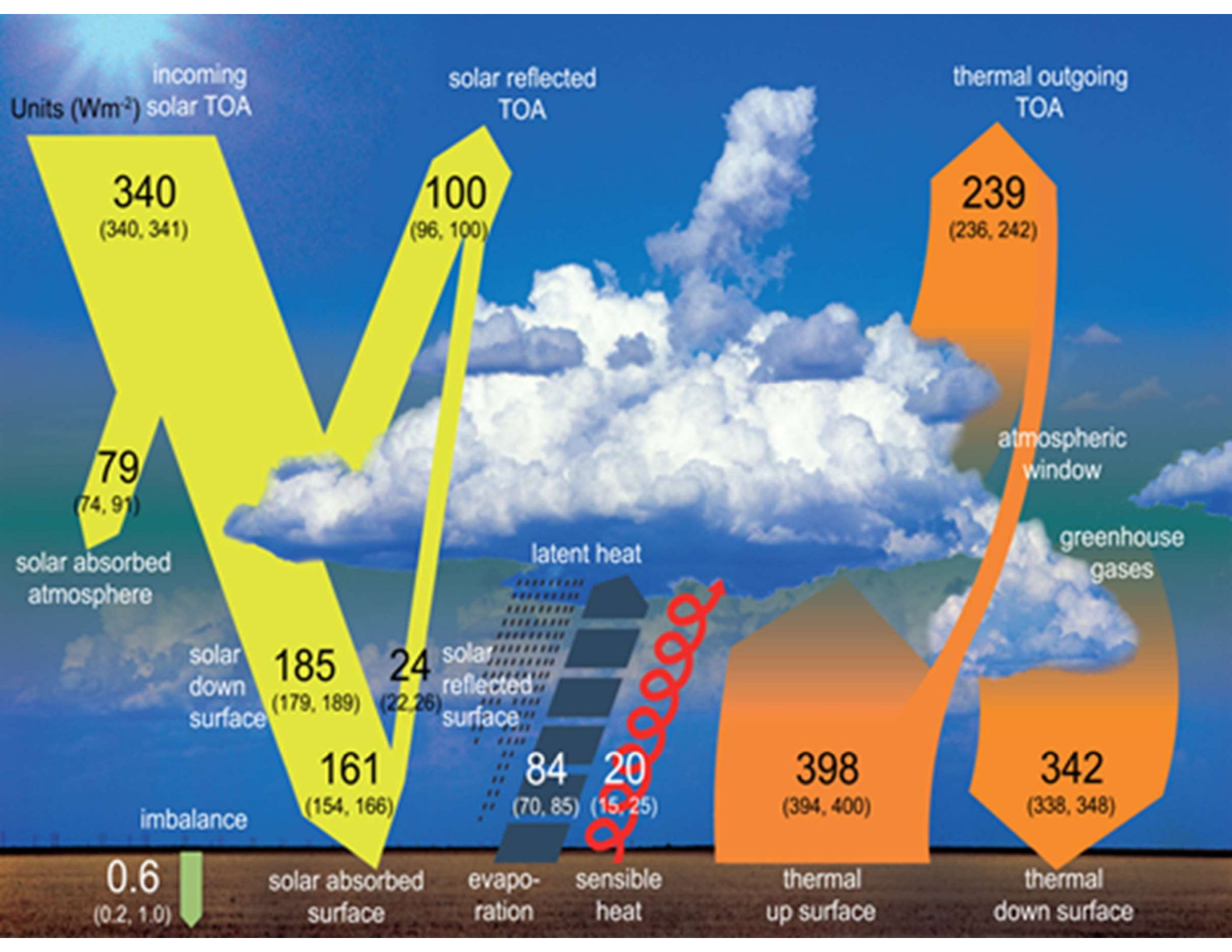


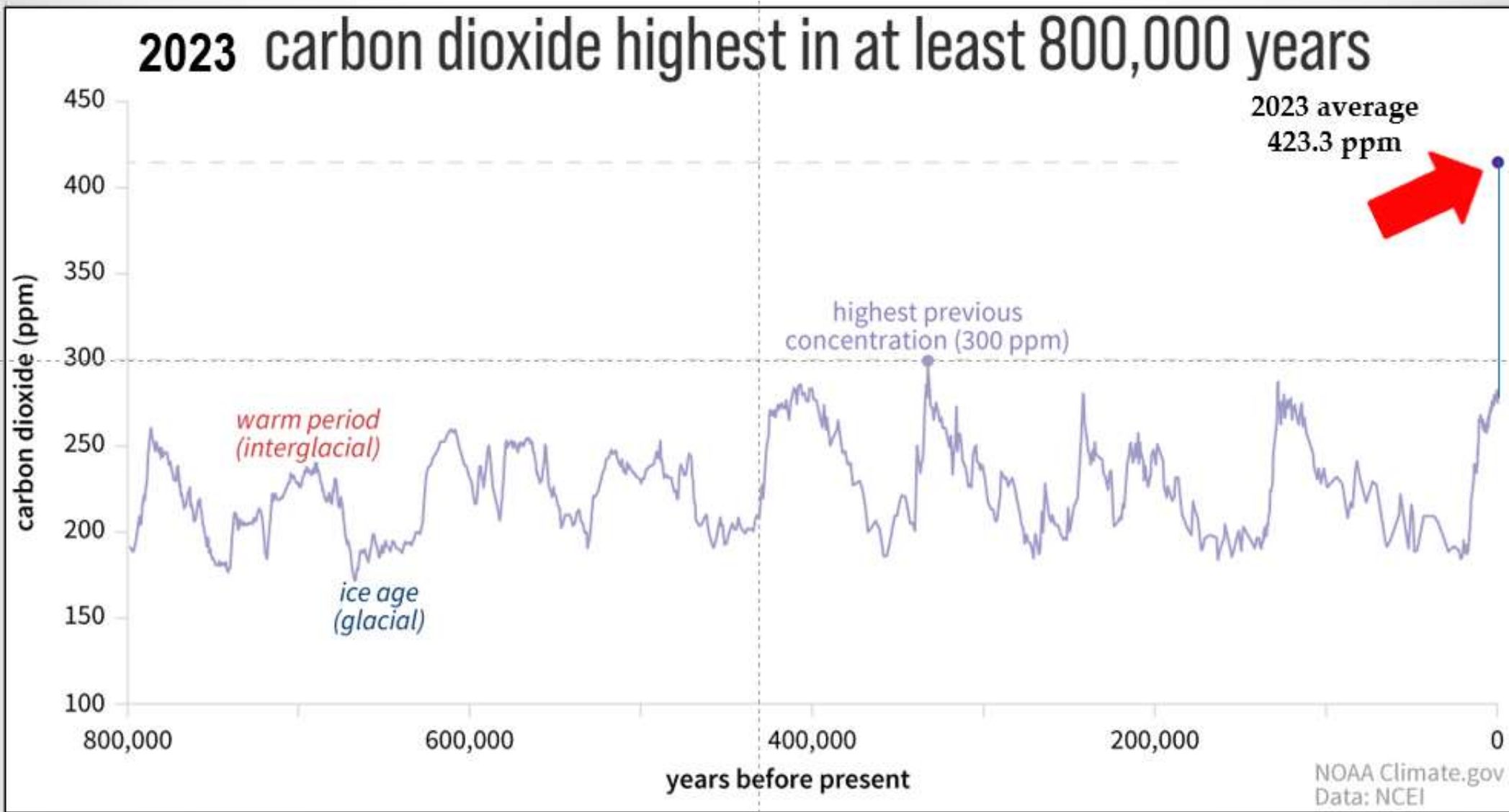
Climate Change and Ecosystems



Ray Wolf (retired)
NOAA / National Weather Service

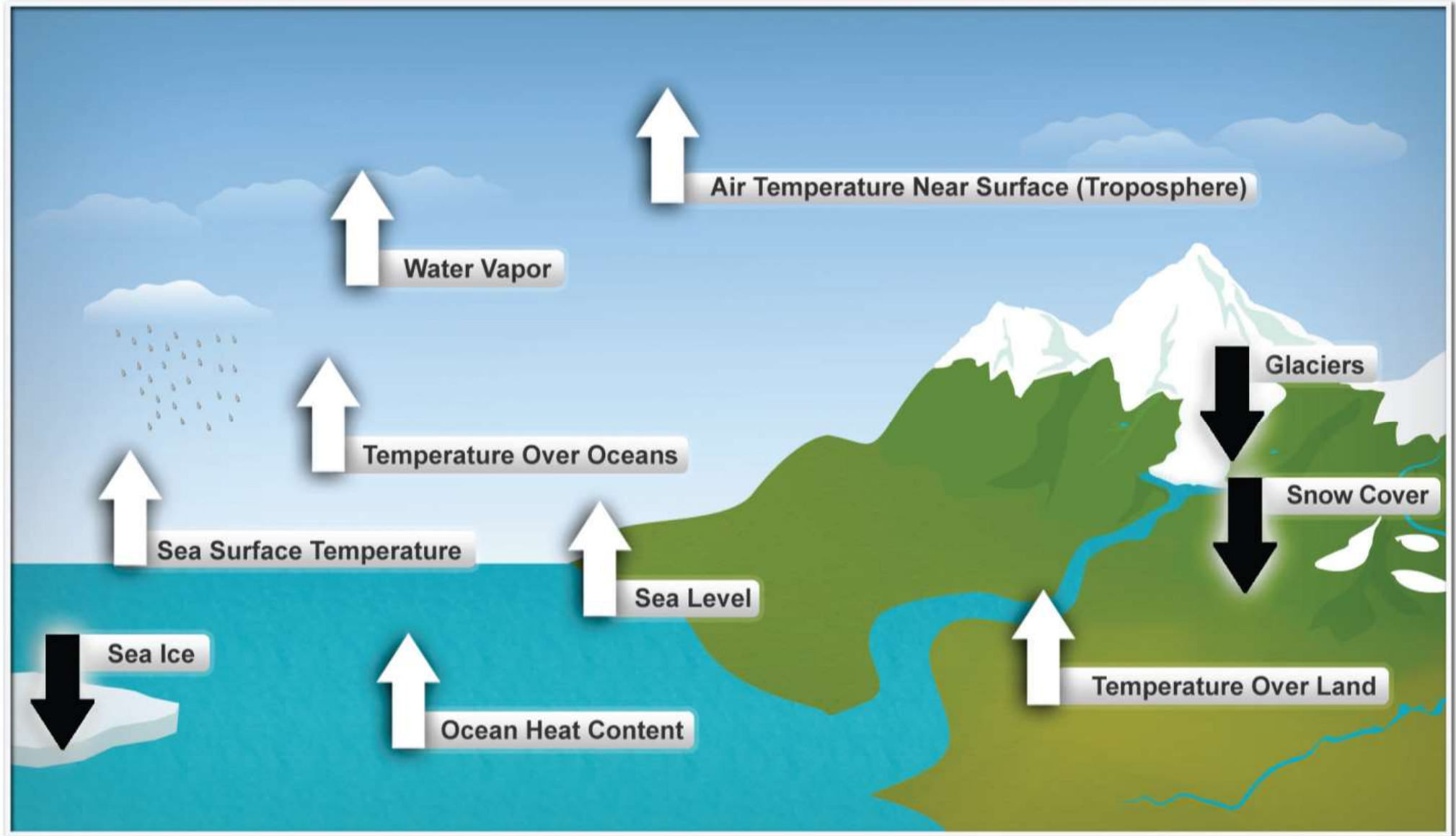


Long Term CO₂ Trends



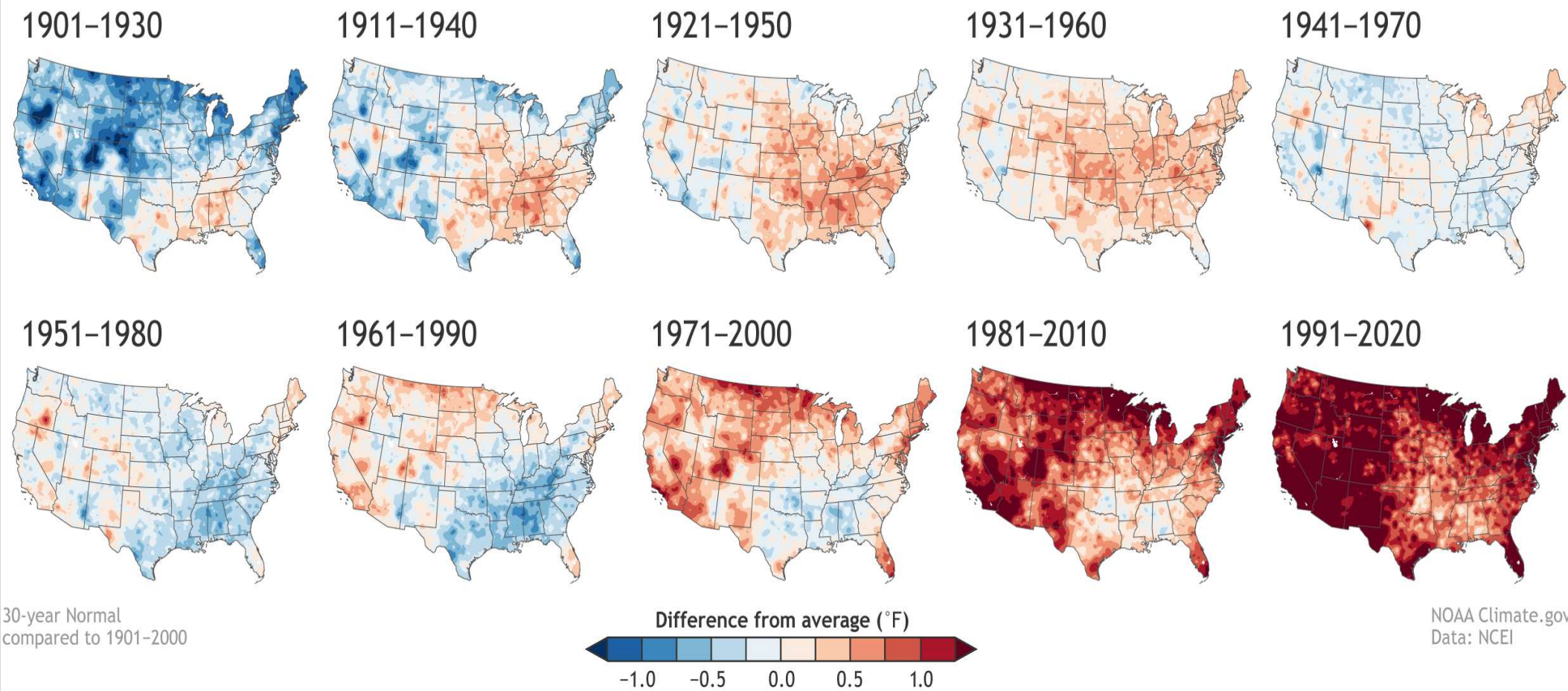
• Similar trends for methane and nitrous oxide •

10 Indicators of a Warming World

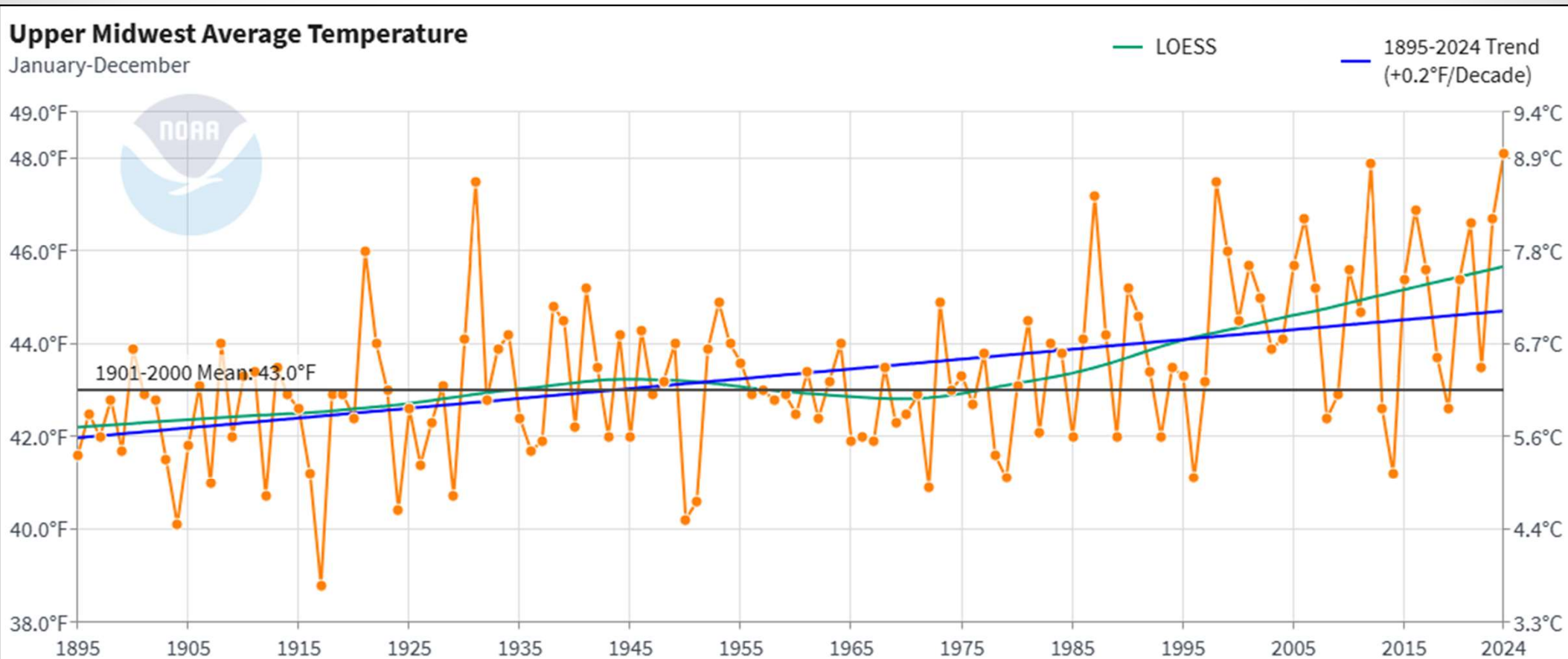


US Temperature Trend

U.S. ANNUAL TEMPERATURE COMPARED TO 20th-CENTURY AVERAGE

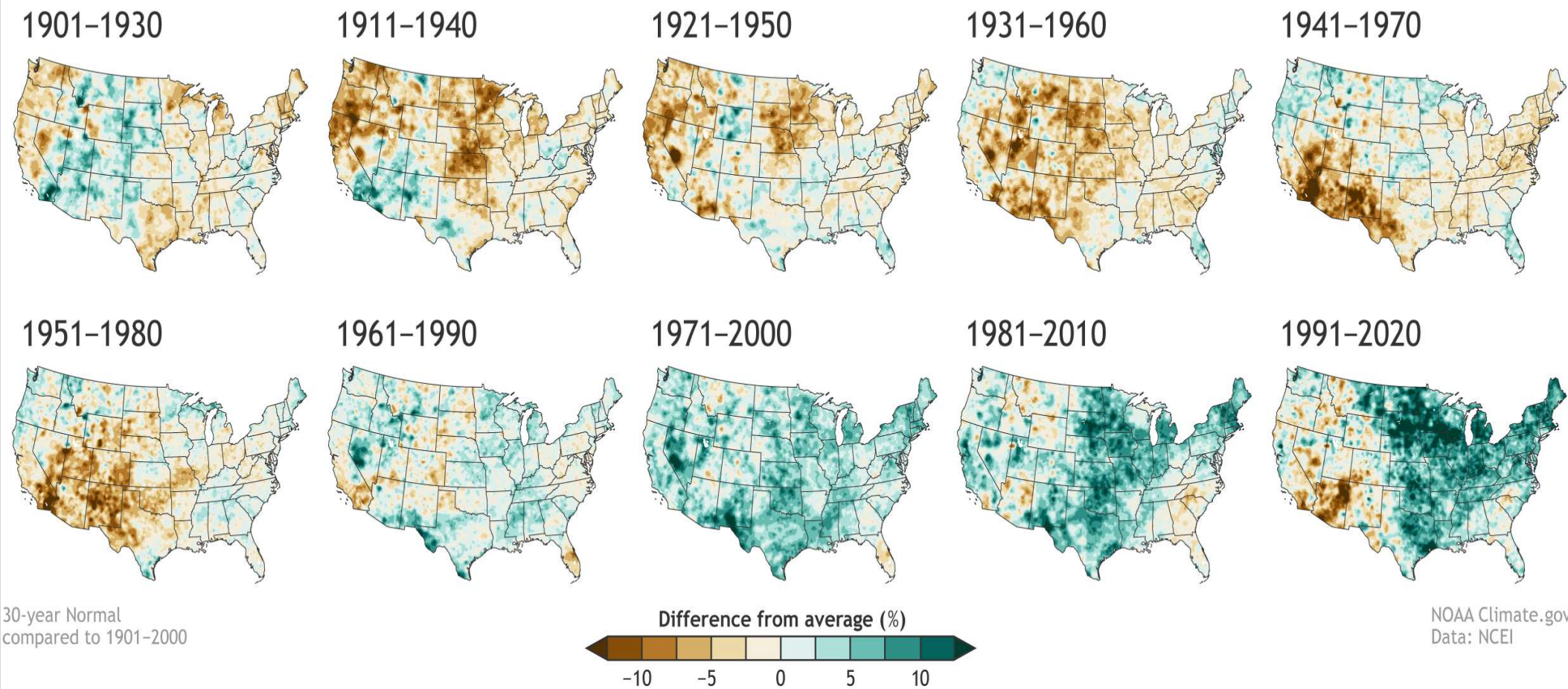


Midwest Temperature Trend



US Precipitation Trend

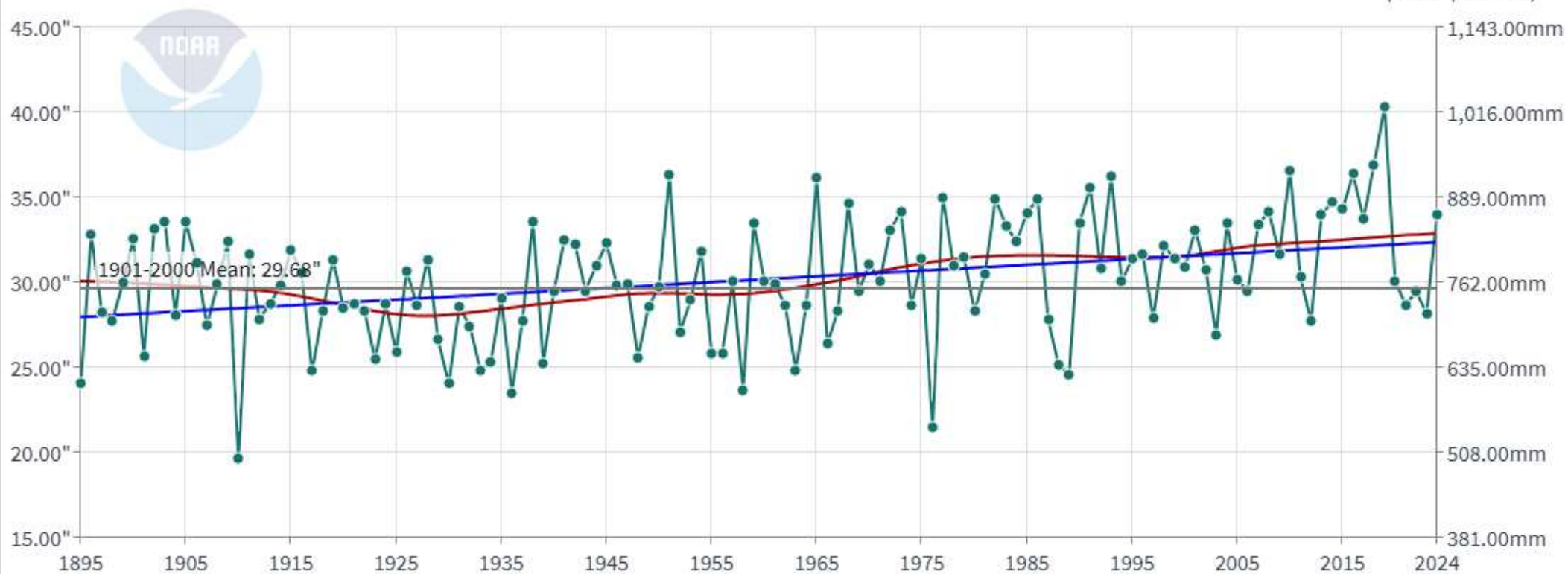
U.S. ANNUAL PRECIPITATION COMPARED TO 20th-CENTURY AVERAGE



Midwest Precipitation Trend

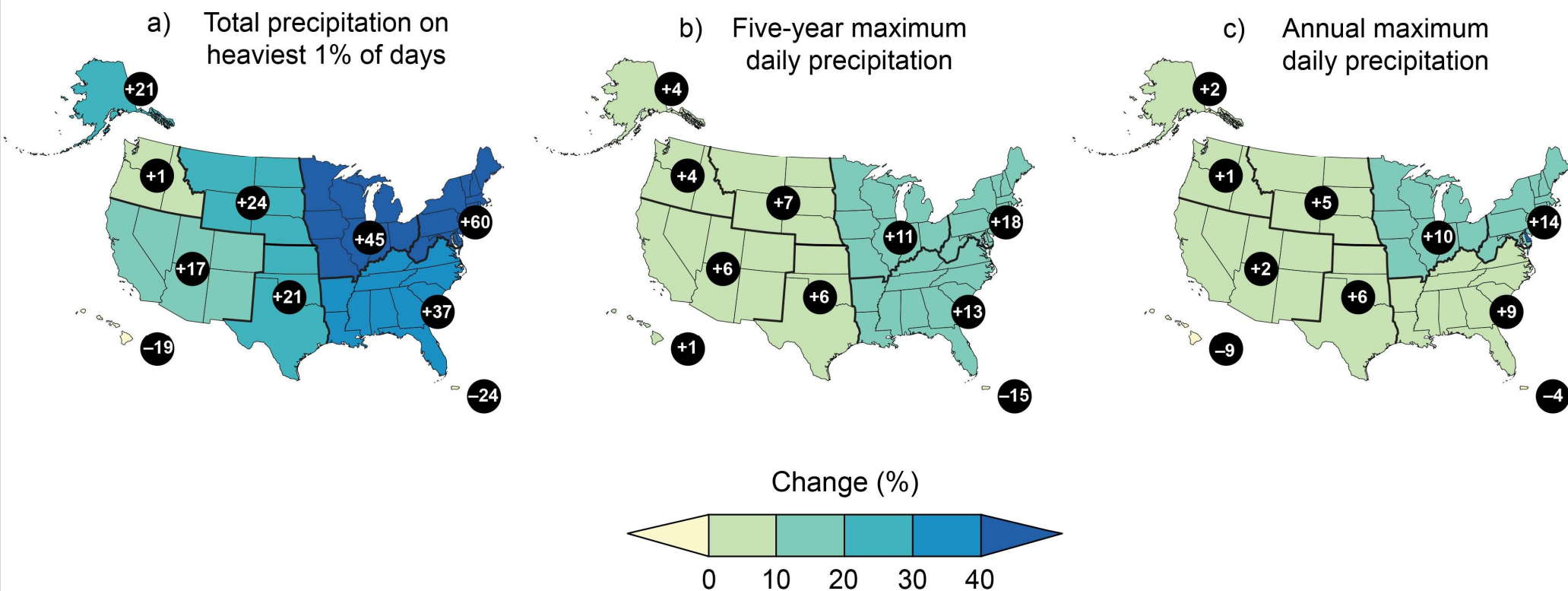
Upper Midwest Precipitation

January-December



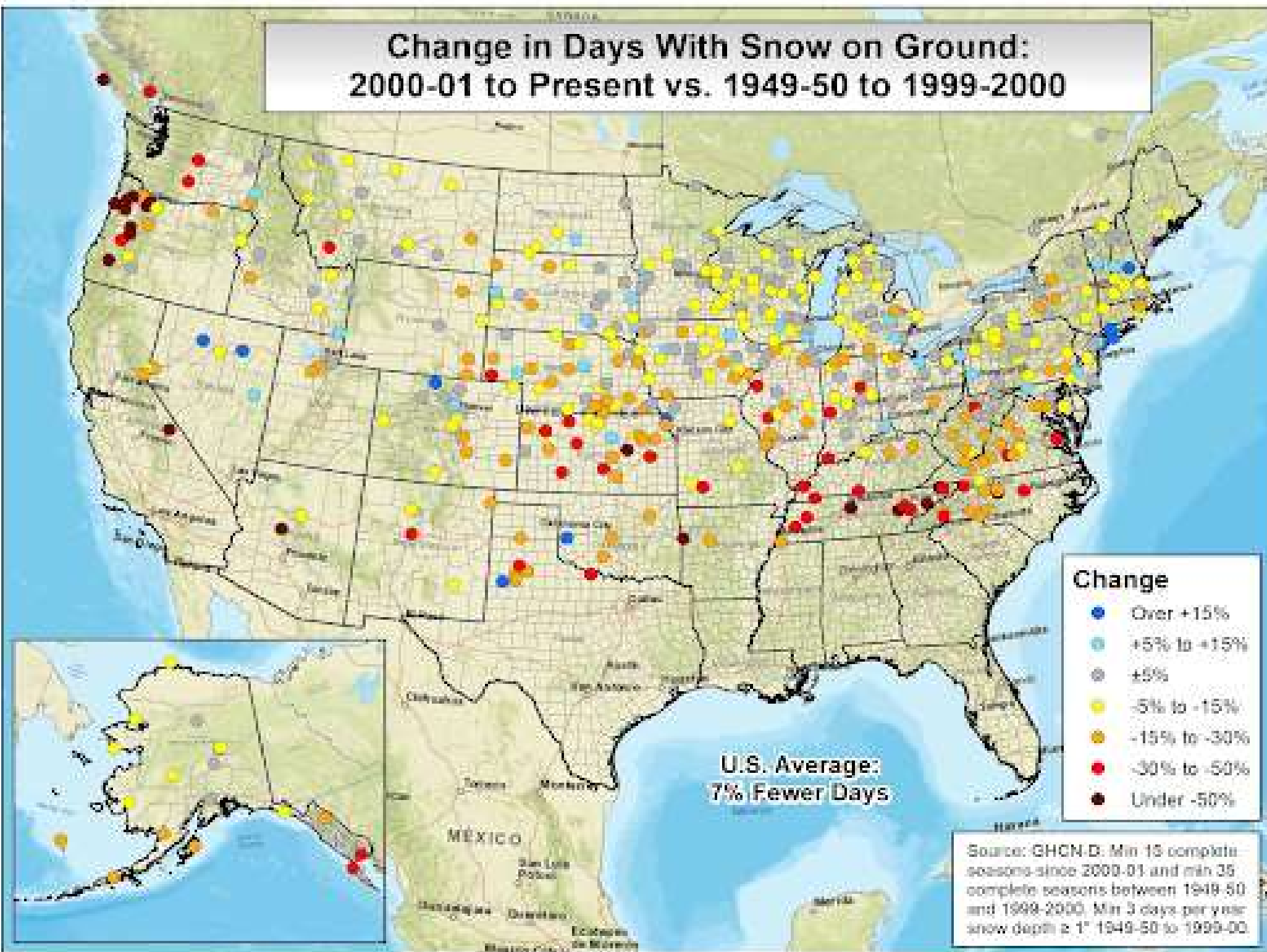
Heavy Precipitation Events

Observed Changes in the Frequency and Severity of Heavy Precipitation Events

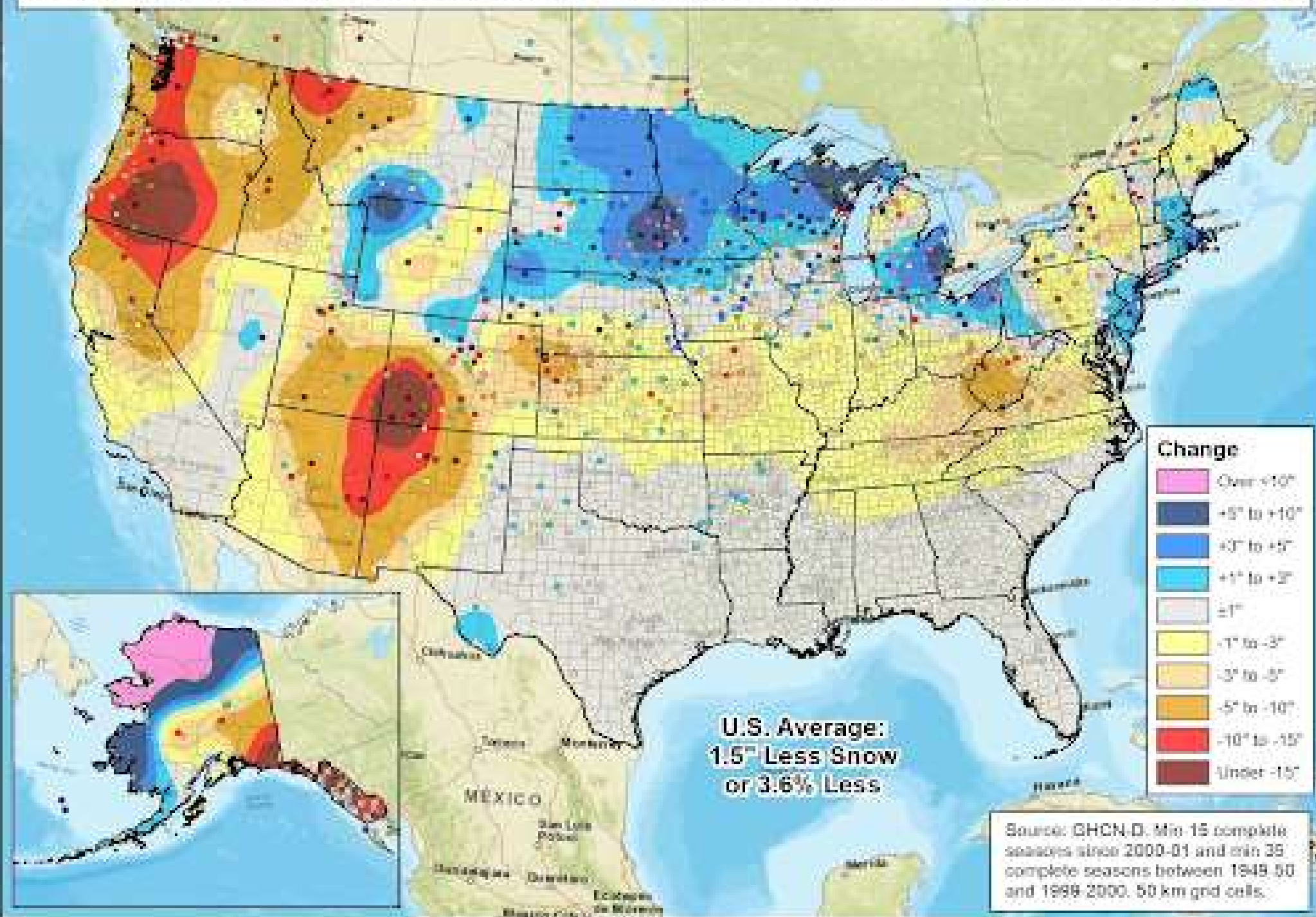


2002–2021 relative to 1901–1960

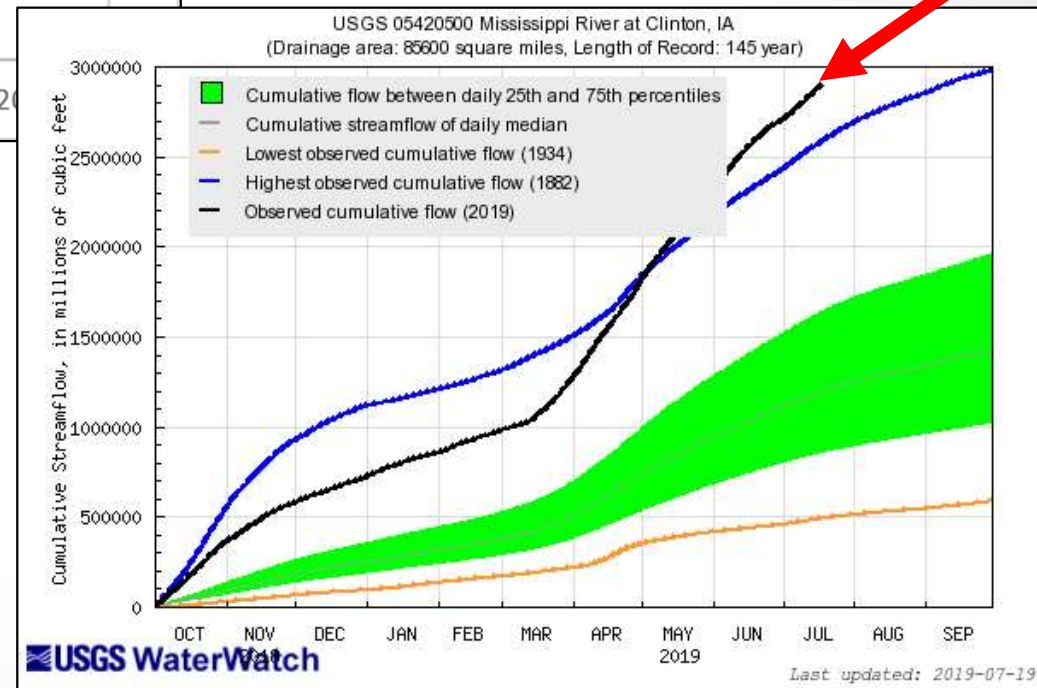
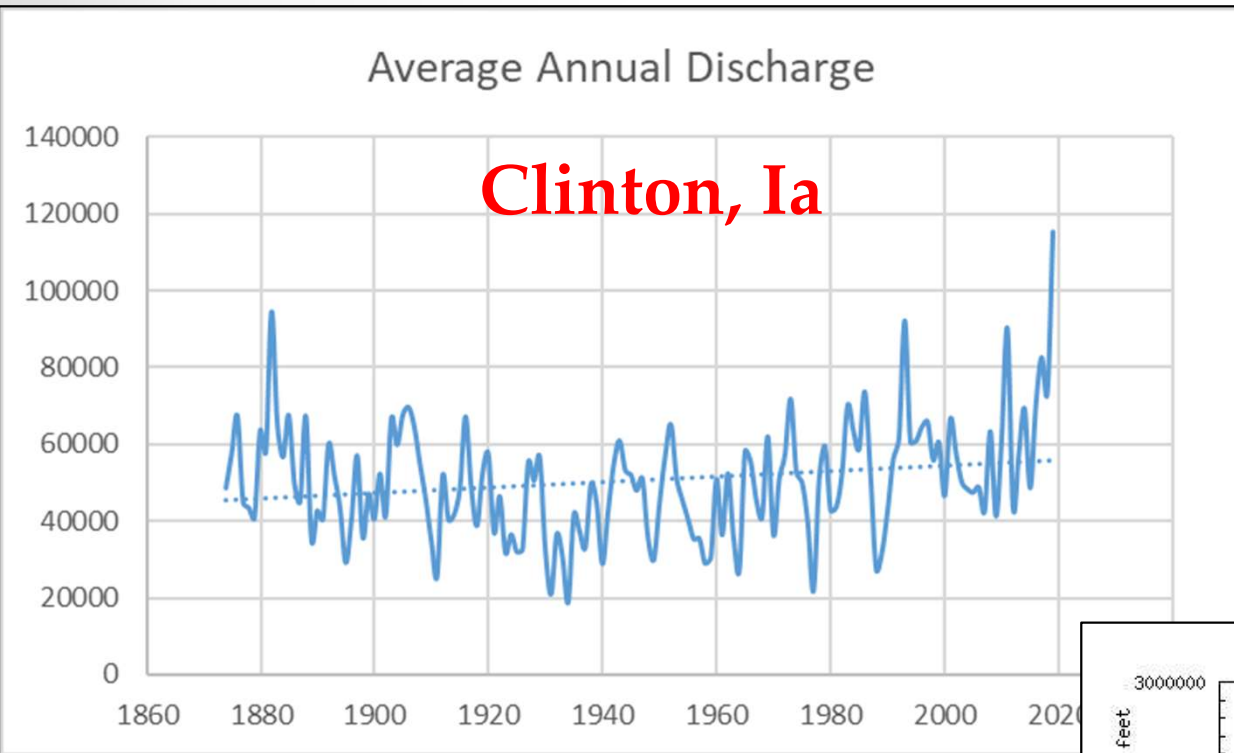
Change in Days With Snow on Ground: 2000-01 to Present vs. 1949-50 to 1999-2000



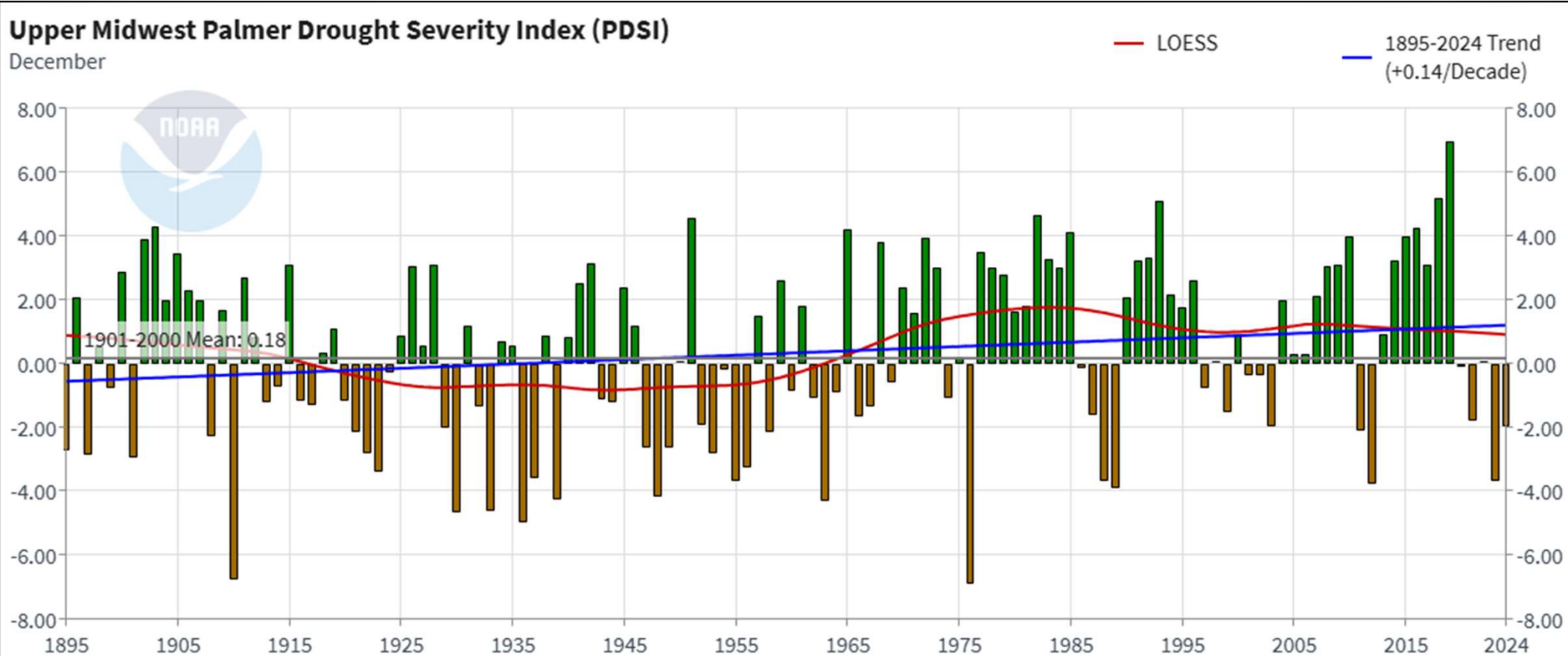
Change in Average Snowfall: 2000-01 to Present vs. 1949-50 to 1999-2000



Mississippi River Streamflow



Midwest Drought Trend



Midwest Observations

- Warmer Winters, especially nighttime temperatures
- Warmer Summer nights
- Longer growing season – shorter winters
- Increased humidity
- Wetter, especially spring
- More extreme rainfall events, especially spring
- Swings from extremes of wet and dry

Future Projections

Global greenhouse gas emissions and warming scenarios

Our World
in Data

- Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
- Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.

Annual global greenhouse gas emissions
in gigatonnes of carbon dioxide-equivalents

150 Gt

100 Gt

50 Gt

Greenhouse gas emissions
up to the present

0

1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

No climate policies

4.1 – 4.8 °C

→ expected emissions in a baseline scenario if countries had not implemented climate reduction policies.

Current policies

2.5 – 2.9 °C

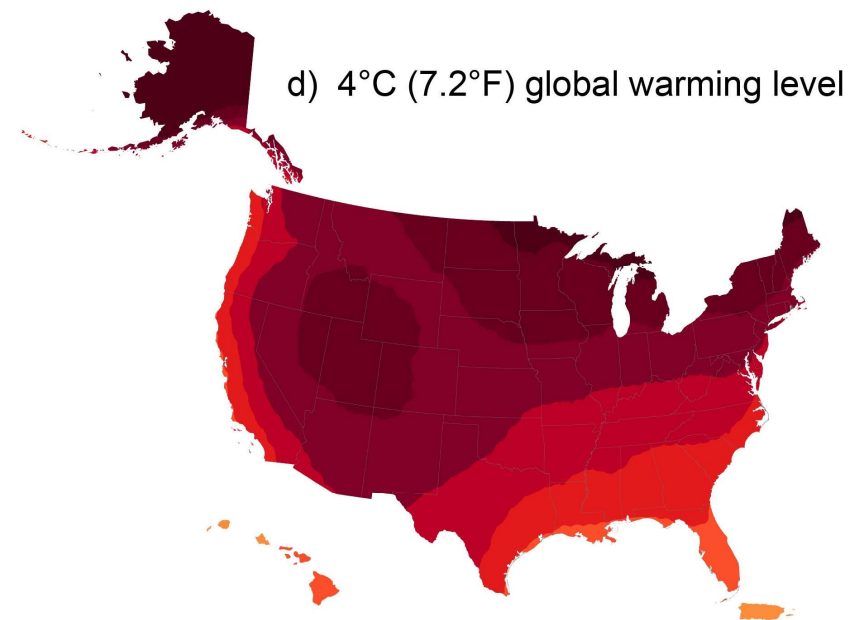
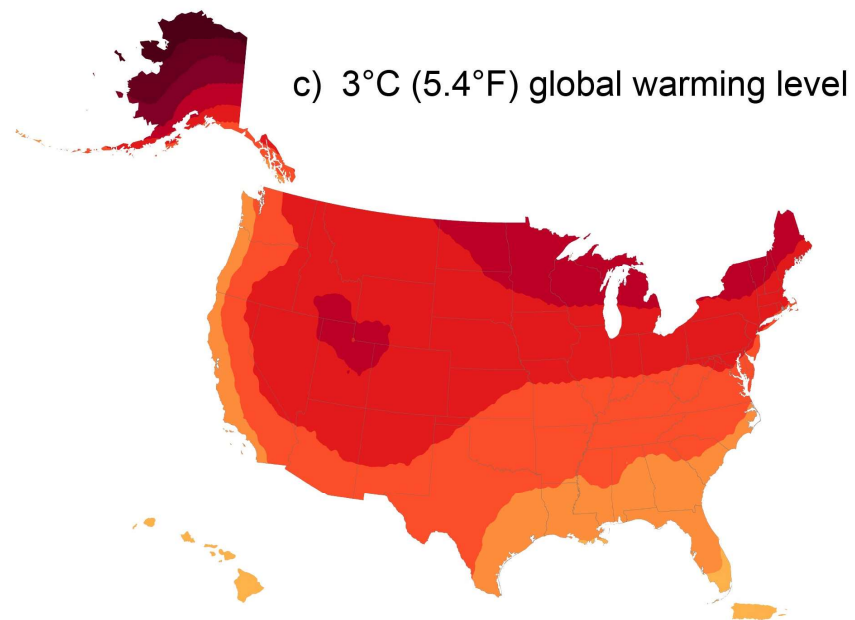
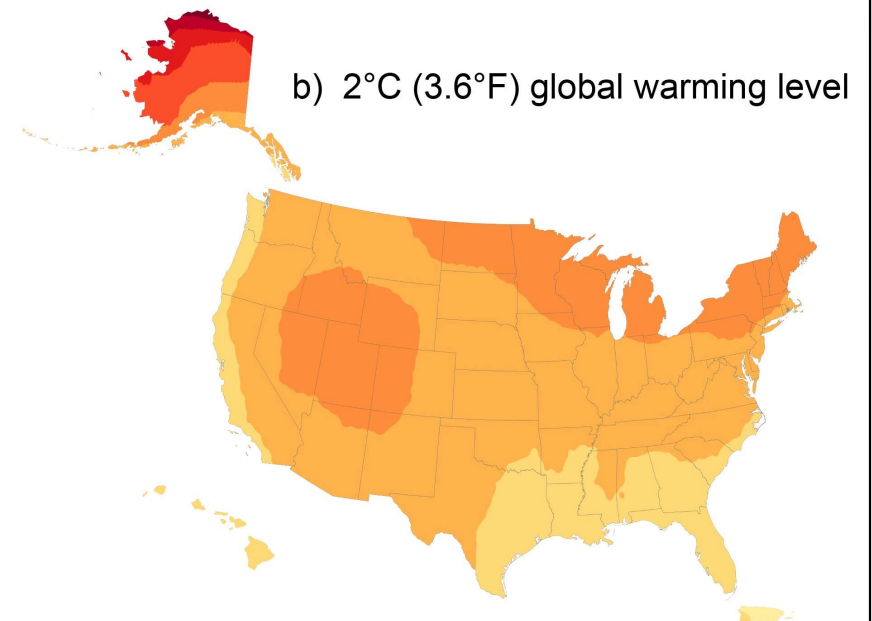
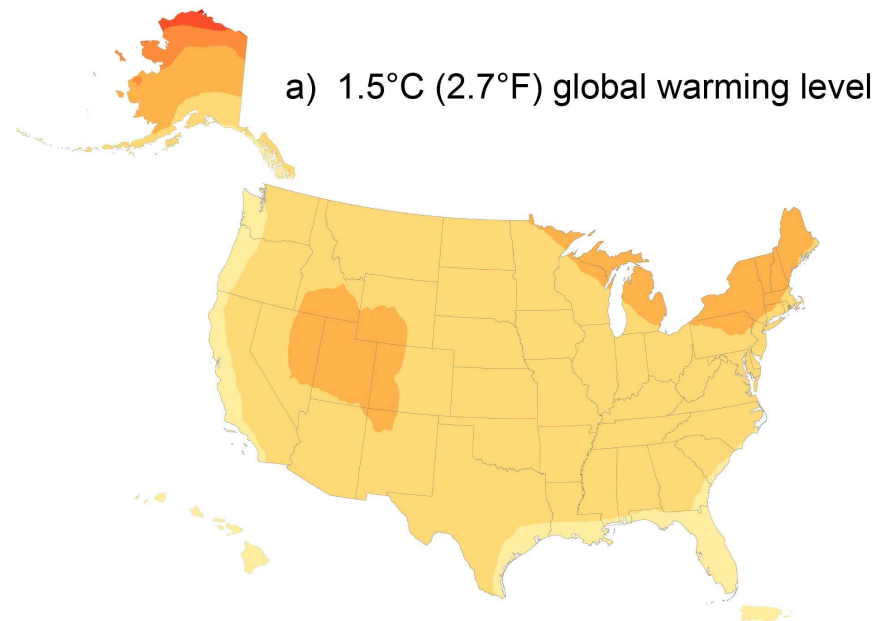
→ emissions with current climate policies in place result in warming of 2.5 to 2.9°C by 2100.

Pledges & targets (2.1 °C)

→ emissions if all countries delivered on reduction pledges result in warming of 2.1°C by 2100.

2°C pathways
1.5°C pathways

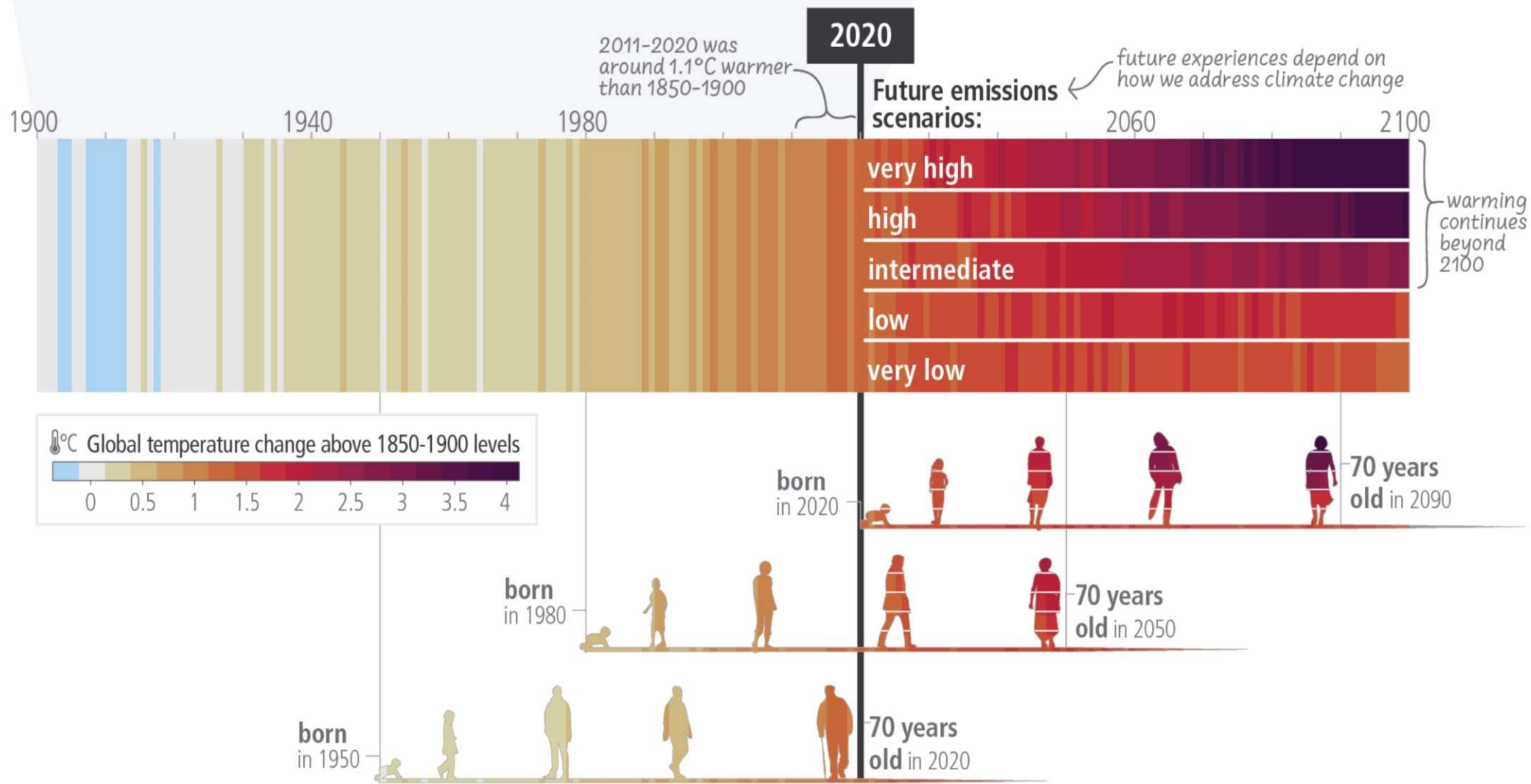
Projected US Temperature Changes at 1.5°C, 2°C, 3°C, and 4°C of Global Warming



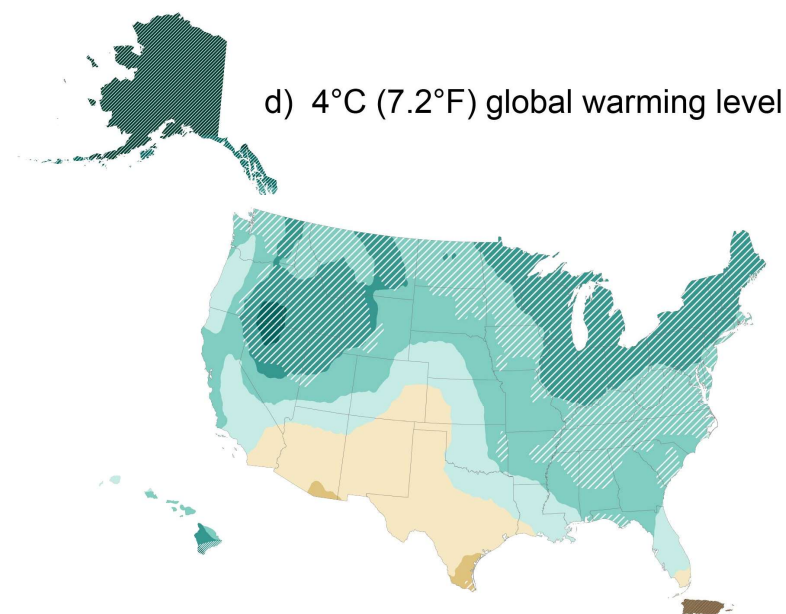
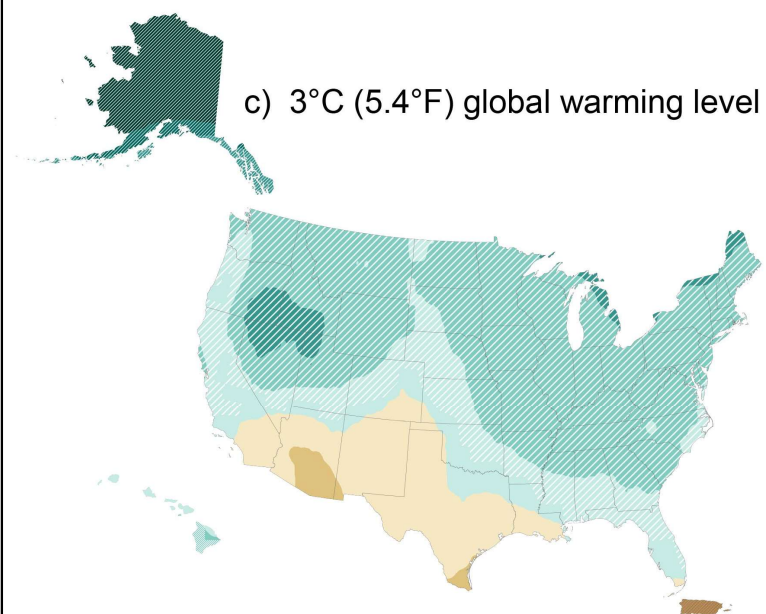
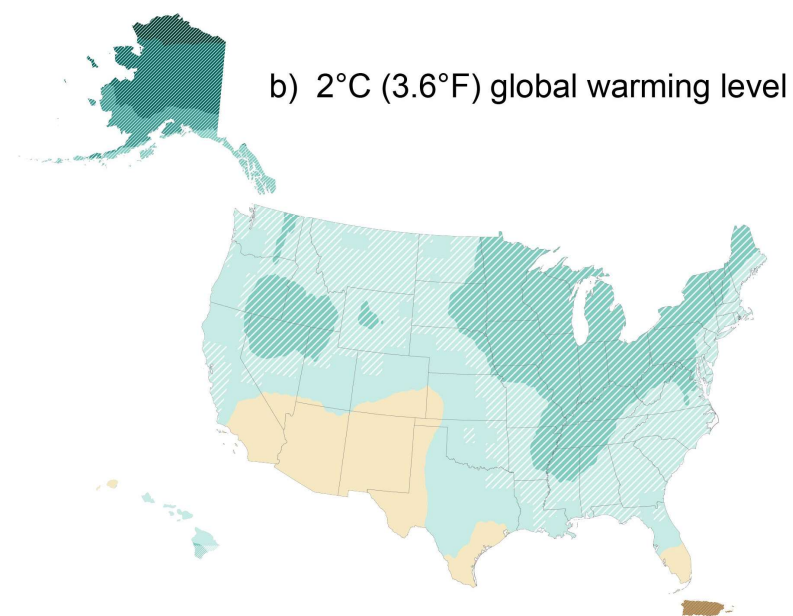
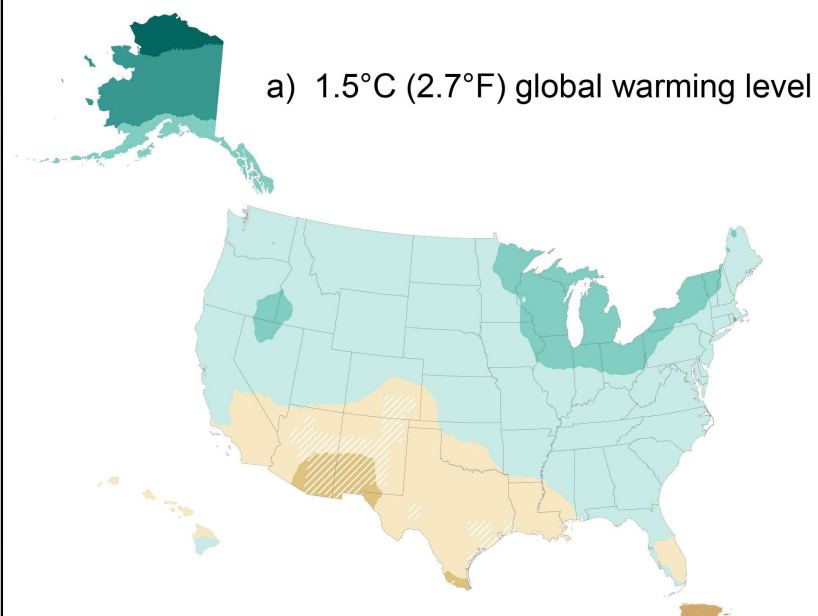
Change in Annual Average Temperature (°F)



c) The extent to which current and future generations will experience a hotter and different world depends on choices now and in the near-term



Projected US Precipitation Changes at 1.5°C, 2°C, 3°C, and 4°C of Global Warming

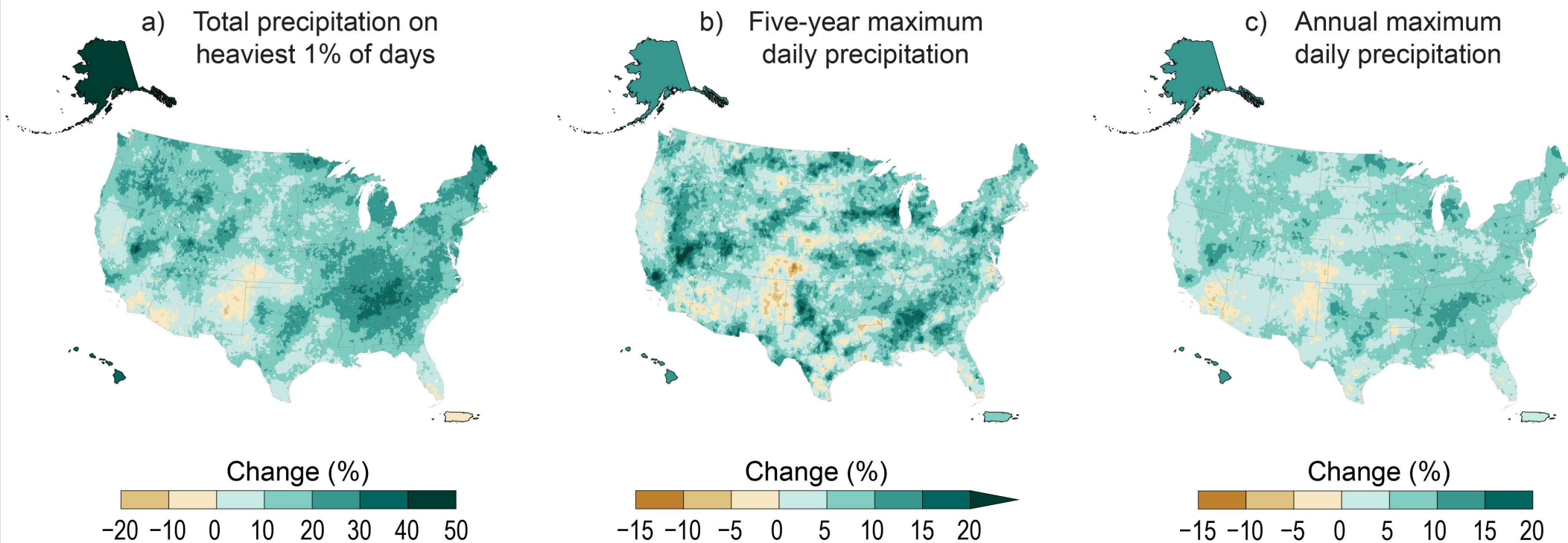


Average Annual Precipitation Change (%)



Heavy Precipitation Events

Projected Changes to Precipitation Extremes at 2°C of Global Warming

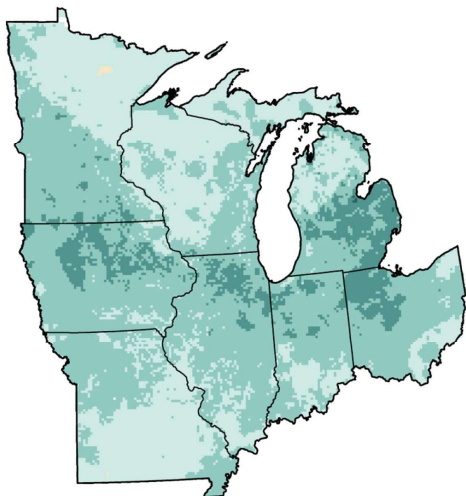


Changes are relative to the period 1991–2020

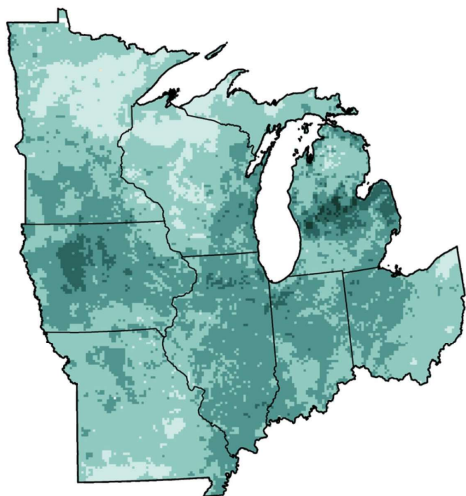
Projected Changes in Cumulative Seasonal and Annual Runoff (2036–2065 compared to 1991–2020)

Annual

a) Intermediate scenario (RCP4.5)

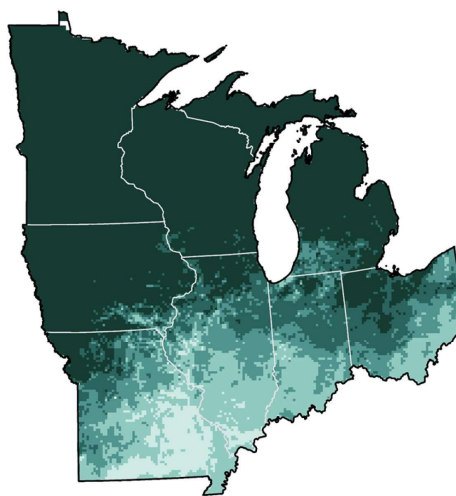


b) Very high scenario (RCP8.5)

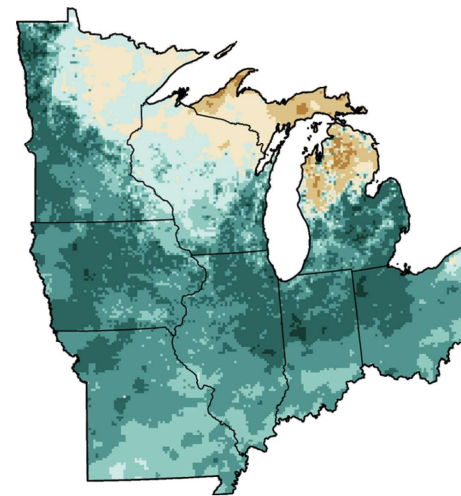


Seasonal

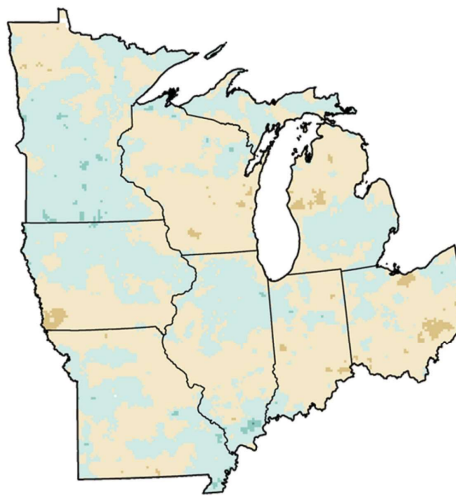
c) Winter (RCP4.5)



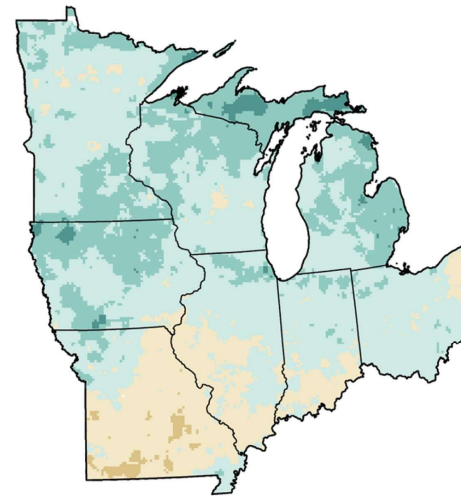
d) Spring (RCP4.5)



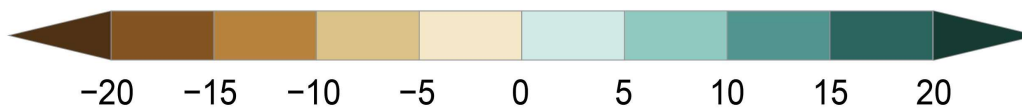
e) Summer (RCP4.5)



f) Fall (RCP4.5)



Runoff change (%)



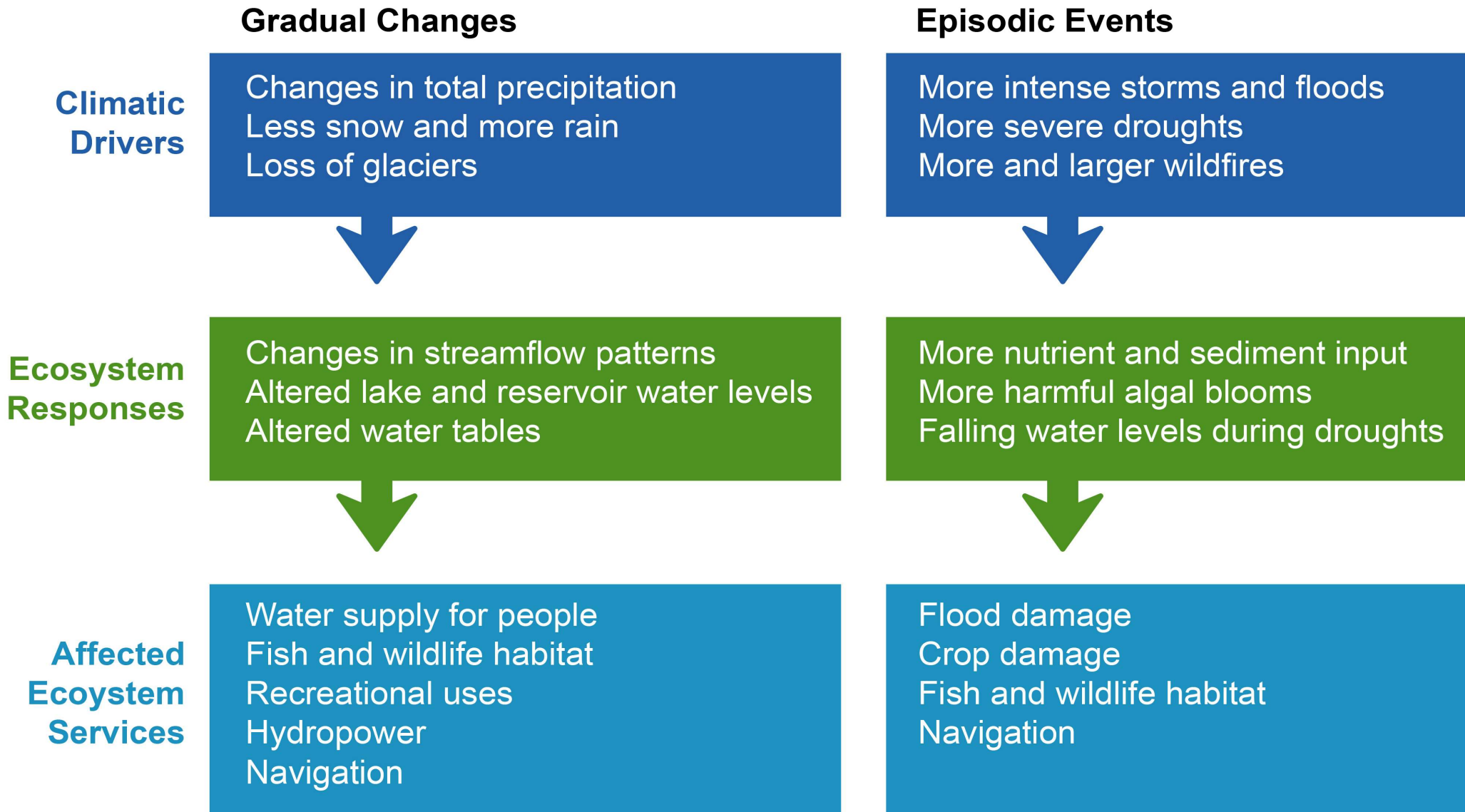
Extreme Weather

- Increases in
 - Heavy rain, flooding
 - Hurricanes – increase in precip and intensity
 - Severe weather events – wind, hail, tornadoes
 - More favorable environments
 - Possible intensity increase
- Confounded with increase in **social vulnerability**



Watershed Impacts

Amplifying Climate Change Effects on Watersheds



Extreme Precipitation Impacts



Flood and drought risk

No adaptation
More extreme precipitation increases risks

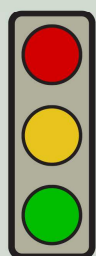
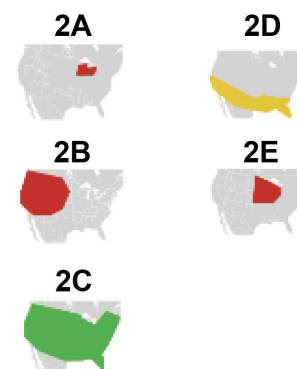
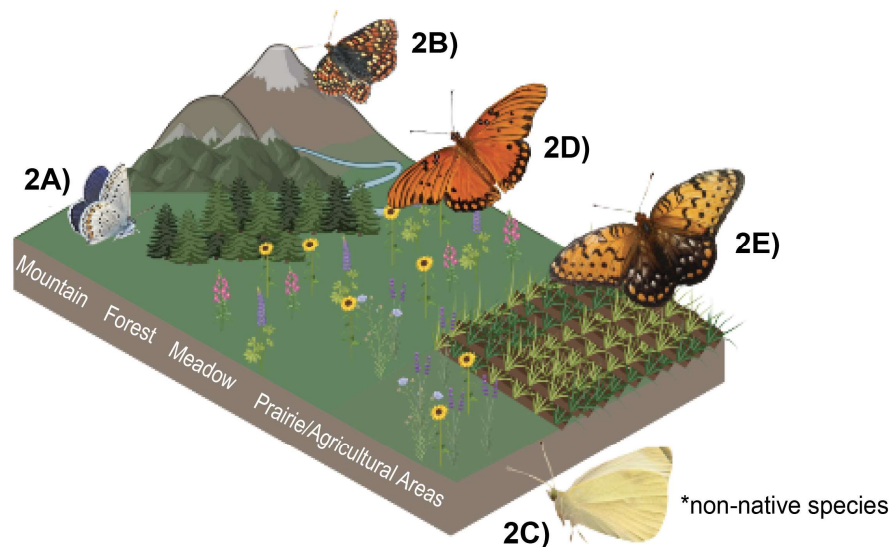
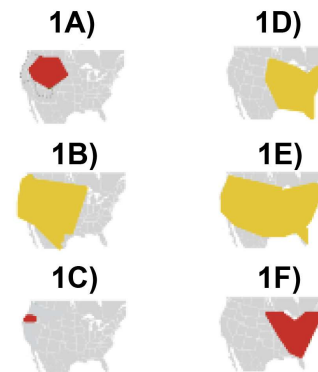
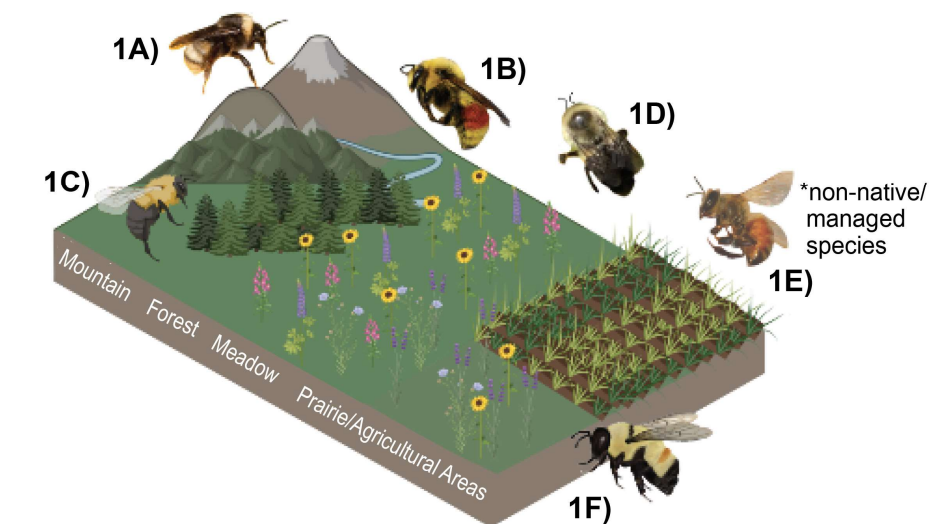


Adaptation benefits

 Increase watershed storage

 Improve fish habitat

Observed Pollinator Sensitivities



Population decrease/range contraction
Uncertain population/range change
Population increase/range expansion

1) Bees (Apidae)

- A) Western bumble bee (*Bombus occidentalis*)
- B) Hunt's bumble bee (*Bombus huntii*)
- C) Franklin's bumble bee (*Bombus franklini*)
- D) Common eastern bumble bee (*Bombus impatiens*)
- E) Western honey bee (*Apis mellifera*)
- F) Rusty patched bumble bee (*Bombus affinis*)

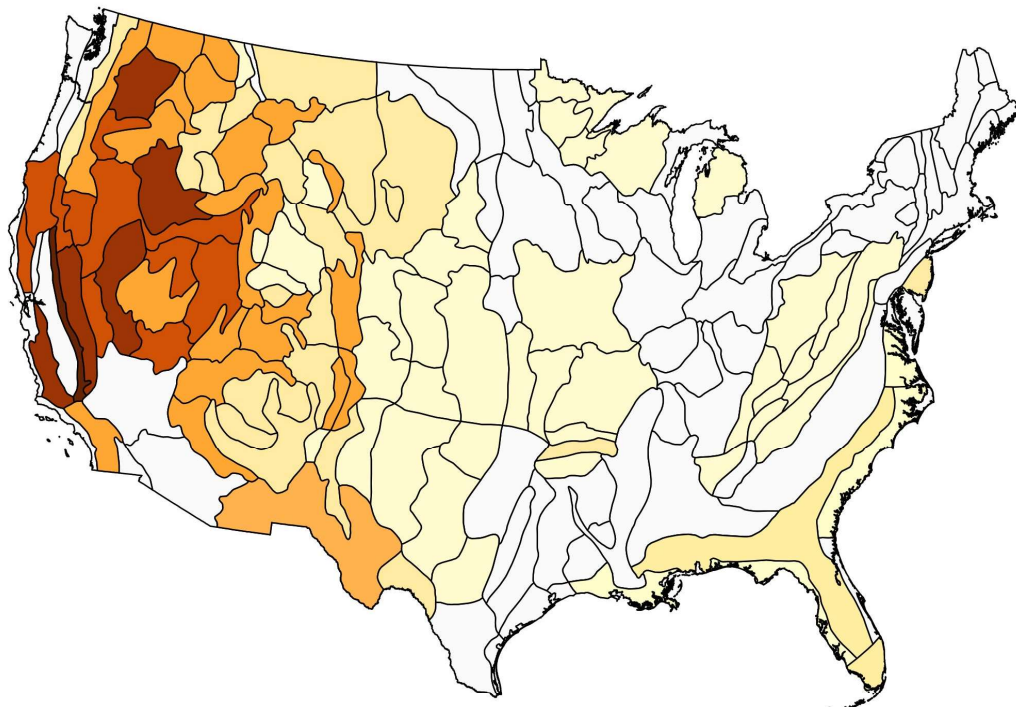
2) Butterflies (Lepidoptera)

- A) Karner blue (*Lycaeides melissa samuelis*)
- B) Edith's checkerspot (*Euphydryas editha*)
- C) Cabbage white (*Pieris rapae*)
- D) Gulf fritillary (*Agraulis vanillae*)
- E) Regal fritillary (*Speyeria idalia*)

Very Large Fires

May–October extreme weather conditions associated with very large fires

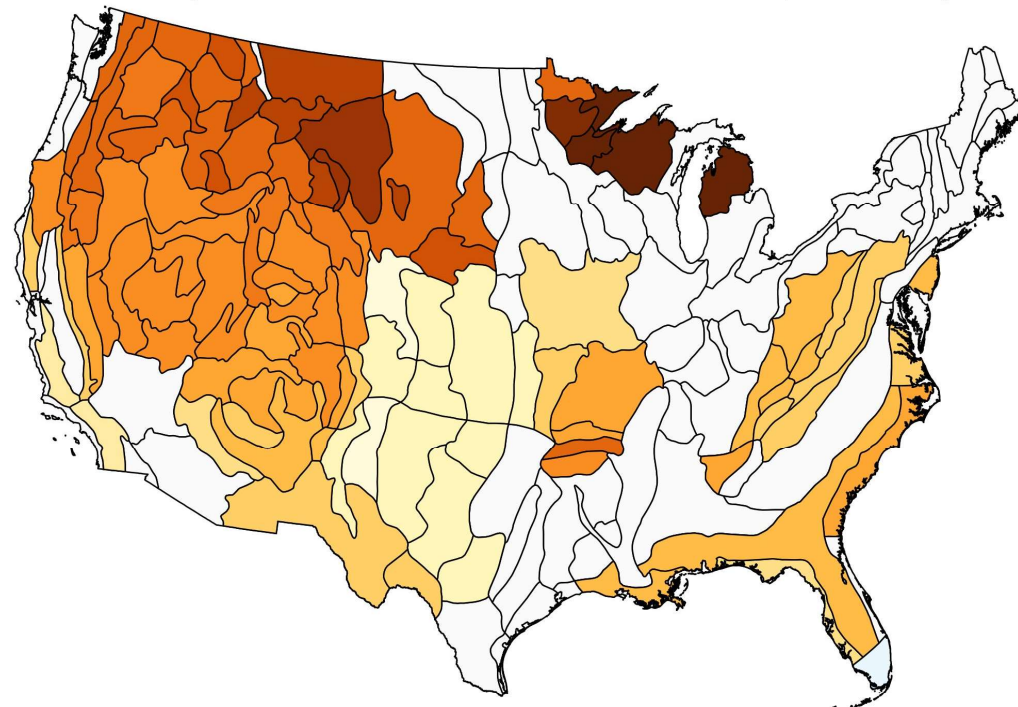
Historical (1971–2000)



Average Number of Days



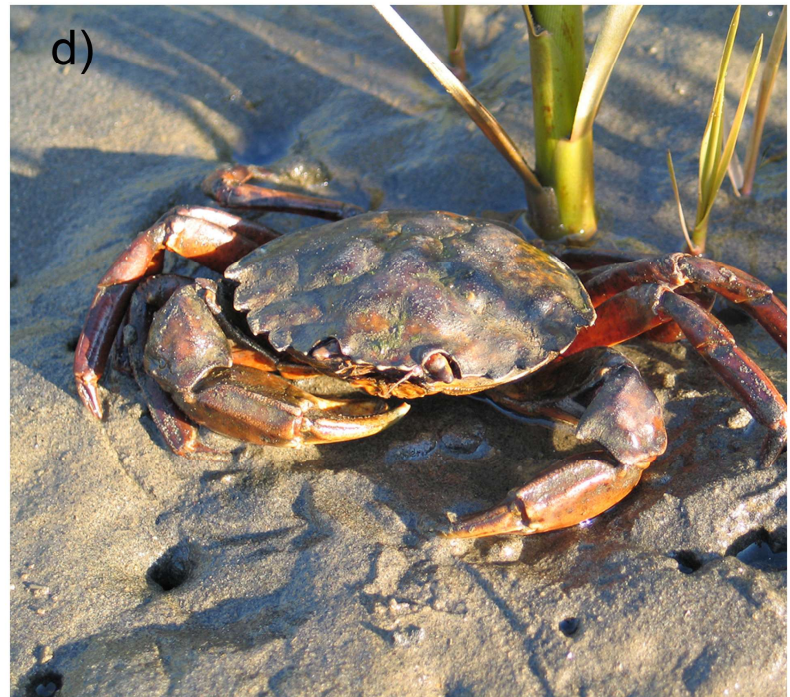
Projected change
(2040–2069 relative to 1971–2000; RCP8.5)



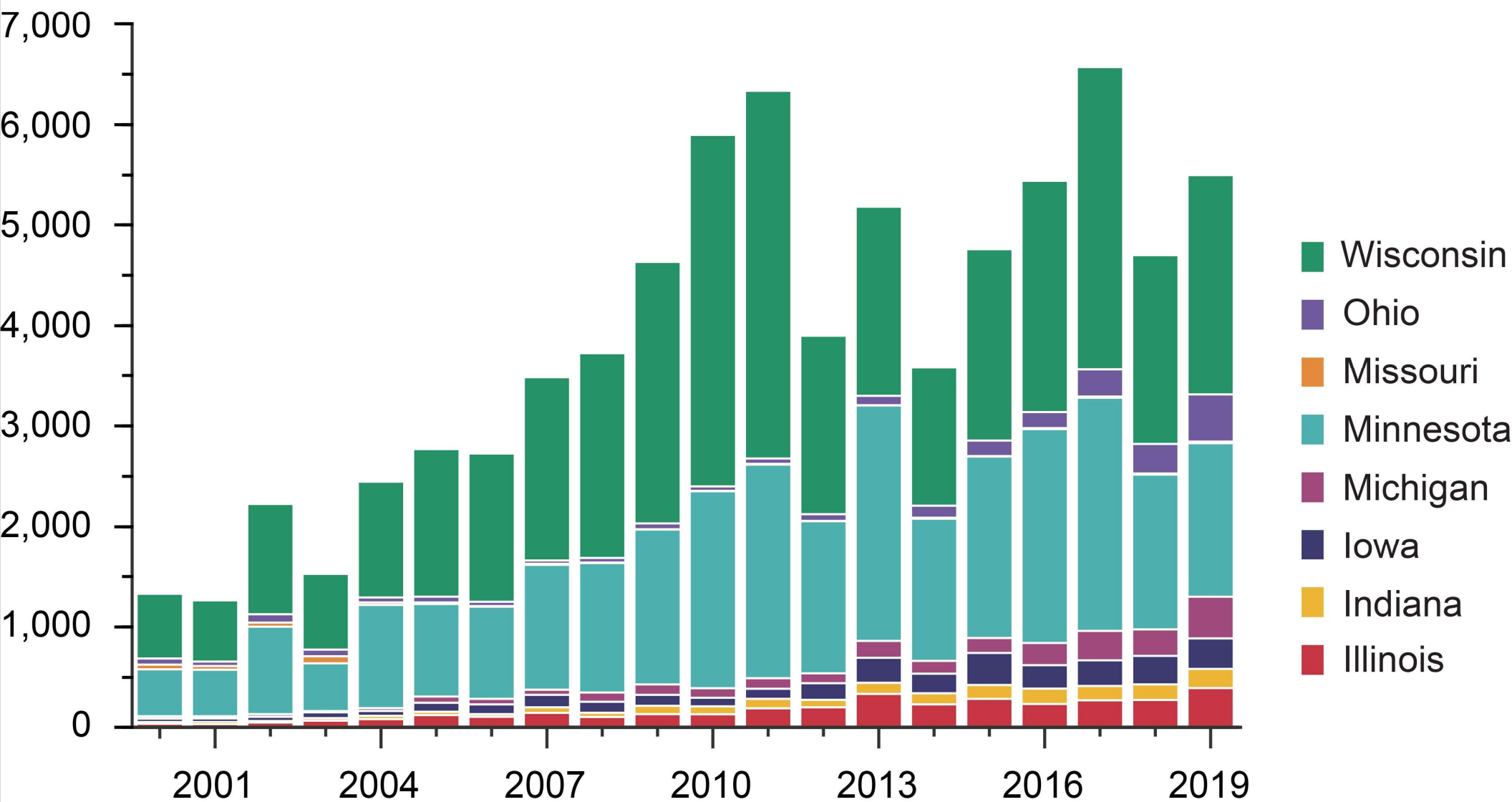
Change in Number of Days (%)



Invasive Species and Climate Change



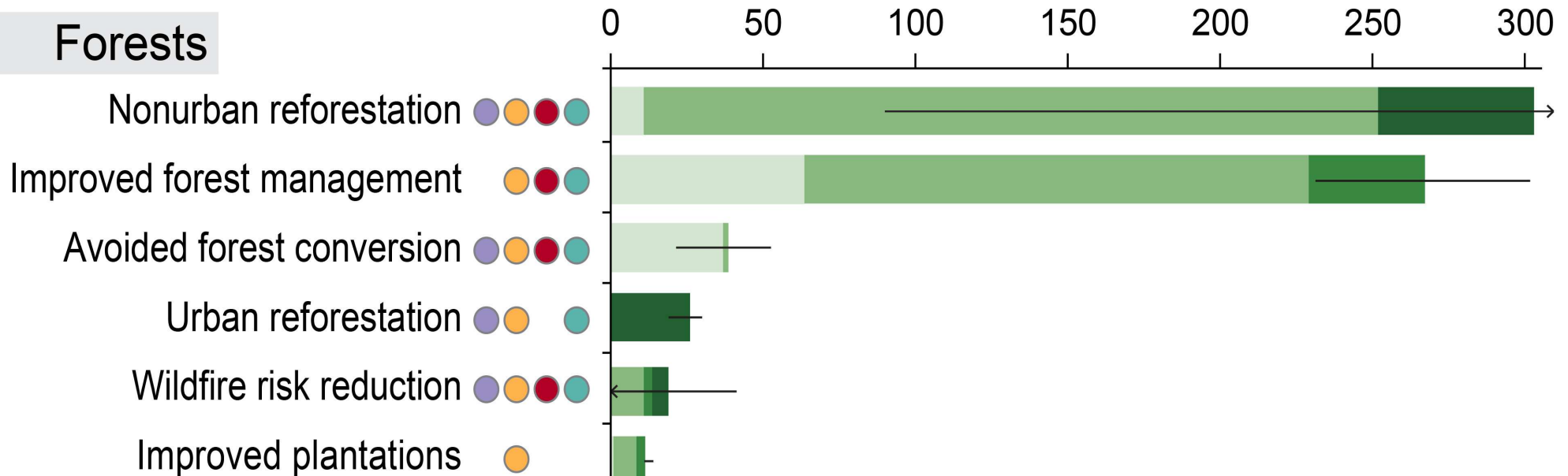
Midwest Region Lyme Disease Case Counts by State (2000–2019)



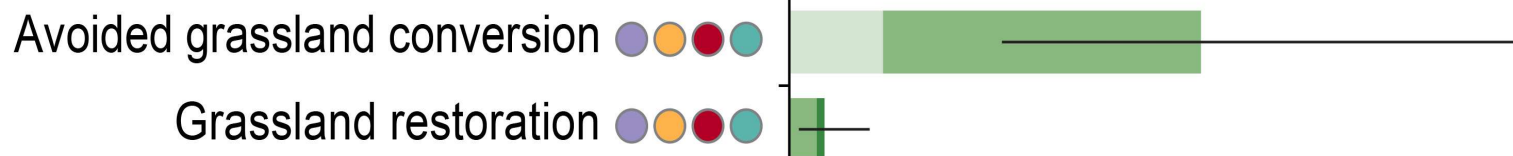
Climate Mitigation Potential of Nature-Based Solutions in 2025

Climate mitigation potential (Tg CO₂-eq per year)

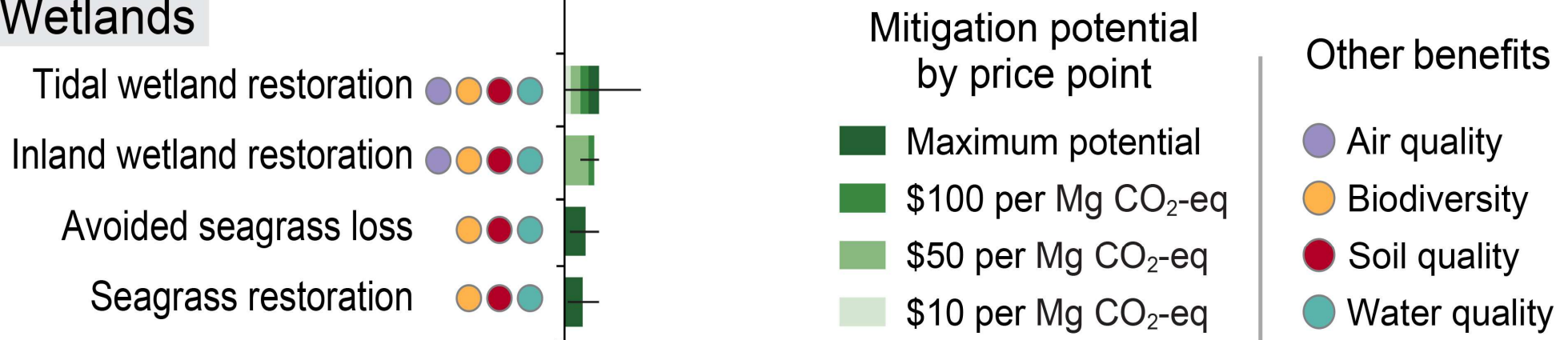
Forests



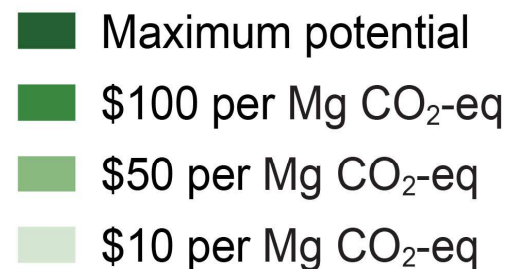
Grasslands



Wetlands



Mitigation potential
by price point



Other benefits



Bottom Line

- *We are and will continue to live with a climate that is trending is warmer and wetter across the Midwest.*
- *Extreme events are becoming more frequent and severe.*
- *How much the climate changes depends on choices made now.*

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<https://nca2023.globalchange.gov/>