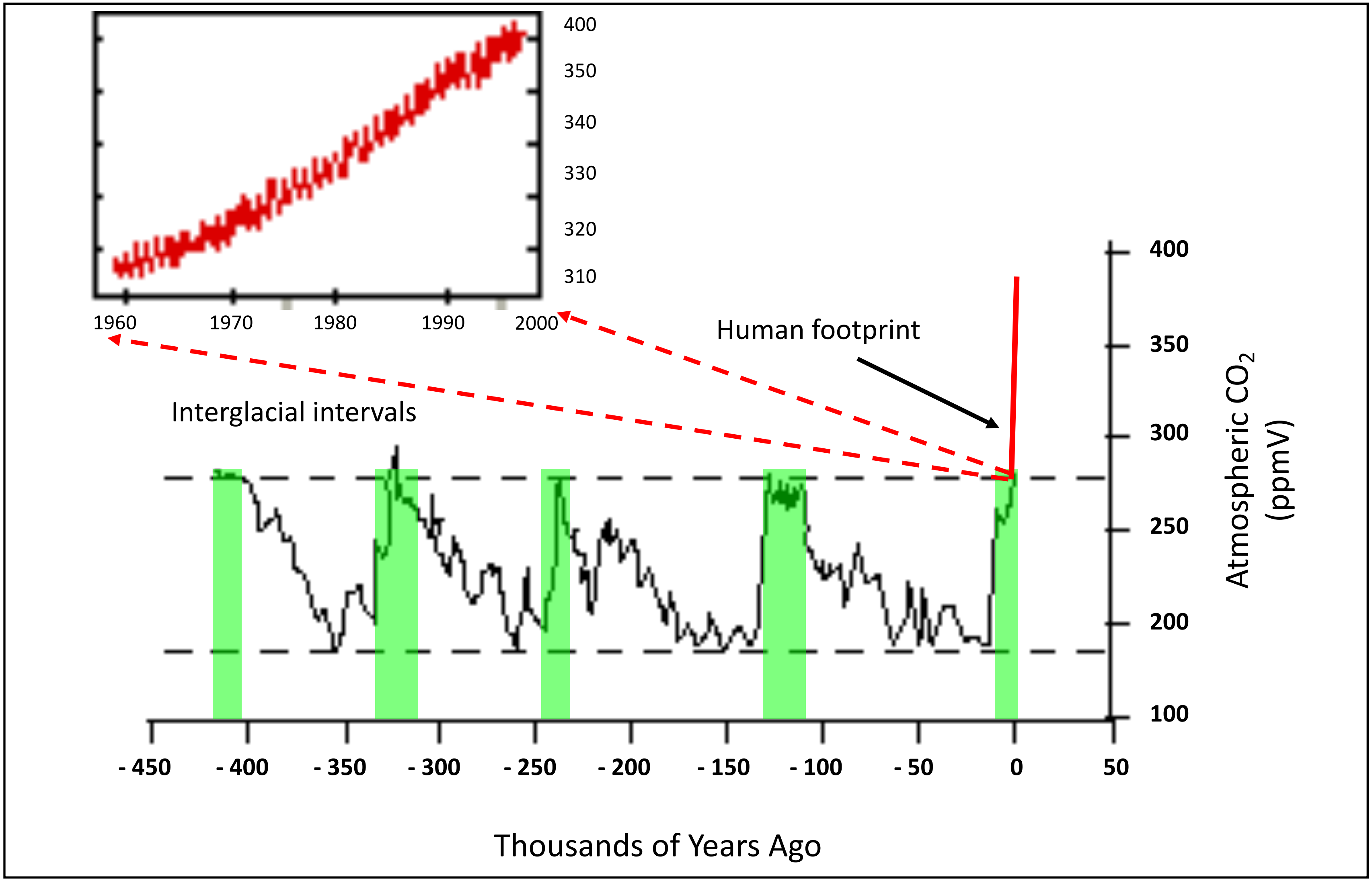


Present-day atmospheric levels of carbon dioxide, methane, and nitrous oxide are notably higher than their pre-industrial averages of 280 ppm CO_2 (left), 700 ppb CH_4 (right), and 270 ppb N_2O (left)..

Scripps Institution of Oceanography and NOAA Earth Systems Research Laboratory). USGCRP 2014.

Chemistry: Atmospheric CO_2

A 450 Thousand Year Record in the Vostok Ice Core



From Petit et al. 1999 (Nature 399, 429-436)

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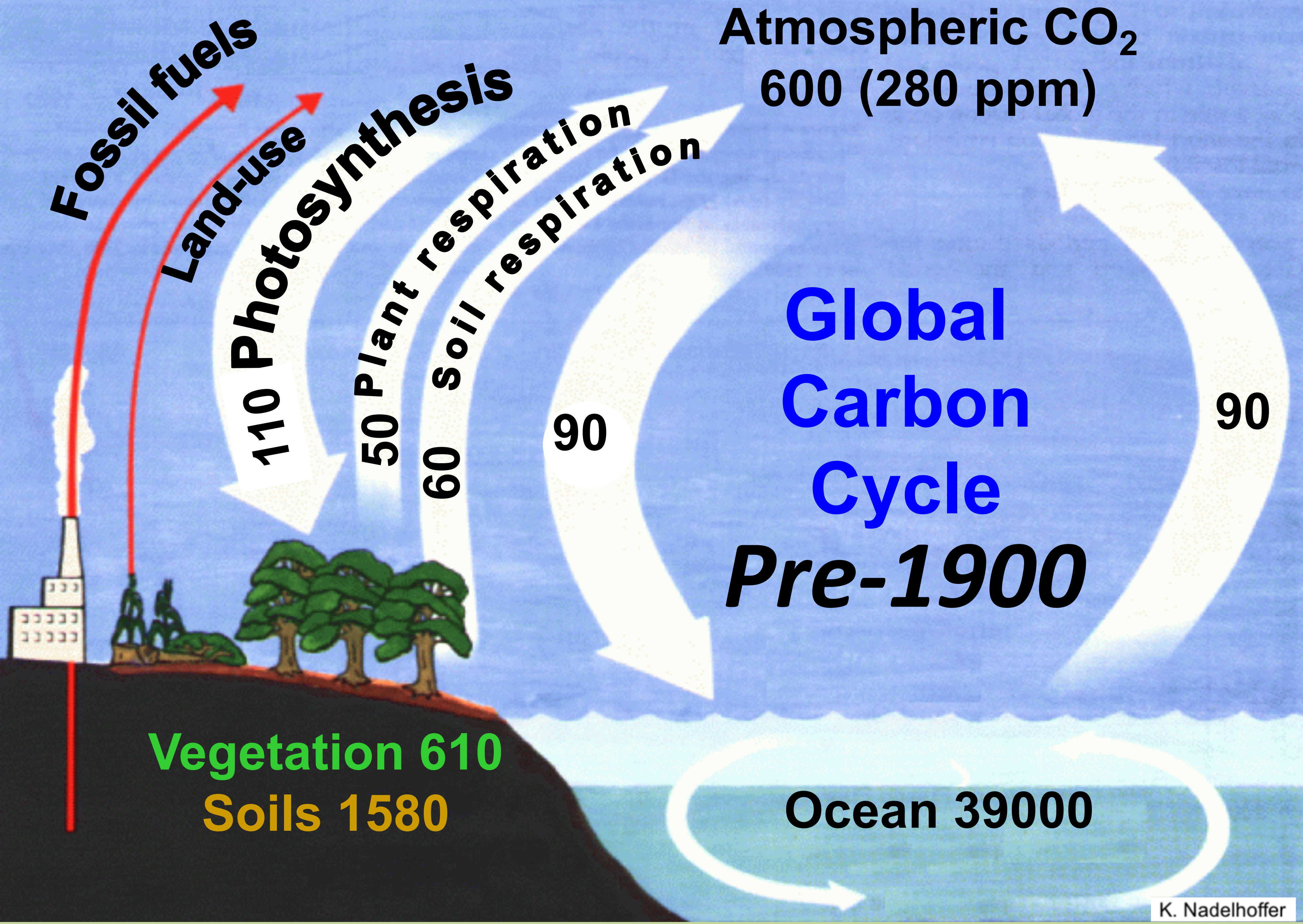
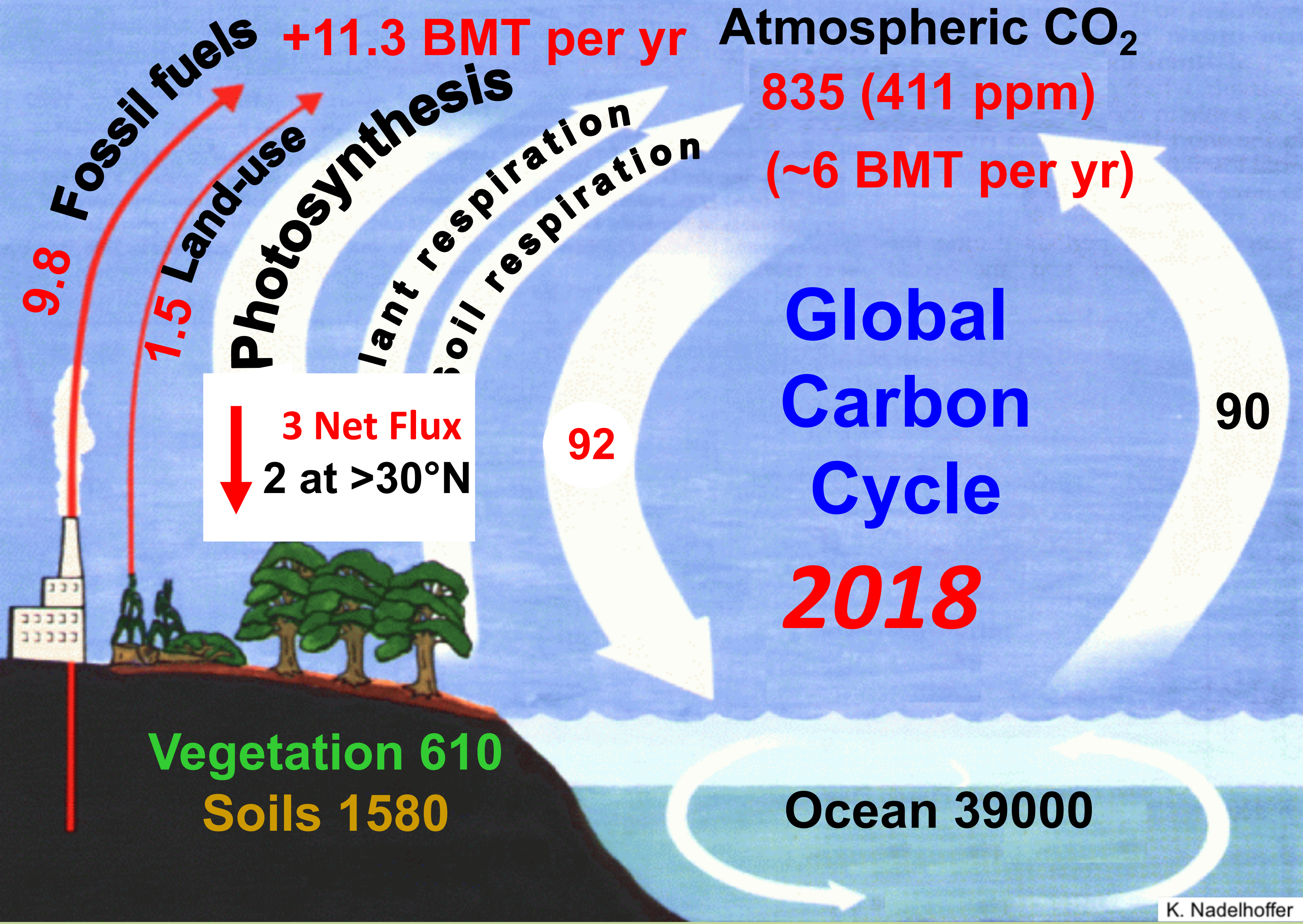
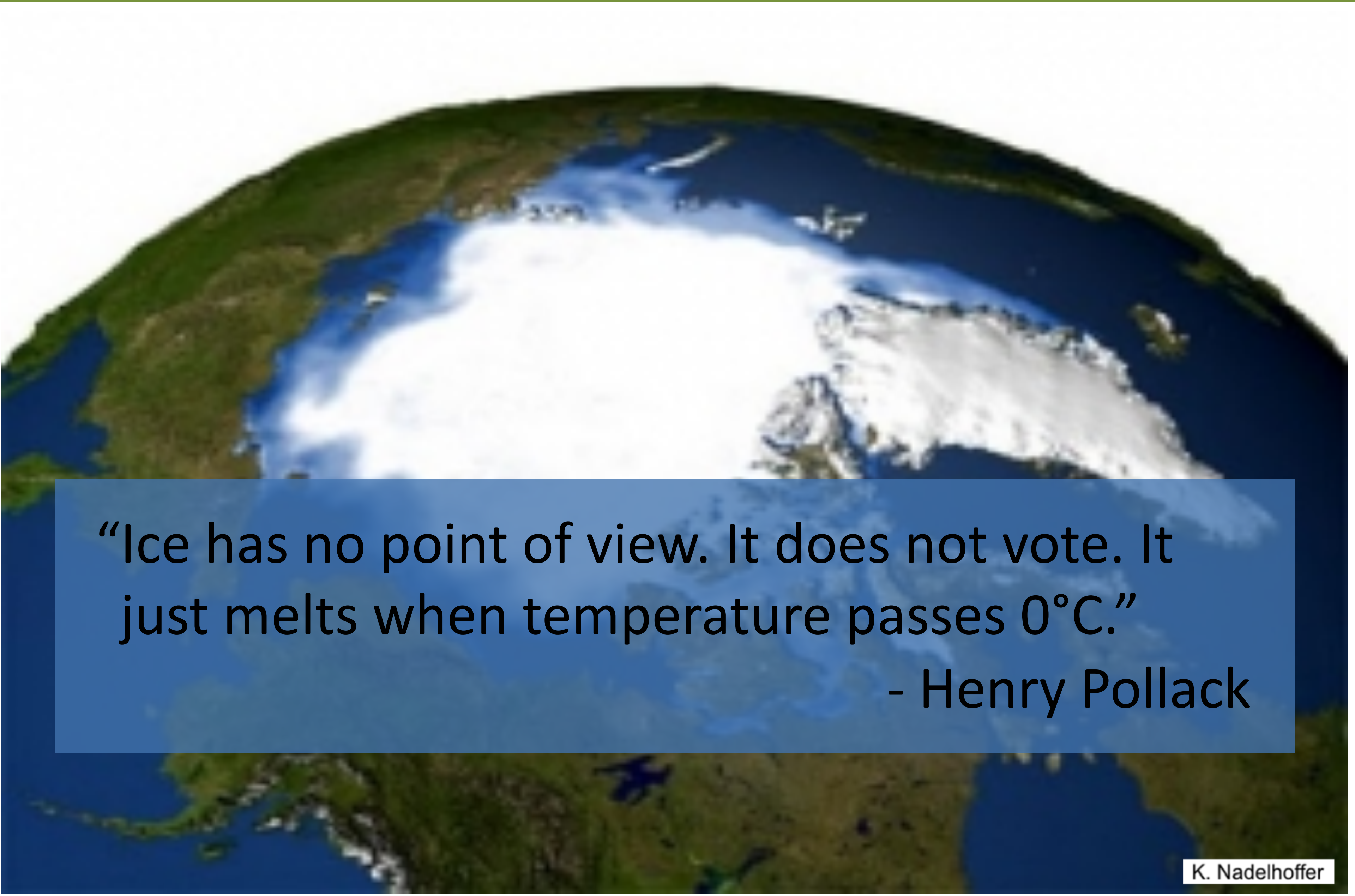


Stocks are <u>billion metric tons</u> C (BMTs); Rates (arrows) are BMTs C per year



Stocks are <u>billion metric tons</u> C (BMTs); Rates (arrows) are BMTs C per year

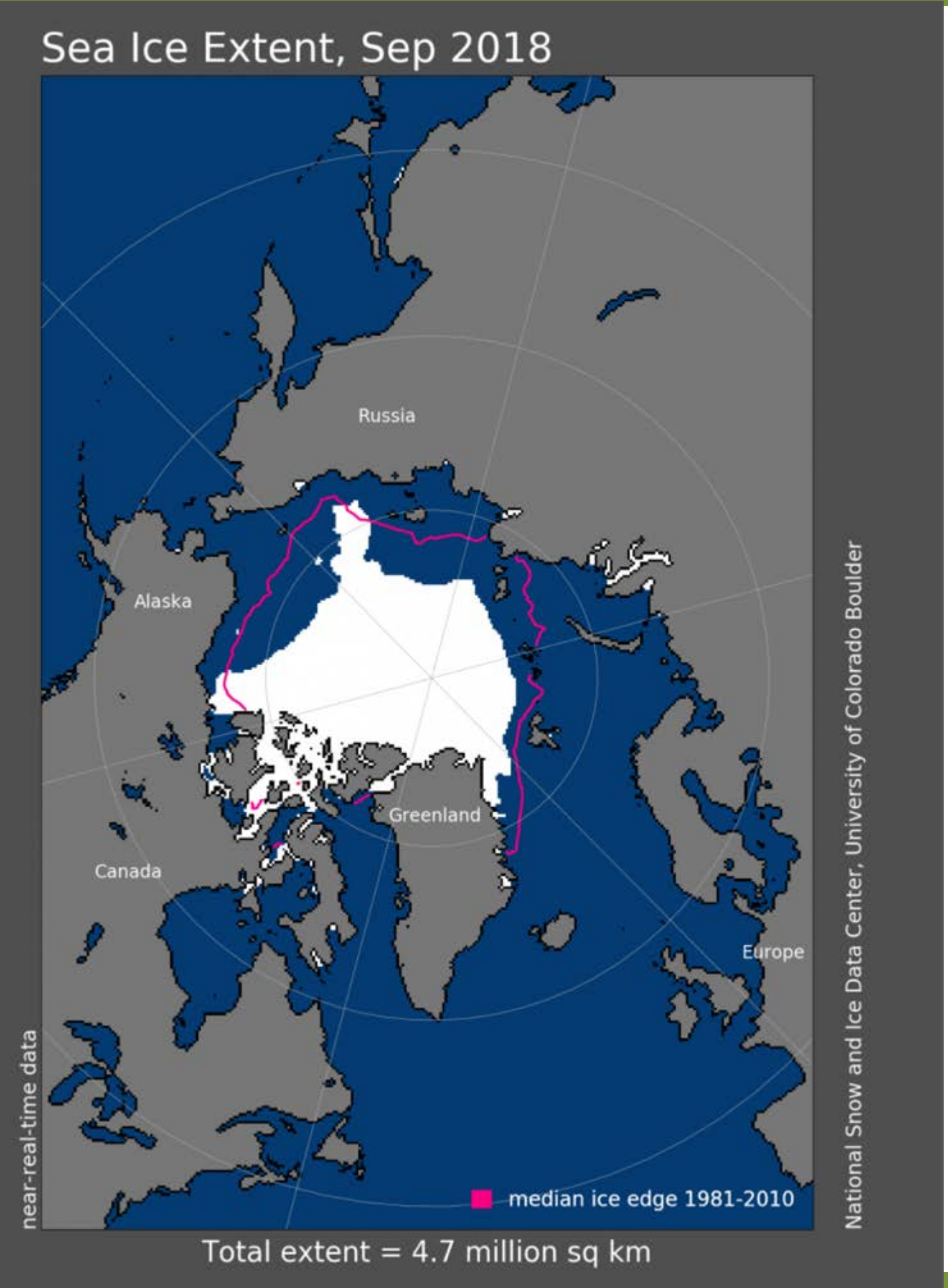
Climate



"Ice has no point of view. It does not vote. It just melts when temperature passes 0°C."

- Henry Pollack

Climate



Arctic Sea Ice Cover

September 2018 Minimum

- The magenta line is the 1979 to 2000 average for September
- The September 2018, sea ice averaged to 4.71 million km^2 (1.82 million $miles^2$).
- This the 6th lowest ice cover in the 39-year satellite record and is about 1.7 million km^2 below the 1981-2010 average.
- The area without ice is more than 11x Michigan's land area (~146,400 km^2)

Source- http://nsidc.org/arcticseaicenews/

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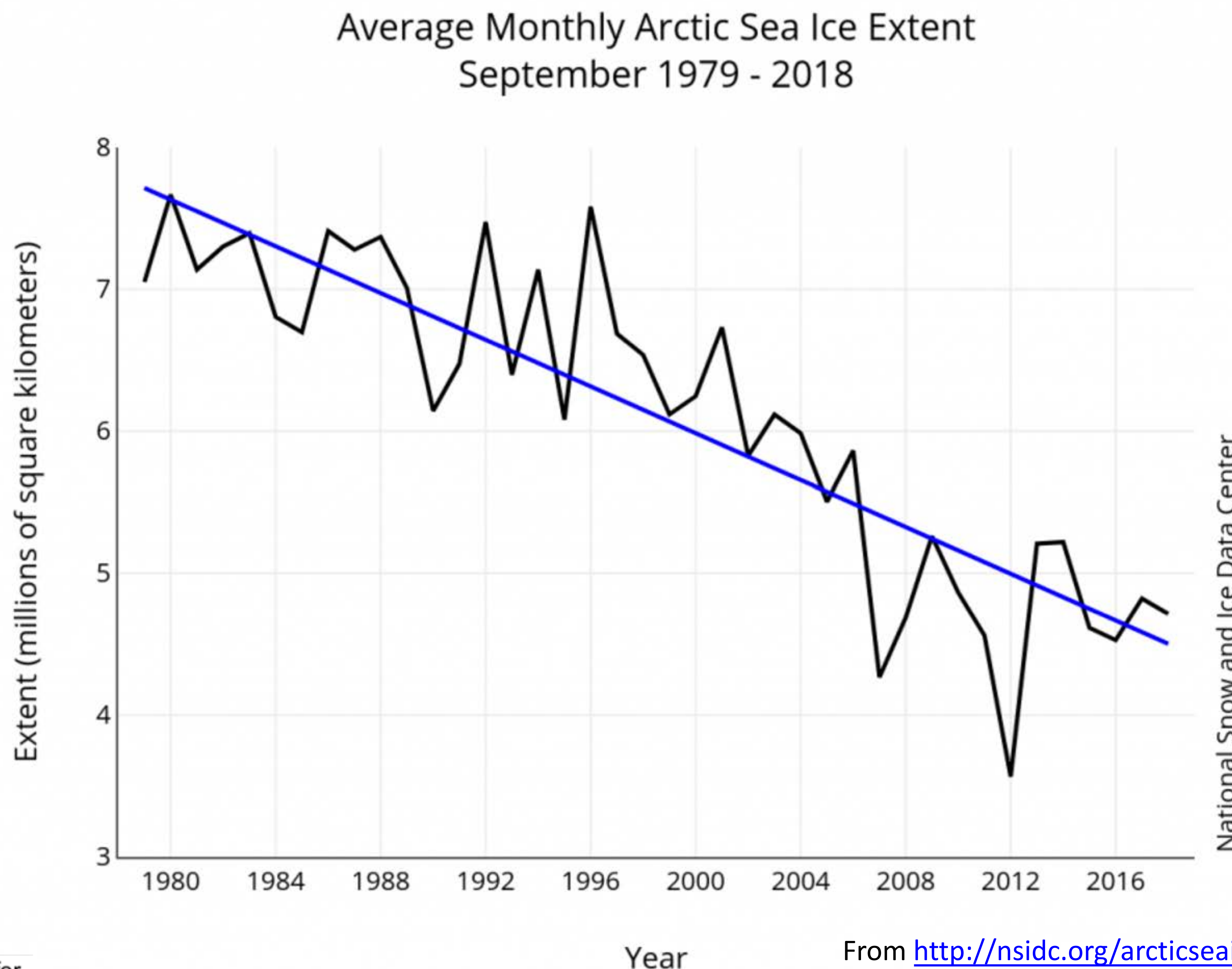
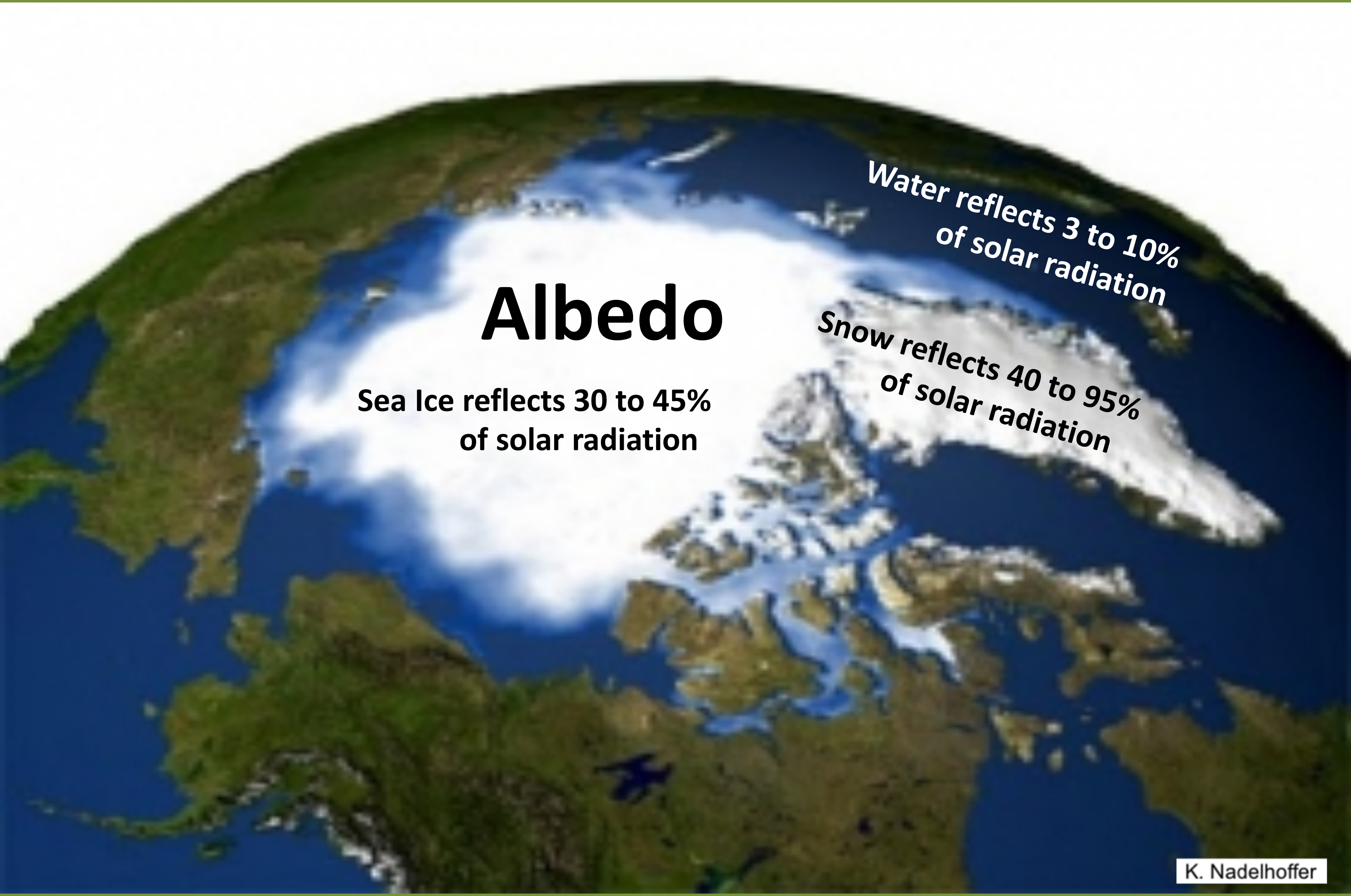
Climate



From http://nsidc.org/arcticseaicenews/

Physics


Albedo
Sea Ice reflects 30 to 45% of solar radiation
Water reflects 3 to 10% of solar radiation
Snow reflects 40 to 95% of solar radiation
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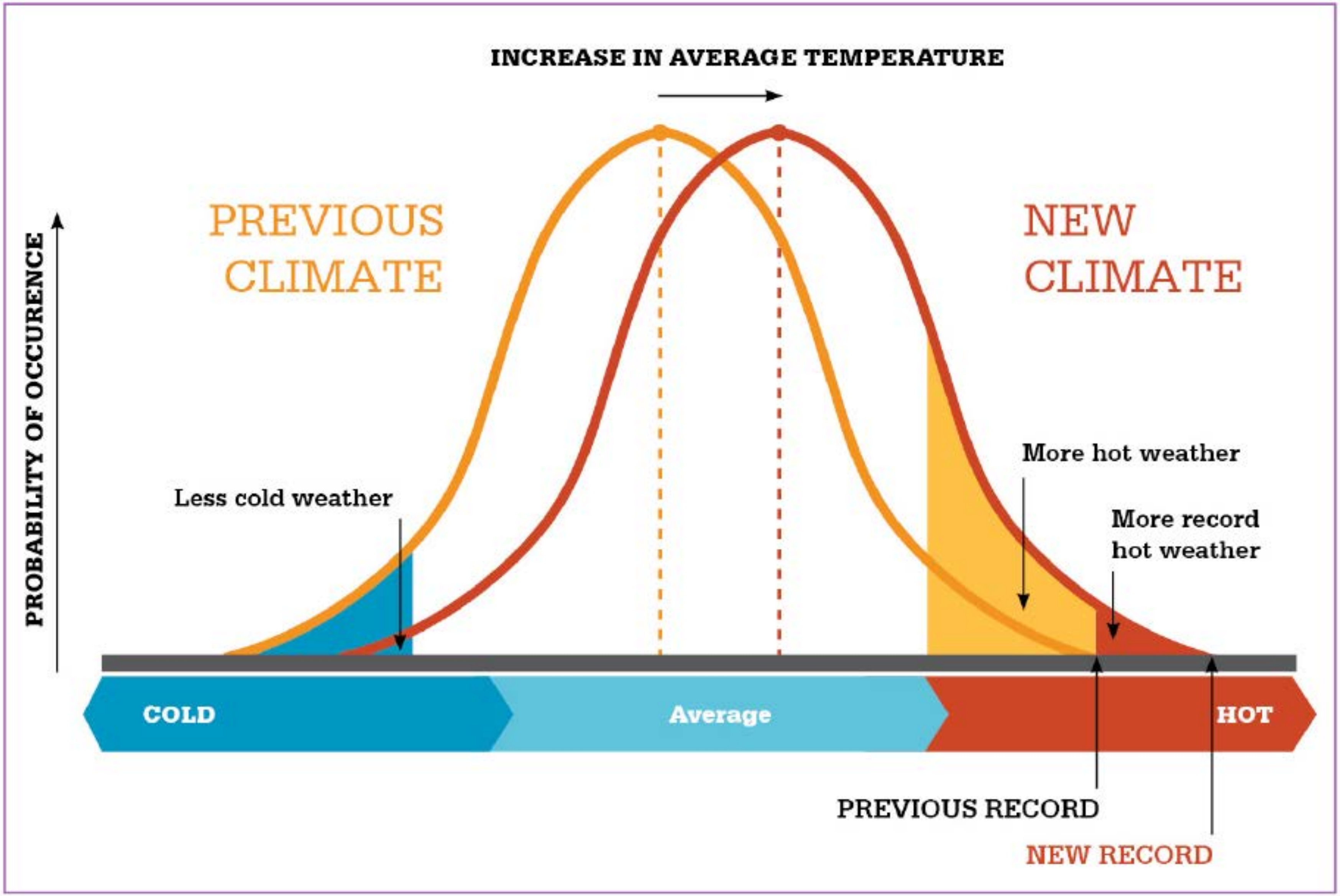
Climate



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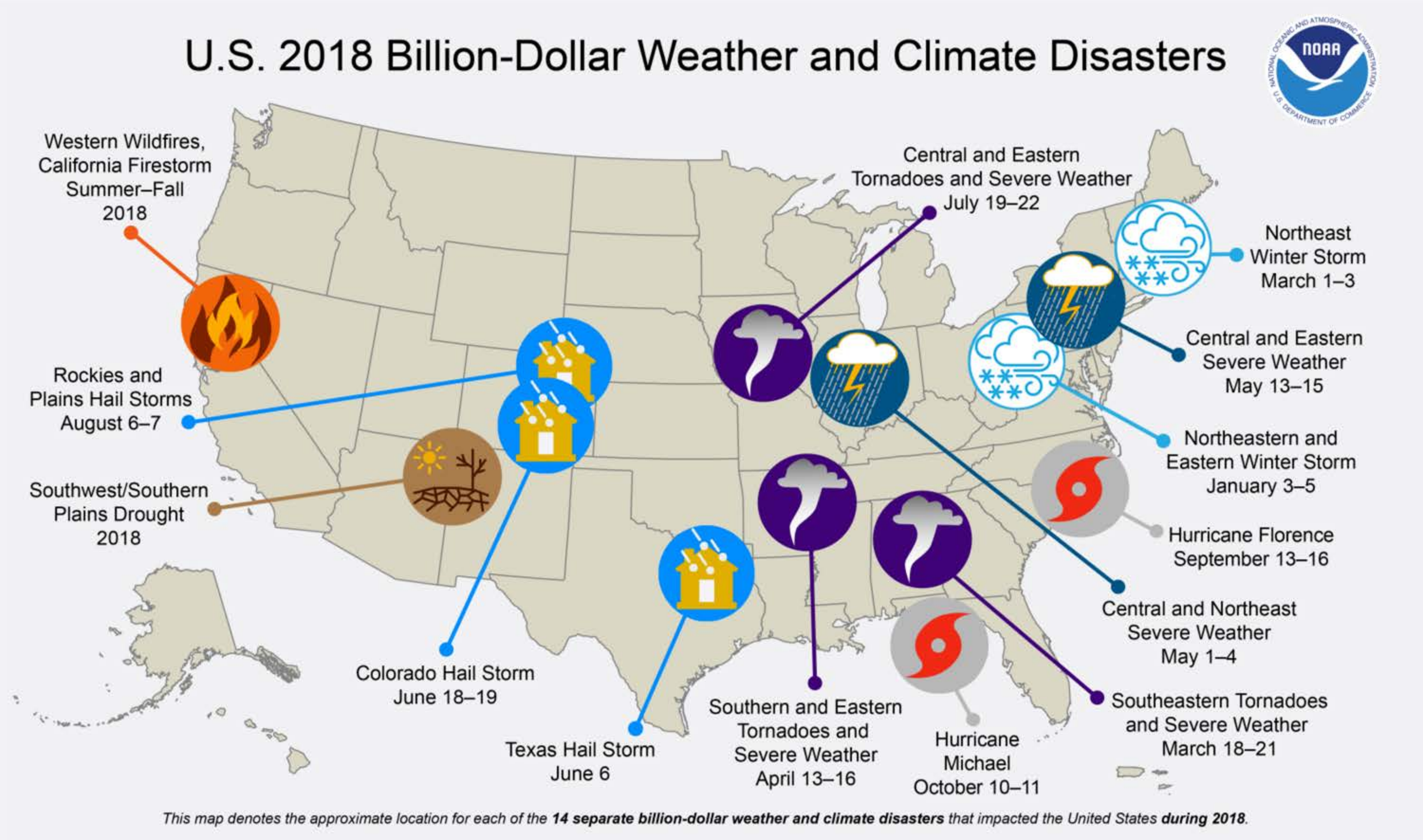
Source: Modified from IPCC, 2007 http://www.climateprediction.net/wp-content/projects/temperature-distribution-australia.jpg

Locations of 14 $1B or greater U.S. Climate Disasters in 2018



https://www.climate.gov/news-features/blogs/beyond-data/2018s-billion-dollar-disasters-context

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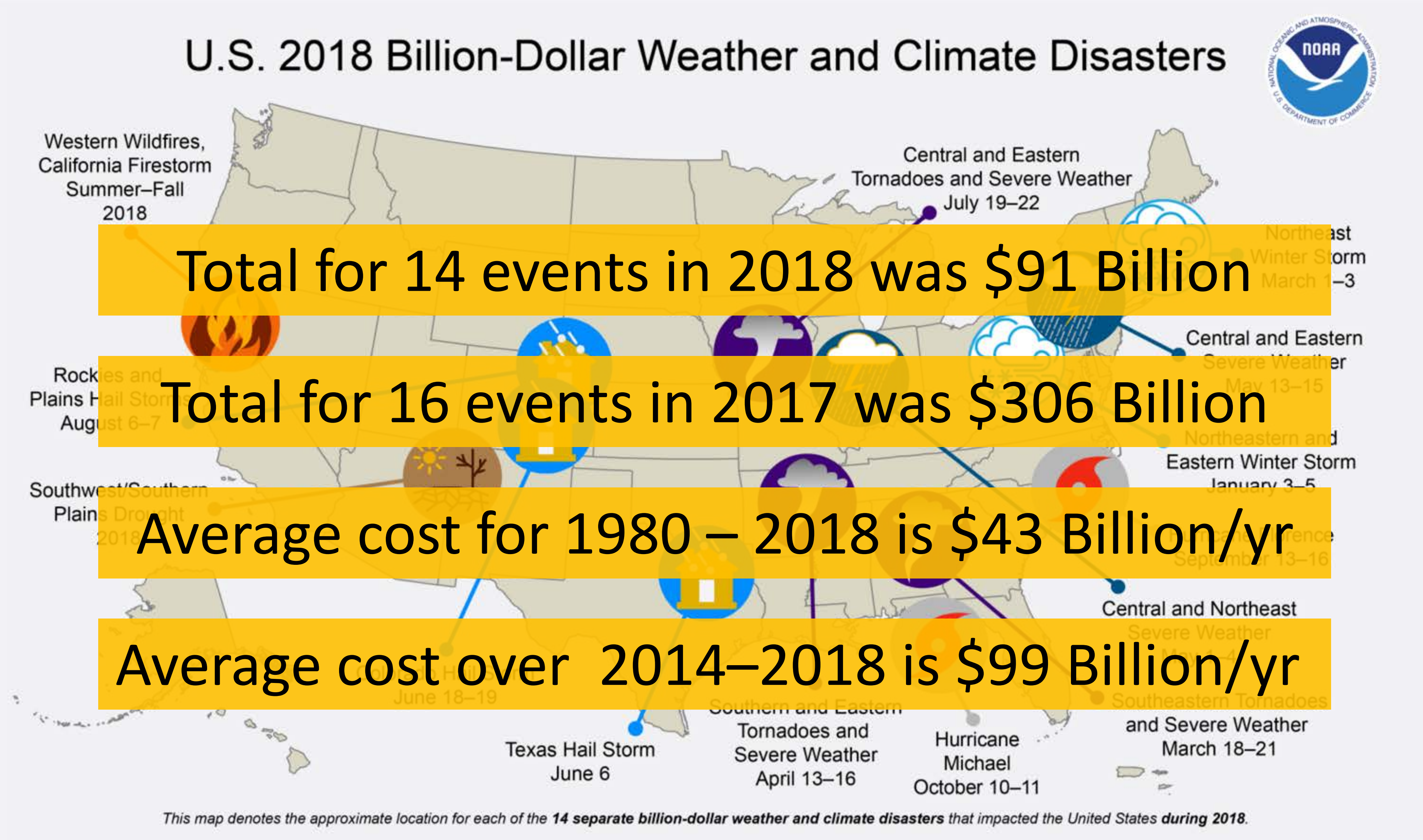
Locations of 14 $1B or greater U.S. Climate Disasters in 2018



This map denotes the approximate location for each of the ***14 separate billion-dollar weather and climate disasters*** *that impacted the United States* ***during 2018****.*

Total for 14 events in 2018 was $91 Billion

Total for 16 events in 2017 was $306 Billion

Average cost for 1980 – 2018 is $43 Billion/yr

Average cost over 2014–2018 is $99 Billion/yr

https://www.climate.gov/news-features/blogs/beyond-data/2018s-billion-dollar-disasters-context

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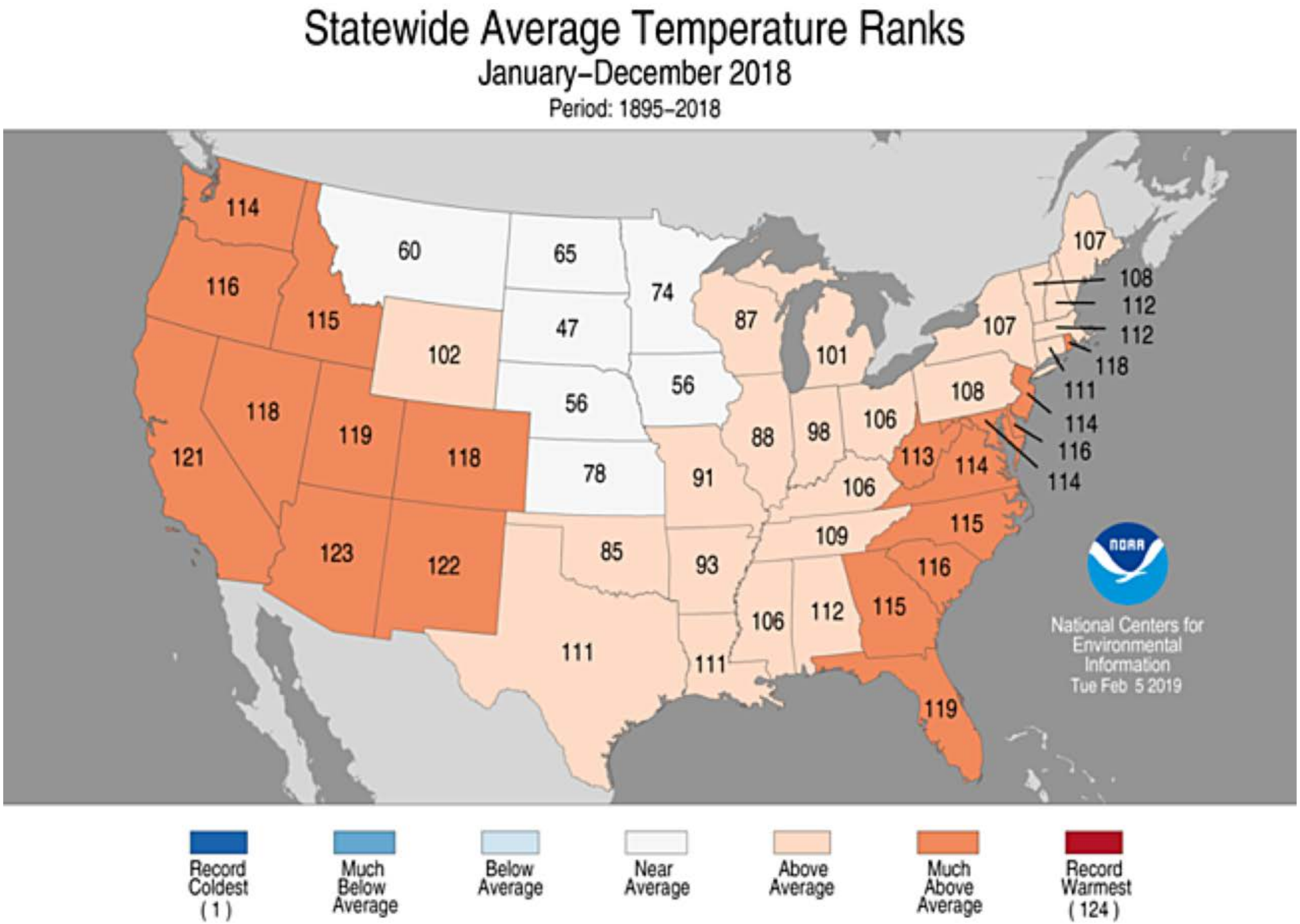
U.S. Temperature in 2018



https://www.ncei.noaa.gov/news/national-climate-201812

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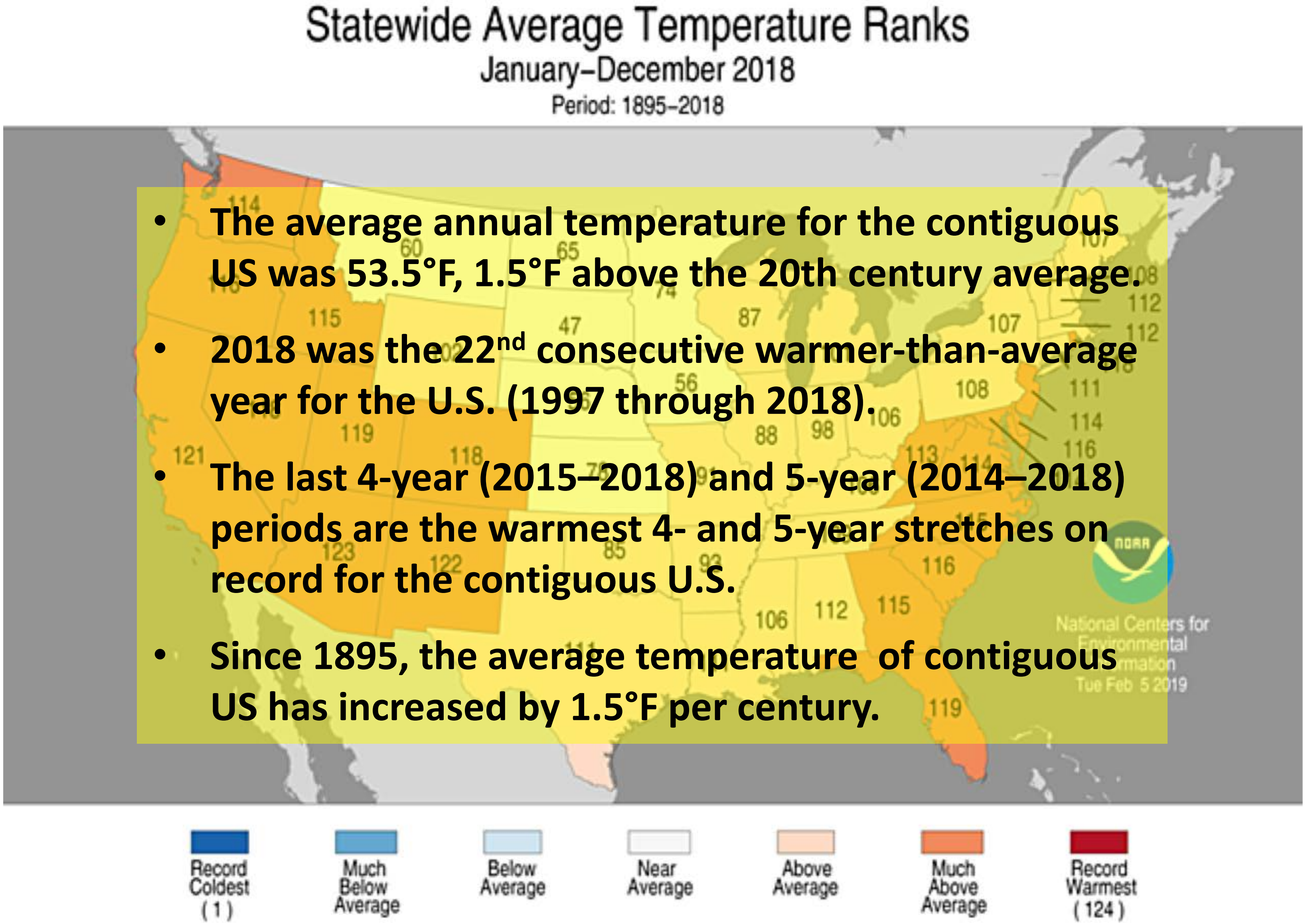
U.S. Temperature in 2018



- **The average annual temperature for the contiguous US was 53.5°F, 1.5°F above the 20th century average.**
- **2018 was the 22nd consecutive warmer-than-average year for the U.S. (1997 through 2018).**
- **The last 4-year (2015–2018) and 5-year (2014–2018) periods are the warmest 4- and 5-year stretches on record for the contiguous U.S.**
- **Since 1895, the average temperature of contiguous US has increased by 1.5°F per century.**

https://www.ncei.noaa.gov/news/national-climate-201812

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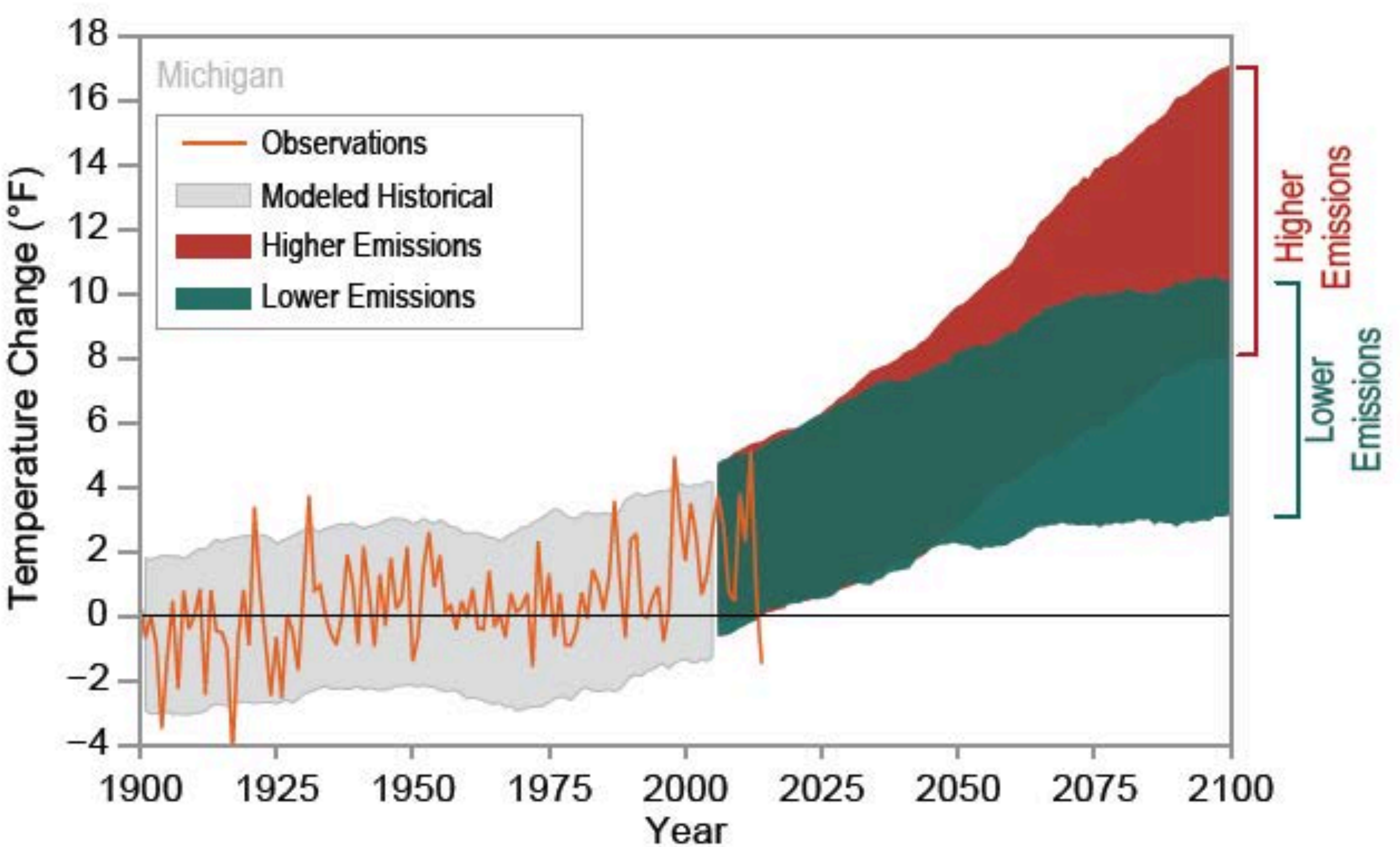
Michigan's Climate, so far & the future

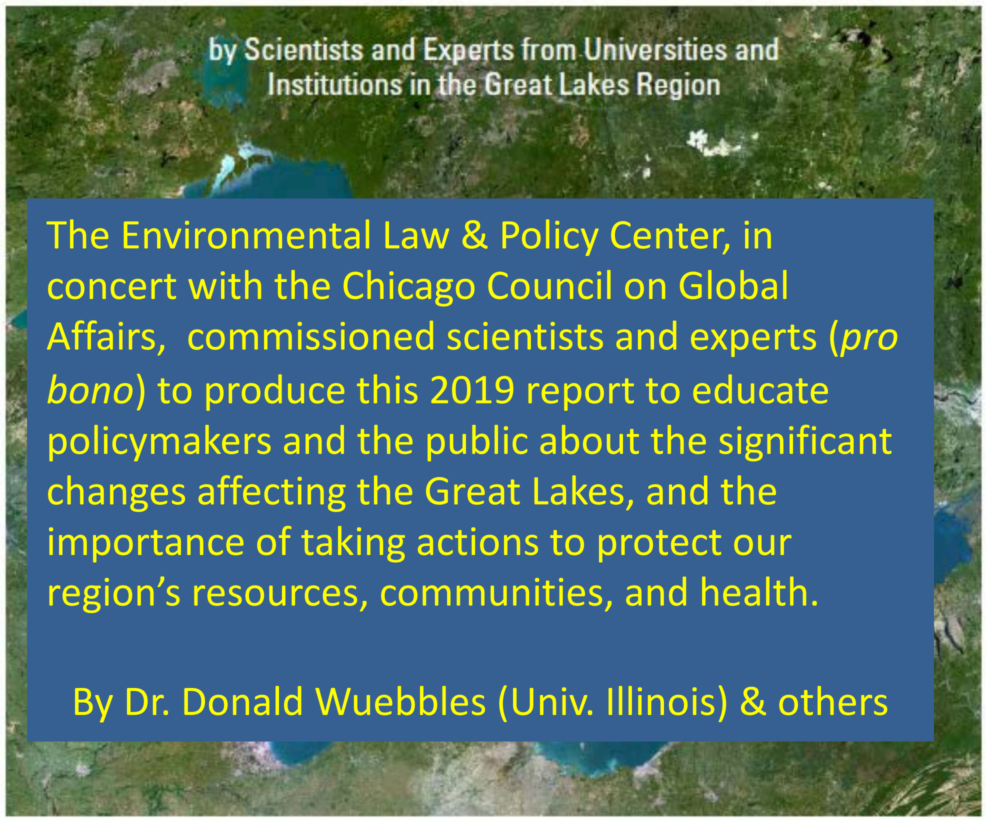
Observed and Projected Temperature Change in Michigan



Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Michigan. Observed data are for 1900–2014. *From* https://statesummaries.ncics.org/mi

Environmental Law & Policy Center

An Assessment of the Impacts of Climate Change on the Great Lakes



The Environmental Law & Policy Center, in concert with the Chicago Council on Global Affairs, commissioned scientists and experts (*pro bono*) to produce this 2019 report to educate policymakers and the public about the significant changes affecting the Great Lakes, and the importance of taking actions to protect our region's resources, communities, and health.

By Dr. Donald Wuebbles (Univ. Illinois) & others

Download the full report at:
http://elpc.org/wp-content/uploads/2019/03/Great-Lakes-Climate-Change-Report.pdf

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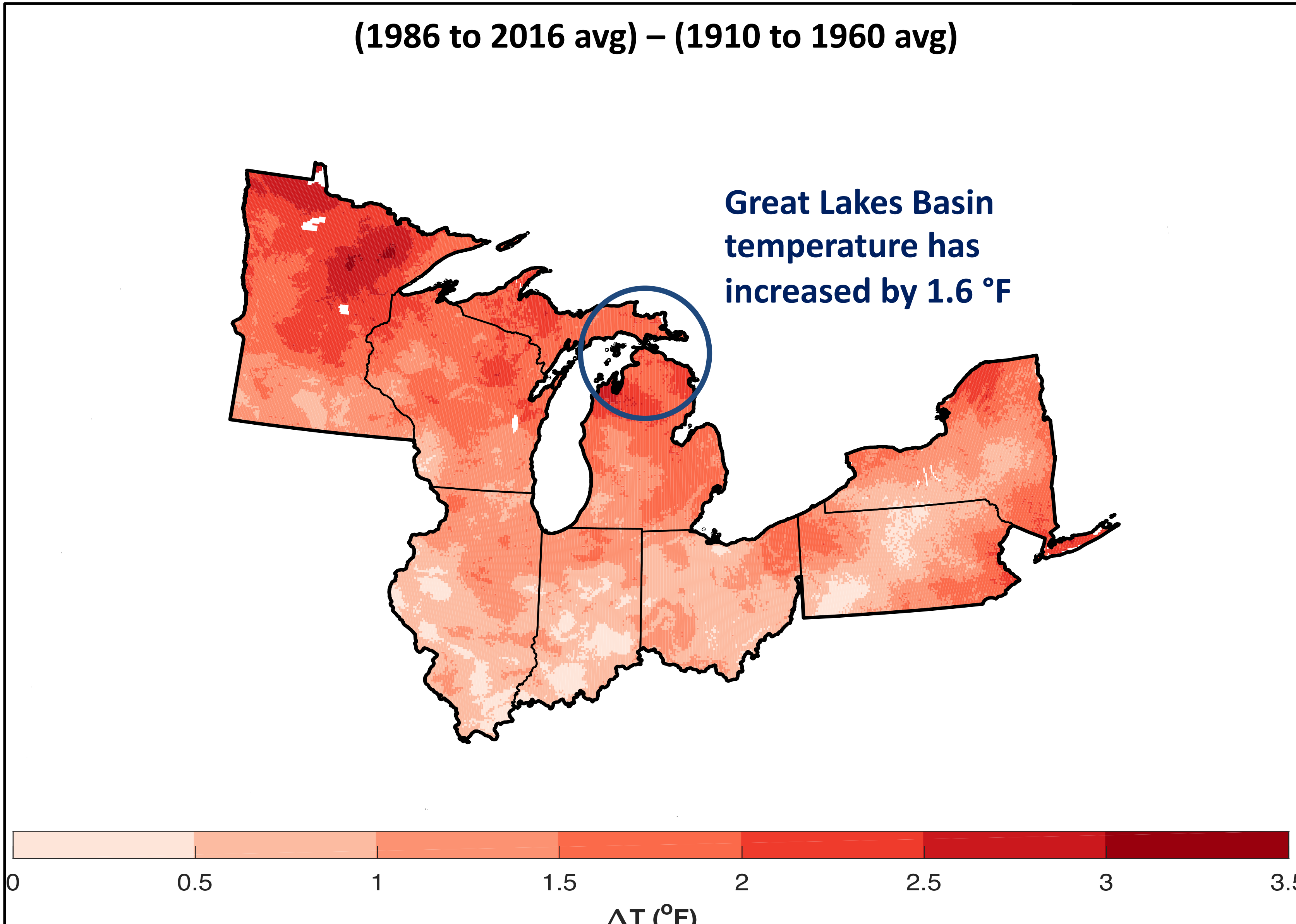
Temperature in U.S. states in Great Lakes region has changed by 1.4°F for 1985-2016 relative to 1901-1960



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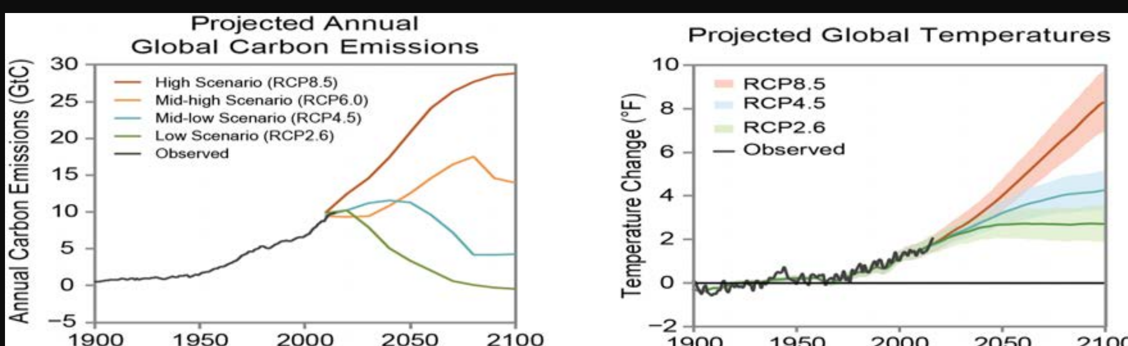
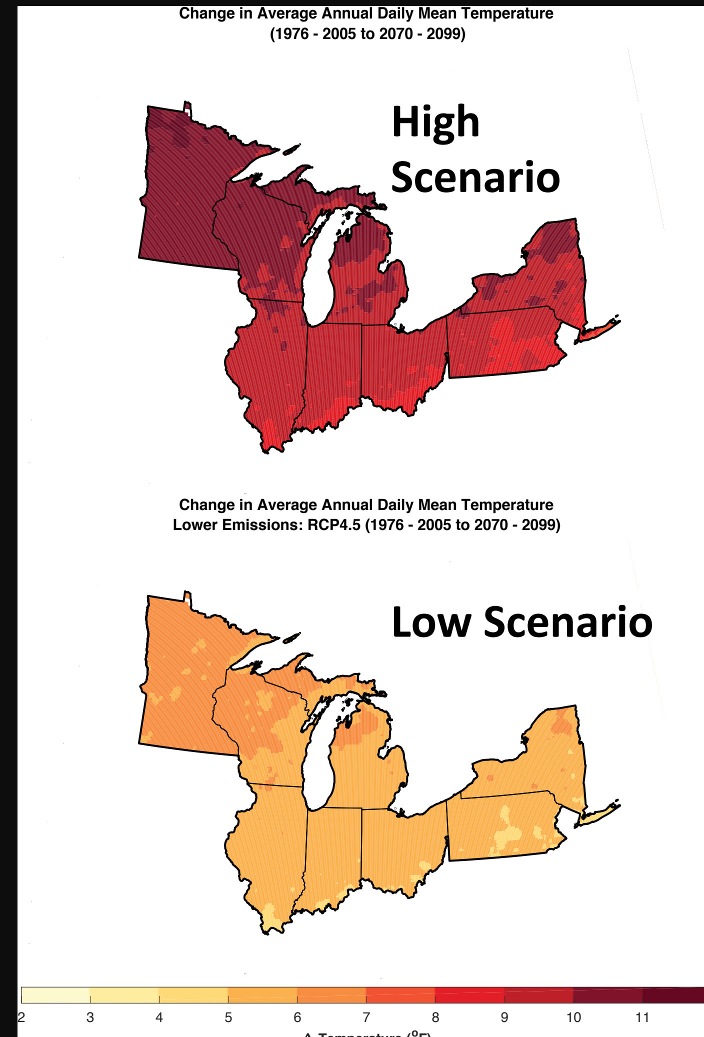
Projecting Future Climate in the Great Lakes Region

Projected changes for the 2085 (2070-2099) time period relative to 1976-2005 are 9.8°F for the High Scenario and 5.7°F for the Low.





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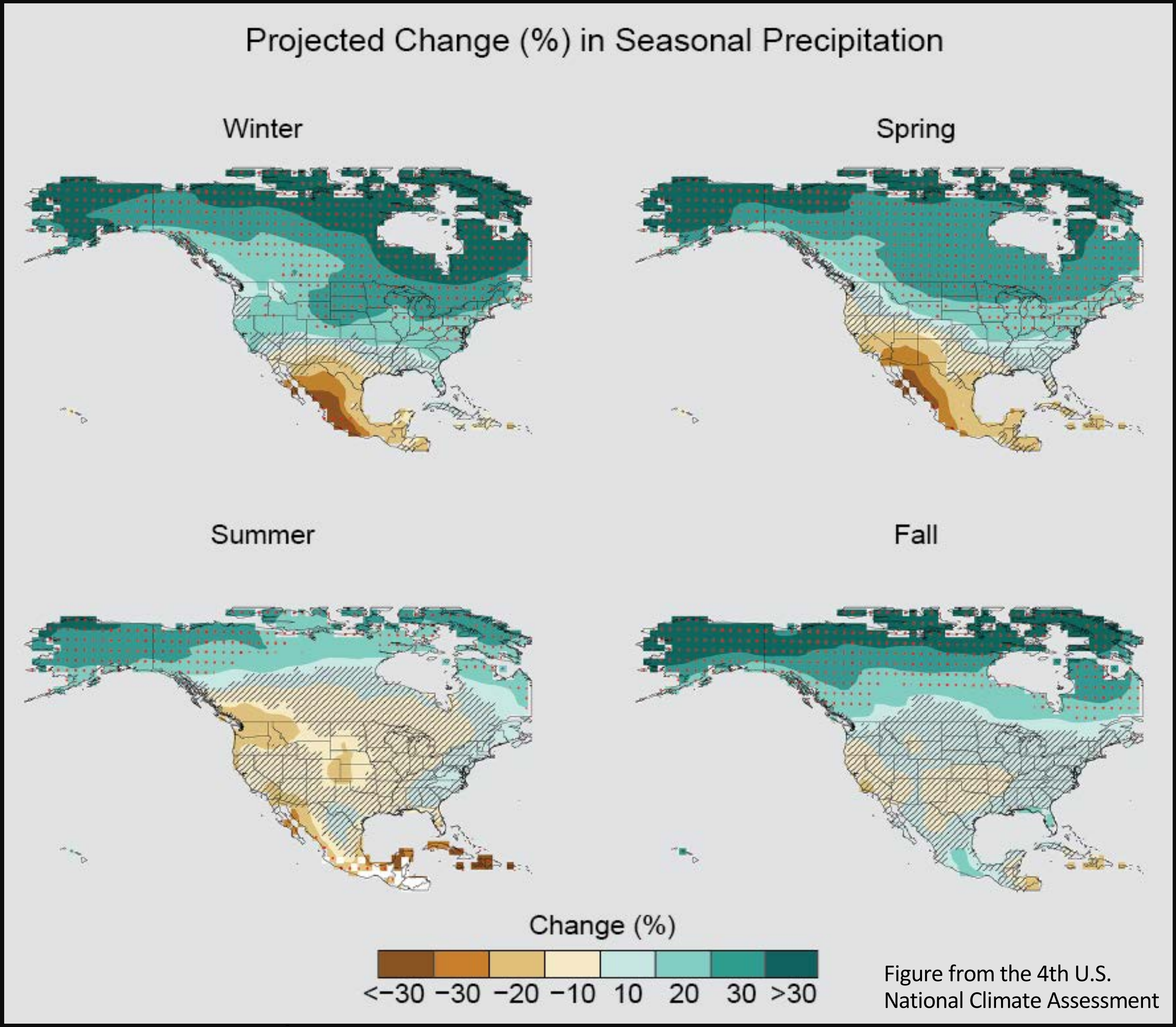
Projected U.S. Precipitation Change

2070-2099 relative to 1975-2005 for RCP8.5 (High scenario)



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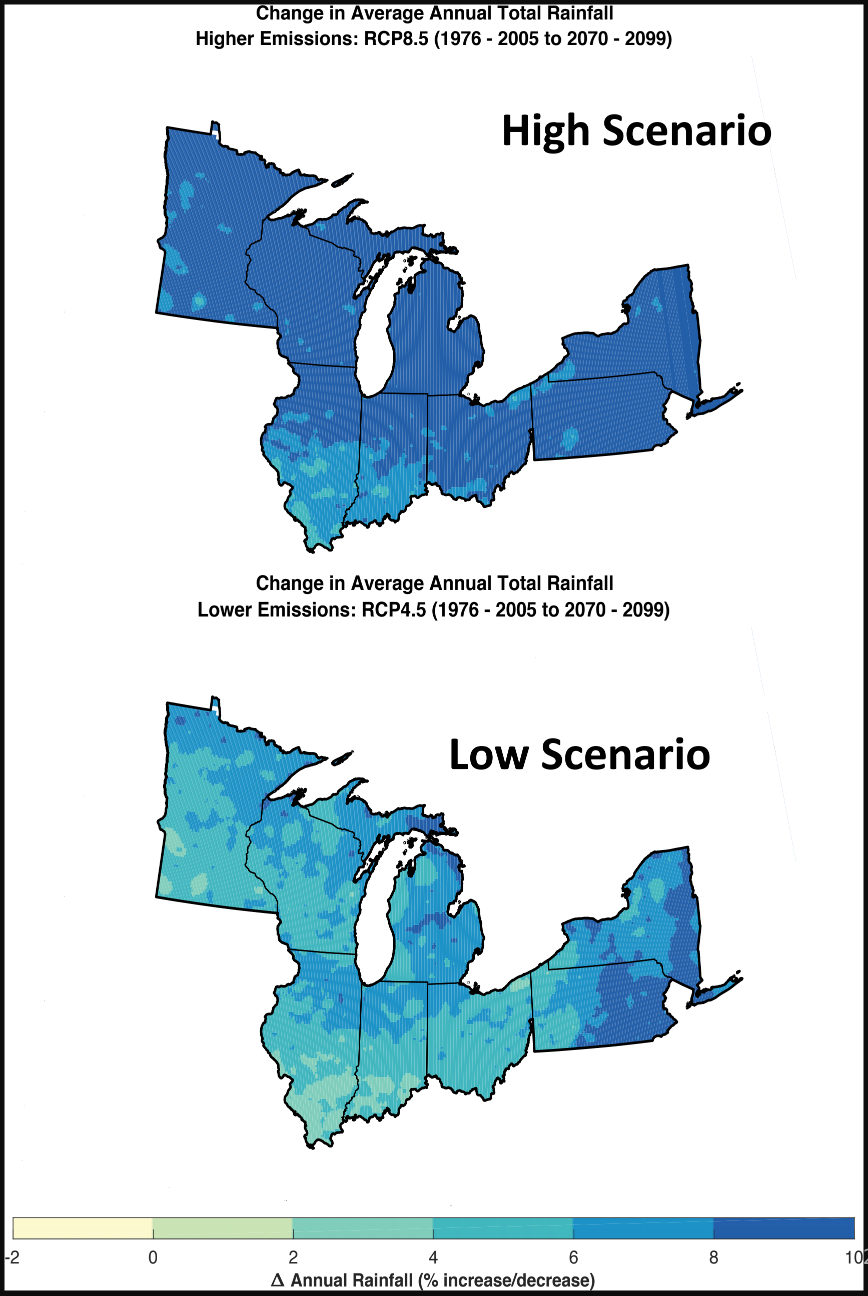
Precipitation: The Great Lakes Region

- Precipitation has increased by almost 10% in the Great Lakes region
- Projected increased precipitation for the 2070-2099 time period relative to 1976-2005 by as much as another 10%
- Increasing trends for precipitation coming as larger events will continue.
- Up to19% more precipitation for 5-year return events (1 in 5 years) by 2070-2099.



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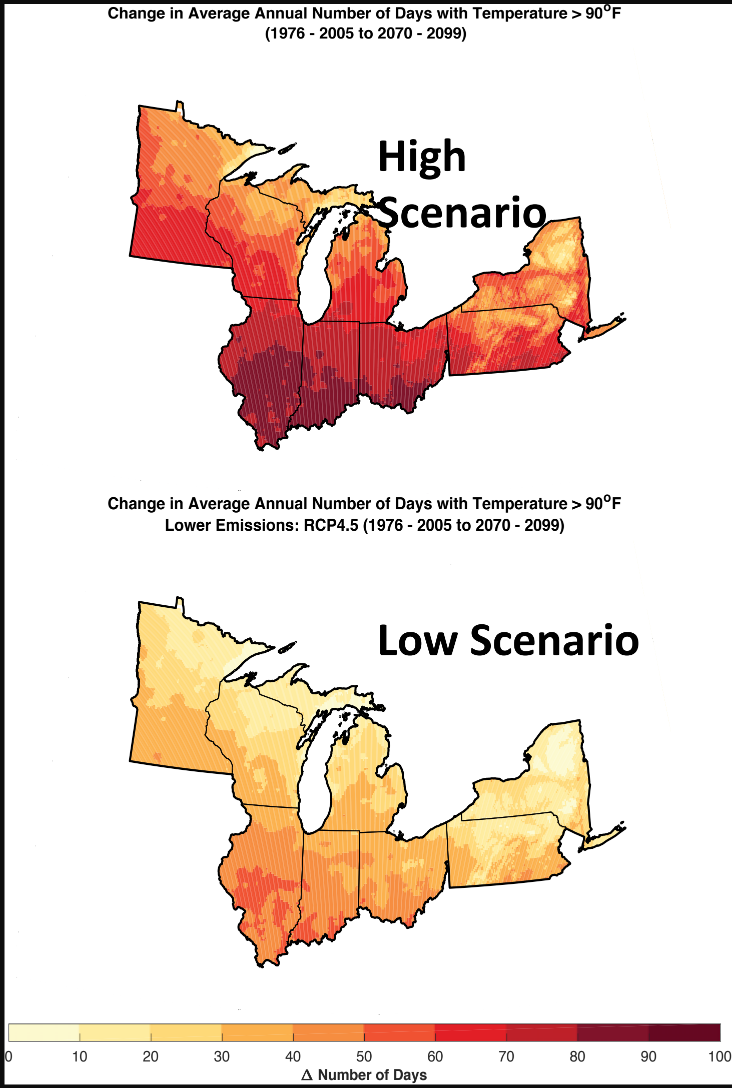
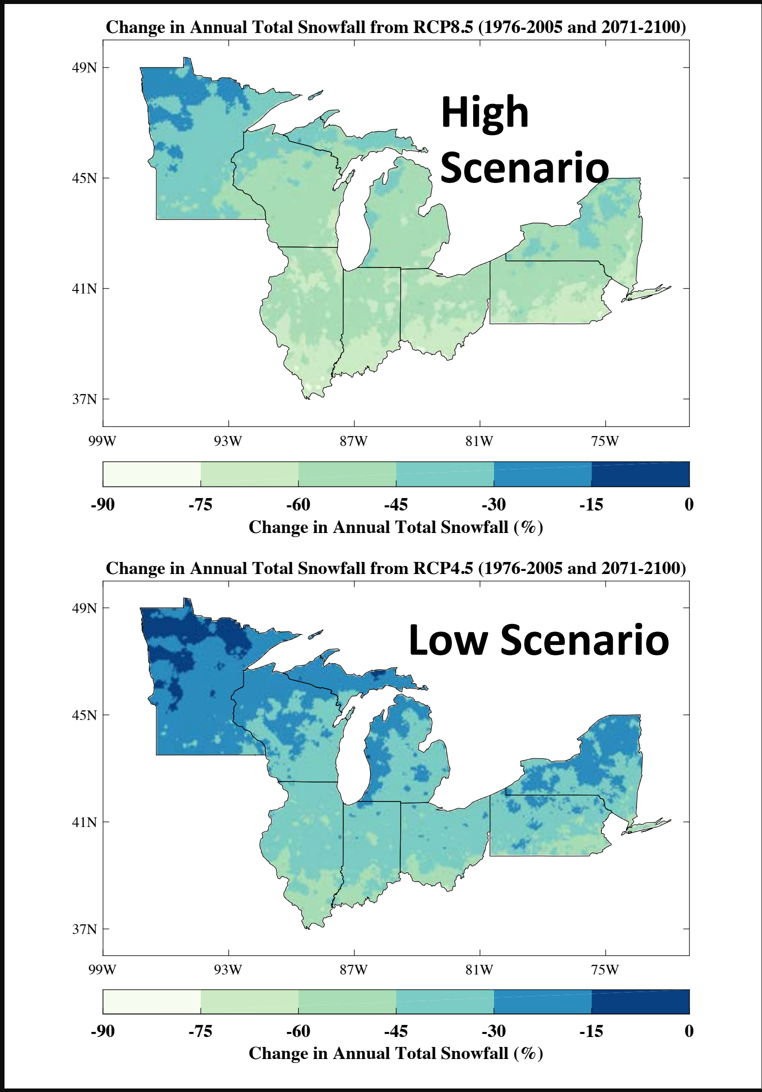
Temperature Extremes

- Days with Maximum temperature >90°F likely to increase significantly, especially under the high scenario.
- Days <32°F likely to decrease significantly (45-55 days by 2070-2100 under the high scenario and 25-35 days under the low scenario)



Snowfall in the Great Lakes Region

- Total amount of snowfall likely to decrease, especially under the high scenario (30-60% by 2070-2100)
- Lake effects snowfall may actually increase.



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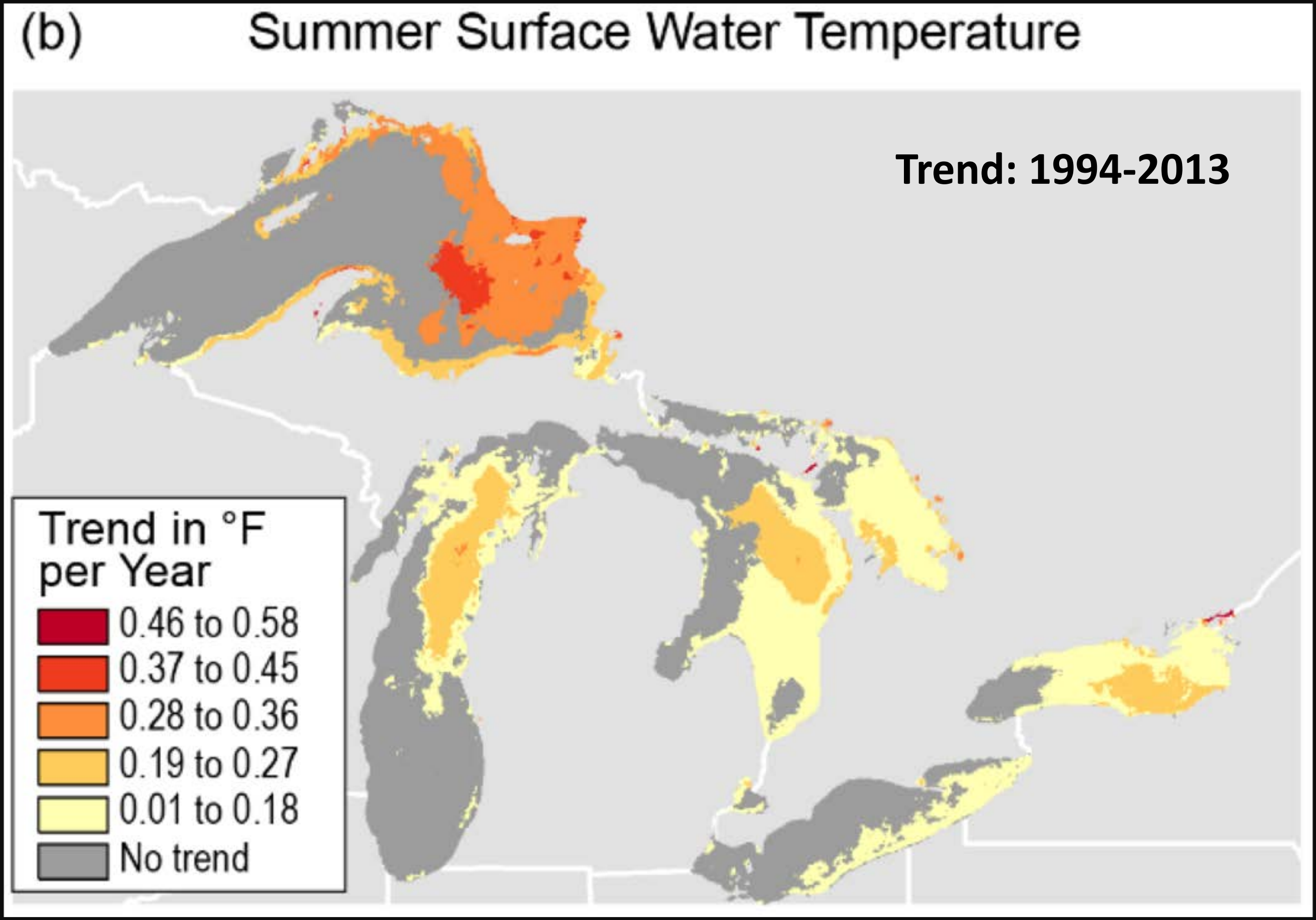
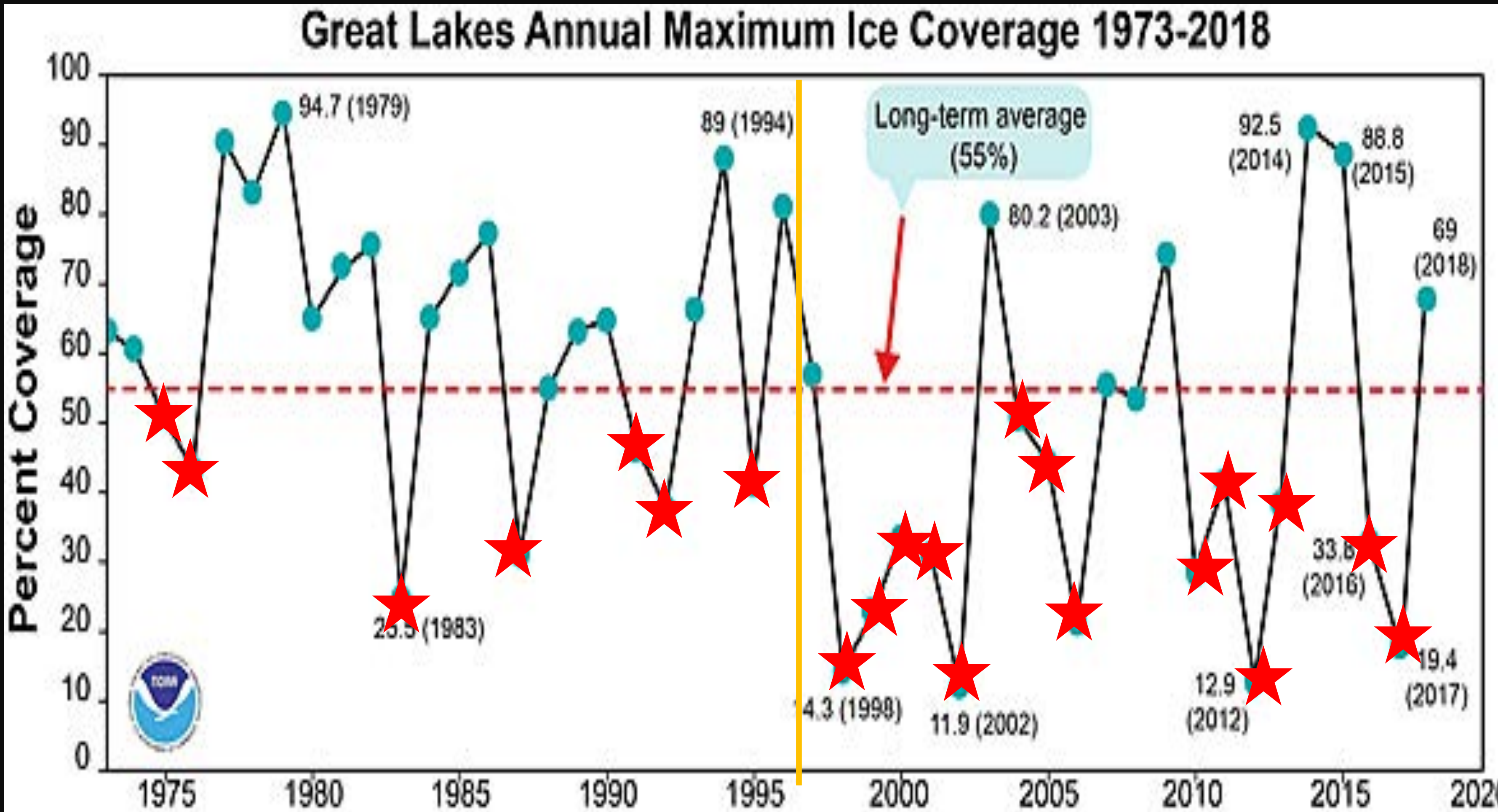
Changes in the Great Lakes: Water Temperature

- **<u>Summer Water Temperatures</u> in Great Lakes have increased over the last 6 decades**
  - **Expected to continue to increase.**
- Greatest rates of increase in deeper water, with smaller increases near shorelines.





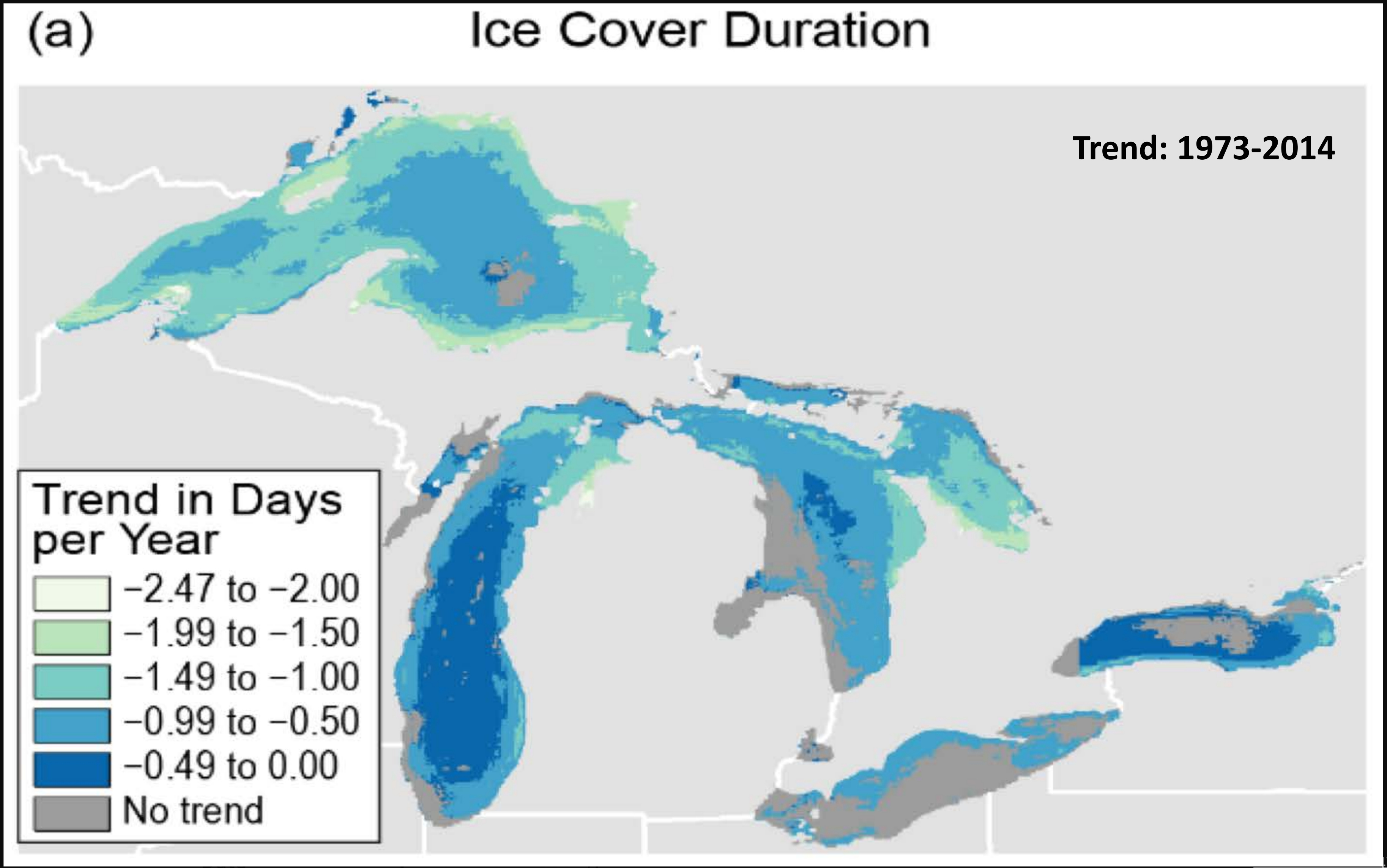
1973 – 1996:
Below Average Ice Cover in 7 of 23 years

1997 – 2018:
Below Average Ice Cover in 14 of 23 years

Source: NOAA GLERL.

Changes in the Great Lakes: Duration of Ice Cover

Duration of Ice Cover has decreased over at least the last 4 decades.



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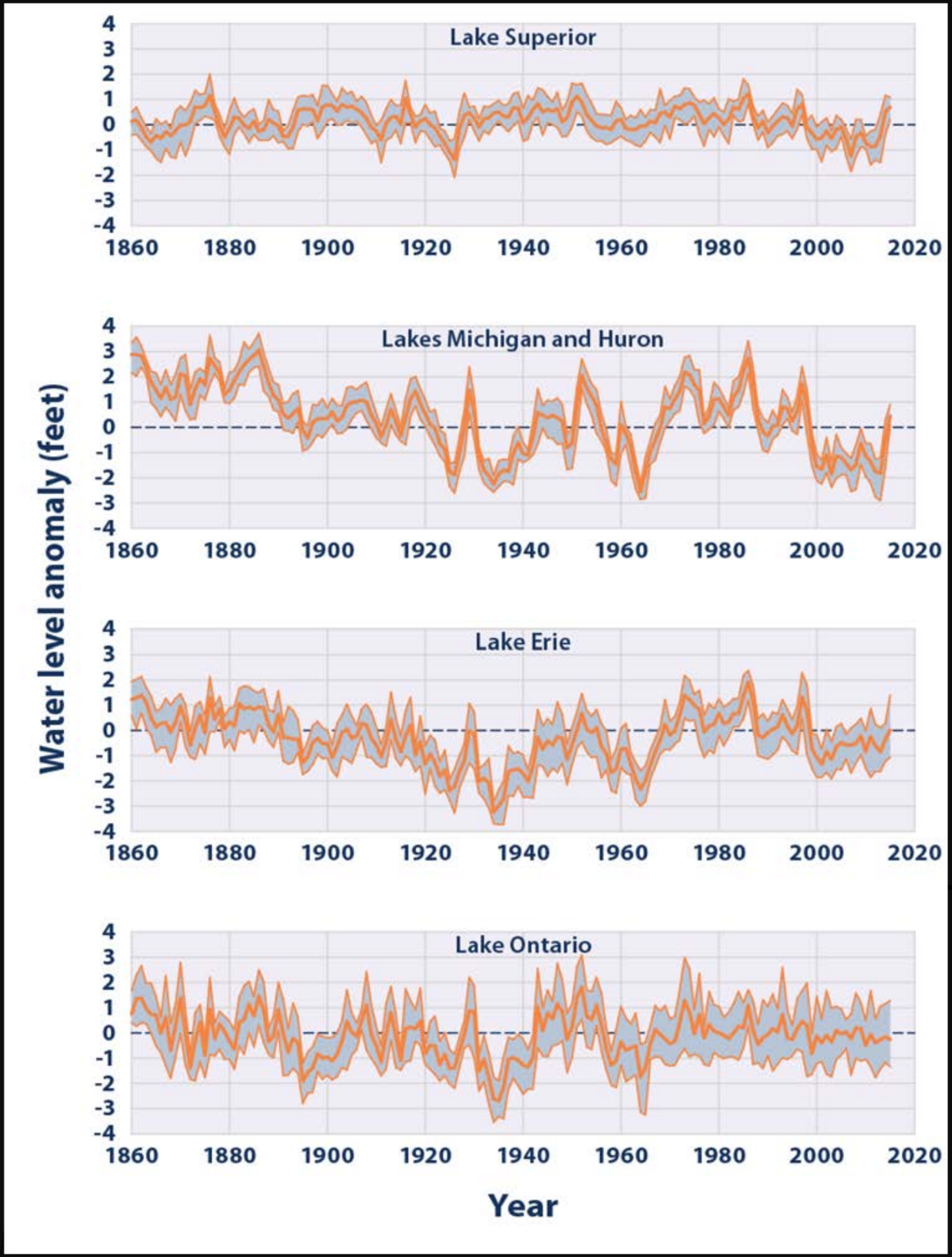
Changes in the Great Lakes: Water Levels

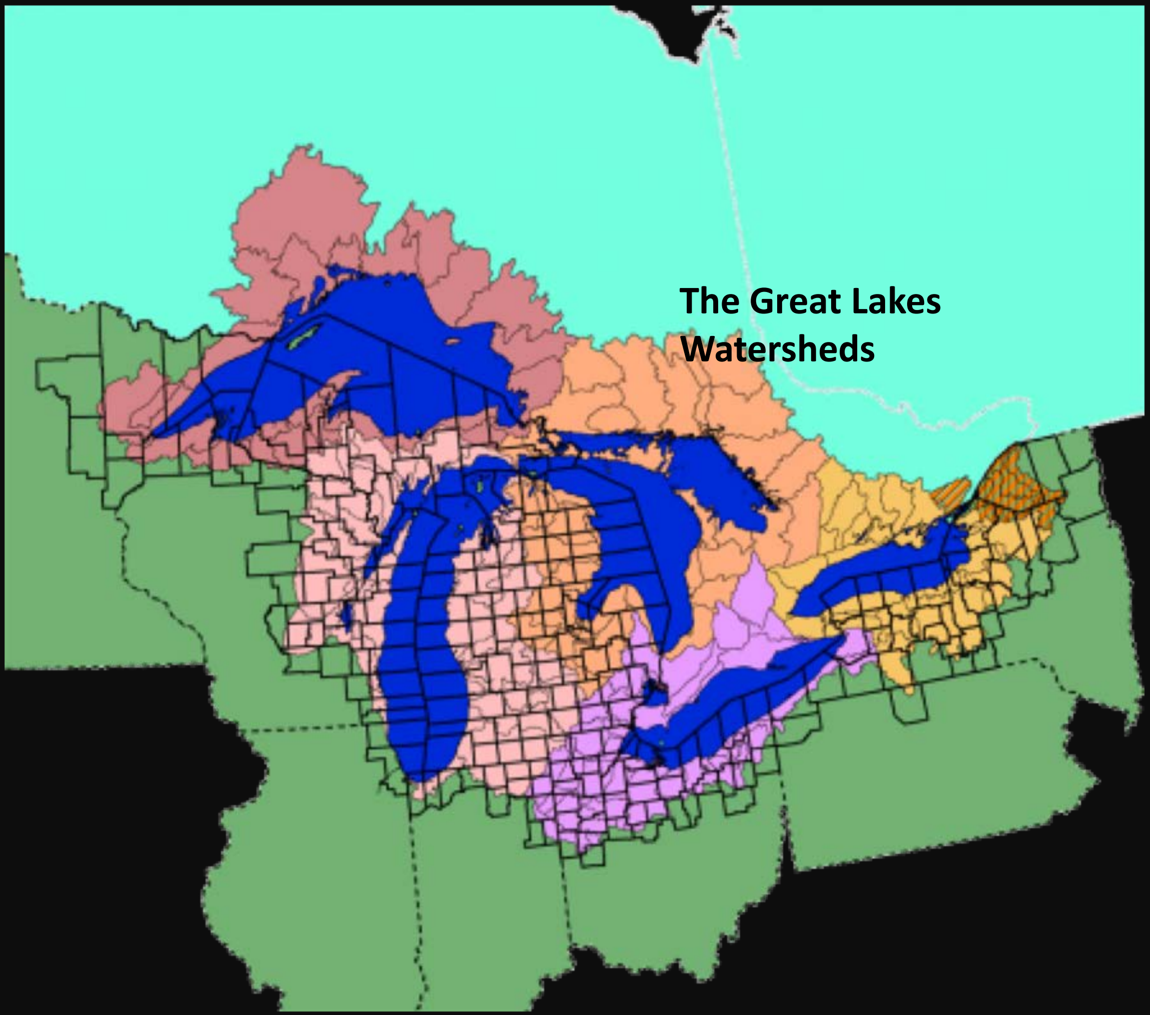
- Water levels have fluctuated considerably over multi-decadal time scales and will continue to do so.



Water levels of the Great Lakes from 1860 to 2015 as an anomaly relative to the 1981- 2010 average.

Changes in Great Lakes Watershed Hydrology

- Increases in precipitation will likely increase flooding across the region.
- Higher summer and fall air temperatures will increase evaporation during growing season.
- Coupled with summer precipitation that is increasingly variable and likely lower, summer river flows will be lower by the end of the century.



Changes in Agricultural Watersheds

- Changes in seasonal precipitation are affecting farmers, with planting delays caused by spring flooding and excessively wet soil conditions.
- Hotter and drier conditions later in the growing season increases the demand for irrigation to mitigate crop losses.
- Climate change will likely reduce crop yields for both soybean and maize by 10% - 30% by mid-century in the southern parts of the Great Lakes watershed.

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Changes in Urban Watersheds

- In the summer, high temperatures and heat waves cause poorer air quality, which harms public health, especially for the most vulnerable people – the elderly and children with asthma.
- Projected increases in extreme precipitation will likely exacerbate flooding, especially in winter, spring, and during summer thunderstorms.
- Climate change will likely threaten drinking water quality and place great stress on water infrastructure.

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Ecology in the Great Lakes

- Increasing concerns about invasive species.
- Ranges are shifting for sport and baitfish populations.
- Harmful algal blooms are increasing in frequency and severity.
  - Larger precipitation events could increase GL nutrients.
  - Increasing duration and intensity of lake stratification.


In 2011, Lake Erie experienced the largest harmful algal bloom in its recorded history

Public & Economic Impacts of Great Lake Changes

- A drop in lake levels reduces cargo capacity (but longer shipping season).
- Irrigation in the region is likely to increase.
- Changing weather & climatic conditions put stresses on physical infrastructure (e.g., roads, sewers).
- Climate change threatens Indigenous peoples' livelihoods and economies, including agriculture, hunting and gathering, fishing, forestry, energy, recreation, and tourism enterprises.

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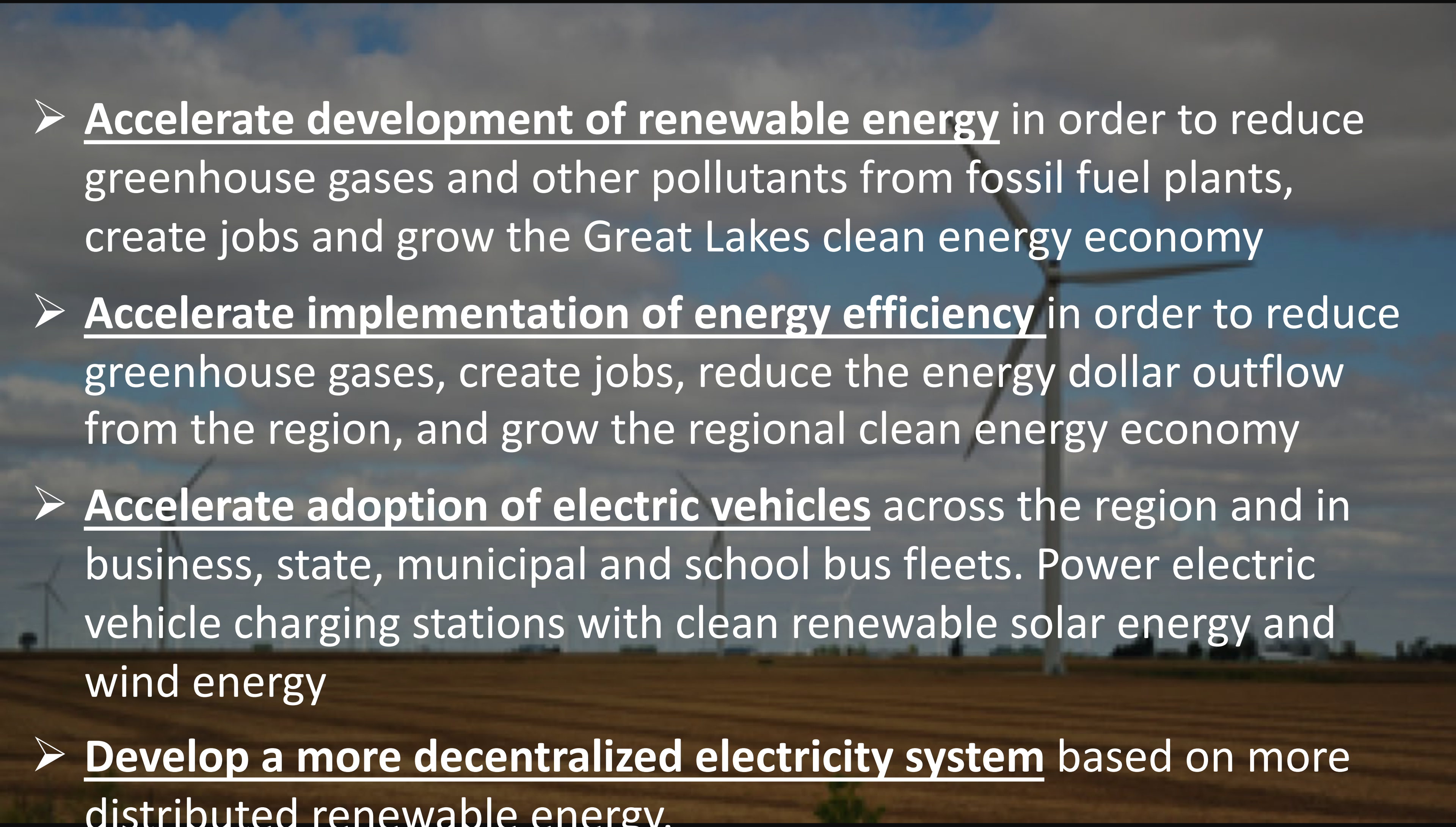
POLICY SOLUTIONS: Modernize Energy Sources



- **Accelerate development of renewable energy** in order to reduce greenhouse gases and other pollutants from fossil fuel plants, create jobs and grow the Great Lakes clean energy economy
- **Accelerate implementation of energy efficiency** in order to reduce greenhouse gases, create jobs, reduce the energy dollar outflow from the region, and grow the regional clean energy economy
- **Accelerate adoption of electric vehicles** across the region and in business, state, municipal and school bus fleets. Power electric vehicle charging stations with clean renewable solar energy and wind energy
- **Develop a more decentralized electricity system** based on more distributed renewable energy.

POLICY SOLUTIONS: Federal, State, and Local

- **Support national policies to reduce greenhouse gas pollution**
- **Align federal and state transportation policies and funding with climate change goals.**
- **States and cities should continue their "We Are Still In" actions to support the Paris Climate Change Accord.**
- **Achieve the airline industry's stated goal of reducing its carbon emissions by 50% by 2050.**
- **Create incentives to *decarbonize* housing, businesses and public institutions**

SOLUTIONS: Protect Waterways and Wetlands

- **Limit agricultural runoff of phosphorus pollution** from manure and excess fertilizer to reduce harmful algae blooms that are exacerbated by climate change and threaten safe drinking water, fisheries and outdoor recreation in western Lake Erie, Green Bay and other shallow bays

- **Design, develop and install green infrastructure**, ranging from wetlands restoration to permeable pavement, to adapt to climate change and protect shorelines and wildlife.

- **Restore the proposed $475 million of annual federal funding for the successful Great Lakes Restoration Initiative.**

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Climate Change & The Great Lakes Region: Conclusions

- Allowing the vast, beautiful natural resource of the Great Lakes to be taken for granted and degraded through human activities, including the effects of climate change, is not an option.
- We all need the Great Lakes and surrounding watersheds to remain healthy, unpolluted and productive.
- Climate change is already having an impact on the region, and there is evidence that such impacts may increase under expected future climate change.
- Responding to these stressors requires both avoiding the unmanageable and managing the unavoidable.

Michigan's Climate, so far & the future

Michigan's Future

- **Average annual temperature has increased by about 2°F since the beginning of the 20th century.**
- **Historically unprecedented future warming is likely. Extreme heat is of particular concern for densely populated urban areas such as Detroit, where high temperatures and high humidity can cause dangerous conditions.**
- **Winter and spring precipitation are expected to increase, raising the risk of springtime flooding, which could cause delayed planting and reduced yields.**
- **Changes in seasonal and multi-year precipitation, evaporation, and temperature can affect water levels in the Great Lakes, causing serious environmental and socioeconomic impacts.**

Key things to know about climate change

1) Climate change refers to a long-term shifts in weather conditions.
2) Over most of Earth's history, natural processes have been responsible for periods of climate change.
3) Human activity is now the main cause of recent climate change.
4) Accumulation of greenhouse gases (CO_2, methane, and nitrous oxide) due to carbon combustion and agricultural practices is unprecedented in human history.
5) Evidence is based on fundamental physics, atmospheric chemistry, and intensive measurements of Earth's surface temperature.
6) Human-caused climate change is leading to droughts, extreme weather events, and ocean acidification.
7) Addressing climate change can improve economies & contribute to social justice.

Image: U.S. Drought Monitor/NASA Earth Observatory

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Climate Change Solutions for the U.S.

- There is a **small window** to avoid the worst-case scenarios.
- Addressing the problem will **require cutting greenhouse gas emission**s, and **making our communities more resilient**.
- **Technological advances** (e.g. wind, solar, tidal power) and energy markets are leading to GHG emissions cuts.
- Companies, including tech giants like Google and Facebook, are **investing in clean energy** even as Washington rolls back climate change regulations.
- **Cities, states and institutio**ns are acting.
- System-wide changes and incentives to reduce, and eventually **eliminate carbon-based energy** are needed.
- **Carbon Fee and Divide**nd is a viable, bi-partisan solution.

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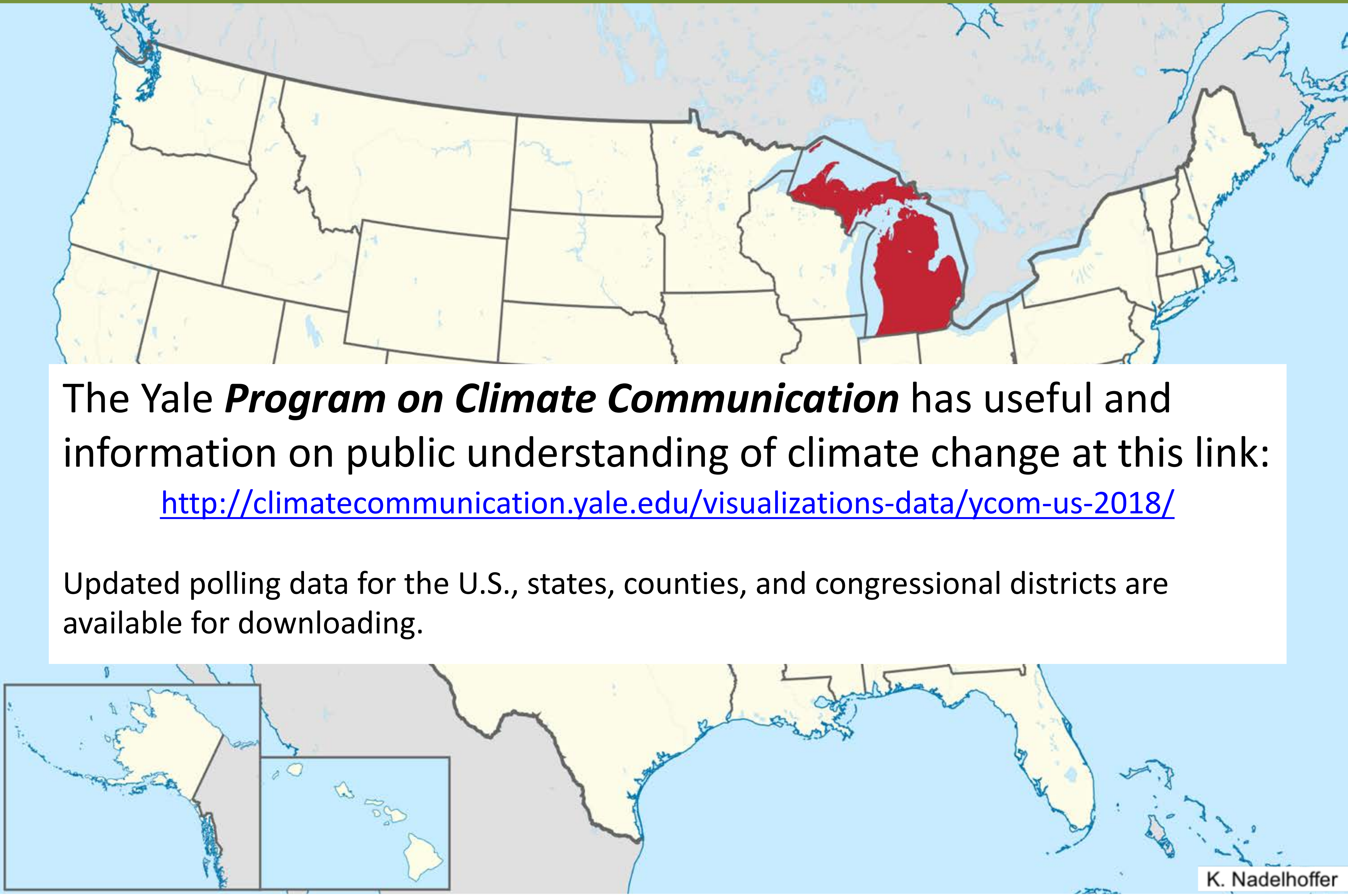
Public Opinion



The Yale ***Program on Climate Communication*** has useful and information on public understanding of climate change at this link:

http://climatecommunication.yale.edu/visualizations-data/ycom-us-2018/

Updated polling data for the U.S., states, counties, and congressional districts are available for downloading.

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