Bringing Climate Change Home

How do we know it is happening &
what does it mean for me?

Dr. Heidi Roop
University of Washington
Climate Impacts Group

CLIMATE IMPACTS GROUP
UNIVERSITY of WASHINGTON
College of the Environment

@heidiroop| @CIG_UW Image with aerial support from LightHawk

Earth Scientist.













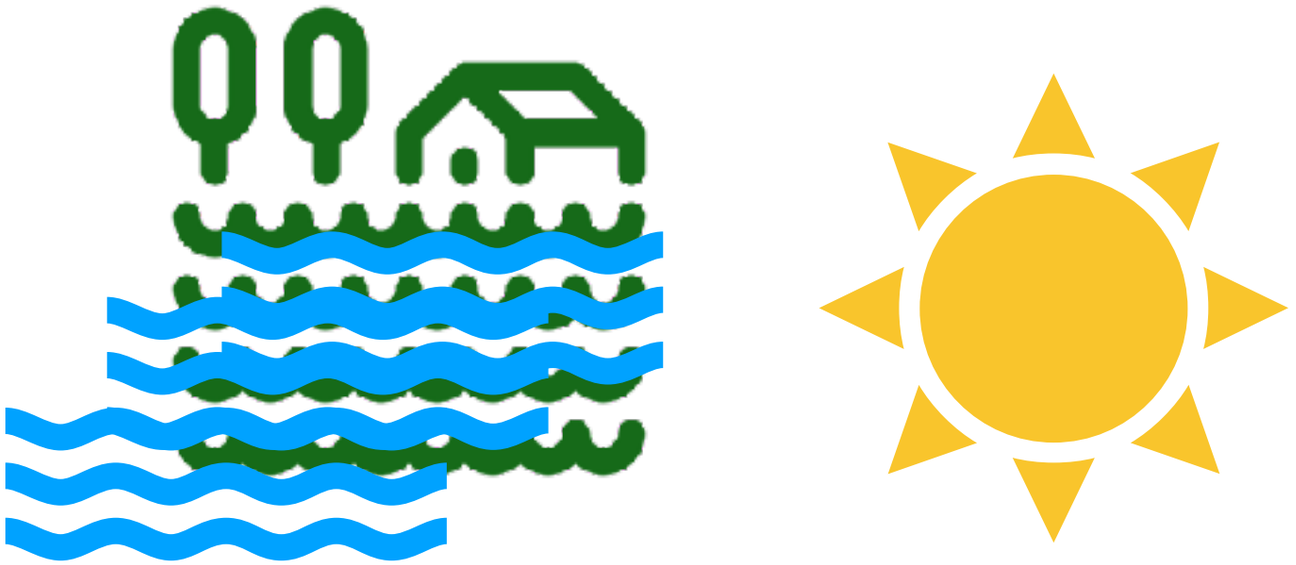
Photos: H. Roop

Established 1995

The **Climate Impacts Group** supports the development of climate resilience by ***advancing understanding*** and ***awareness*** of climate risks. We work closely with public & private entities ***to apply*** this information as they act to shape ***society's future.***

COLLEGE OF THE ENVIRONMENT
UNIVERSITY of WASHINGTON

A FOCUS ON...



WATER.

(when we have too much & not enough)

H. Roop

HOW IS CLIMATE CHANGE CONNECTED TO FLOODS & DROUGHTS?

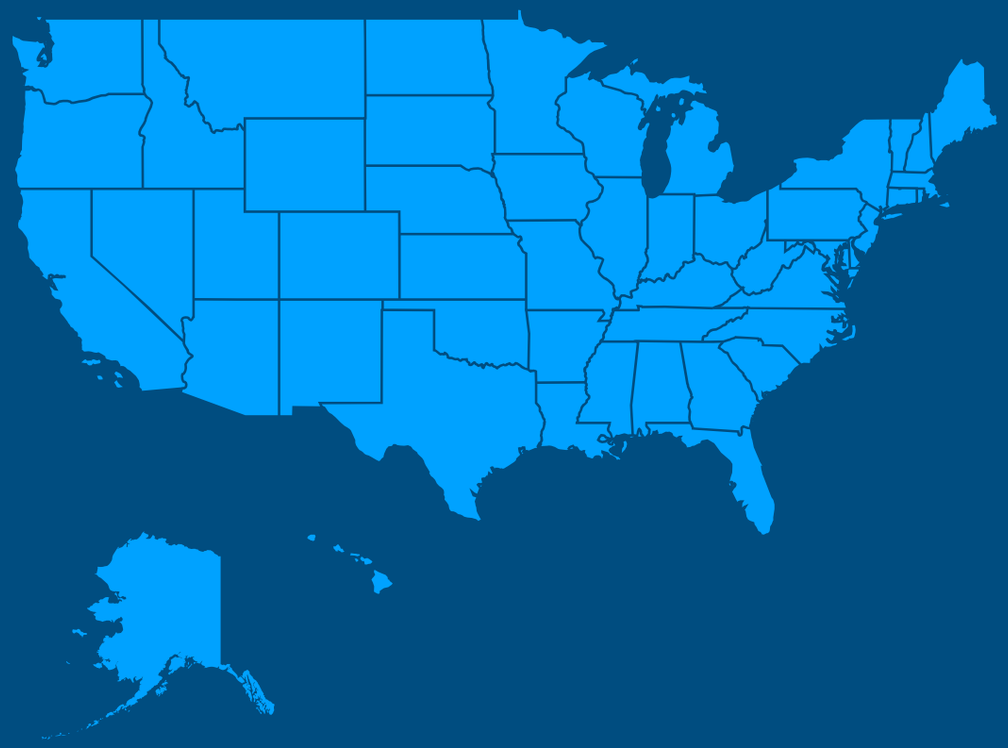
H. Roop

“Increasingly, humanity is adding to weather-related factors, as human-induced warming increases heavy downpours, causes more extensive storm surges due to sea level rise, and leads to more rapid spring snowmelt.”

Modified from NCA, 2019

Worldwide, from 1980 to 2009, floods affected more than 2.8 billion people.

Modified from NCA, 2019



In the United States, floods caused an average of nearly **$8 billion per year in damages** to property and crops from 1981 to 2011.

In 2011 dollars

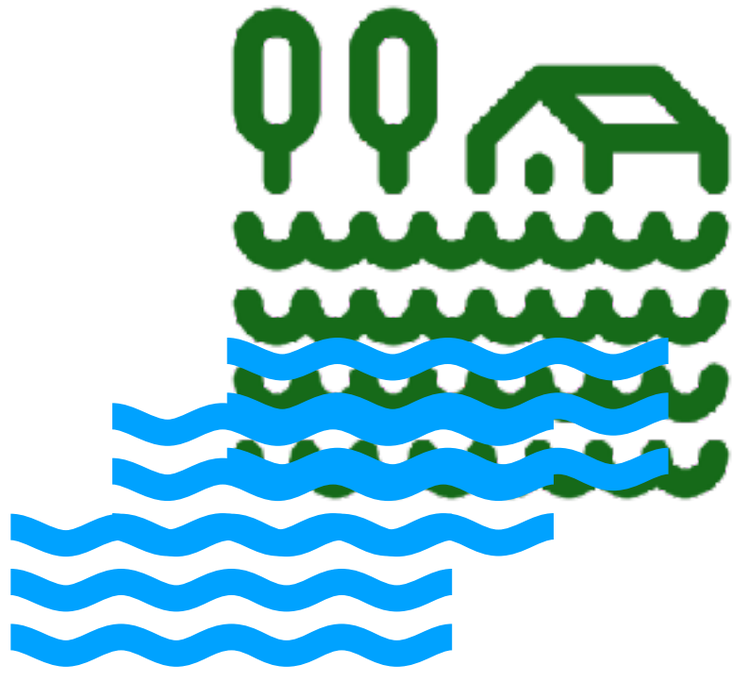
Modified from NCA, 2019

The risks from future floods are significant, given expanded development in coastal areas and floodplains, unabated urbanization, land-use changes, & human-induced climate change.

Modified from NCA, 2019

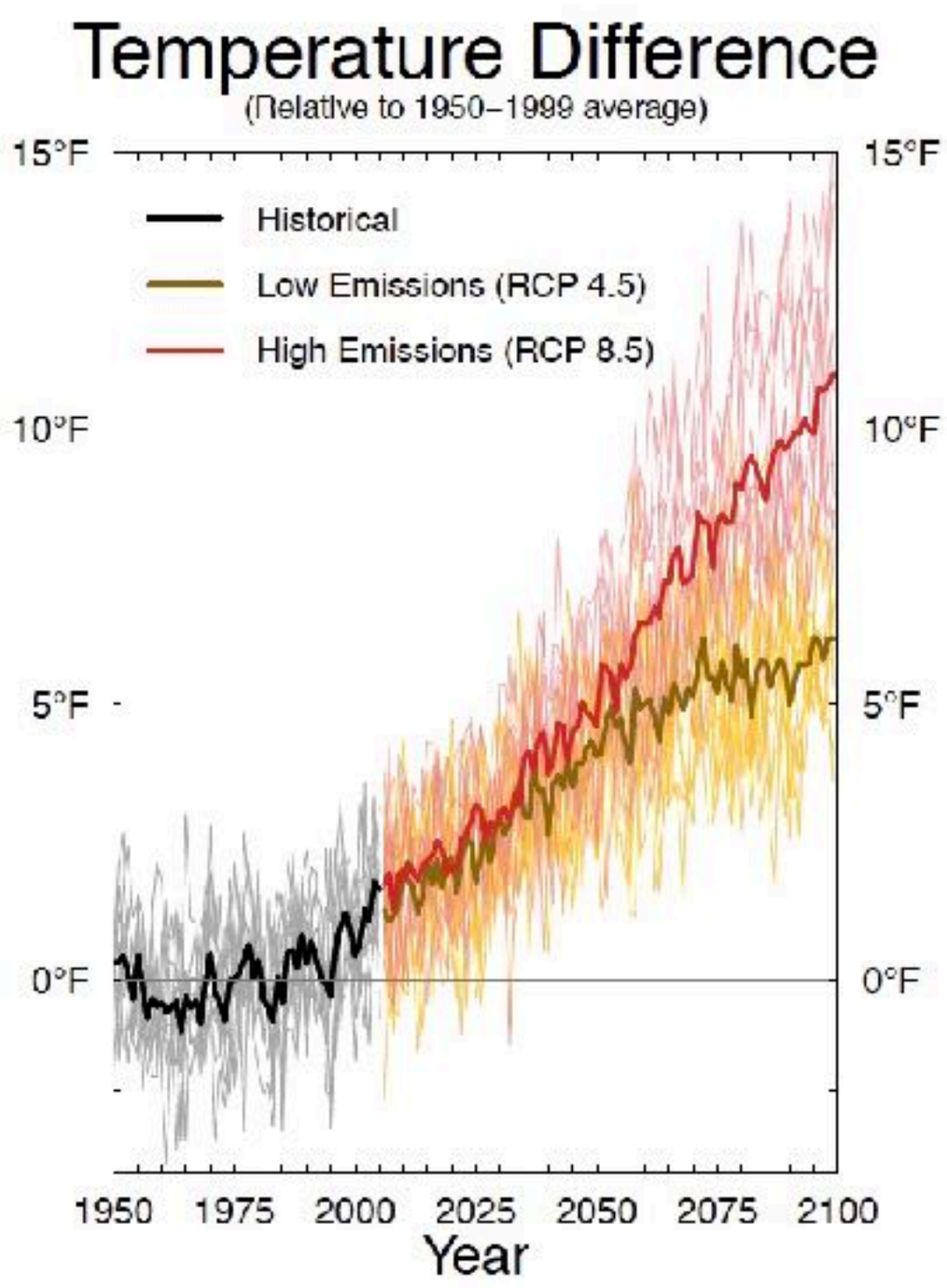
A vintage car sits in flood water on March 20, 2019 in Hamburg, Iowa.
(Photo: SCOTT OLSON, Getty Images)

CHANGING HYDROLOGY & FLOODS IN THE PNW



H. Roop

Projected changes in temperature & precipitation in the Puget Sound:



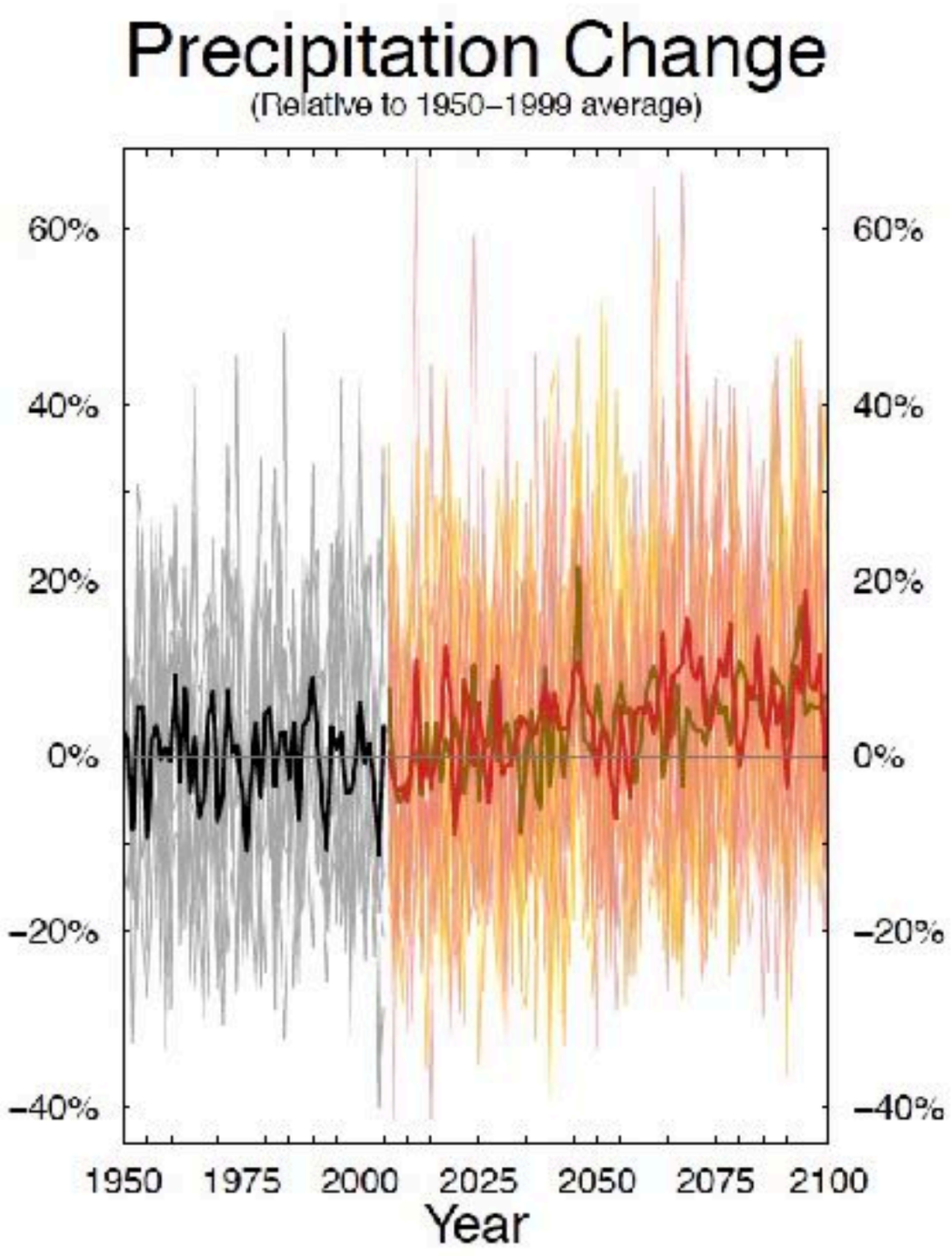


Figure 2-2. All scenarios project warming in the Puget Sound region for the 21st century; projected changes in annual precipitation are small compared to year-to-year variability.

Mauger et al., 2015

BY THE 2050's, THE AVERAGE YEAR IN PUGET SOUND IS PROJECTED TO BE +5.5°F WARMER.

RCP 8.5 | range: +4.3-7.1°F, relative to 1970-99 | Mauger et al., 2015

BY THE 2080's, THE WETTEST DAYS IN THE PACIFIC NORTHWEST ARE PROJECTED TO INCREASE BY 22%.

RCP8.5 | relative to 1970-1999 | Mauger et al., 2015

All flood types are affected by climate-related factors, some more than others.

H. Roop

Flash floods occur in small and steep watersheds and waterways and can be caused by short-duration intense precipitation, dam or levee failure, or collapse of debris and ice jams. Most flood-related deaths in the U.S. are associated with flash floods.

Urban flooding can be caused by short-duration very heavy precipitation. Urbanization creates large areas of impervious surfaces (such as roads, pavement, parking lots, and buildings) that increased immediate runoff, and heavy downpours can exceed the capacity of storm drains and cause urban flooding.

NCA, 2019

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Flash floods & urban flooding are directly linked to heavy precipitation & are expected to increase as a result of increases in heavy precipitation events.

NCA, 2019

Coastal flooding is predominantly caused by storm surges that accompany storms that push seawater toward the shore. Storm surge can cause widespread infrastructure damage, and severe erosion. Storm-related rainfall can also cause inland flooding.

Climate change affects coastal flooding through sea level rise and storm surge, and increases in heavy rainfall during storms.

Modified from NCA, 2019

Sea level rise increases the potential for higher tidal & storm surge reach, and increased coastal inundation, erosion & flooding.

Mauger et al., 2015; Photo: H. Roop with aerial support from LightHawk

U.S. Coastal Flood Days Since 1950

Orange shows human-driven global sea level rise effects
Floods totaled across 27 sites; must top NWS 'nuisance' thresholds
Source: Kopp et al. 2016 (PNAS)

CLIMATE CENTRAL

From 1950 through 2014, out of the 8,726 actual nuisance flood days, 5,809 of them — two-thirds — would not have taken place if you remove human-caused global sea level rise.

Even using a low estimate, **more than 3,500** of the flood days **would not** have taken place.

Modified from
Climate Central 2019

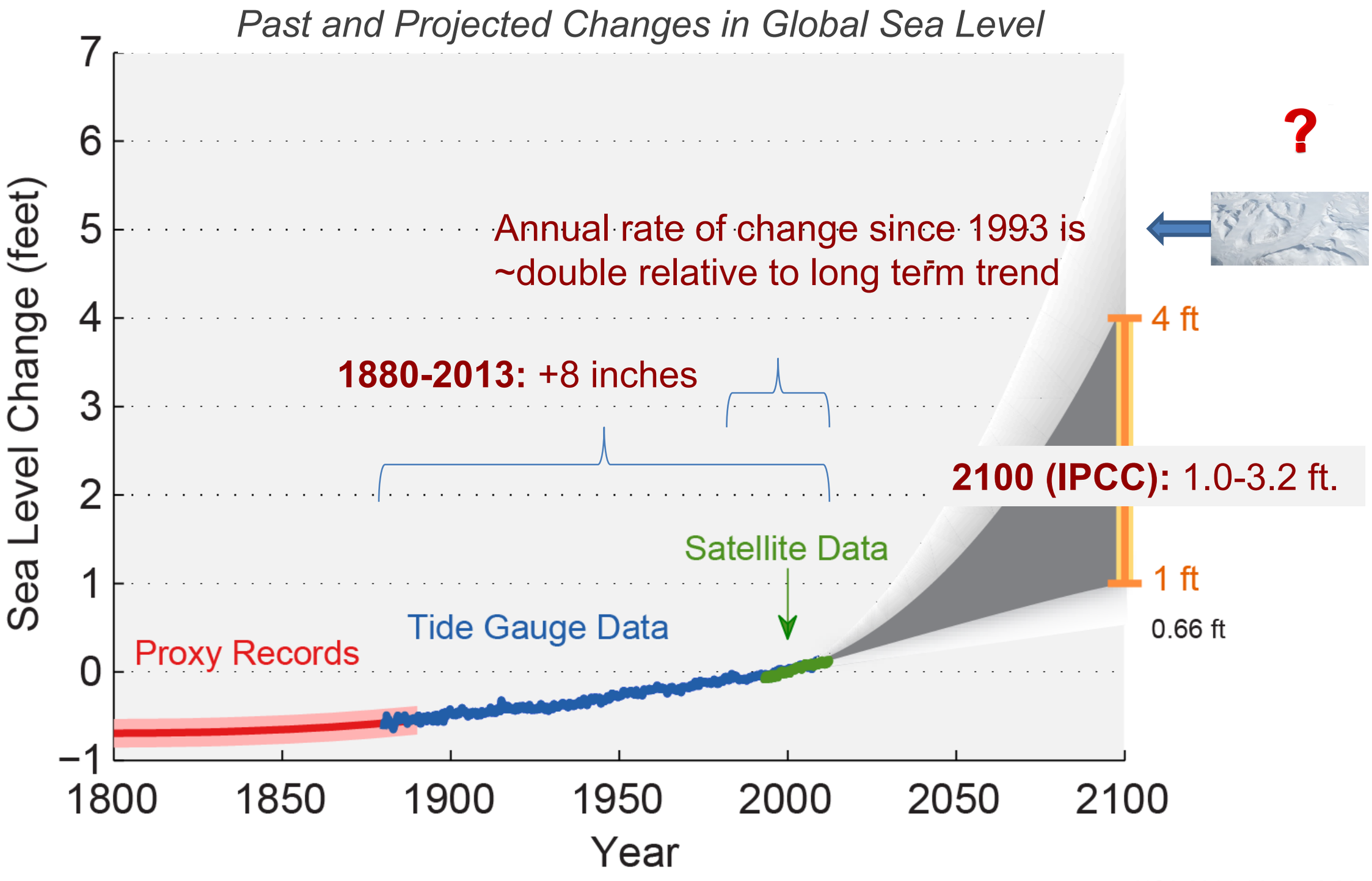
+8.6 INCHES OF SEA LEVEL RISE SINCE 1900.

1900-2008 | Seattle tide gauge | Mauger et al., 2015

CLIMATE CHANGE WILL INCREASE THE RISK OF SALTWATER INTRUSION.

RISING SEAS WILL ACCELERATE THE ERODING EFFECT OF WAVES & SURGE CAUSING BEACHES & BLUFFS TO RECEDE MORE RAPIDLY.

Global sea level is rising, and the rate of change is increasing



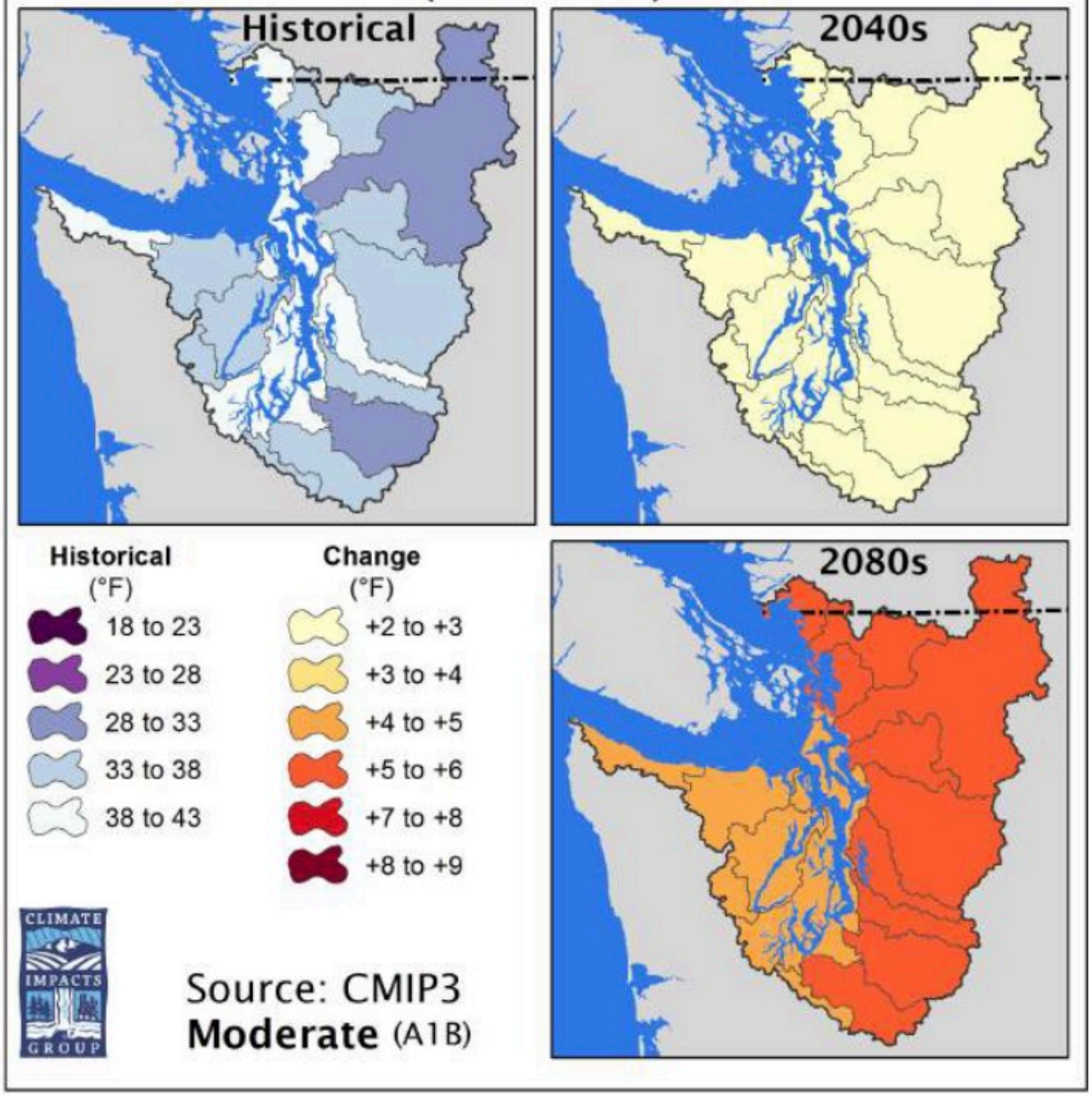
NCA 2014, Figure 2.26

River flooding occurs when surface water drained from a watershed into a stream or a river **exceeds channel capacity, overflows the banks, and inundates adjacent low lying areas**. Riverine flooding depends on **precipitation** as well as many other factors, such as existing **soil moisture conditions** and **snowmelt**.

Modified from NCA, 2019

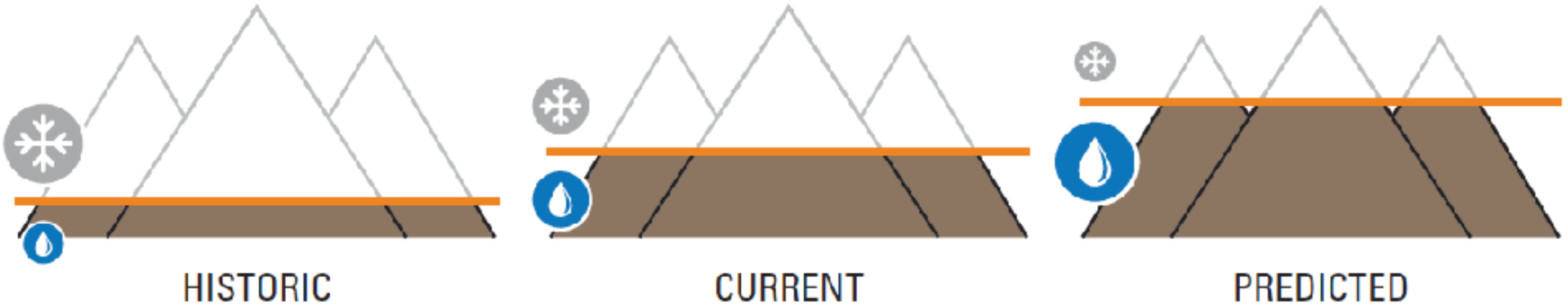
Expected 21st century changes in temperature and precipitation will *transform* the hydrologic behavior of many mountain watersheds in the West.

Average Winter Temperature (Dec-Feb)



Mauger et al., 2015

More Precipitation as Rain & Rising Winter Freezing Levels



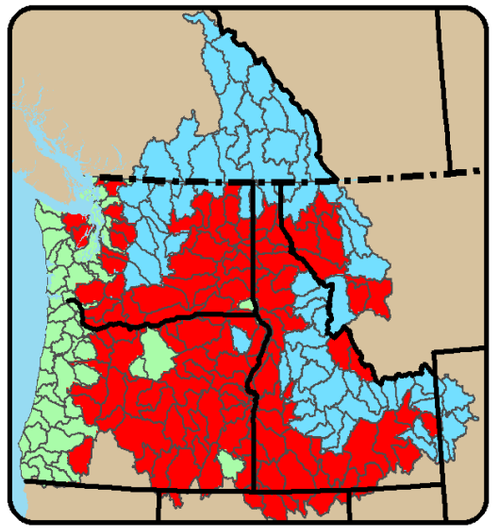
Modified from Skagit Climate Consortium

PEAK STREAMFLOW IS OCCURRING UP TO 20 DAYS EARLIER

Puget Sound | 1948-2002

Basin Transformations: Shifting from snow to rain

Historical

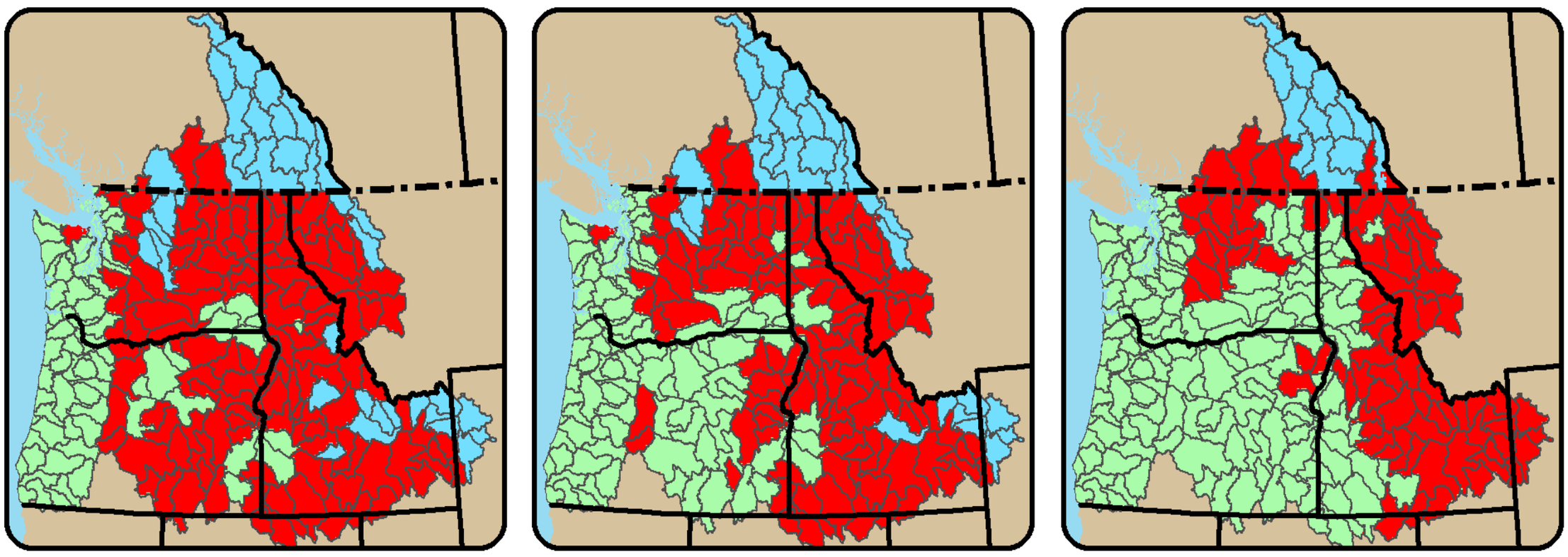


Ratio of Peak SWE to Oct. to March Precipitation

- < 0.1 Rain dominant
- 0.1 - 0.4 Transition
- > 0.4 Snow dominant

2020s **2040s** **2080s**

A1B



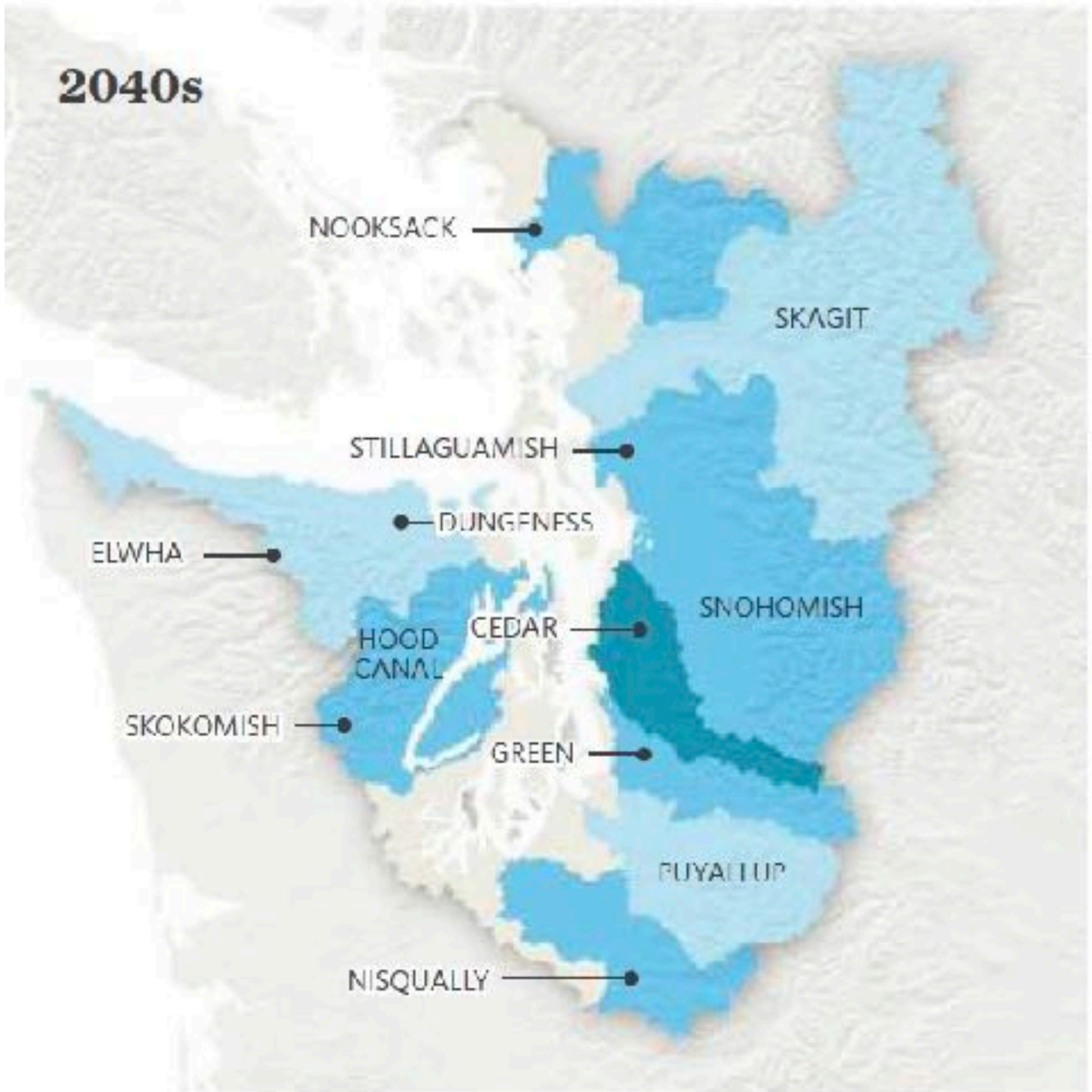
A1B: Medium emissions scenario

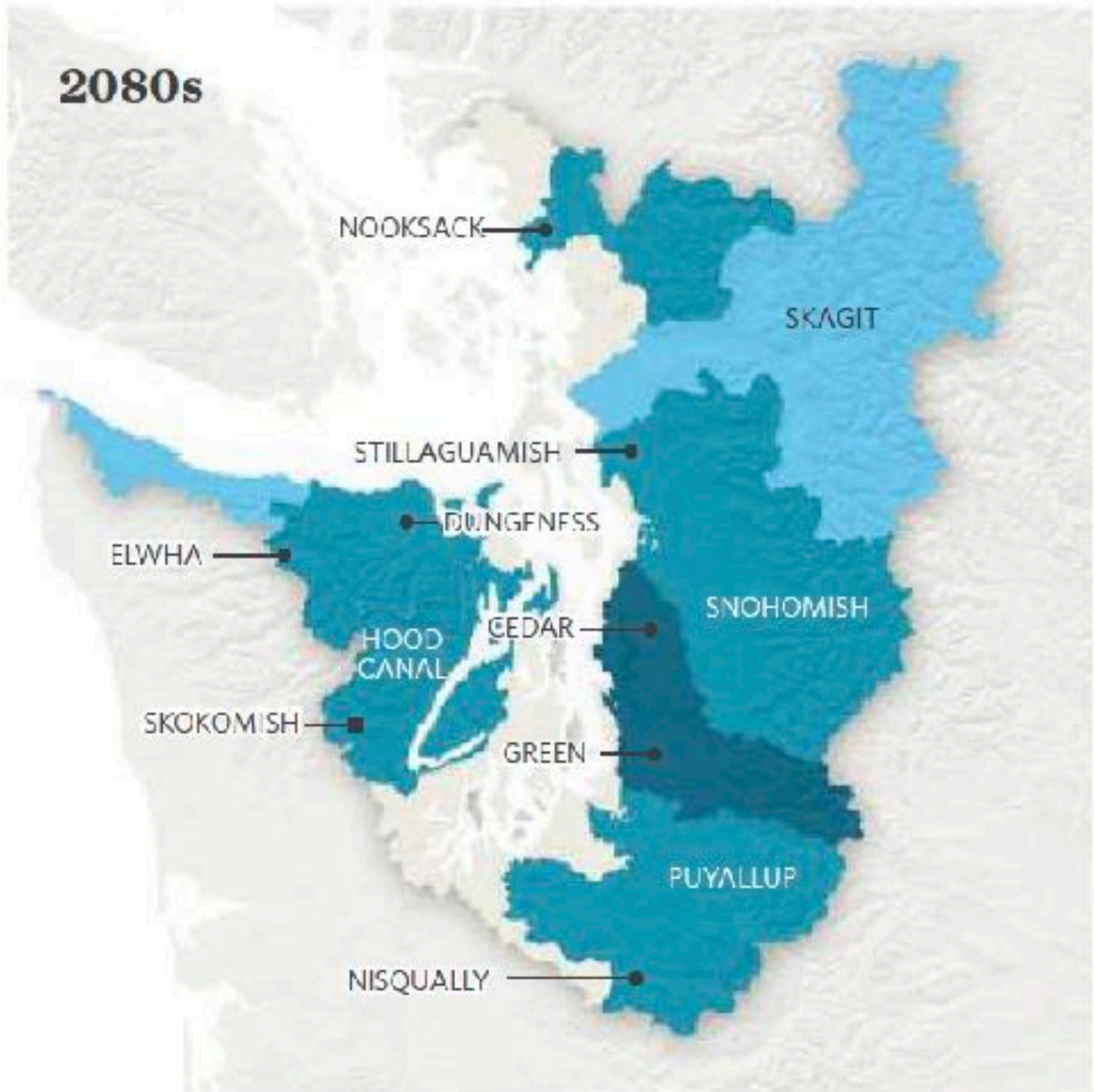
Mauger et al., 2015

By 2050, snowmelt is projected to shift 3 to 4 weeks earlier than the 20th century average

Barnett et al., 2005

APRIL 1ST SNOWPACK CHANGES





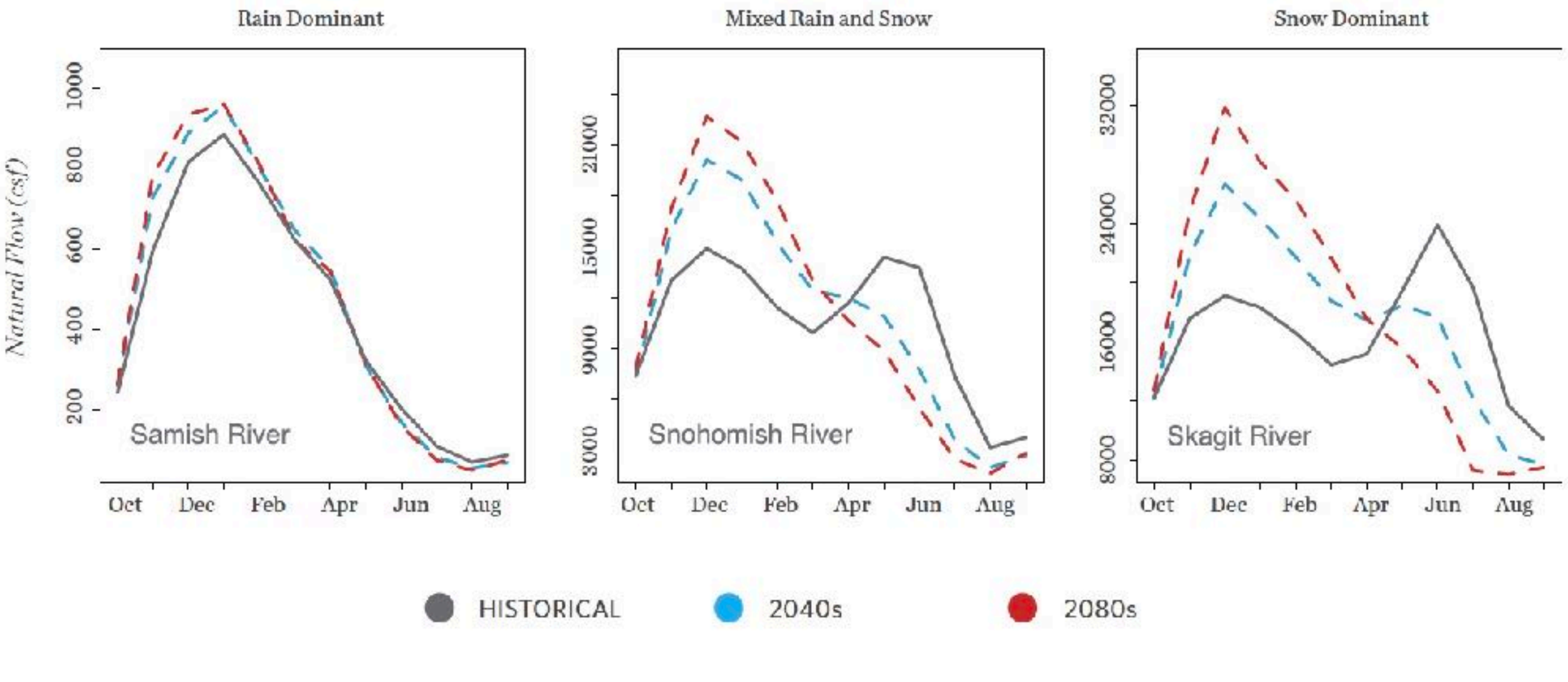
% Change in April 1st Snow Water Equivalent (SWE)

0 TO -20% | -21 TO -40% | -41 TO -60% | -61 TO -80% | -81 TO -100%

The Nature Conservancy, Mauger et al., 2015

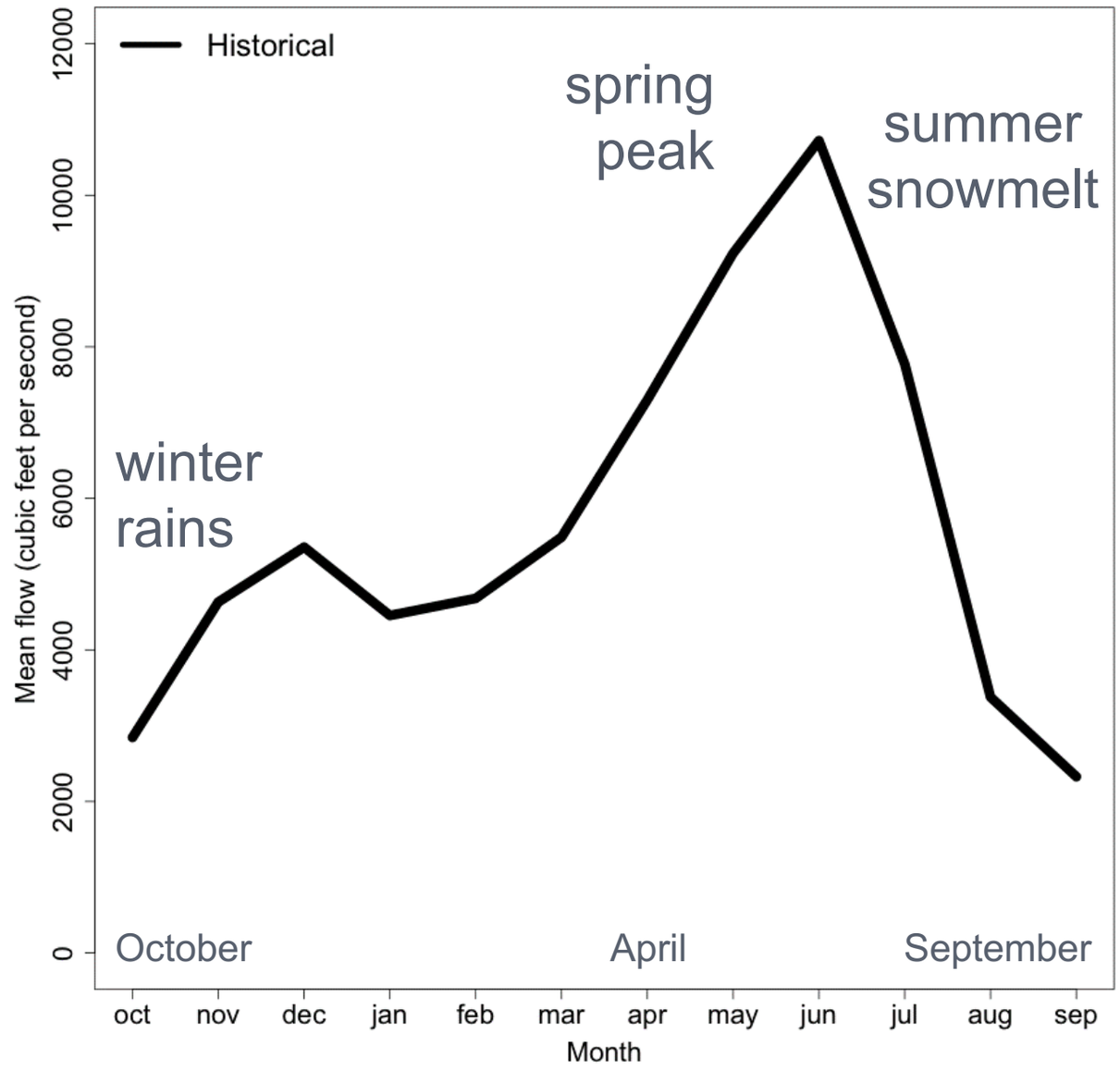
TIMING OF STREAMFLOW

Most Puget Sound watersheds will be rain dominant by the end of the 21st century



The Nature Conservancy, Mauger et al., 2015

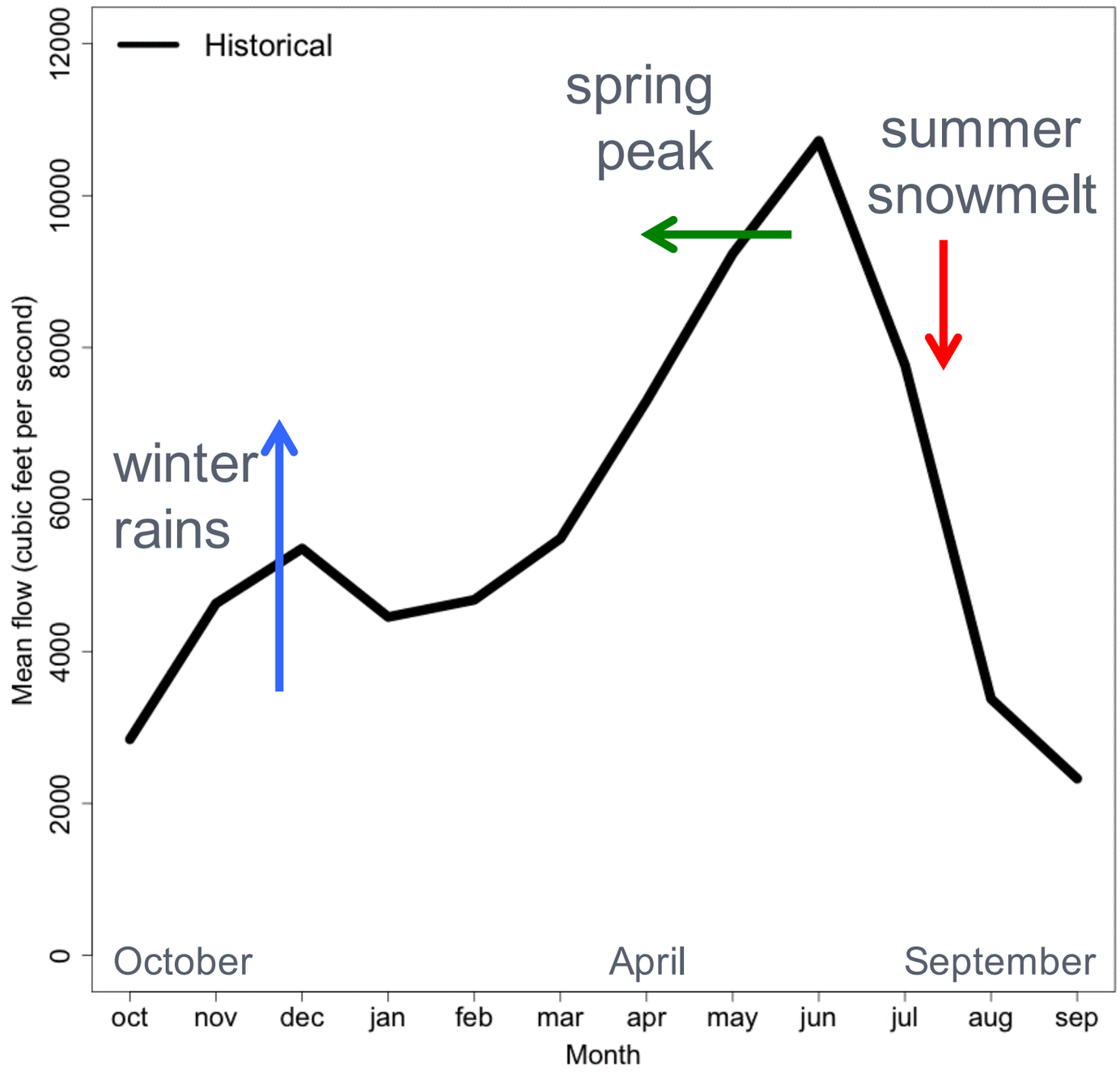
Shifting Streamflows – Yakima Basin



Elsner et al. 2010

Change in flood risk depends on many factors, but is projected to increase the most in mixed basins (those with both winter rainfall & summer snowmelt-related runoff peaks) & decrease in higher basins.

Shifting Streamflows – Yakima Basin



Elsner et al. 2010

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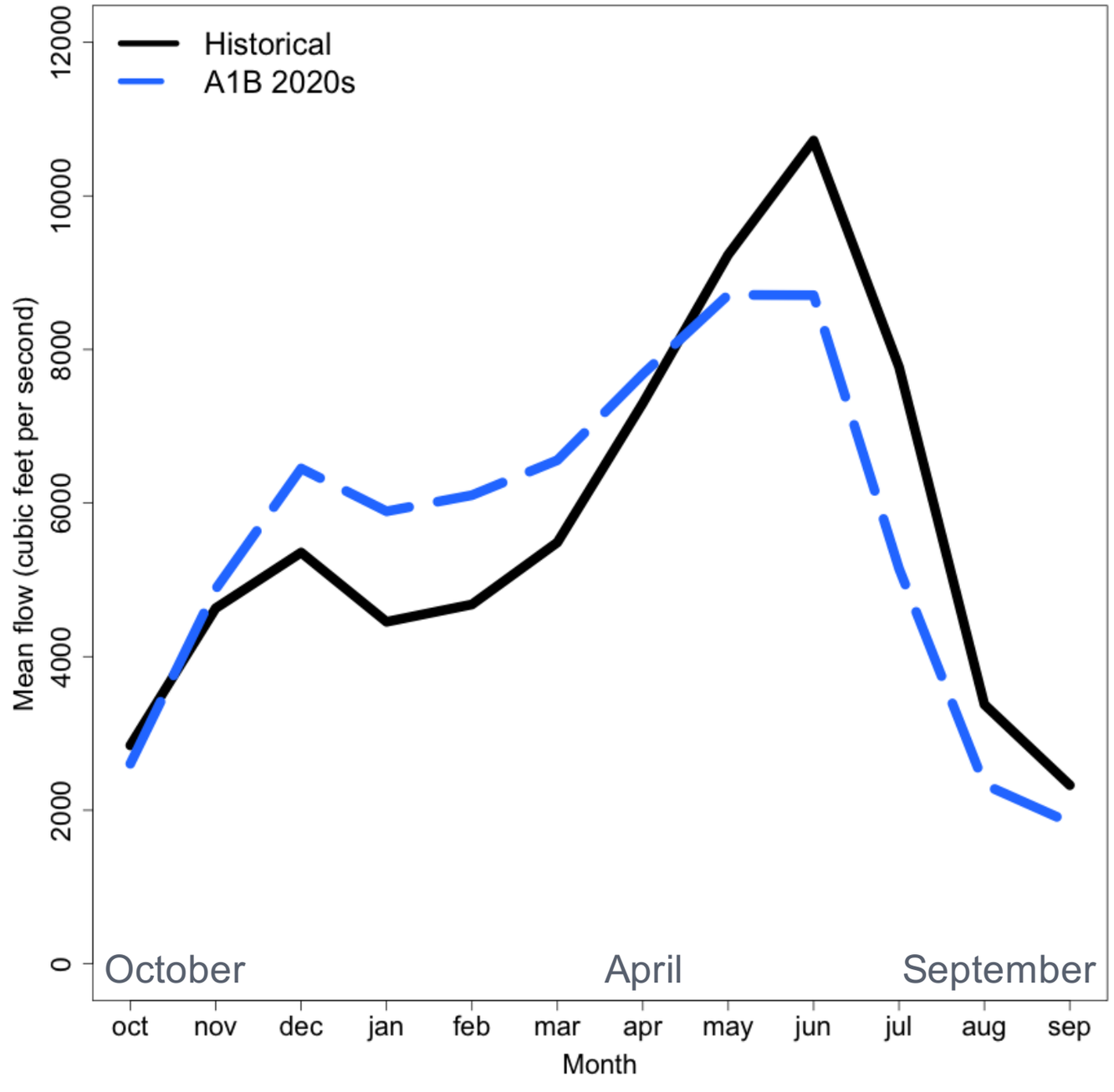
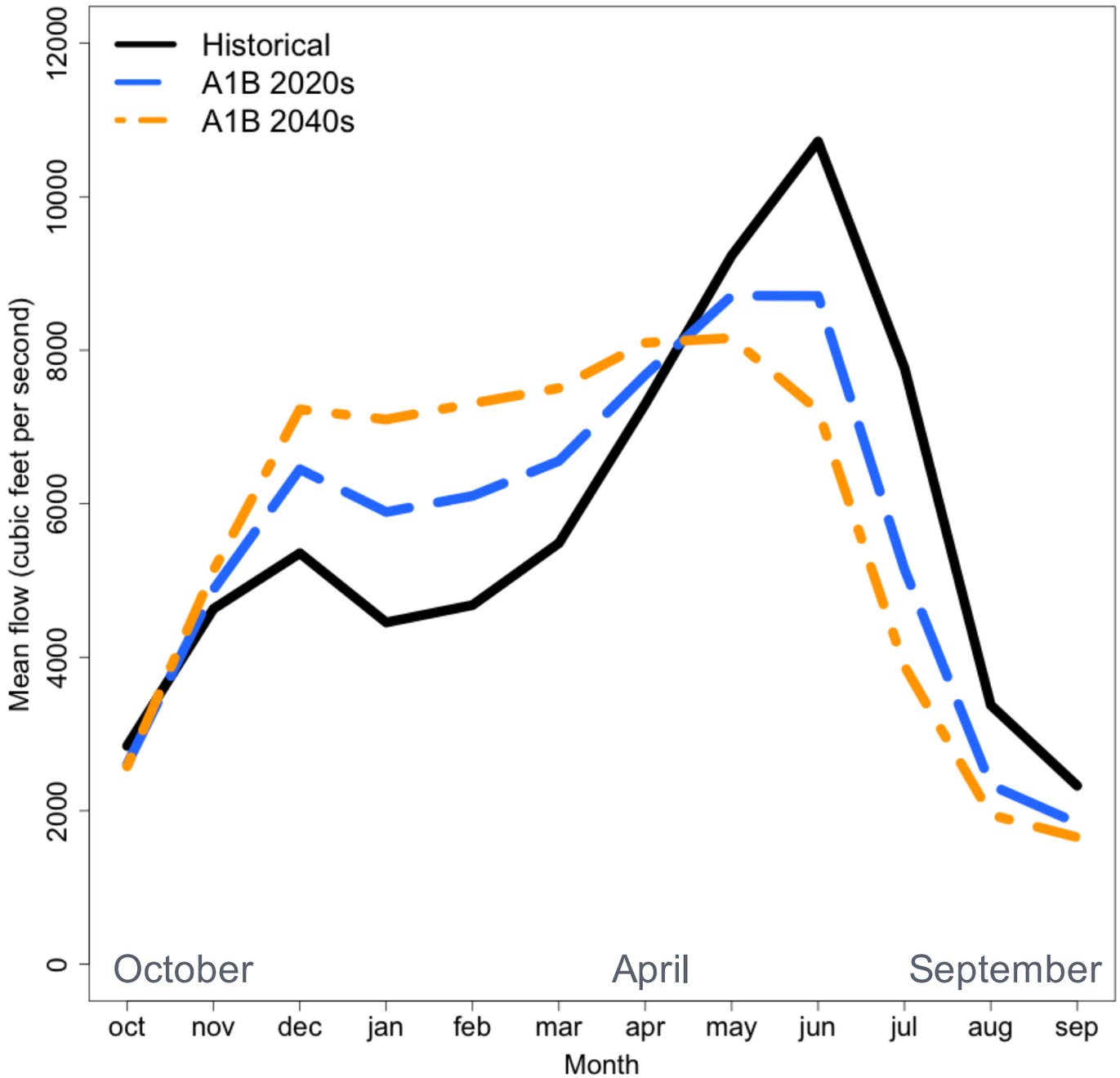


Elsner et al. 2010

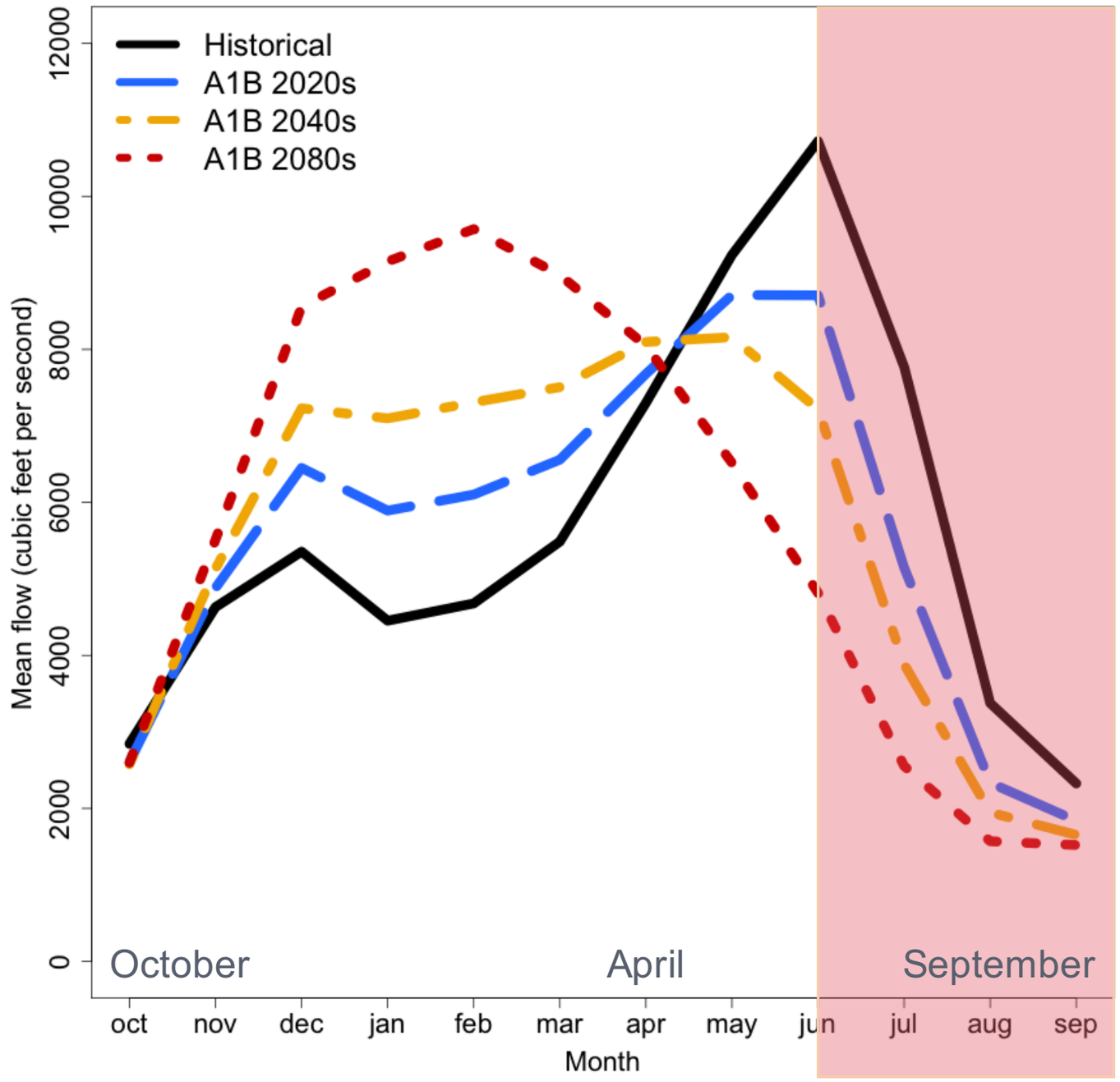
A1B: medium emissions scenario

Shifting Streamflows – Yakima Basin



Elsner et al. 2010

Shifting Streamflows – Yakima Basin



Water needed for:

- irrigation,
- instream flows,
- fall hydro-production

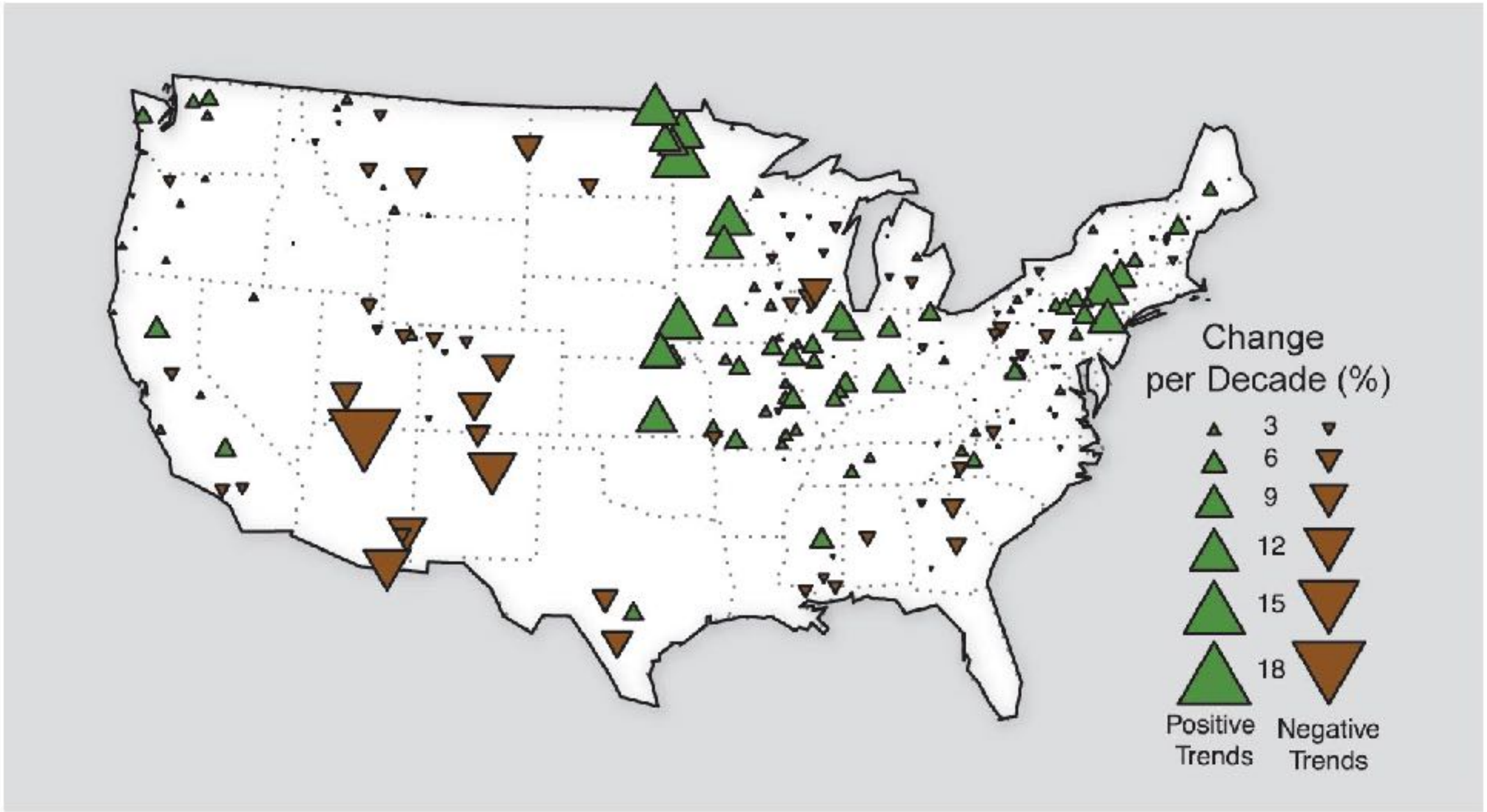
Elsner et al. 2010

In the Yakima basin, water shortage years – years with **curtailed water delivery** to junior water rights holders – are projected to **increase from 14%** of years historically to **36% to 77%** of years by the 2080s.

1979-1999 | for low & medium greenhouse gas scenario

Vano et al., 2010

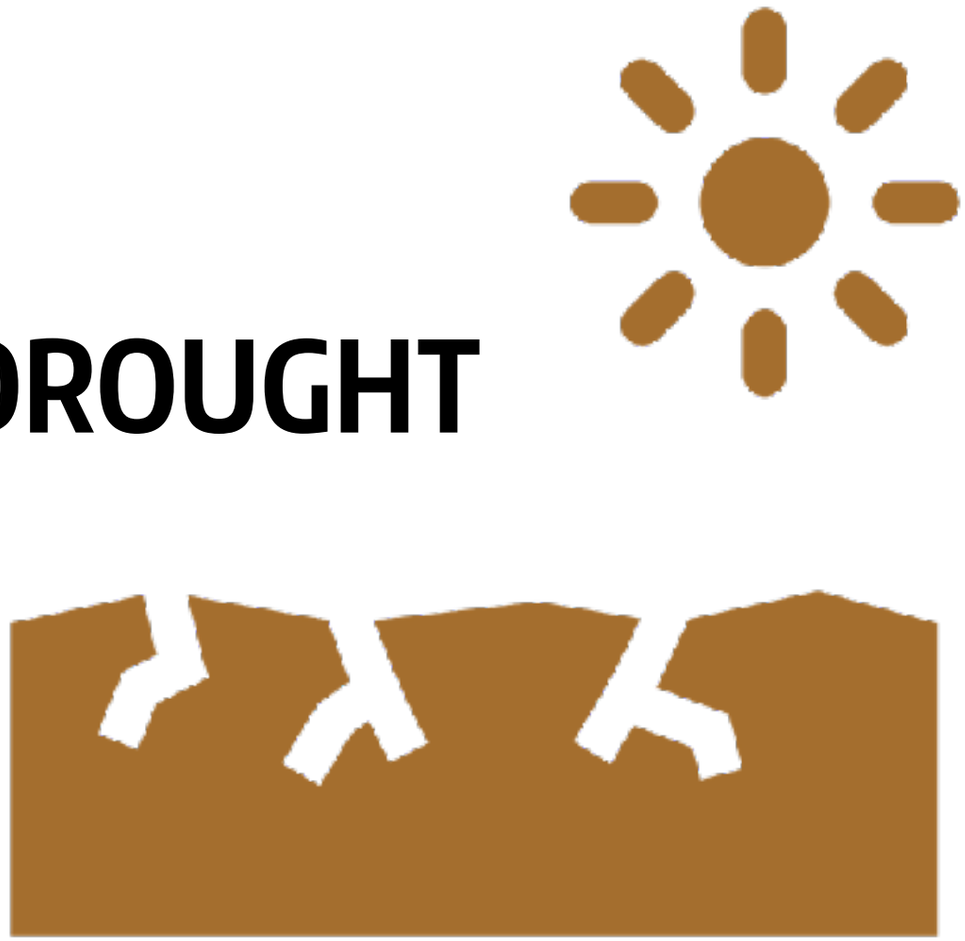
Trends in Flood Magnitude



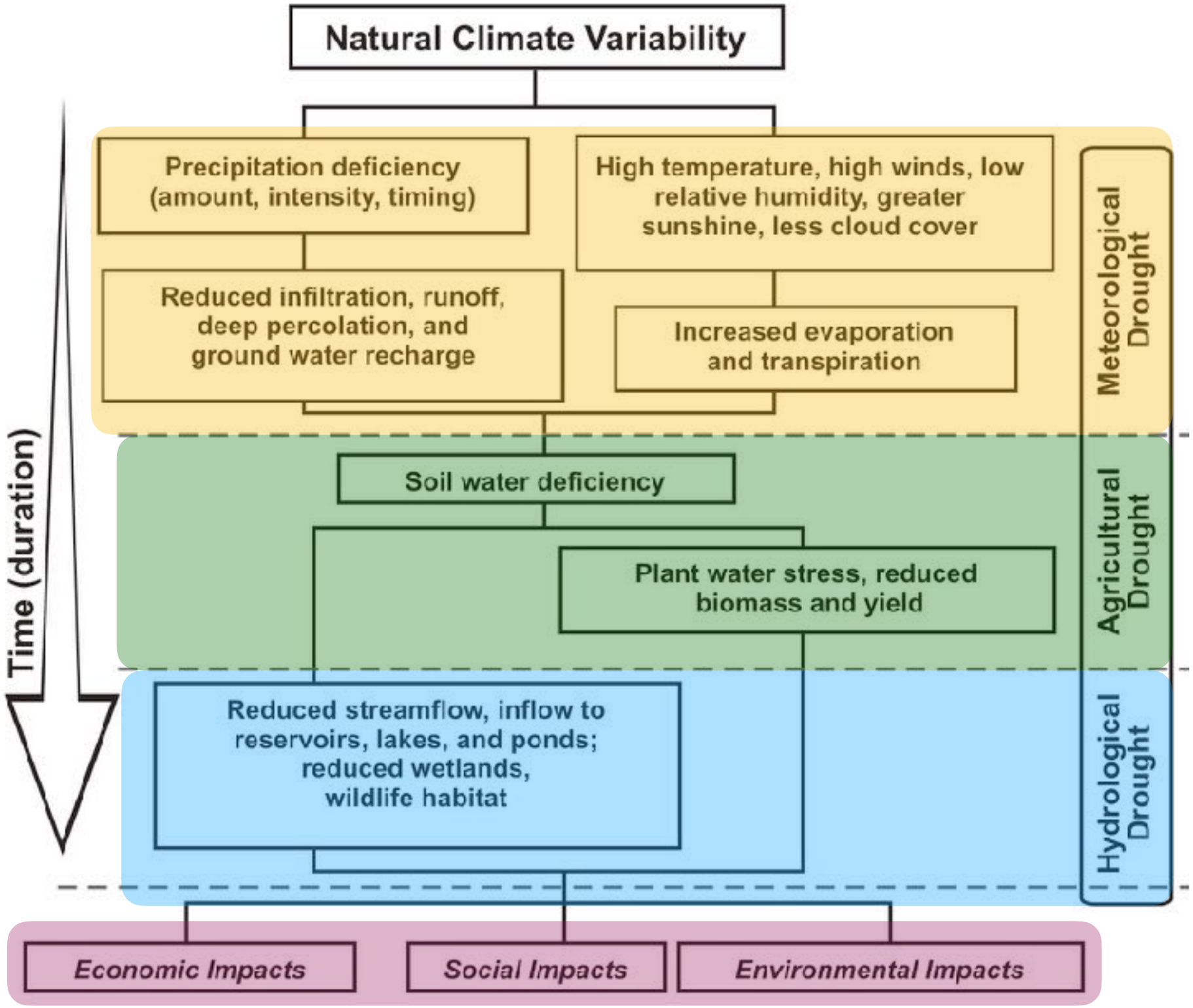
There are significant trends in the magnitude of river flooding in many parts of the United States.[1,2,3,4] River flood magnitudes (from the 1920s through 2008) have decreased in the Southwest and increased in the eastern Great Plains, parts of the Midwest, and from the northern Appalachians into New England.[5] The map shows increasing trends in floods in green and decreasing trends in brown. The magnitude of these trends is illustrated by the size of the triangles. (Figure source: Peterson et al. 2013[5]).

Modified from NCA, 2019

DROUGHT



There are different types of drought:

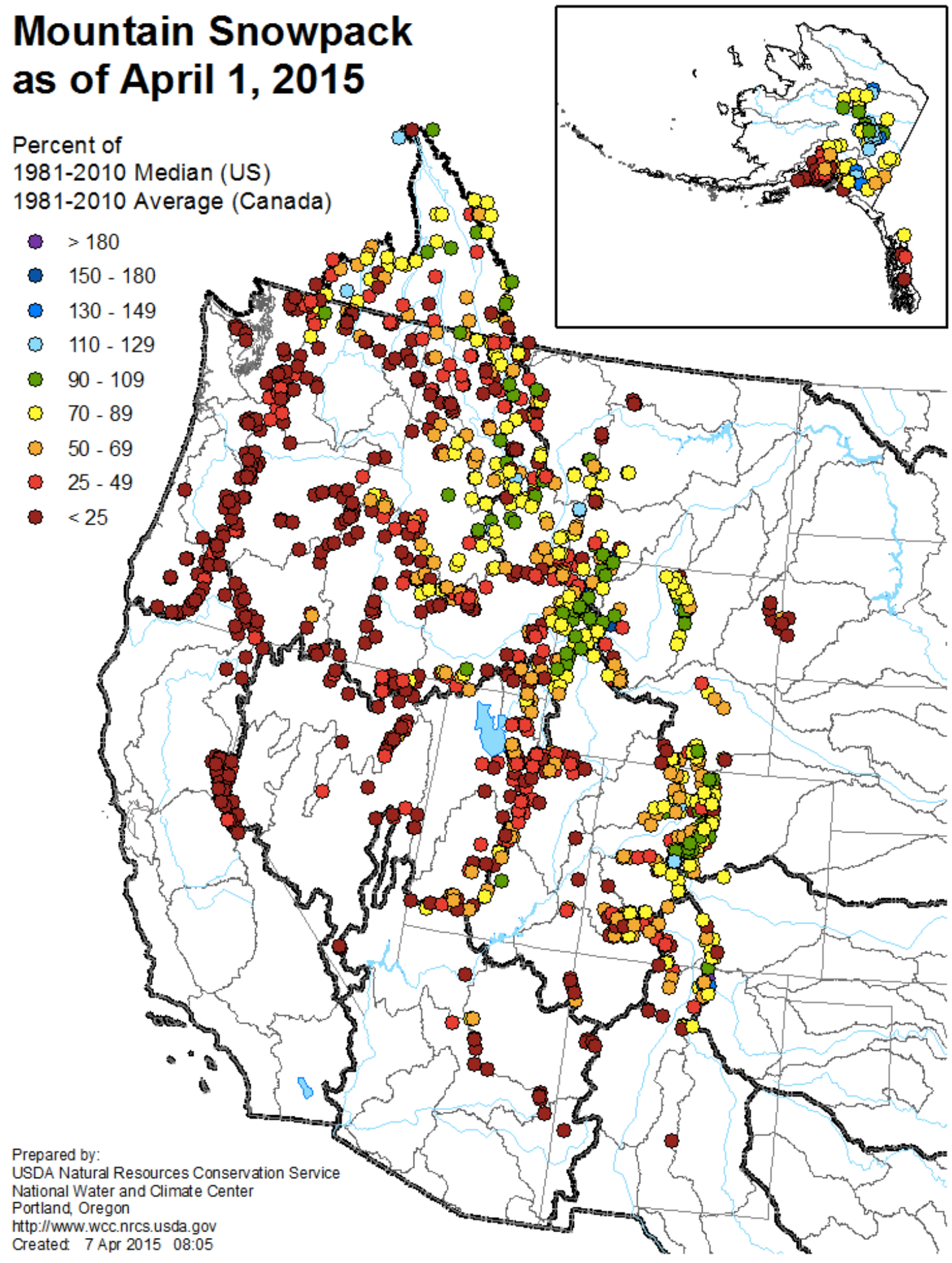


All droughts originate from a deficiency of precipitation or meteorological drought, but other types of drought and impacts cascade from this deficiency. (Source: NDMC)

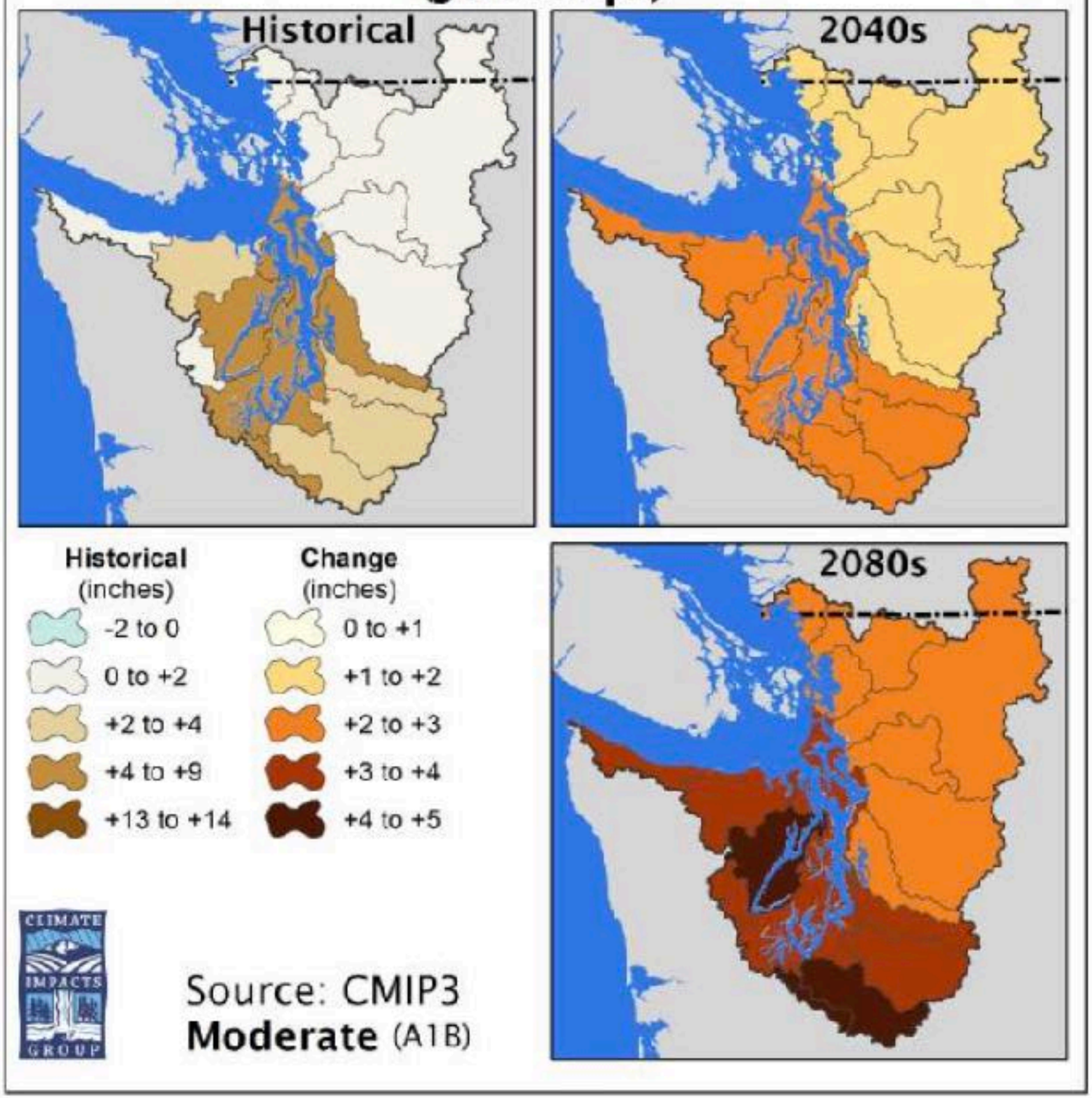
2015
Snowpack ‘drought’

Most watersheds across western Cascades = ~30% of April 1 Snow Water Equivalent (SWE)

Similar to projected changes in the ~2050-2080’s



Summer Water Deficit
(Jul.-Sep.)



Mauger et al., 2015

Learn more about the US Drought Monitor

D0 - Abnormally Dry

- Short-term dryness slowing planting, growth of crops
- Some lingering water deficits
- Pastures or crops not fully recovered

31.7% of State

35.5% D0-D4

D1 - Moderate Drought

- Some damage to crops, pastures
- Some water shortages developing
- Voluntary water-use restrictions requested

3.8% of State

3.8% D1-D4

D2 - Severe Drought

- Crop or pasture loss likely
- Water shortages common
- Water restrictions imposed

0.0% of State

0.0% D2-D4

D3 - Extreme Drought

- Major crop/pasture losses
- Widespread water shortages or restrictions

0.0% of State

0.0% D3-D4

D4 - Exceptional Drought

- Exceptional and widespread crop/pasture losses
- Shortages of water creating water emergencies

0.0% of State

NIDIS. 2018

Drought in Washington

in March, 2019

Residents in drought:

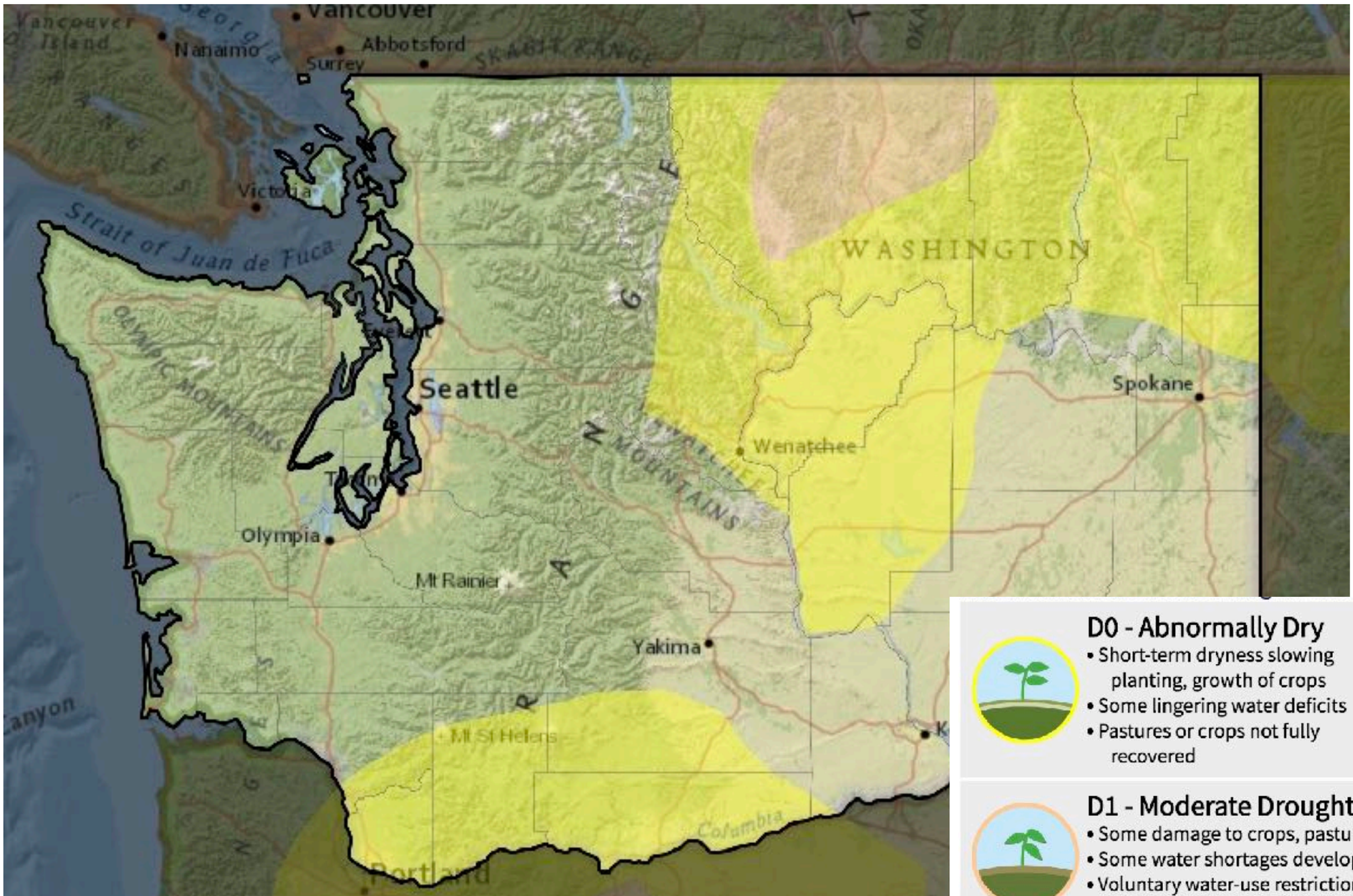
20,000

898,000 more in abnormally dry areas.

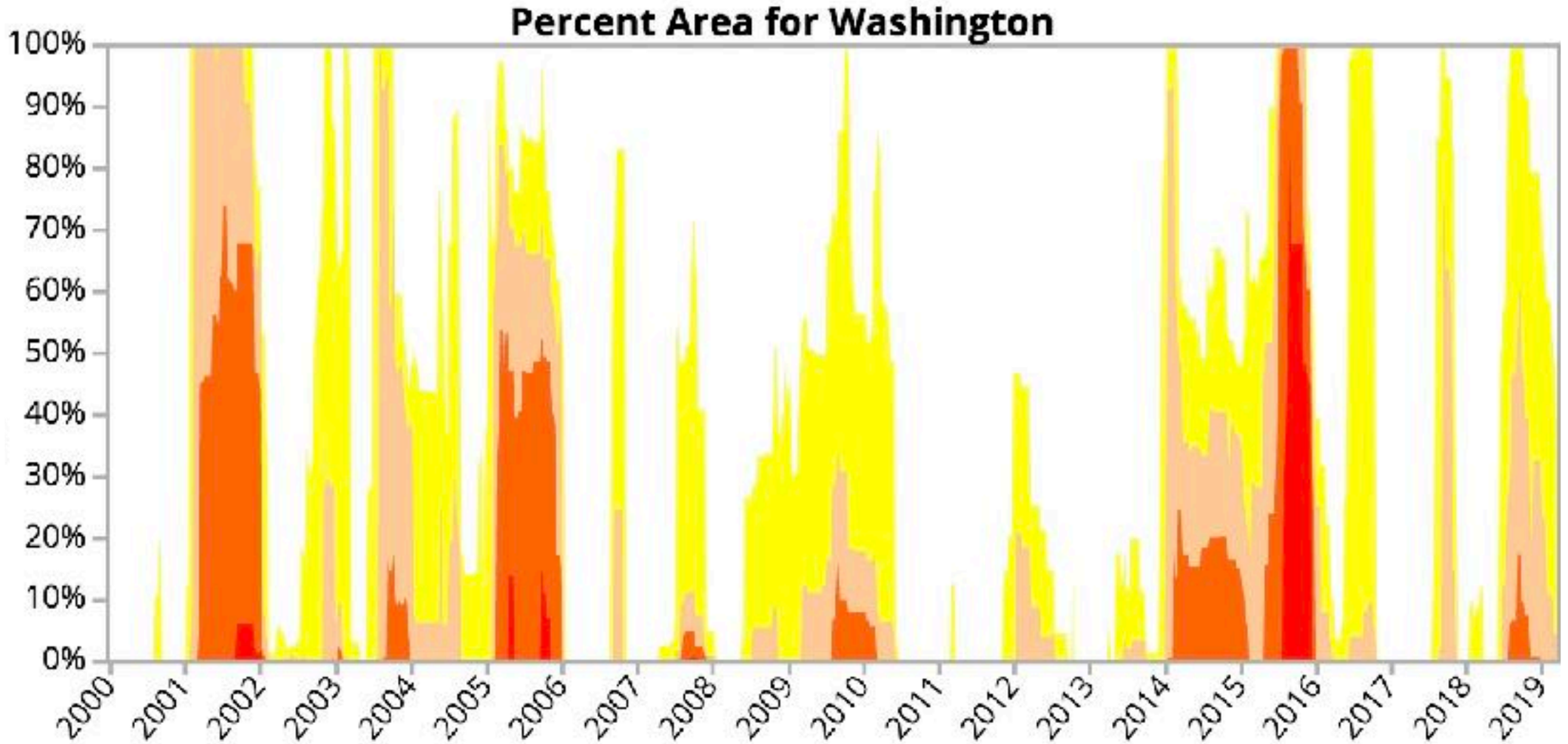
This is:

0%

of the state's population,
14% more in abnormally dry areas.



D0 - Abnormally Dry • Short-term dryness slowing planting, growth of crops • Some lingering water deficits • Pastures or crops not fully recovered	31.7% of State	35.5% D0-D4
D1 - Moderate Drought • Some damage to crops, pastures • Some water shortages developing • Voluntary water-use restrictions requested	3.8% of State	3.8% D1-D4



D0 D1 D2 D3 D4

Learn more about the US Drought Monitor

D0 - Abnormally Dry

- Short-term dryness slowing planting, growth of crops
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31.7% of State | 35.5% D0-D4

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- Some water shortages developing
- Voluntary water-use restrictions requested

3.8% of State | 3.8% D1-D4

D2 - Severe Drought

- Crop or pasture loss likely
- Water shortages common
- Water restrictions imposed

0.0% of State | 0.0% D2-D4

D3 - Extreme Drought

- Major crop/pasture losses
- Widespread water shortages or restrictions

0.0% of State | 0.0% D3-D4

D4 - Exceptional Drought

- Exceptional and widespread crop/pasture losses
- Shortages of water creating water emergencies

0.0% of State

2015

Temperature: ~2.7°C (4.8°F) warmer than pre-industrial
Snowpack: ~70% below normal (1970-1999 average)

FISHERIES

Low summer streamflow & warm waters resulted in fishery closures

>250,000 Columbia River sockeye salmon died

RECREATION

Low snowpack led to reductions in winter & summer recreation

42% shorter ski season at Stevens Pass

WILDFIRE

The most severe wildfire season in Washington's recorded history

>1,000,000 acres burned

>$253 million fire supression

AGRICULTURE

Warm temperatures & reduced water availability stressed WA agriculture

17 major crops with reduced yields

$633-733 million economic losses

Climate Impacts Group, 2019

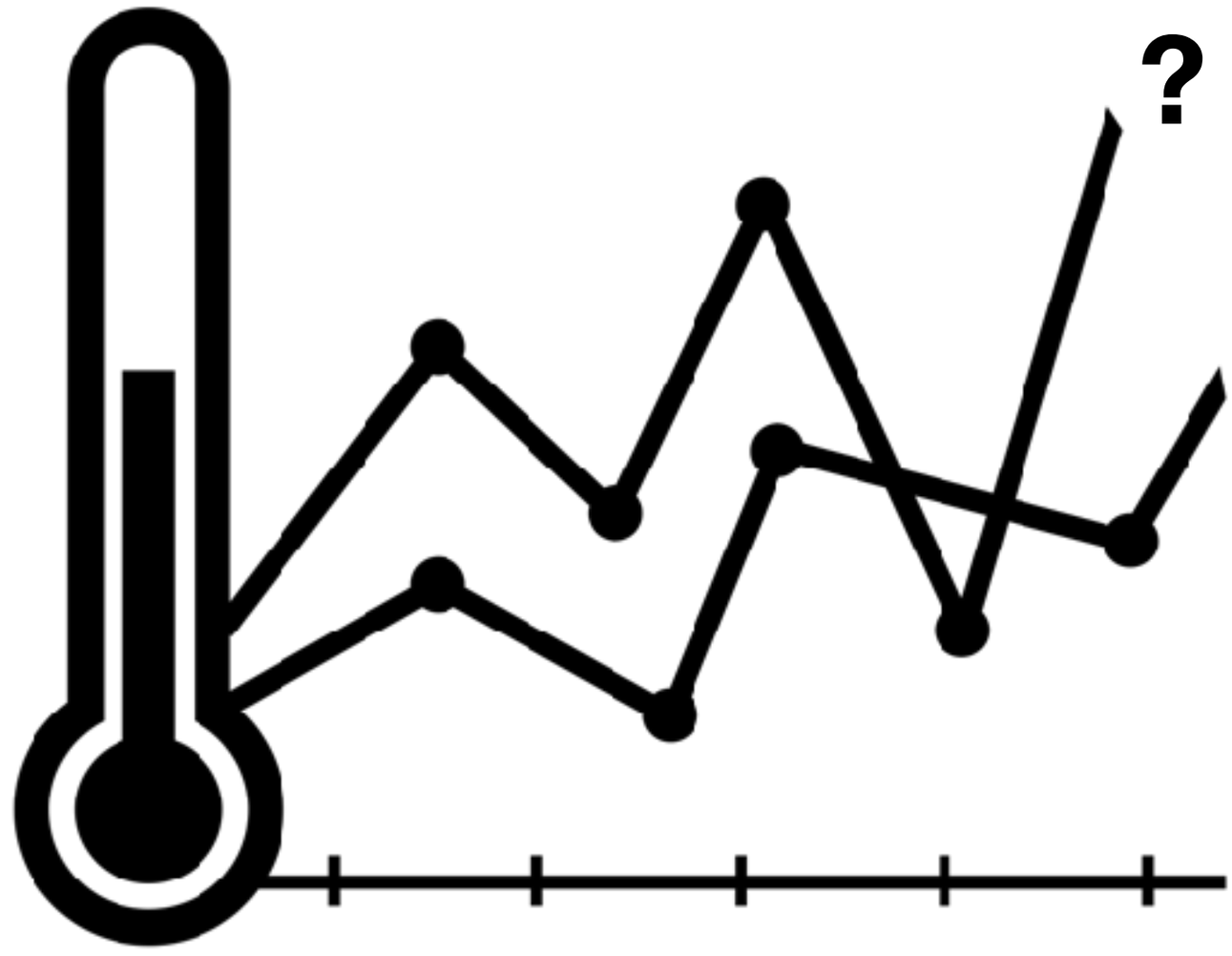
WA State's Scientific Resources

From: UW Climate Impacts Group

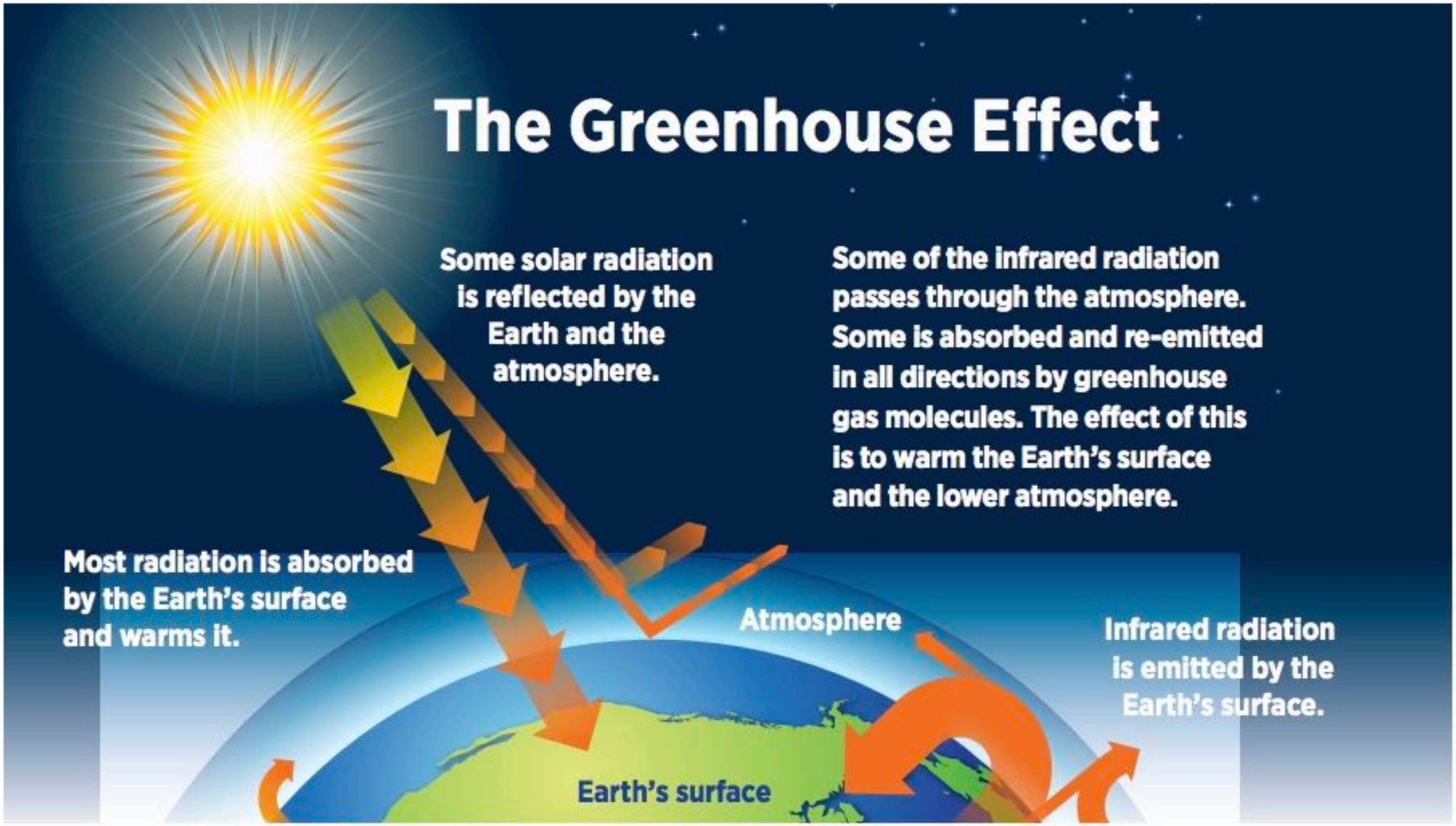
The NW leads the nation in the breadth & depth of public sector/NGO attention to building climate resilience – at all levels of governance.

From: UW Climate Impacts Group

BUT,
WHERE DOES THE
HEAT COME FROM?



Greenhouse gases create Earth's "duvet".



From: EPA

GHG = Greenhouse Gas

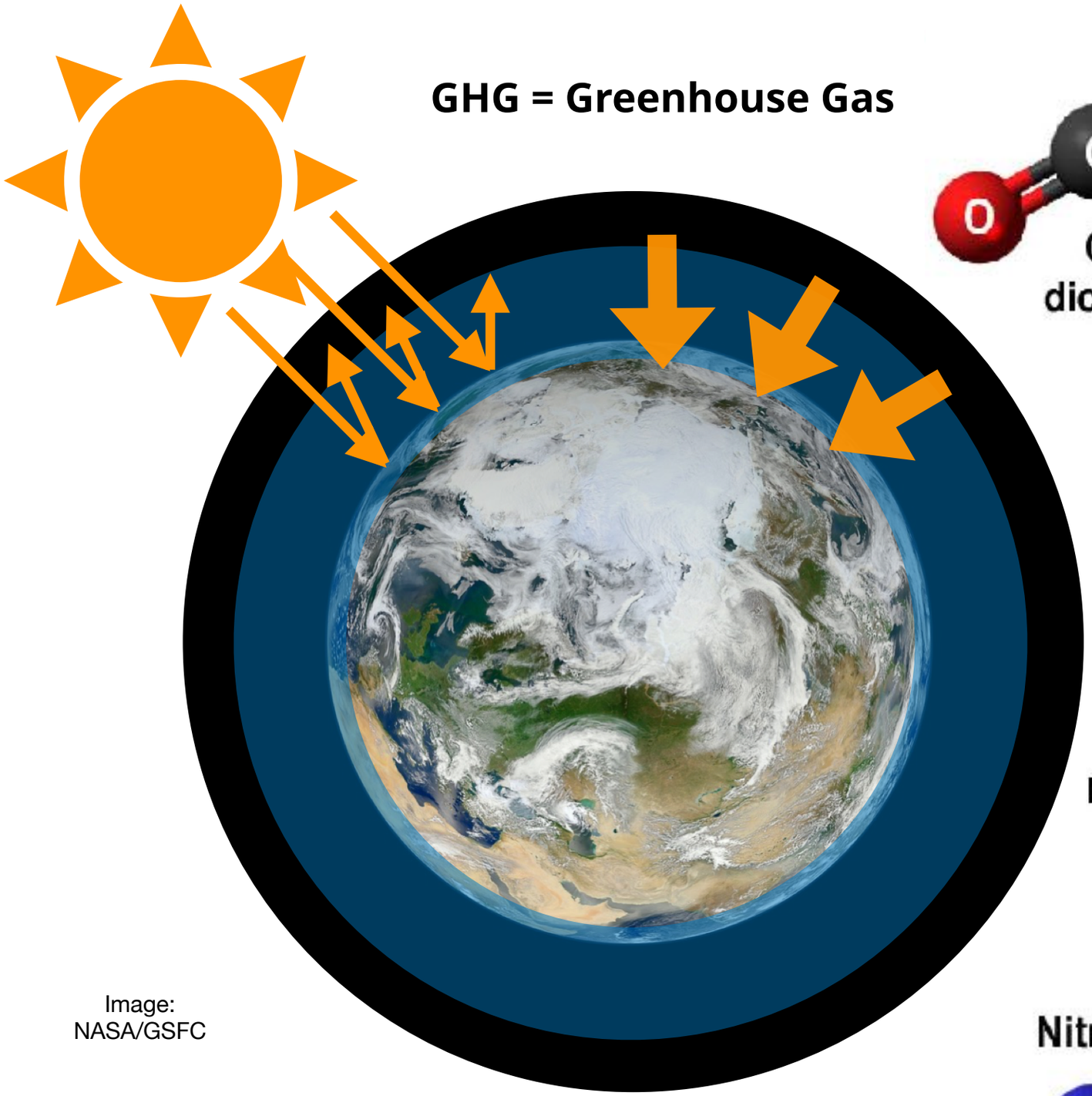
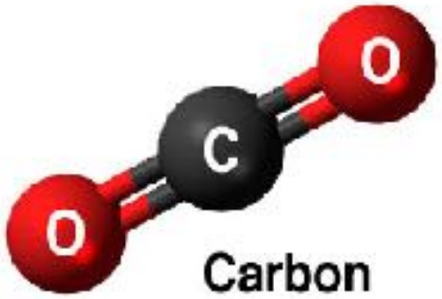
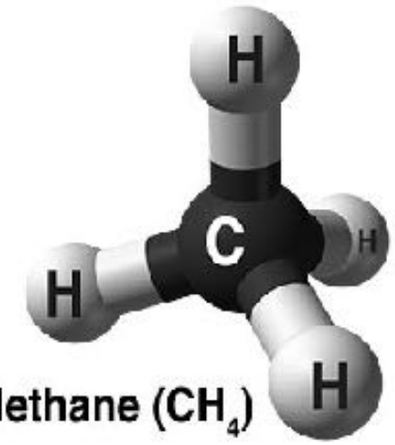


Image:
NASA/GSFC



Carbon dioxide (CO_2)

Released through natural (volcanic eruptions) & human activities (deforestation, land use changes & burning fossil fuels).



Methane (CH_4)

Produced by natural sources & human activities, including the decomposition of waste in landfills, agriculture, rice cultivation, and ruminant digestion.

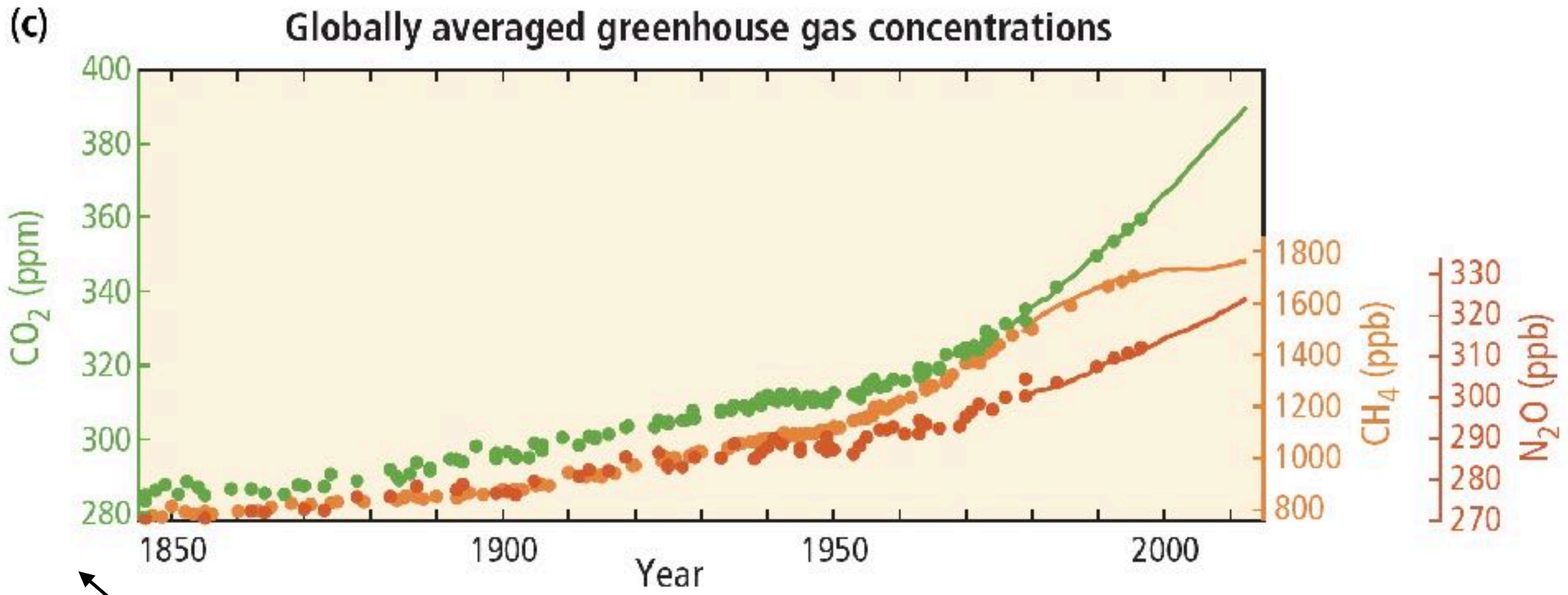
The most abundant GHG. Water vapor increases as the atmosphere warms.

Water vapor (H_2O)

Nitrous oxide (N_2O)

Produced by the use of commercial & organic fertilizers, fossil fuel combustion, nitric acid production & biomass burning.

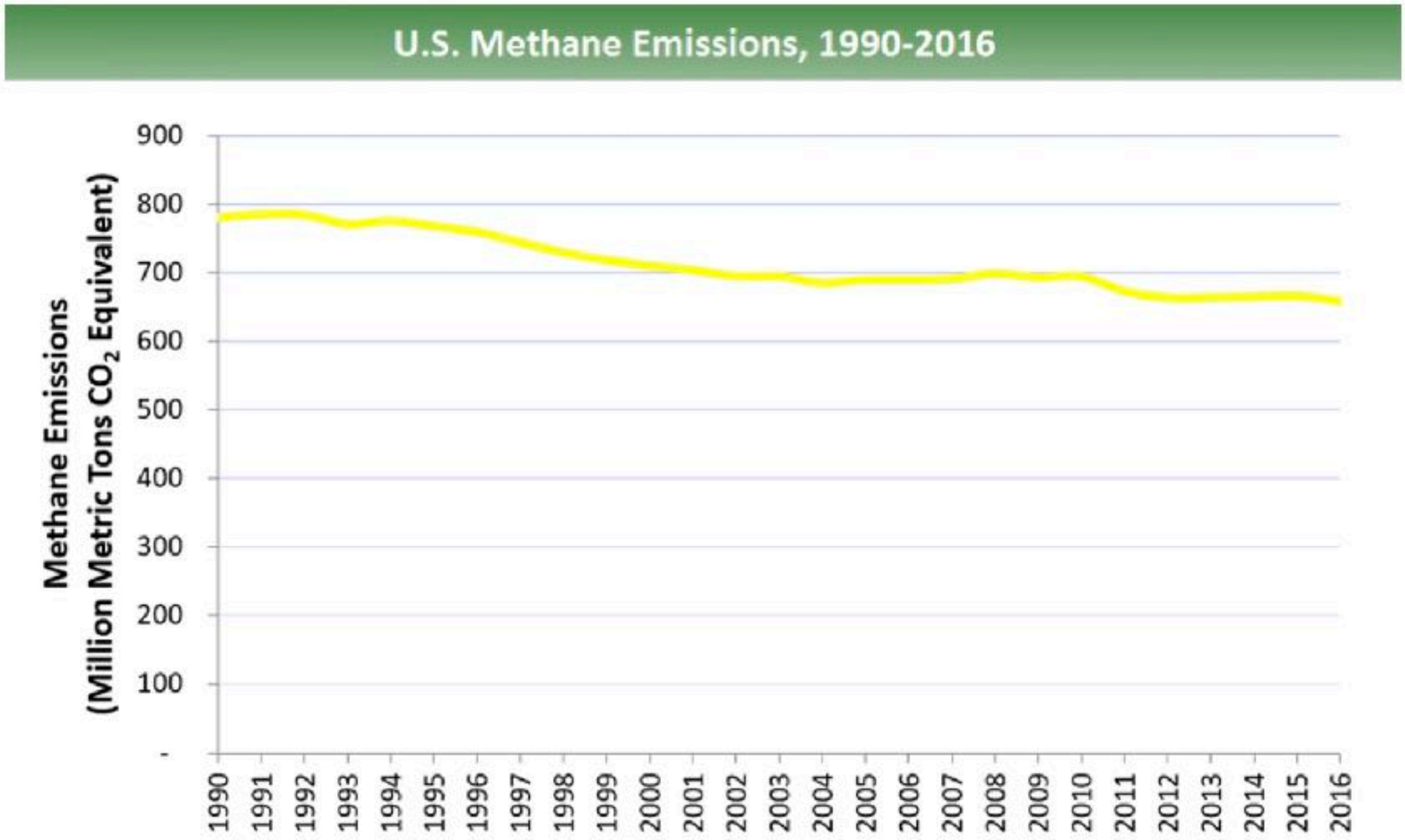
Modified from NASA.gov



We are going to look at the past later…

From: IPCC, 2014

Methane emissions decreased by 16 percent between 1990 and 2016.

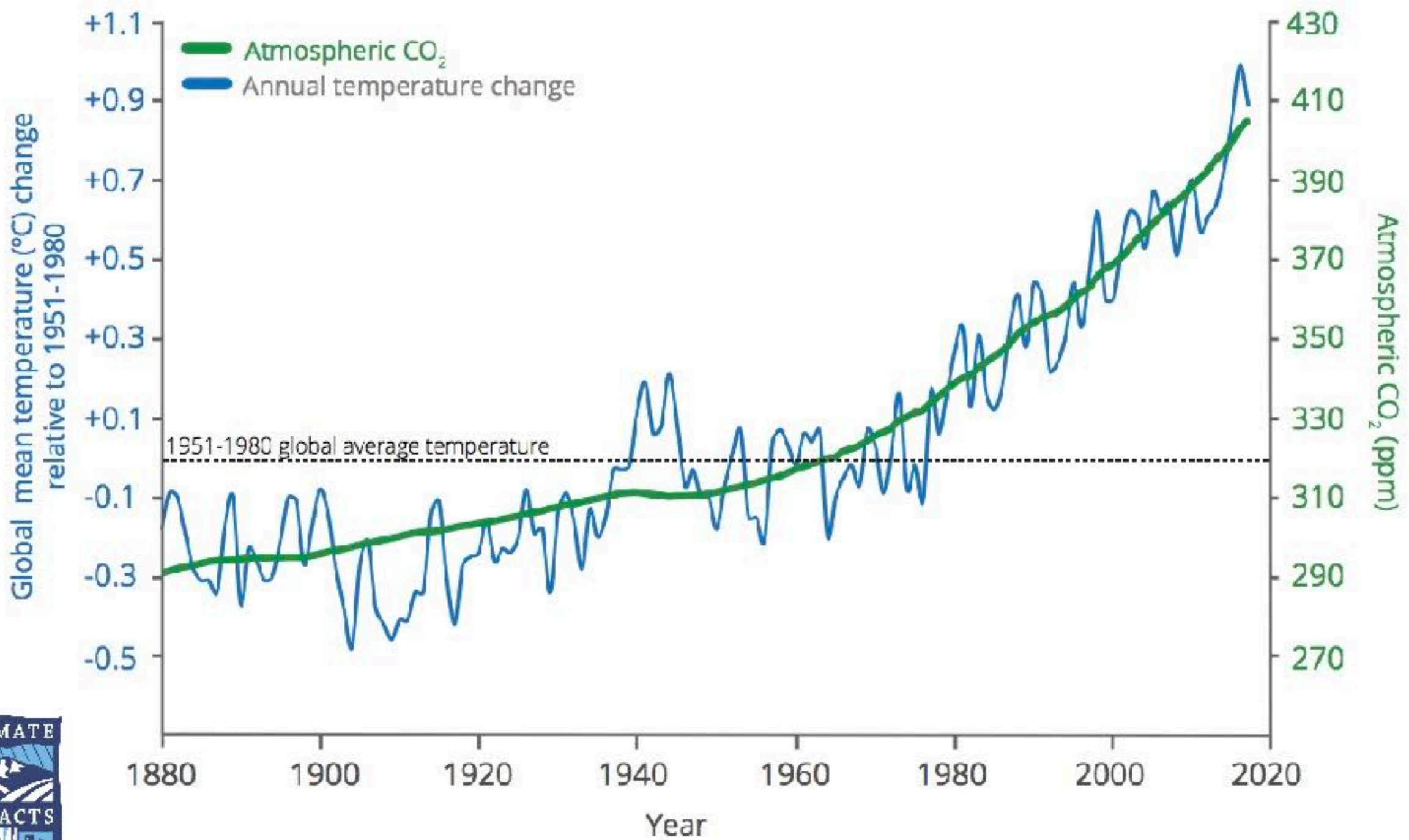


Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016*. These estimates use a global warming potential for methane of 25, based on reporting requirements under the United Nations Framework Convention on Climate Change.

During this time period, emissions increased from sources associated with agricultural activities, while emissions decreased from sources associated with landfills, coal mining, and the exploration through distribution of natural gas and petroleum products.

EPA, 2019

~1.8ºF warming globally since the late 1800's



Created by H. Roop from NASA GISS, NOAA ESRL, NOAA NCEI data

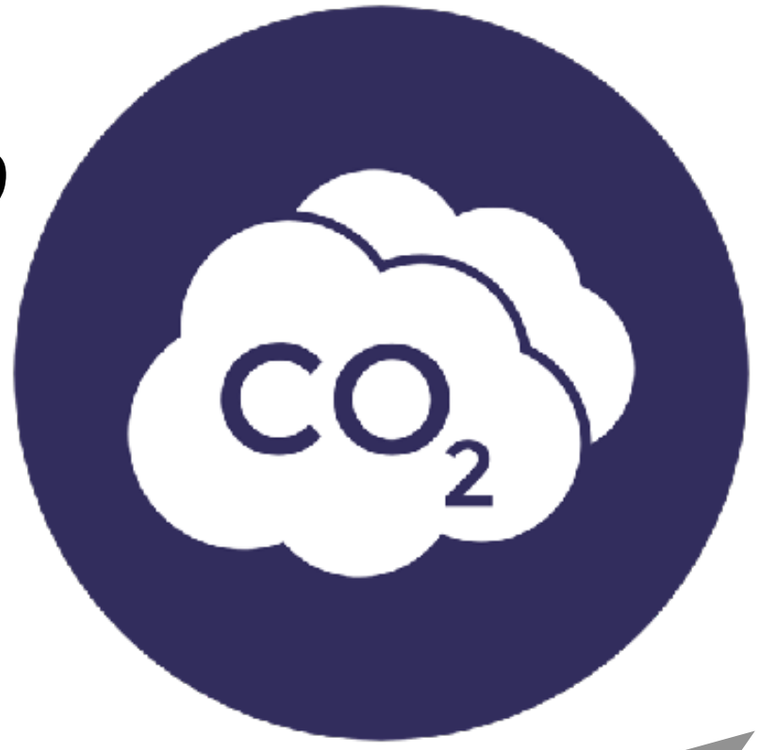
There is high confidence (>95%) that human-produced greenhouse gases have caused much of the observed increase in Earth's temperature over the past 50 years.

IPCC, 2014; Images: H. Roop

Future

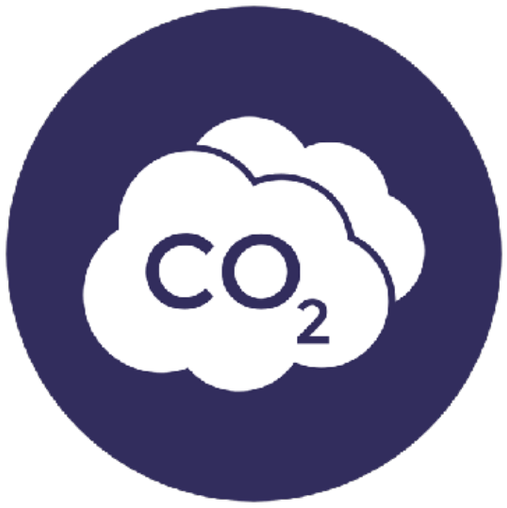
Uncertainty = us.

May, 2019



413 ppm

Pre-industrial

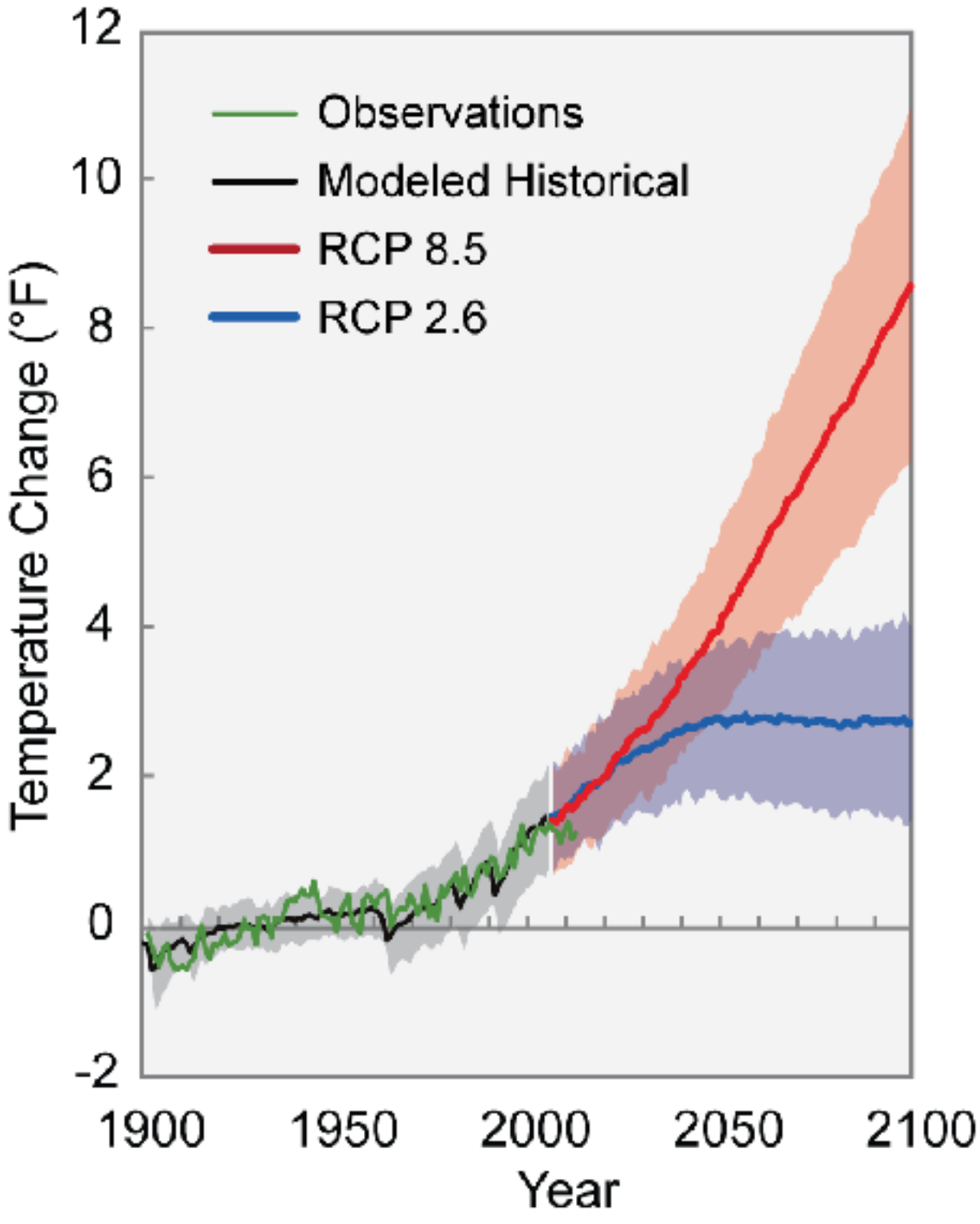


280 ppm

ppm= parts per million

Heidi Roop, UW Climate Impacts Group

Emissions of Greenhouse Gases Determine Temperature Rises



NCA, 2018

HOW HAS CLIMATE CHANGED?

Lakes & Ice!

Ice!

H. Roop, Climate Impacts Group

FROM ICE CORES WE HAVE DIRECT MEASUREMENTS OF GREENHOUSE GASES BACK 800,000 years!

May, 2019

CO_2 413 ppm

Pre-industrial (late 1800's)

CO_2 280 ppm

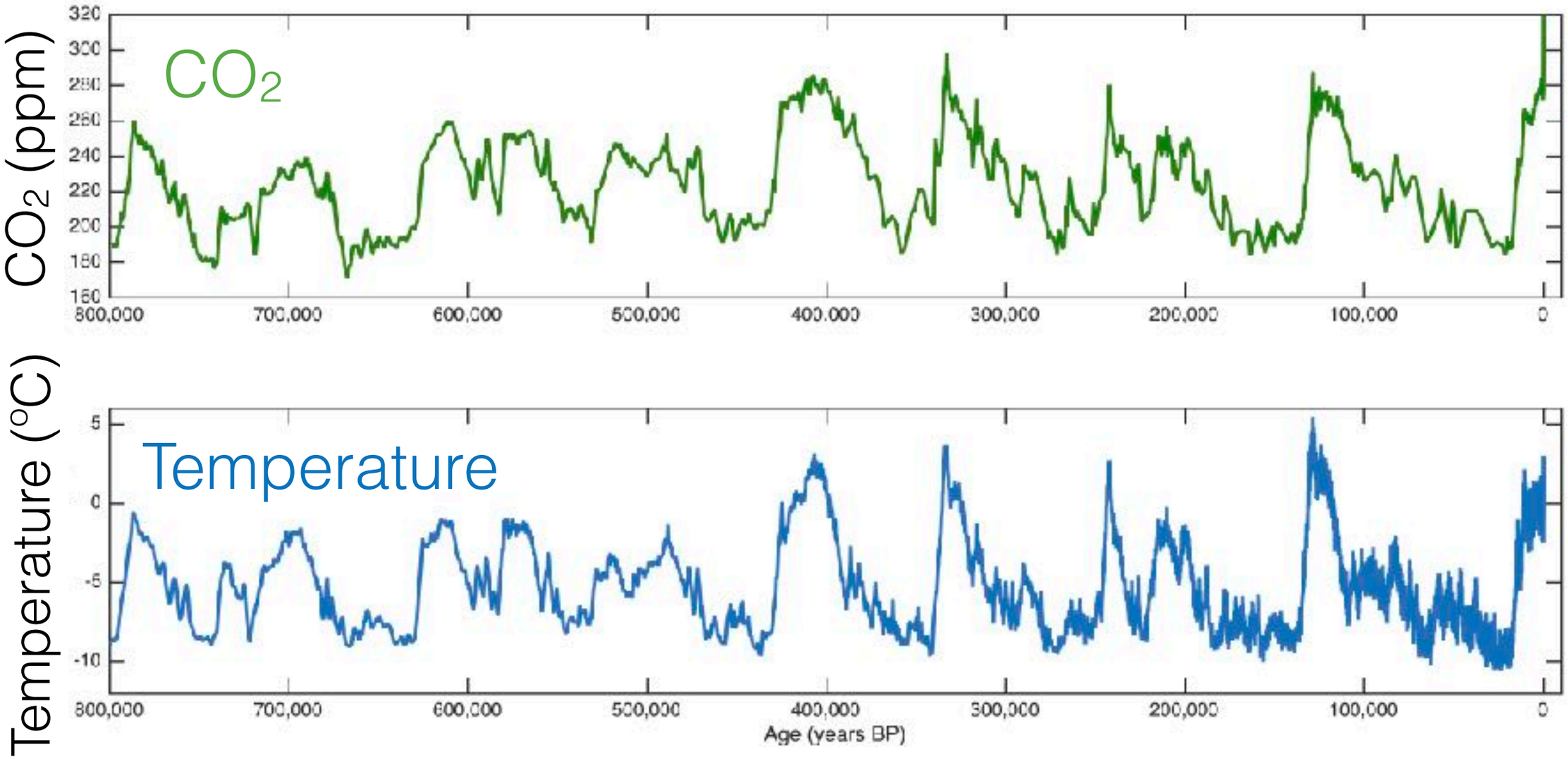
ppm= parts per million

Image: H. Roop; Taylor Glacier, Antarctica

ANCIENT AIR!

Image: P. Neff

800,000 yrs of CO_2 & Temperature



800,000 years ago

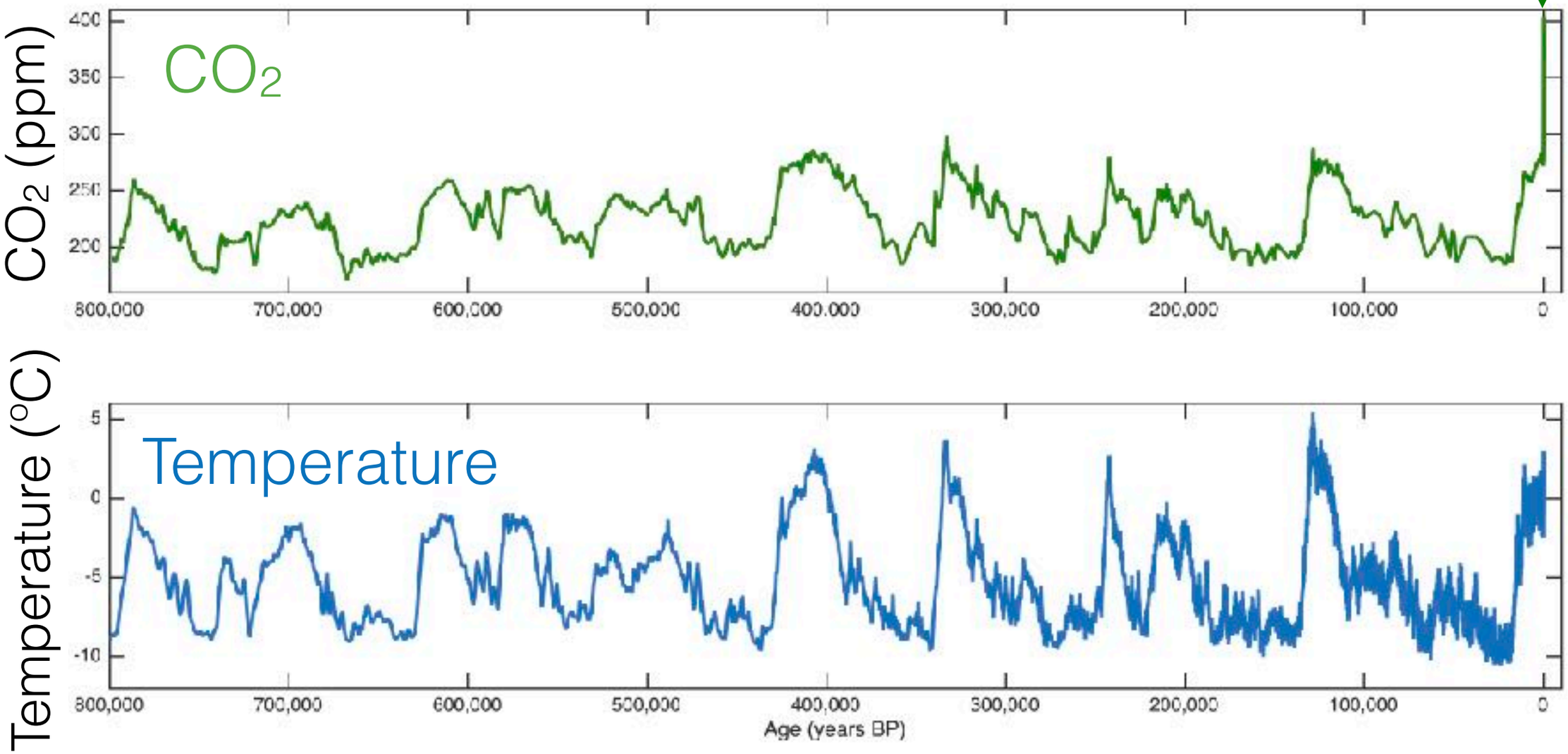
Time ⟶

Today

Data: Jouzel et al., 2007; Luthi et al., 2008

800,000 yrs of CO_2 & Temperature

410 ppm today

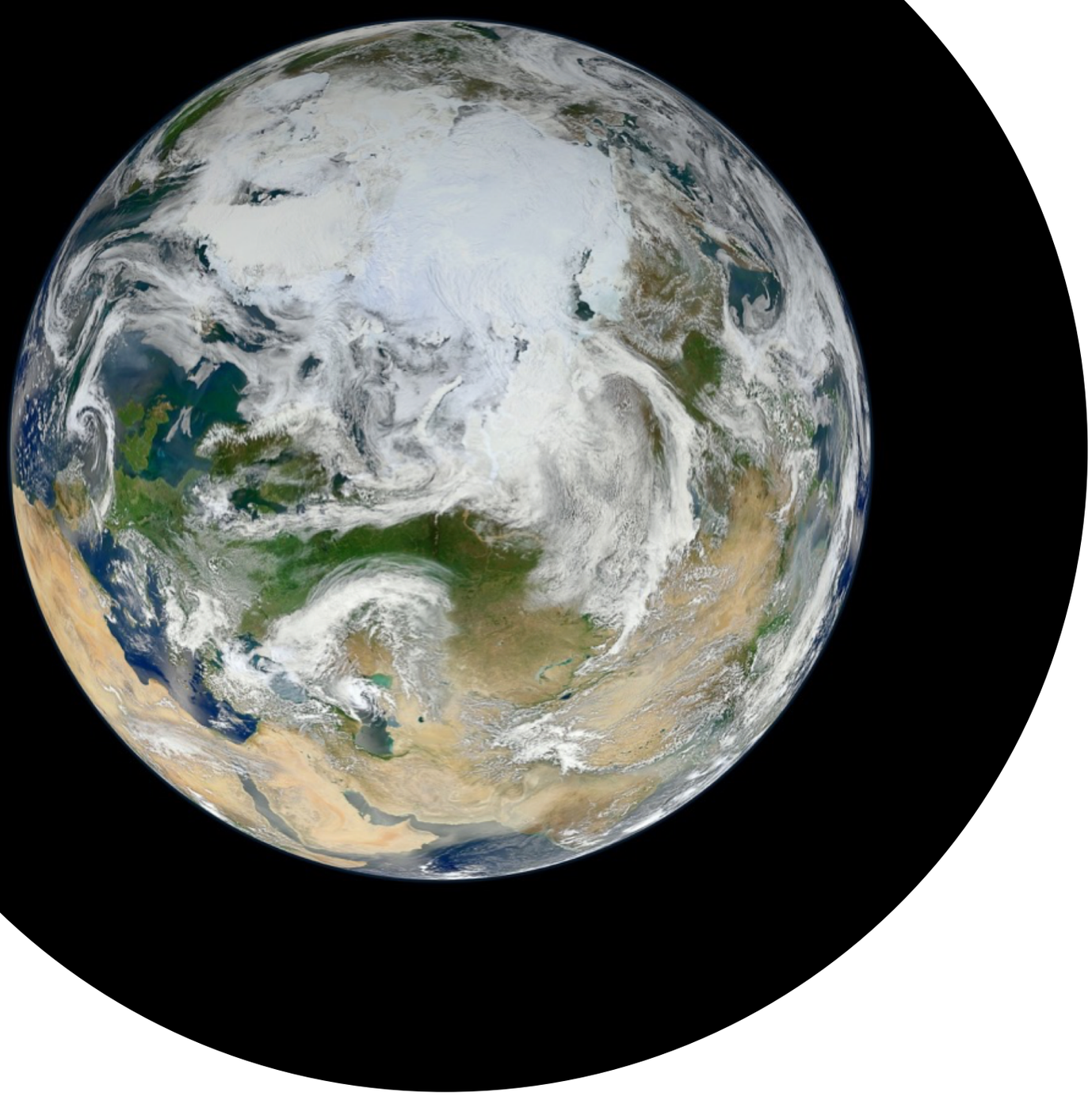


800,000 years ago

Time ⟶

Today

Data: Jouzel et al., 2007; Luthi et al., 2008

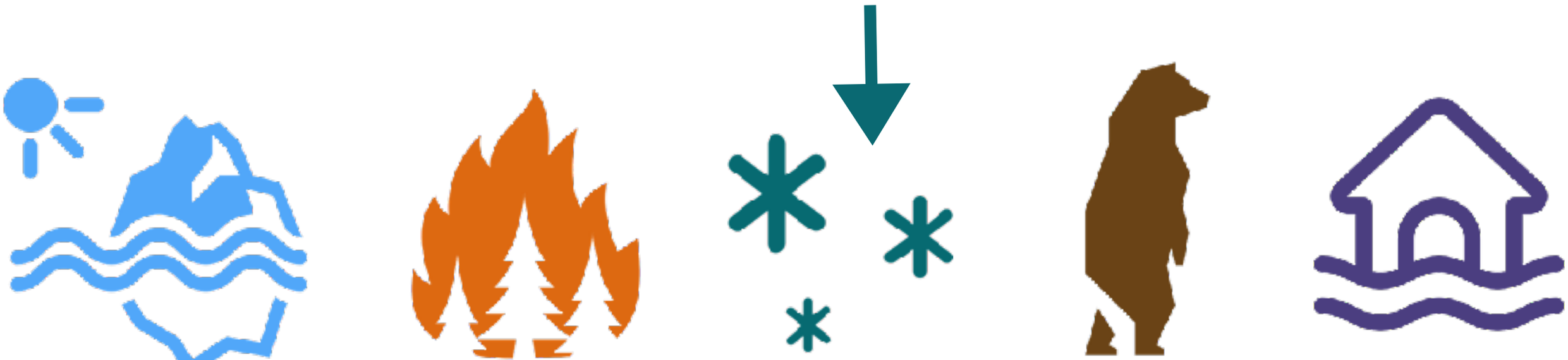


"The global climate continues to change rapidly compared to the pace of the natural variations in climate that have occurred throughout Earth's history."

- 4th National Climate Assessment
November 2017

Image: NASA/GSFC/Suomi NPP

So we have evidence that today is different.



What can we do about it?

HOW WE 'FEEL' FUTURE CLIMATE CHANGE DEPENDS ON:

Our actions **now** to reduce emissions of greenhouse gases (*mitigation*)

+

How well we **prepare** our communities & the systems we rely on (*adaptation*)

Heidi Roop, UW Climate Impacts Group

“We need to adapt to climate change even as we seek to mitigate it.”

- Nives Dolsak & Aseem Prakash, 2018

Photo: H. Roop

Heidi A. Roop

UW Climate Impacts Group

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