

Climate Change: What is the current understanding and what to expect

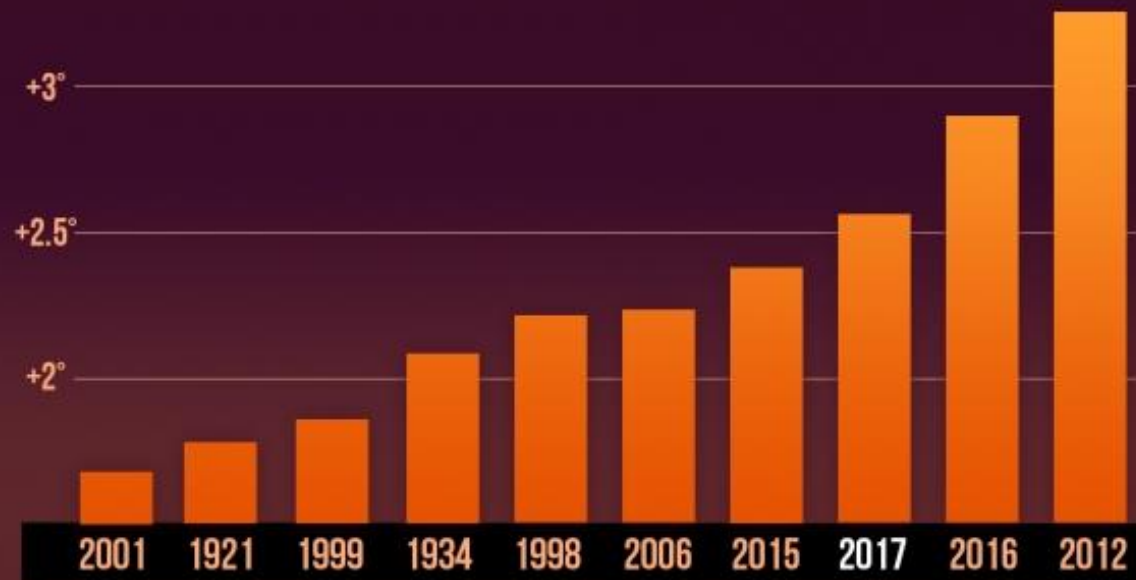


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Some recent statistics:

10 HOTTEST U.S. YEARS ON RECORD



Source: NOAA/NCEI Climate at a Glance
Difference from 20th century average temperature (°F). Data as of 1/8/2017

CLIMATE  CENTRAL

Some recent statistics:

- In Seattle, the five hottest years on record since 1948 were:
 - 2015 (63.4 degrees)
 - 2014 (62.6 degrees)
 - 2016 (62.5 degrees)
 - 1992 (62.5 degrees)
 - 2018 (62.3 degrees)

Some recent statistics:

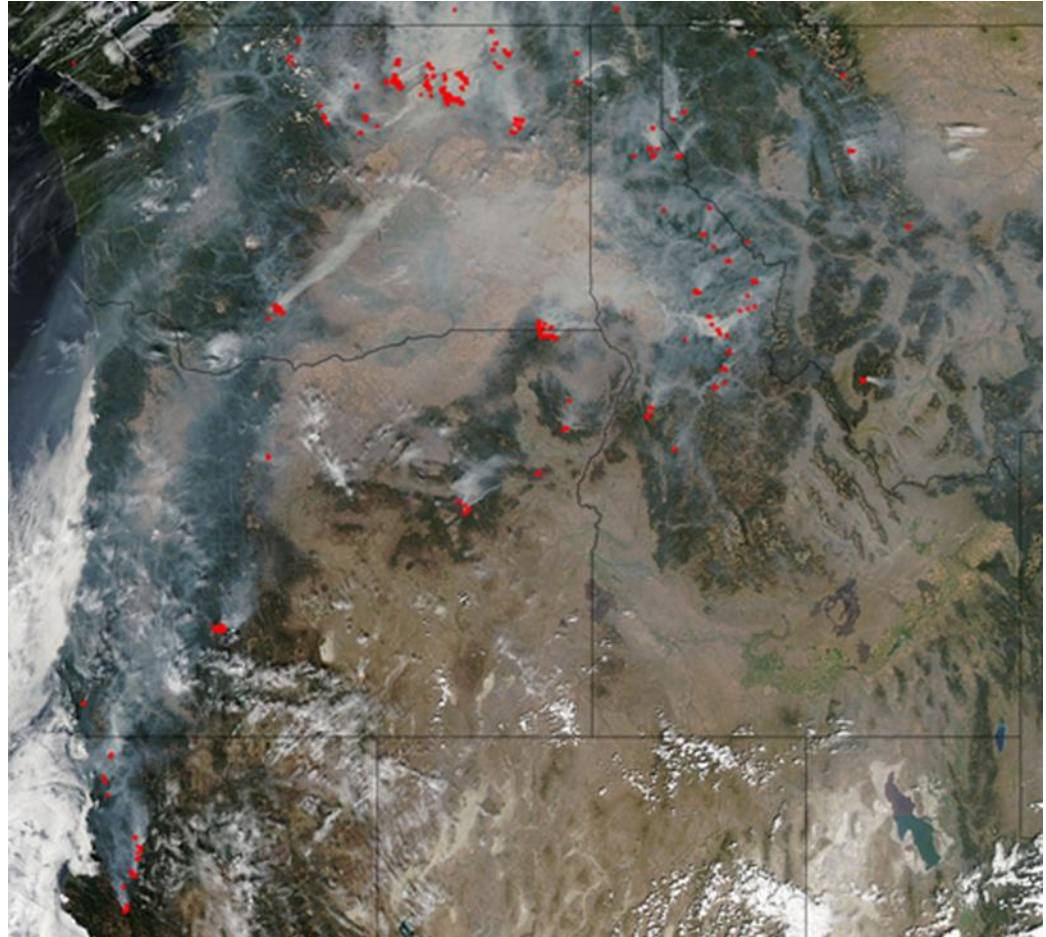
In 2014, a record was set for the largest wildfire in Washington State history, the 256,100-acre Carlton Complex Fire



Some recent statistics:

In 2015, 1.7 million acres were burned in Oregon and Washington, with over 9 million acres burned in the western United States.

Pacific Northwest, August 30, 2015



NASA MODIS

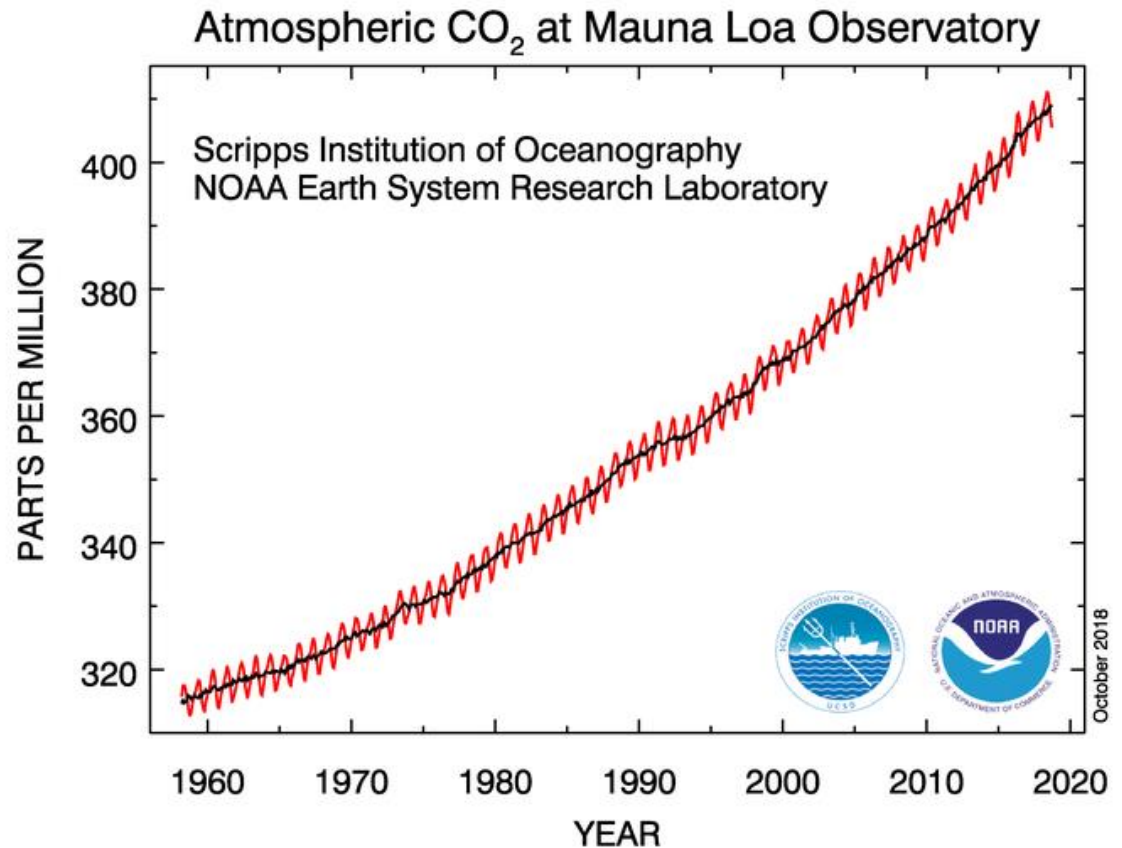
Several fires in 2015 occurred in west-side conifer forests, including a rare fire event in coastal temperate rainforest on the Olympic Peninsula.



Carbon dioxide is increasing

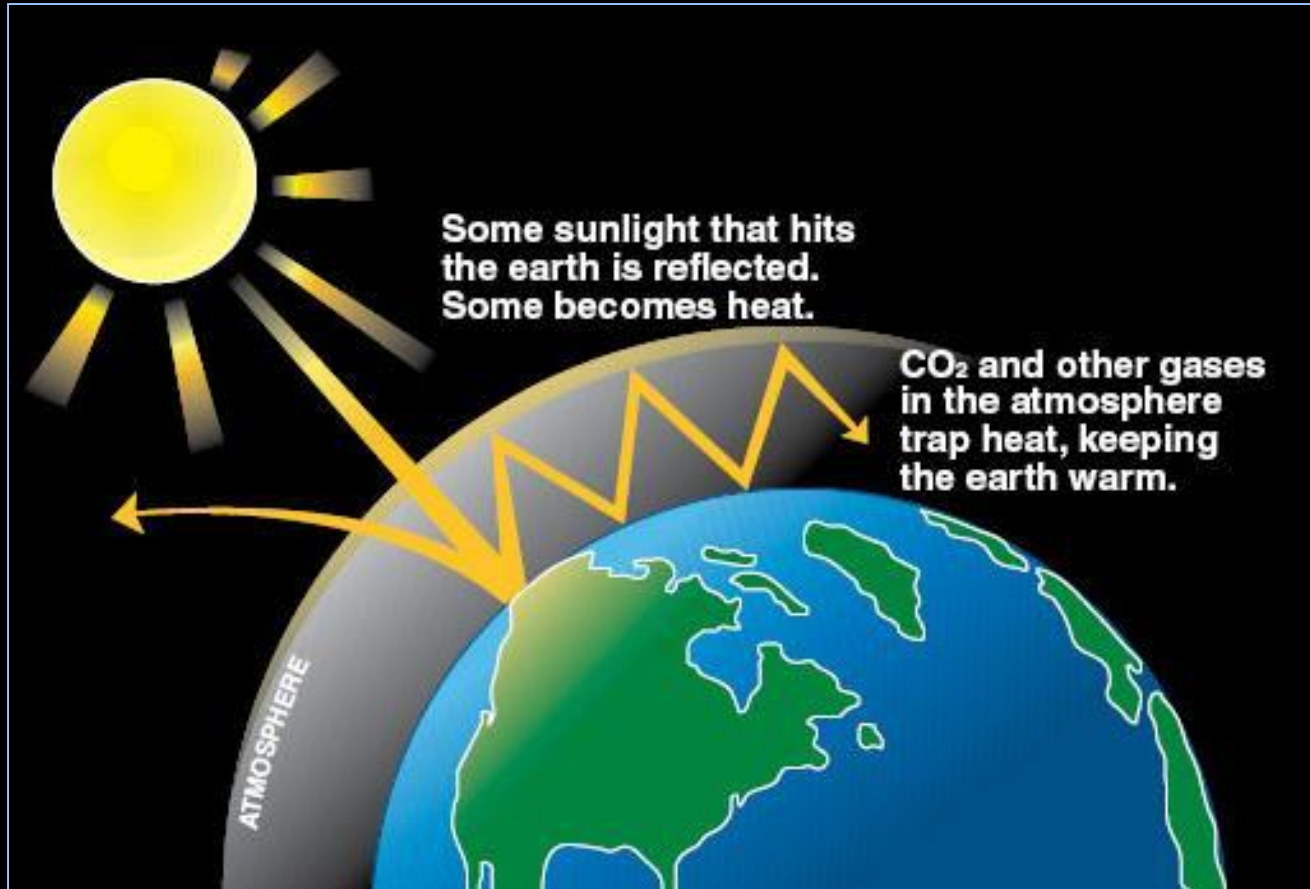
Atmospheric CO₂
is now **409 ppm**.

It was **260 ppm** in
1850.



Source: <https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html>

Greenhouse gases (water vapor, CO₂, CH₄, N₂O) play a critical role in determining global temperature



Rapid increases in greenhouse gases are changing this natural balance



**Radiative
forcing**

2.3 Watts



----- 1 meter -----

----- 1 meter -----



1 meter

1 meter

X 500 trillion
for the entire Earth



In 2100?



1 meter



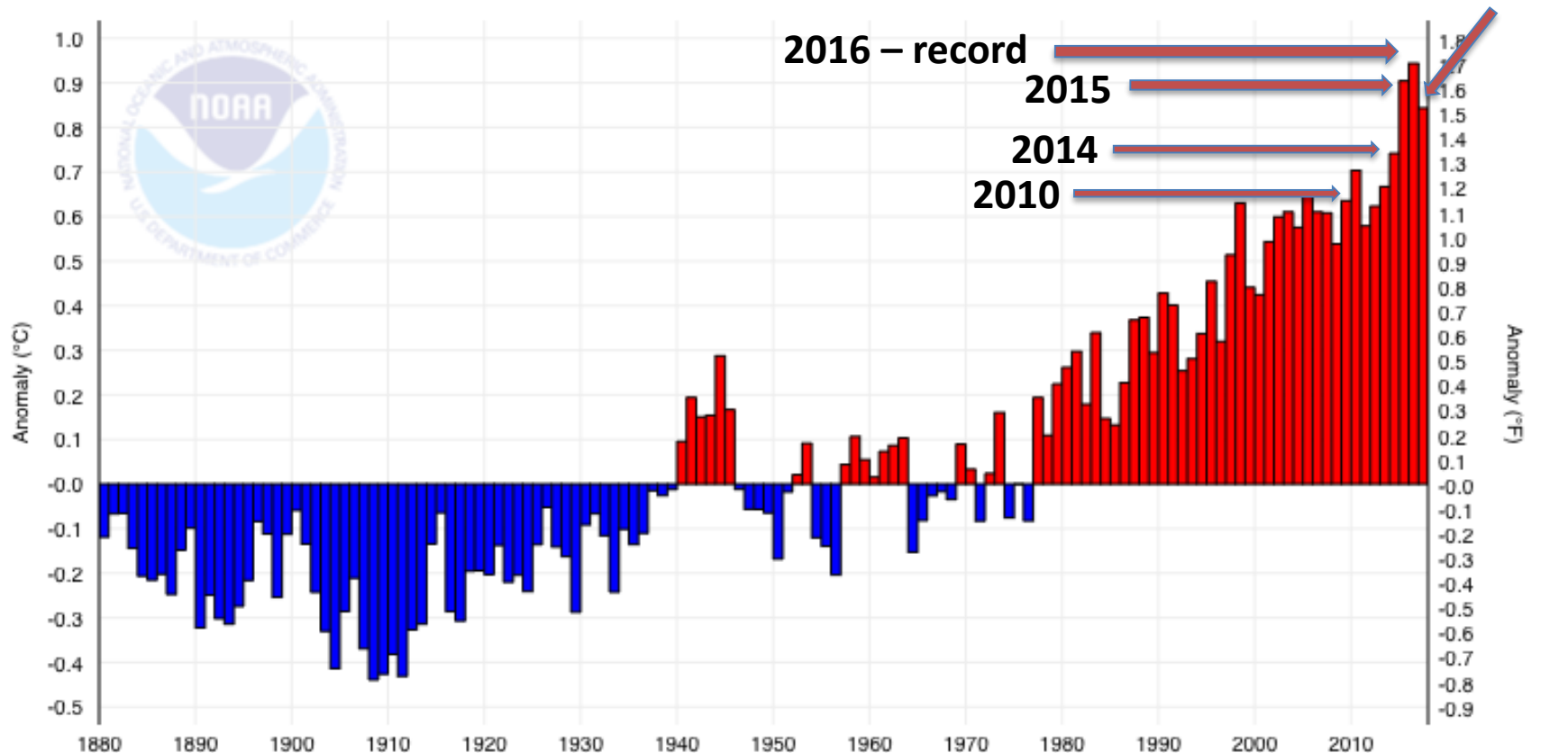
1 meter

X 500 trillion



Global temperature trend

Global Land and Ocean Temperature Anomalies, January-December



Source: <https://www.ncdc.noaa.gov/cag/time-series/global>

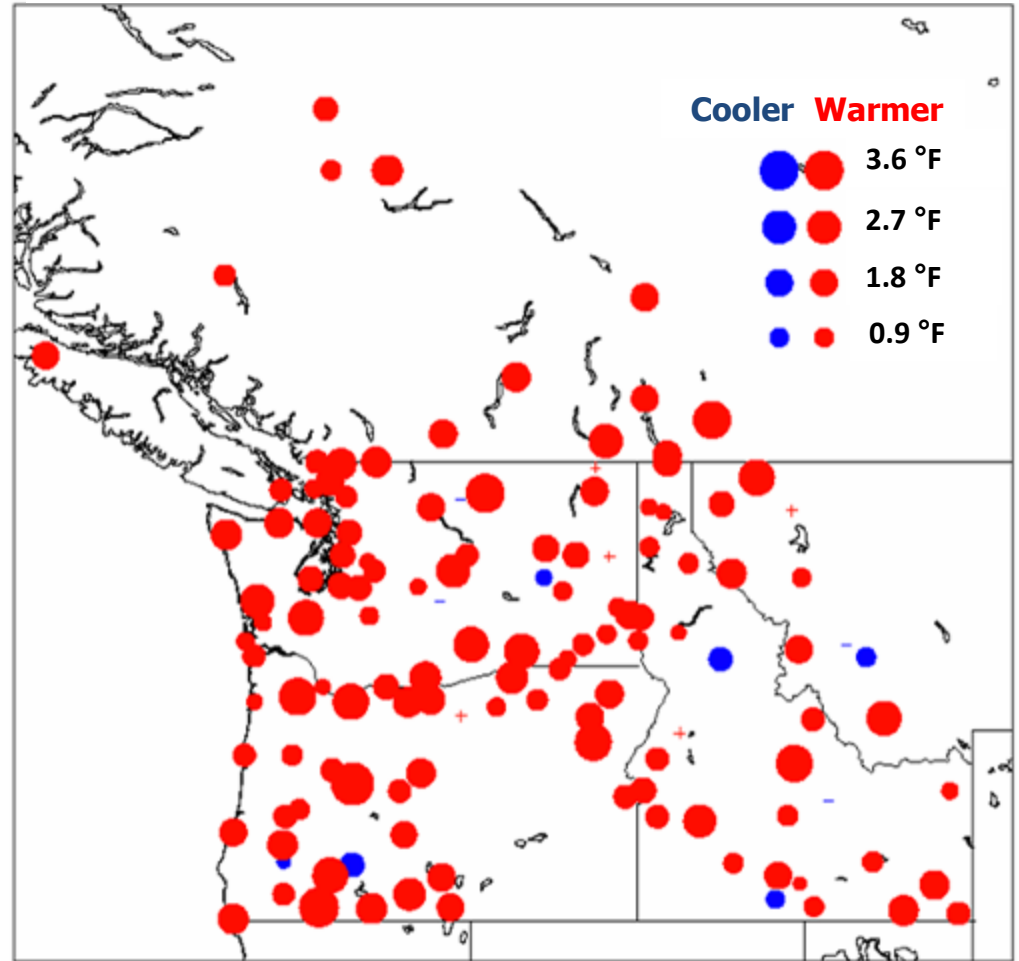
Temperature trends by station

Average annual temperature has increased $+1.6^{\circ}\text{F}$ since 1920.

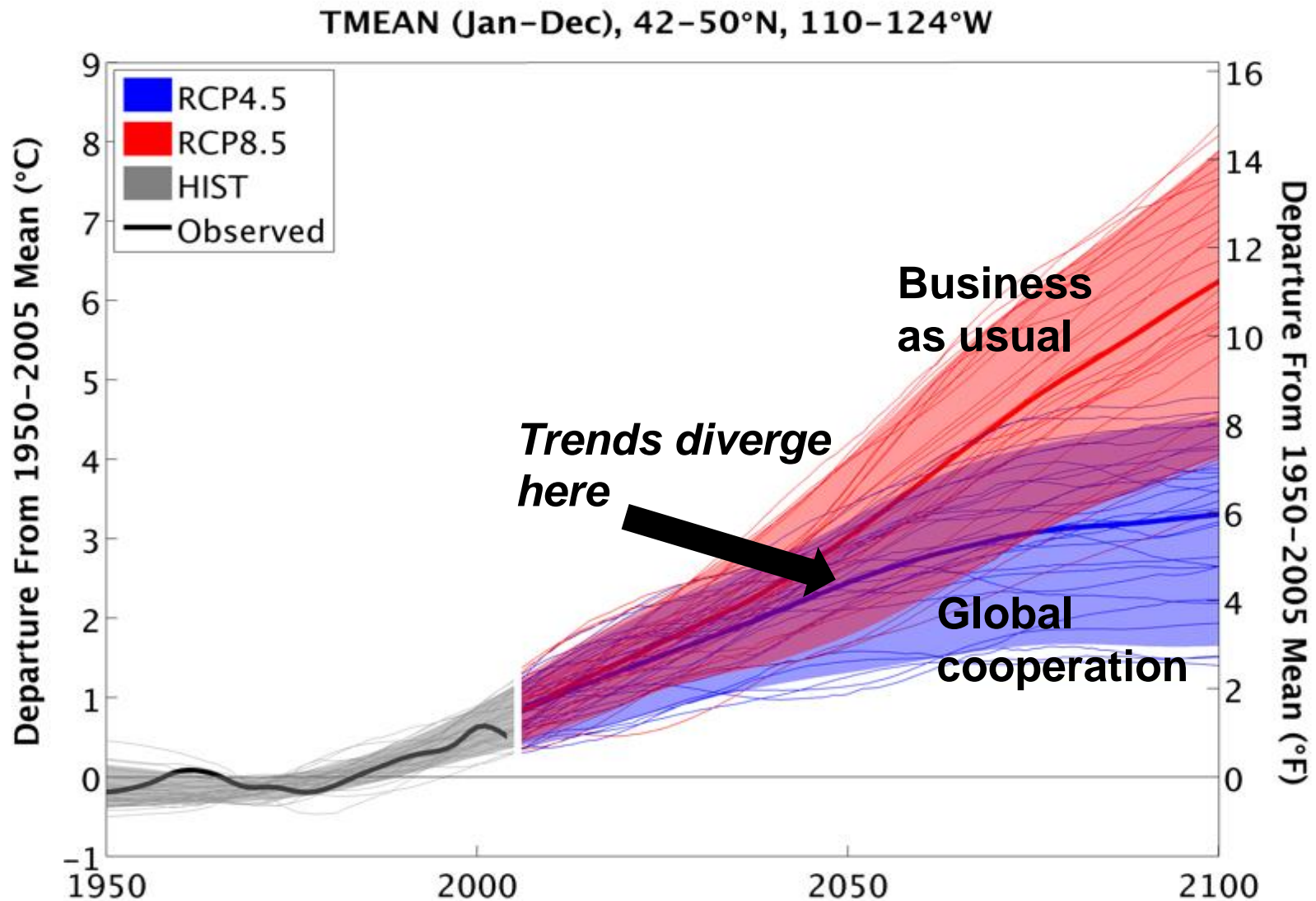
Almost every station shows warming.

Extreme cold conditions have become rarer.

Minimum temperatures rose faster than maximum temperatures.



Projected temperature in Pacific Northwest



What about precipitation?

Global climate models do not project precipitation reliably.

Most models project a small increase in winter or no change.



What will future climate feel like?



Olympia, WA

What will future climate feel like?



Sacramento, CA

This is what we know...

There is a natural greenhouse effect.

Humans are increasing the greenhouse effect by adding carbon dioxide and other gases to the atmosphere.

Effects of a changing climate are already apparent.

There will be more global warming to come.

Climate controls ecosystem processes



The hydrologic cycle

Climate controls ecosystem processes



The hydrologic cycle



Plant establishment,
growth, and mortality

Climate controls ecosystem processes



The hydrologic cycle

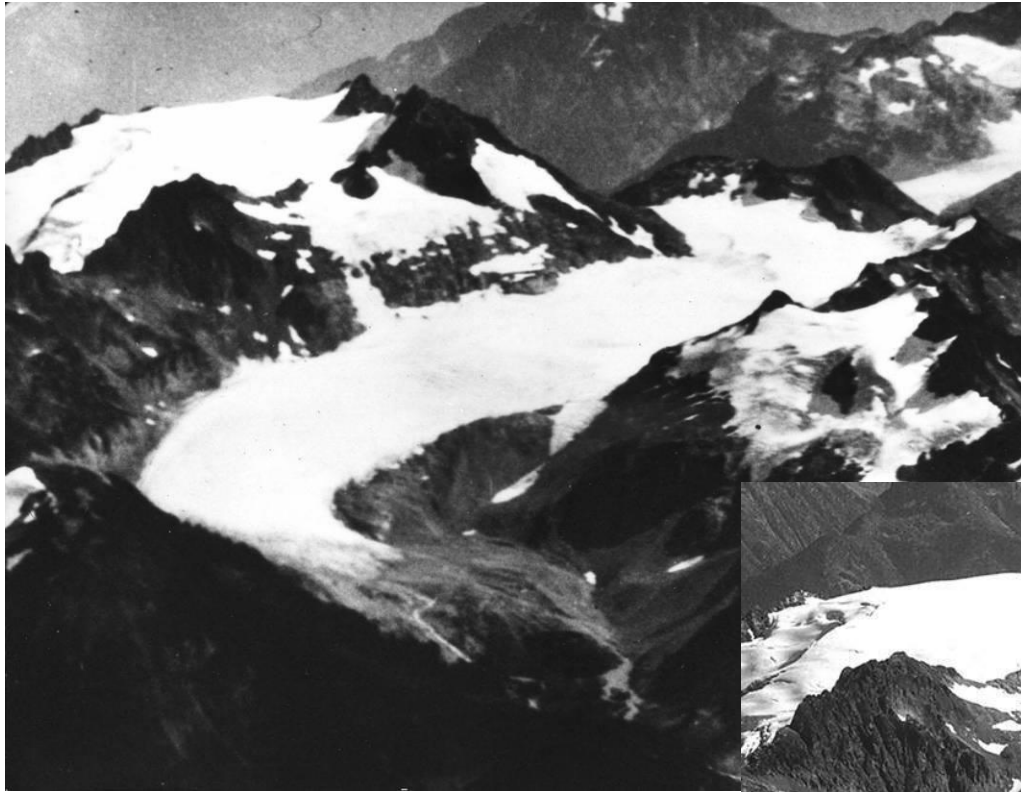


Plant establishment,
growth, and mortality



Disturbance

**Nearly every glacier in the
Cascade Range has
retreated during the past
100 years**



***South Cascade Glacier,
1928 (top)
2016 (right)***



USGS



**Nearly every glacier in the
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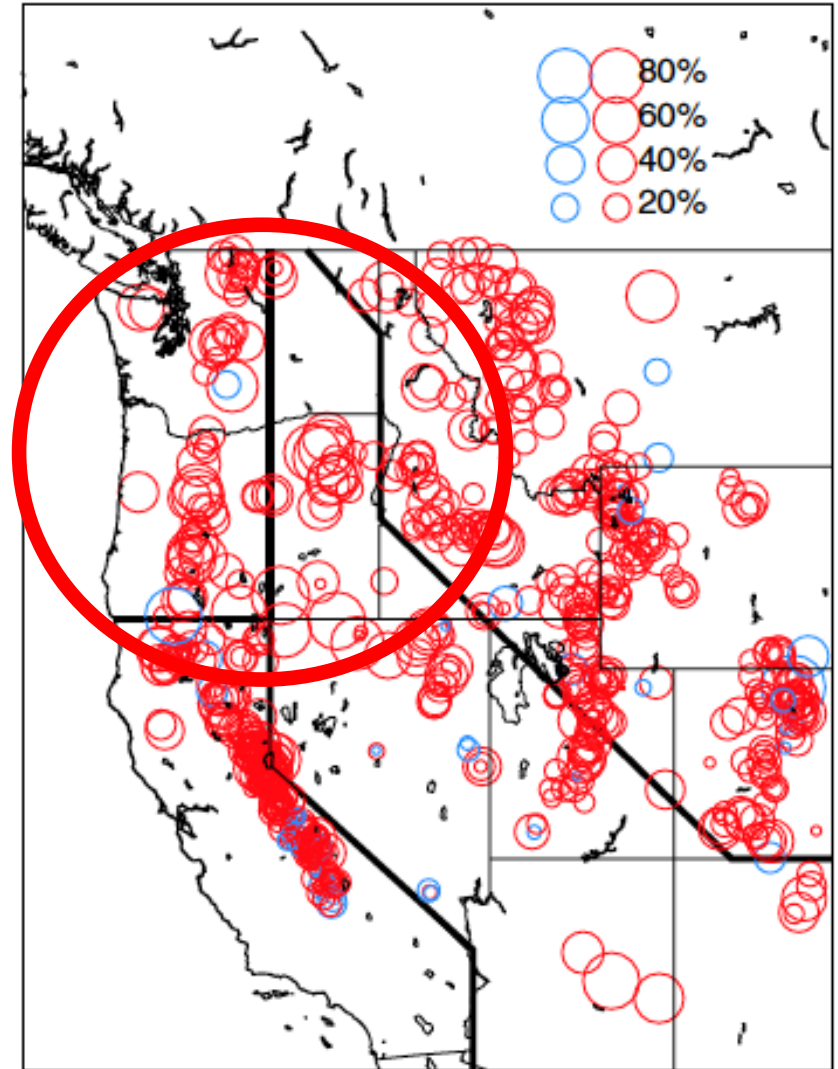
**Since 1900, glacial area in the North Cascades
has decreased by 46%**

***South Cascade Glacier,
1928 (top)
2016 (right)***



Snowpack is decreasing

**Snow-water equivalent
1955-2016**



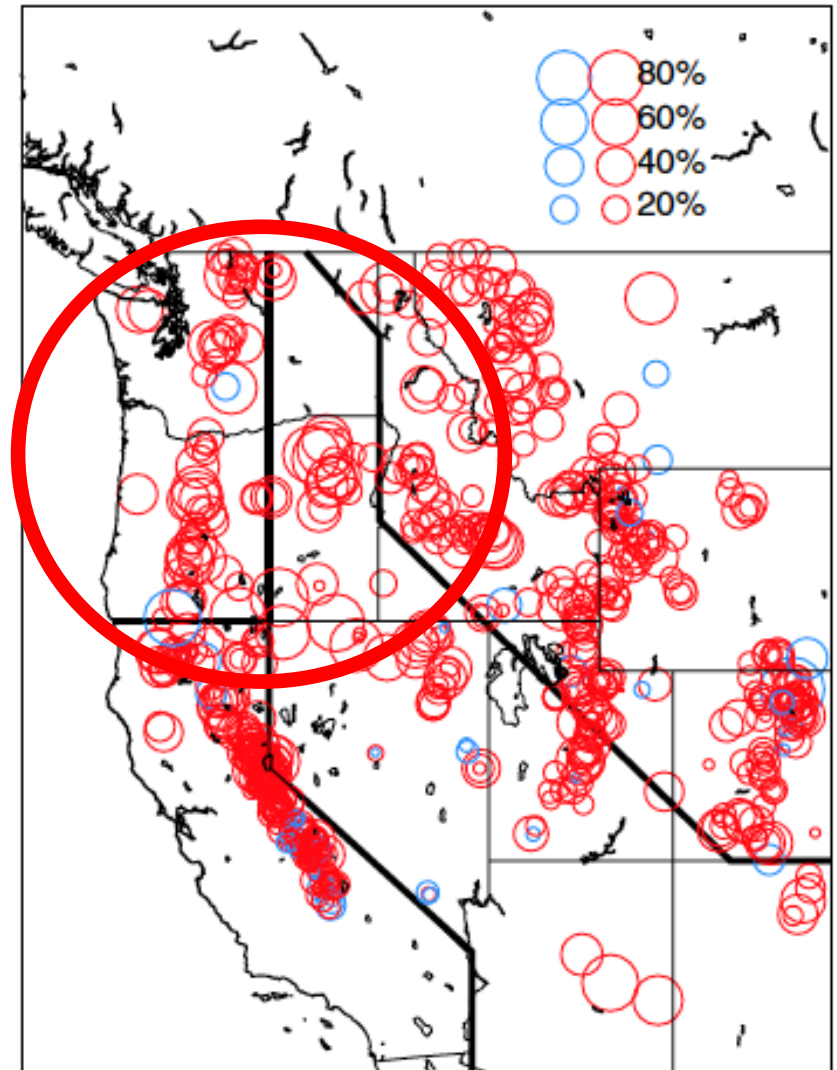
Snowpack is decreasing

**Snow-water equivalent
1955-2016**

Snow-dominant
watersheds



Rain-dominant
watersheds

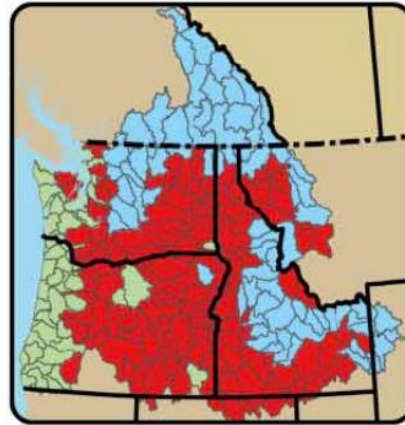


Watershed Classification

Ratio of Peak SWE to October to March Precipitation



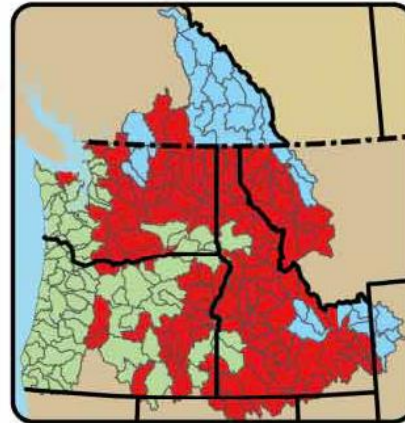
Historical



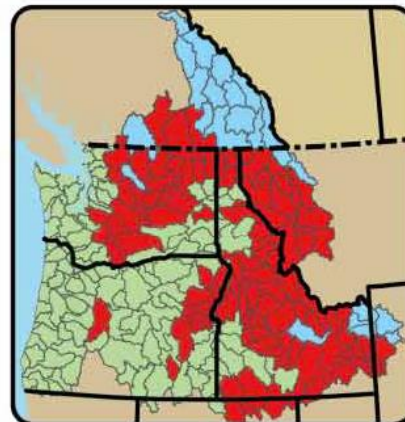
A1B

B1

2040s



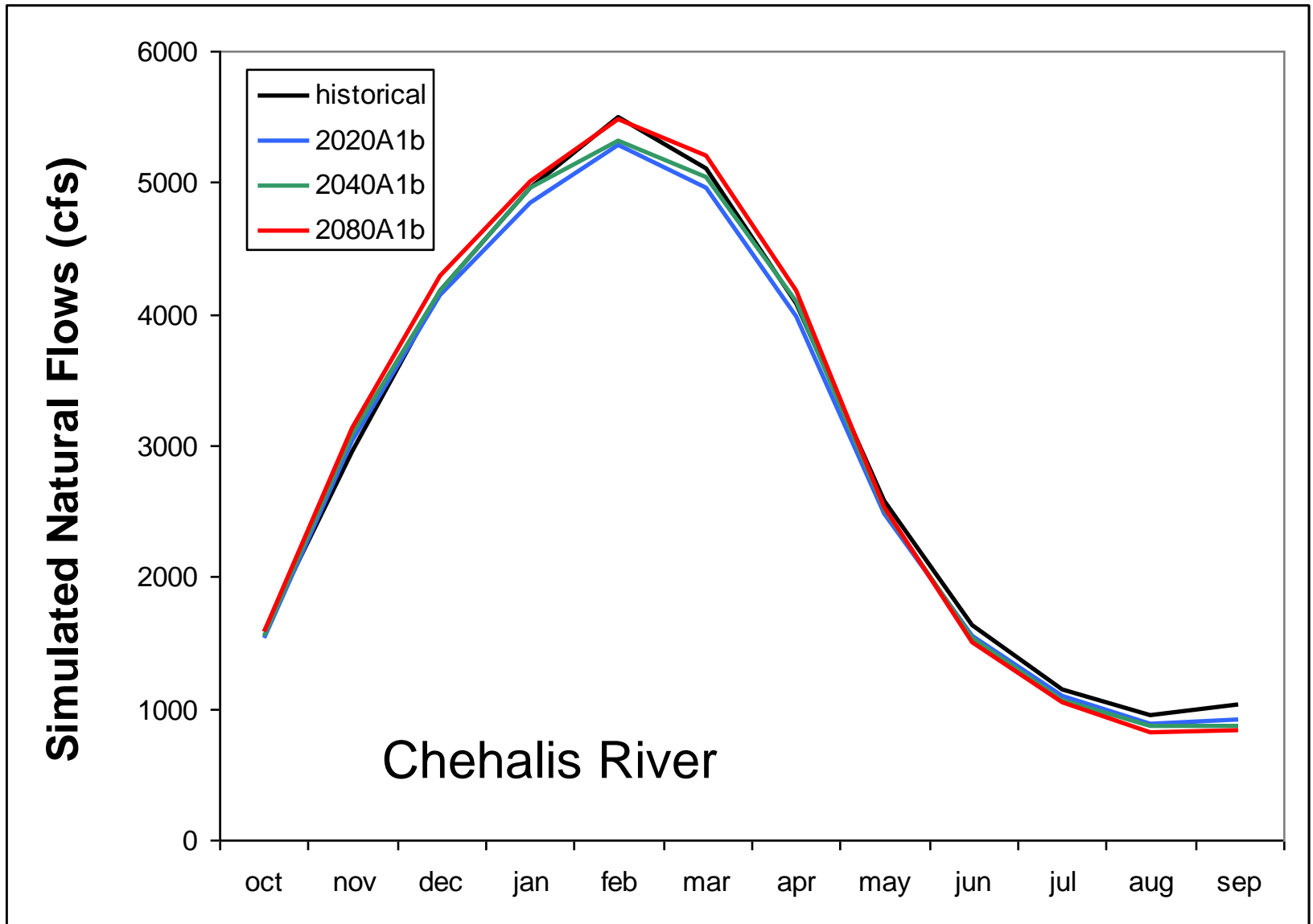
2080s



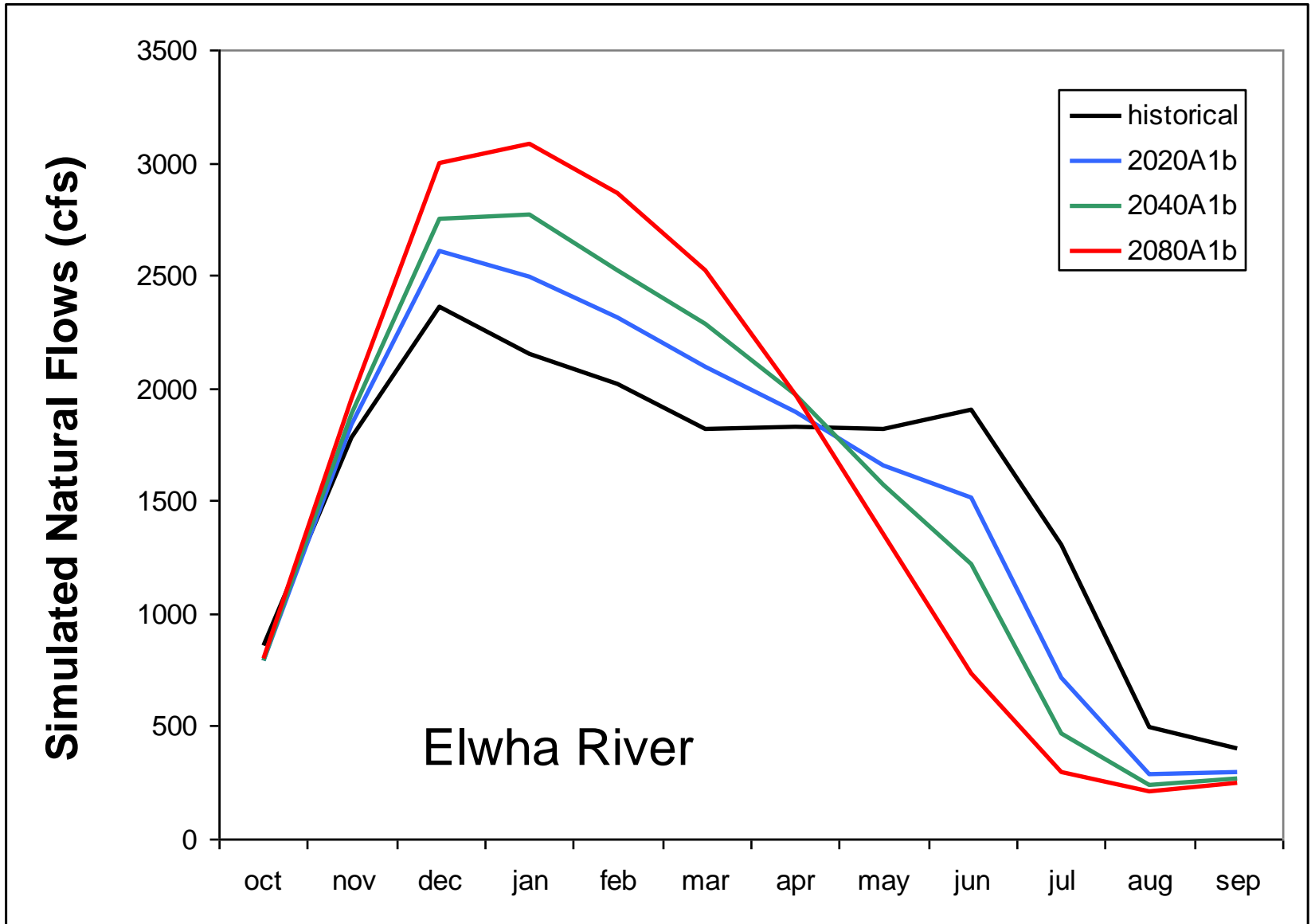
Watershed types will shift

- Snow dominant watersheds become transitional (mixed rain and snow).
- Transitional watersheds become rain dominant.

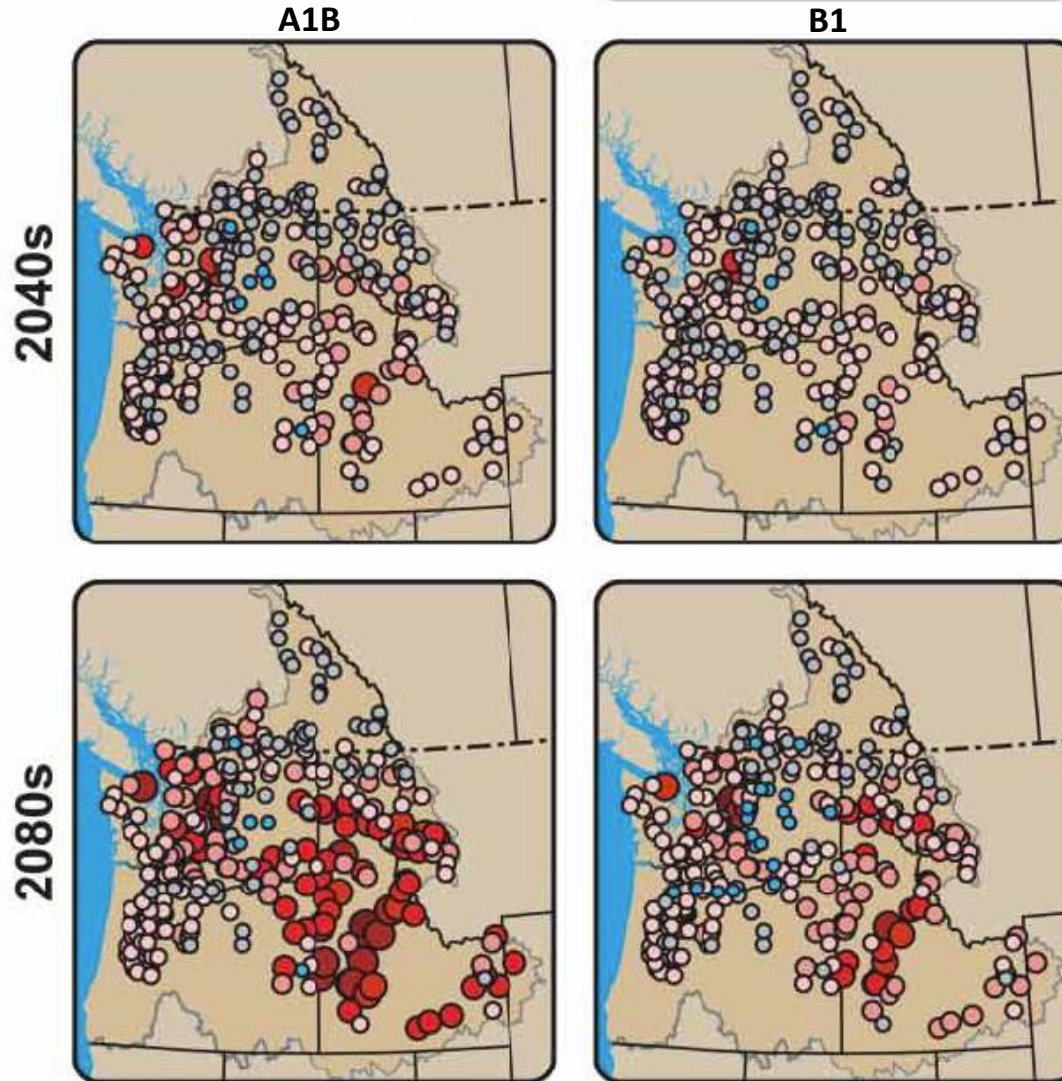
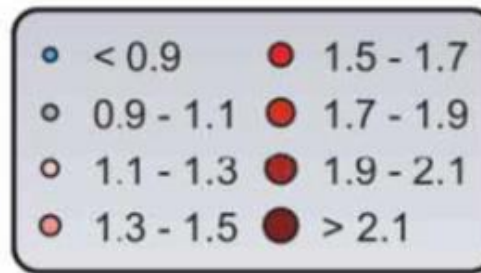
Streamflow will change



Streamflow will change



Ratio of 100-year Flood Statistics (21st Century : 20th Century)



Future projections of flood risk in the PNW

Changes in Hydrologic Extremes



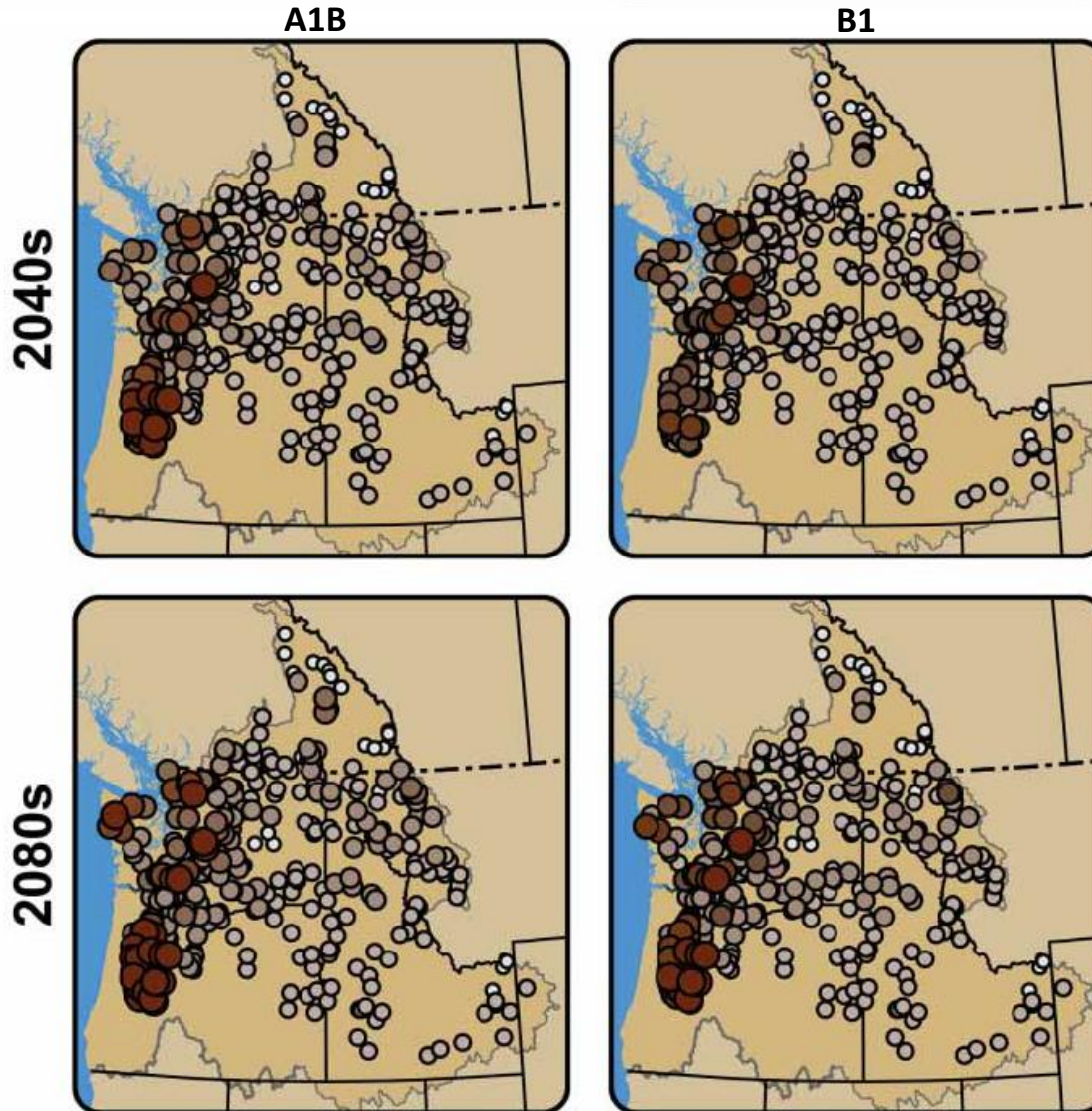
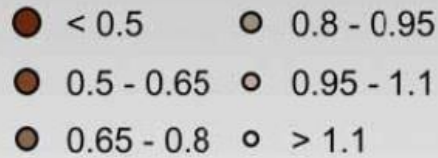
Changes in Hydrologic Extremes



Jan 2009 Flood, Hwy 97 – Blewett Pass



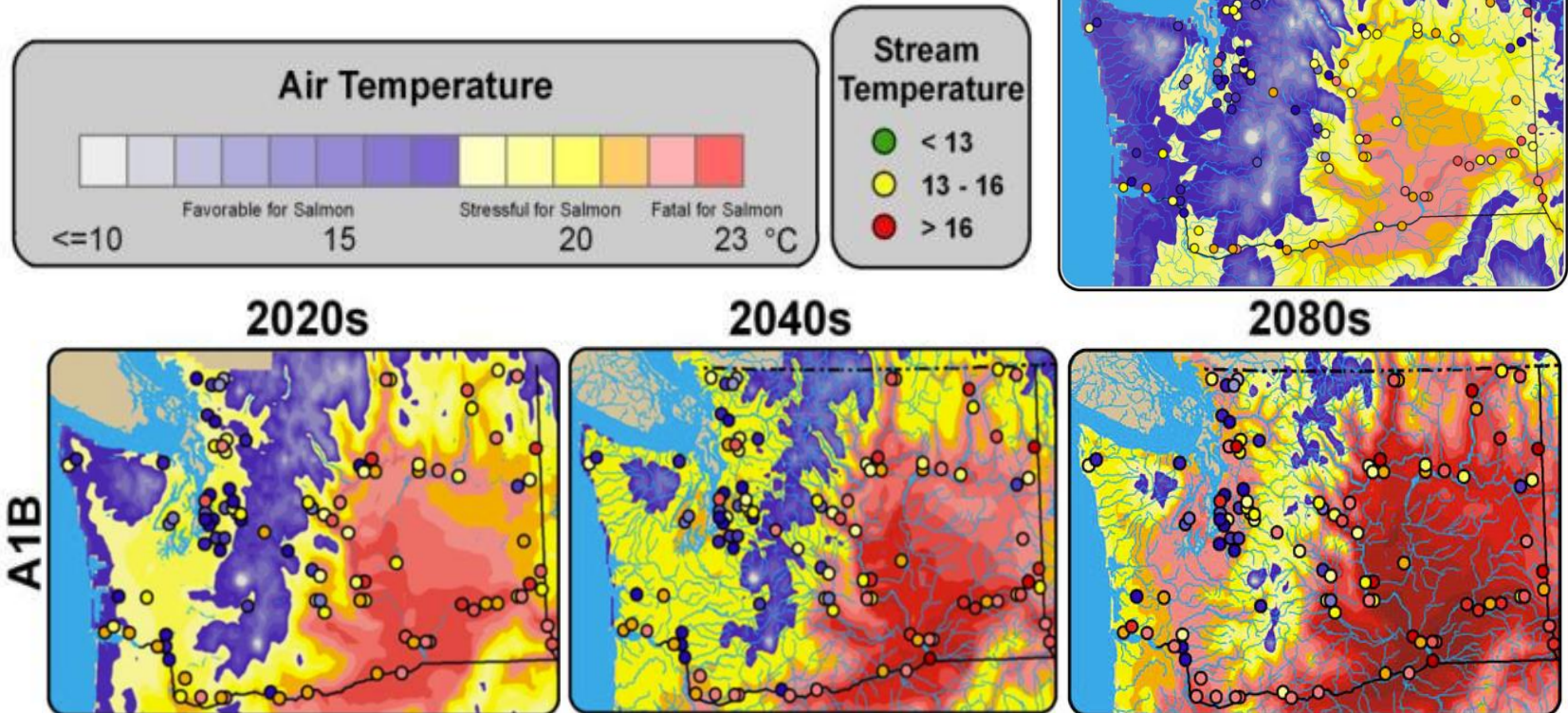
Ratio of Low Flow (7Q10) Statistics (21st Century : 20th Century)



Future projections of low flow risks in the PNW

Higher temperatures will stress salmon

Summer Mean Surface Air Temperature and Maximum Stream Temperature



13°C: Spawning, incubation and optimal growth temperature

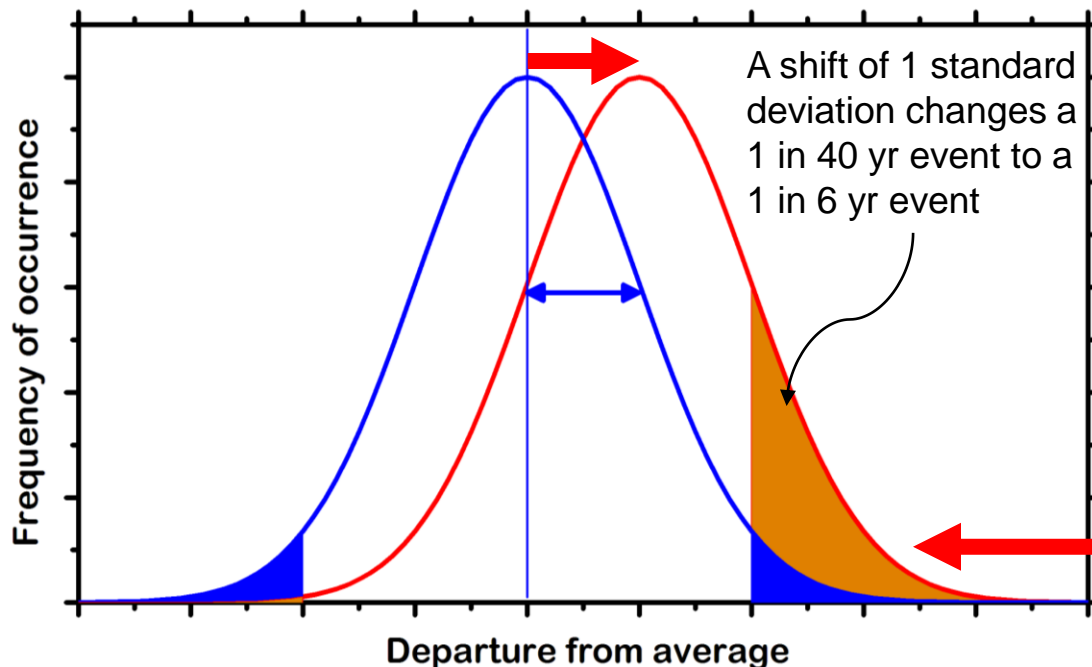
16°C: core salmon habitat temperature

Extreme weather + increased disturbance: Our primary challenge



Extremes matter

Frequency, extent, and severity of disturbances may be affected by climate change, altering the mean and *variability* of disturbance properties.



A shift in *distribution* of disturbance properties has a larger relative effect at the *extremes* than near the mean.

It's all about the tail!

U.S. Drought Monitor Washington

August 25, 2015

(Released Thursday, Aug. 27, 2015)

Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	99.99	84.64	0.00
Last Week 8/18/2015	0.00	100.00	100.00	99.99	50.80	0.00
3 Months Ago 5/26/2015	9.77	90.23	51.81	23.76	0.00	0.00
Start of Calendar Year 12/30/2014	51.87	48.13	36.15	14.83	0.00	0.00
Start of Water Year 9/30/2014	34.22	65.78	40.27	20.17	0.00	0.00
One Year Ago 8/26/2014	32.61	67.39	40.32	19.99	0.00	0.00

Intensity:

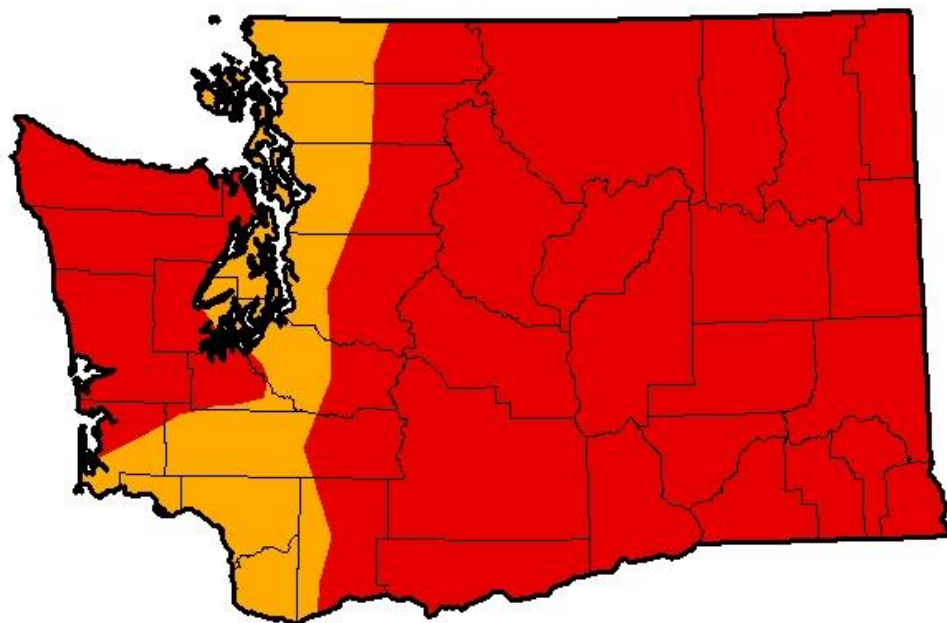
 D0 Abnormally Dry	 D3 Extreme Drought
 D1 Moderate Drought	 D4 Exceptional Drought
 D2 Severe Drought	

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:

Anthony Artusa

NOAA/NWS/NCEP/CPC




<http://droughtmonitor.unl.edu/>

Environmental Research Letters

LETTER

The 2015 drought in Washington State: a harbinger of things to come?

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Keywords: drought, climate change, fire risk, hydrology

Supplementary material for this article is available [online](#)

Abstract

Washington State experienced widespread drought in 2015 and the largest burned area in the observational record, attributable in part to exceptionally low winter snow accumulation and high summer temperatures. We examine 2015 drought severity in the Cascade and Olympic mountains relative to the historical climatology (1950–present) and future climate projections (mid-21st century)

Seattle Times

It's official: Seattle breaks record for most consecutive days without rain

Originally published August 9, 2017 at 7:06 am | Updated August 9, 2017 at 1:37 pm



2017

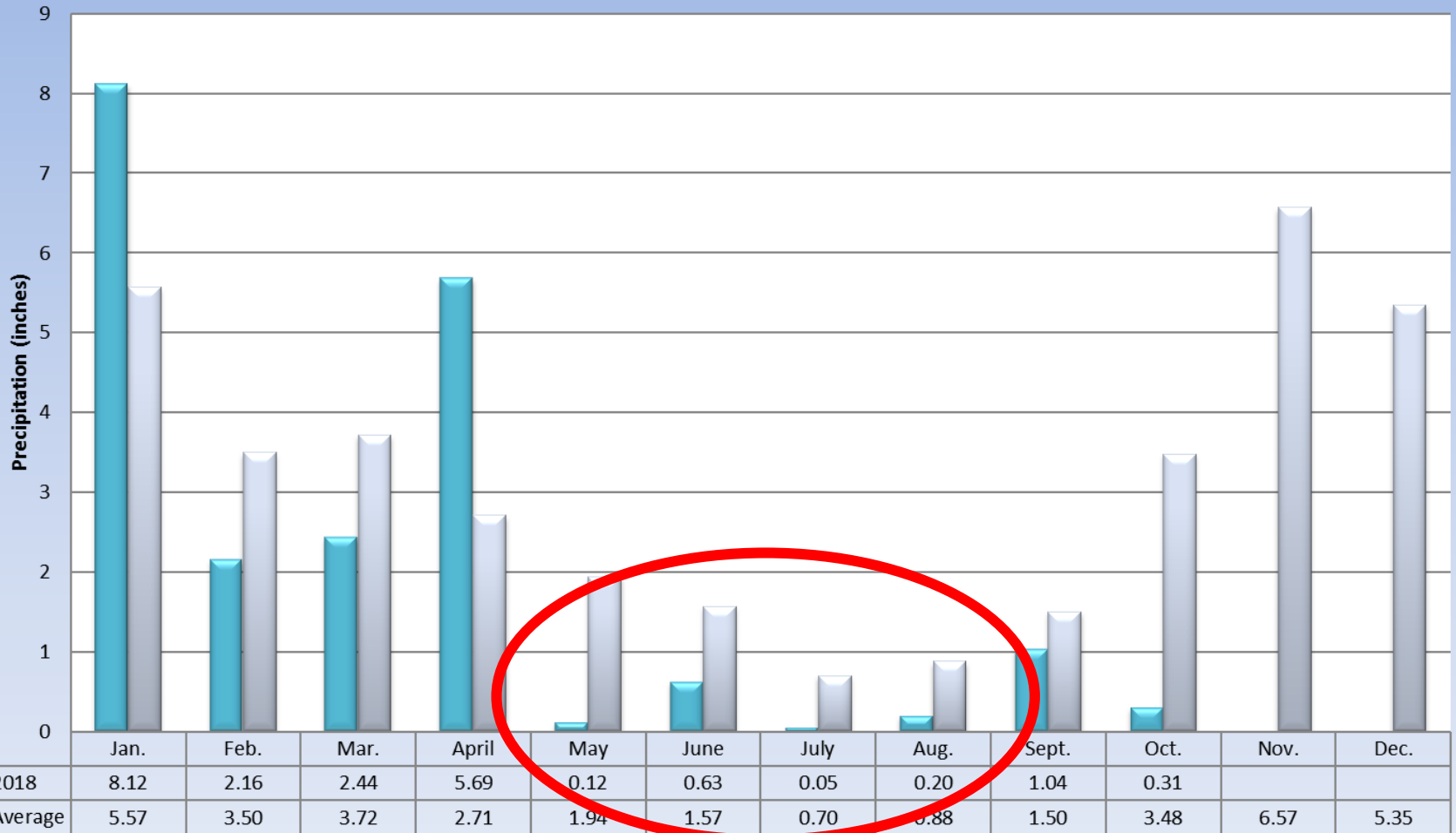
A haze continues to hang over Seattle, as viewed Monday from Kerry Park on Seattle's Queen Anne Hill. (Ken Lambert / The Seattle Times)

Also, the city's air quality is at unhealthy levels as of Wednesday morning, according to the Department of Ecology.

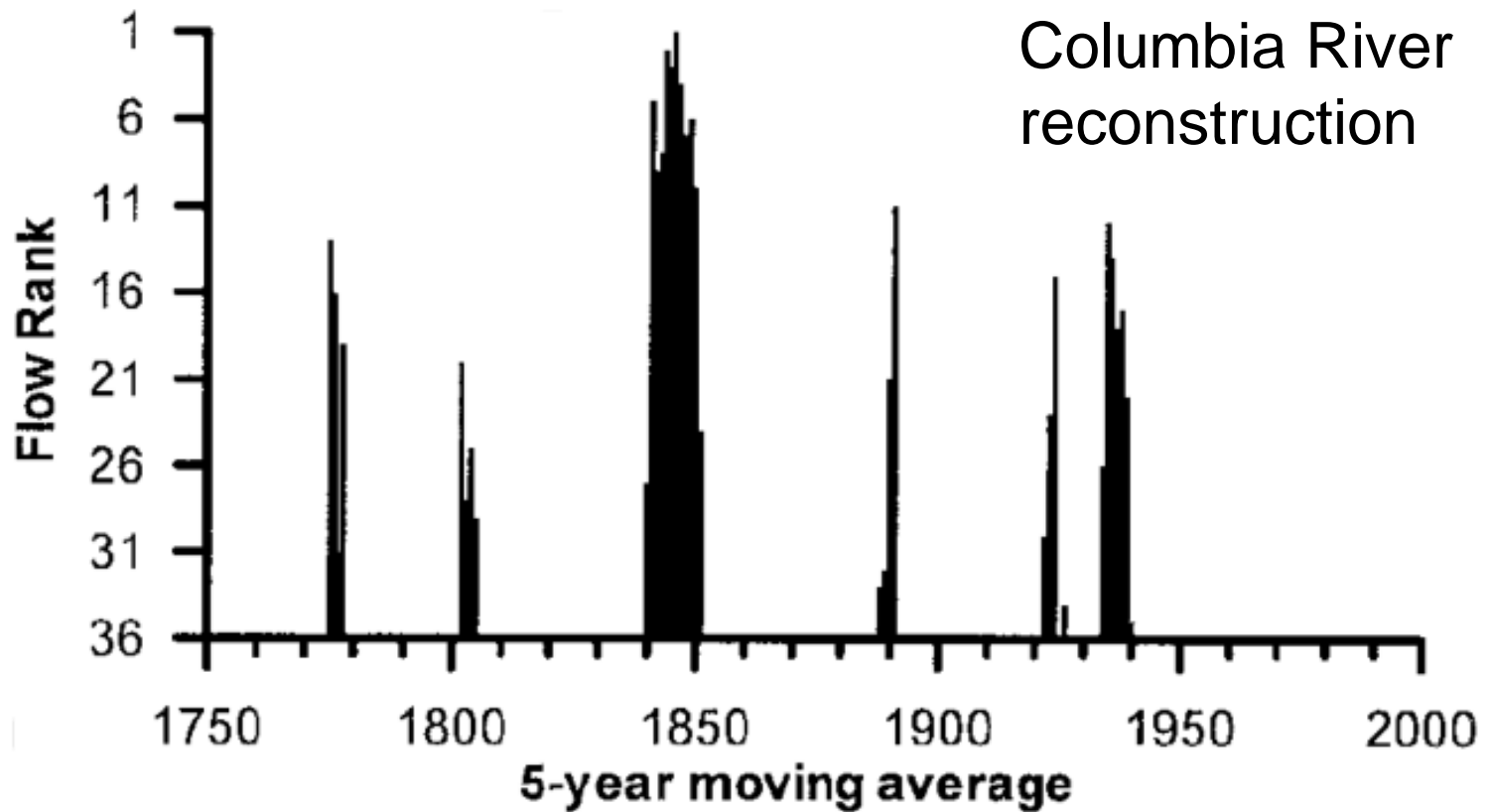
2018: a very dry summer

Seattle Monthly Precipitation, 2018

Year-to-date through Oct. 4: 20.76" (Average: 22.37")



Droughts were formerly more common



Gedalof et al. 2004

Climate change affects insects

Mountain pine beetle



Warmer temperature has favored MPB by:

- Increasing its reproductive rate
- Allowing an expanded geographic range



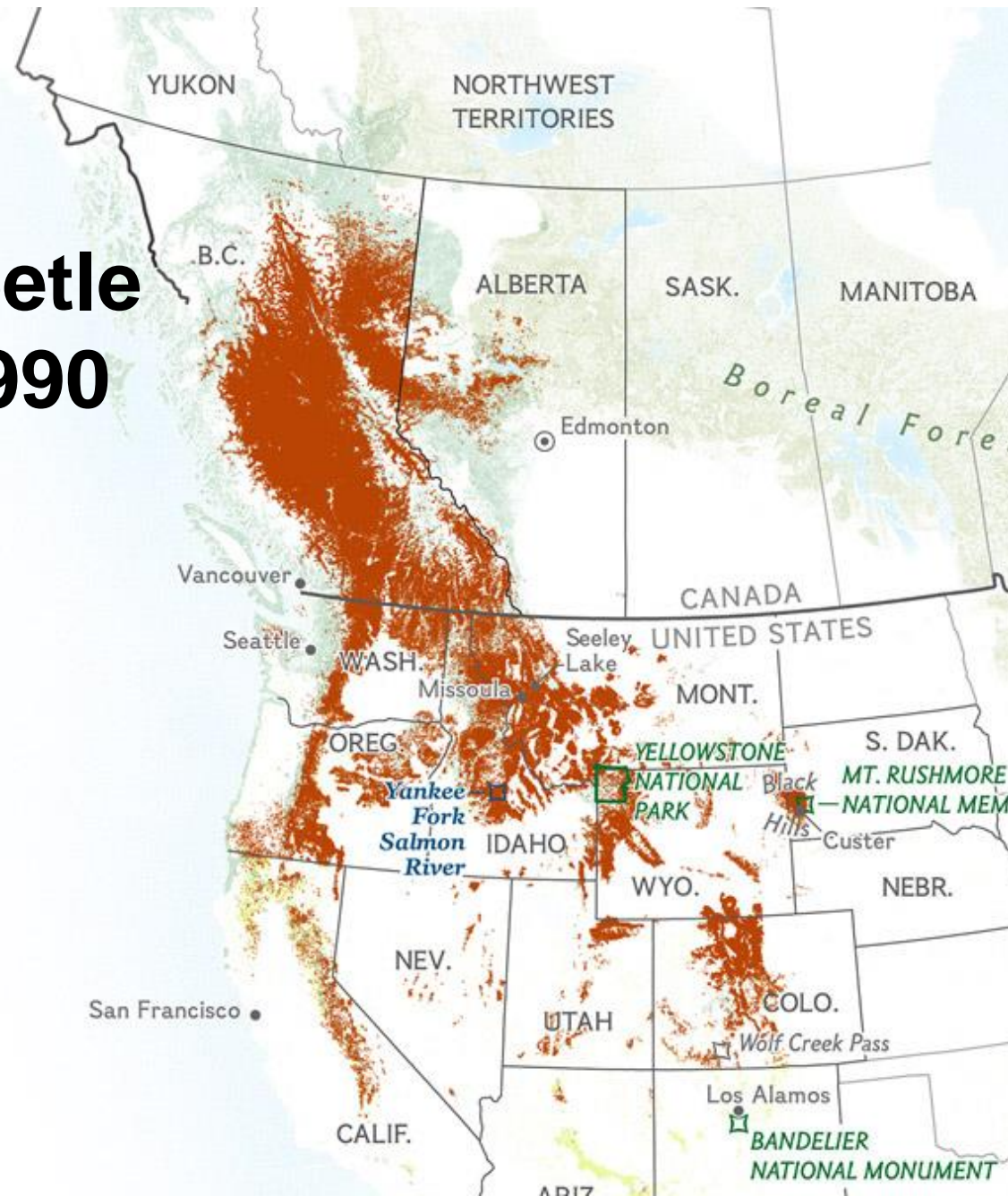
Mountain pine beetle outbreak since 1990

50 million acres

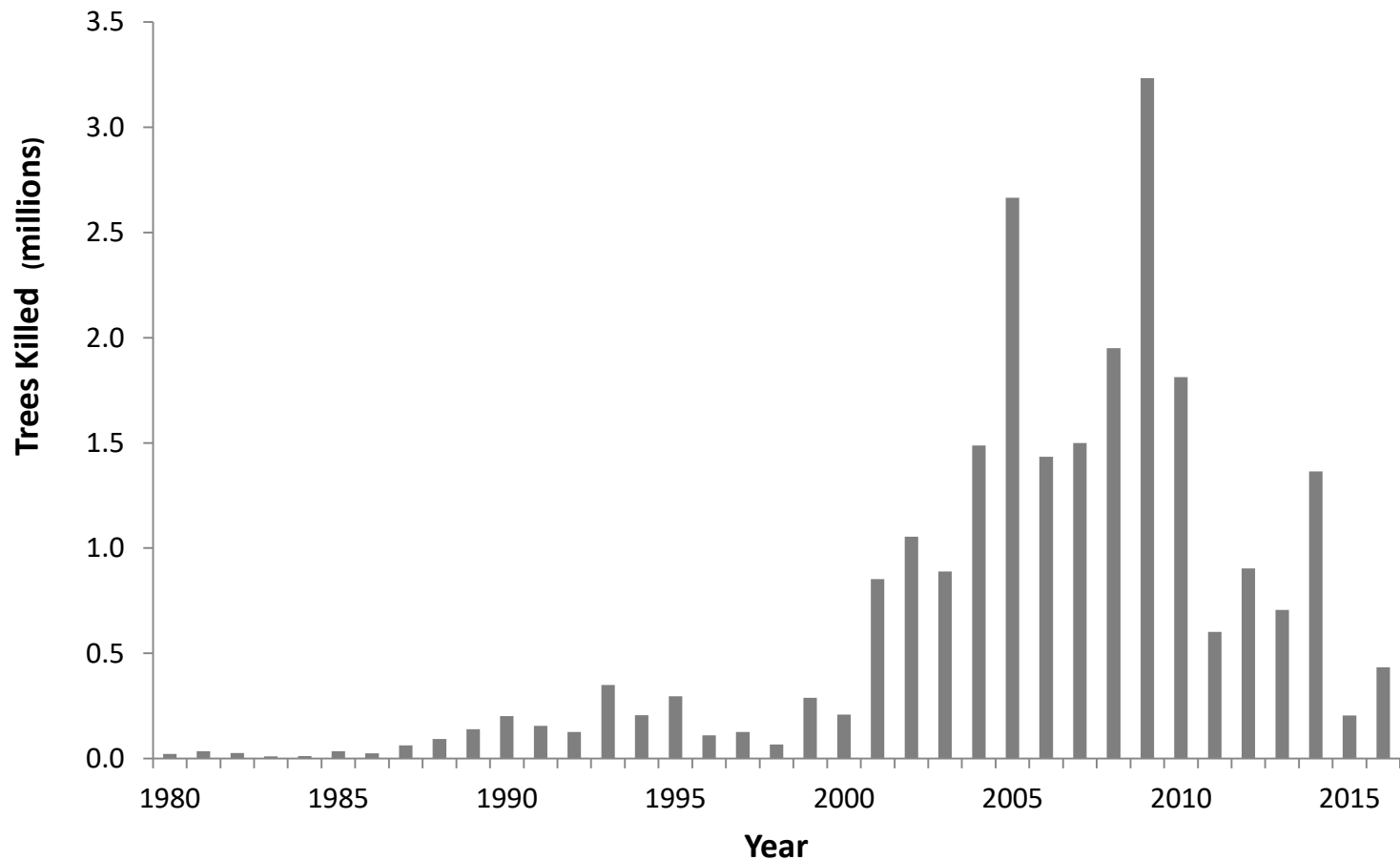
THE BEETLE AND ITS HOSTS

- Mountain pine beetle occurrence
- Lodgepole pine range
- Jack pine range
- Other pine species

0 mi 200
0 km 200



Trees killed by mountain pine beetles (Okanogan-Wenatchee NF)



How will climate change affect wildfire?



How will climate change affect wildfire?



Anacortes – August 26, 2016

How will climate change affect wildfire?



Goodell Creek Fire, Newhalem (August 2015)

Washington wildfires — 2015

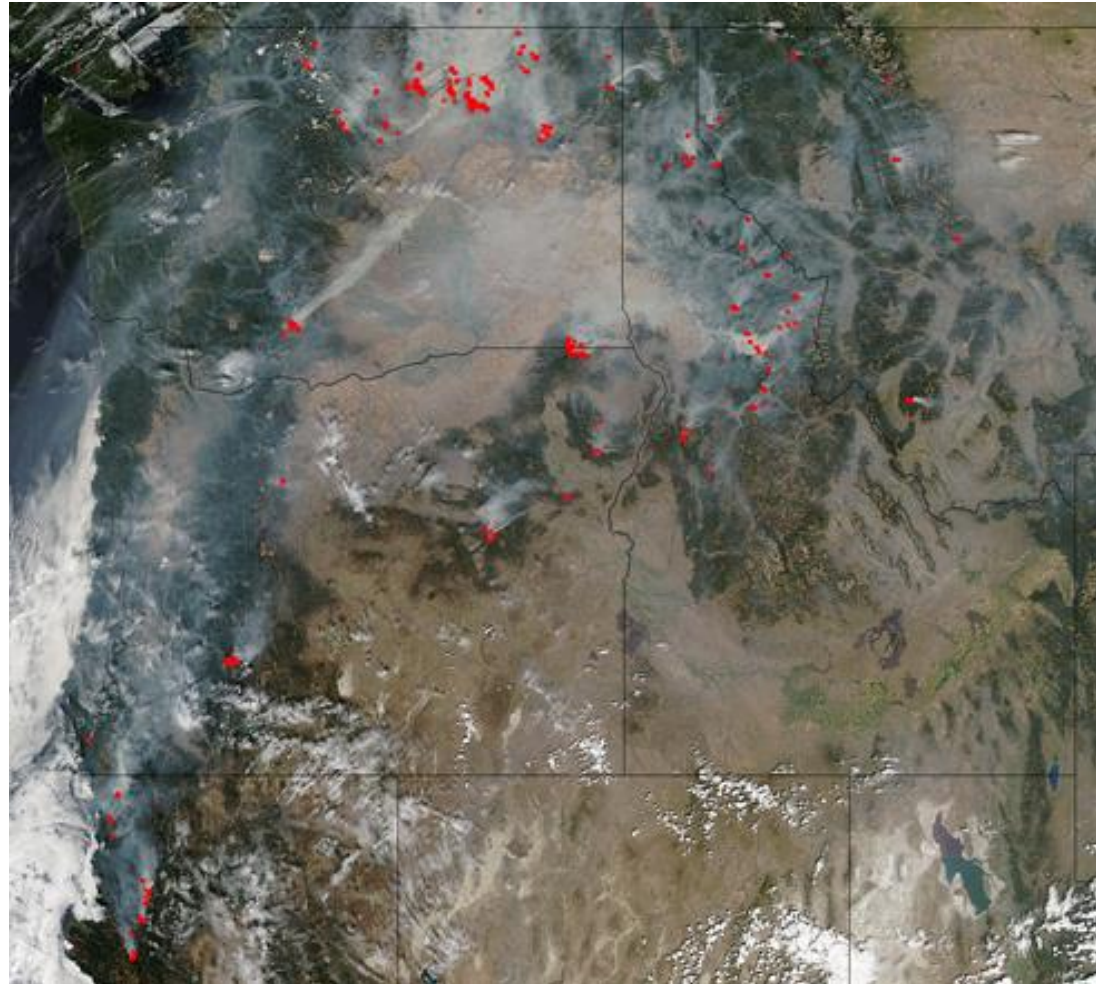
- 1,541 fires
- 1 million acres burned (387,000 acres in 2014)
- \$253 million fire suppression cost
- Large economic losses in rural communities



Climatic change and regional wildfires

- As temperature increases, more water evaporates from the landscape and plant tissues
- Larger areas of low fuel moisture
- Regional synchronization of fires occurs

Pacific Northwest, August 30, 2015



MODIS, NASA

More fires = more smoke

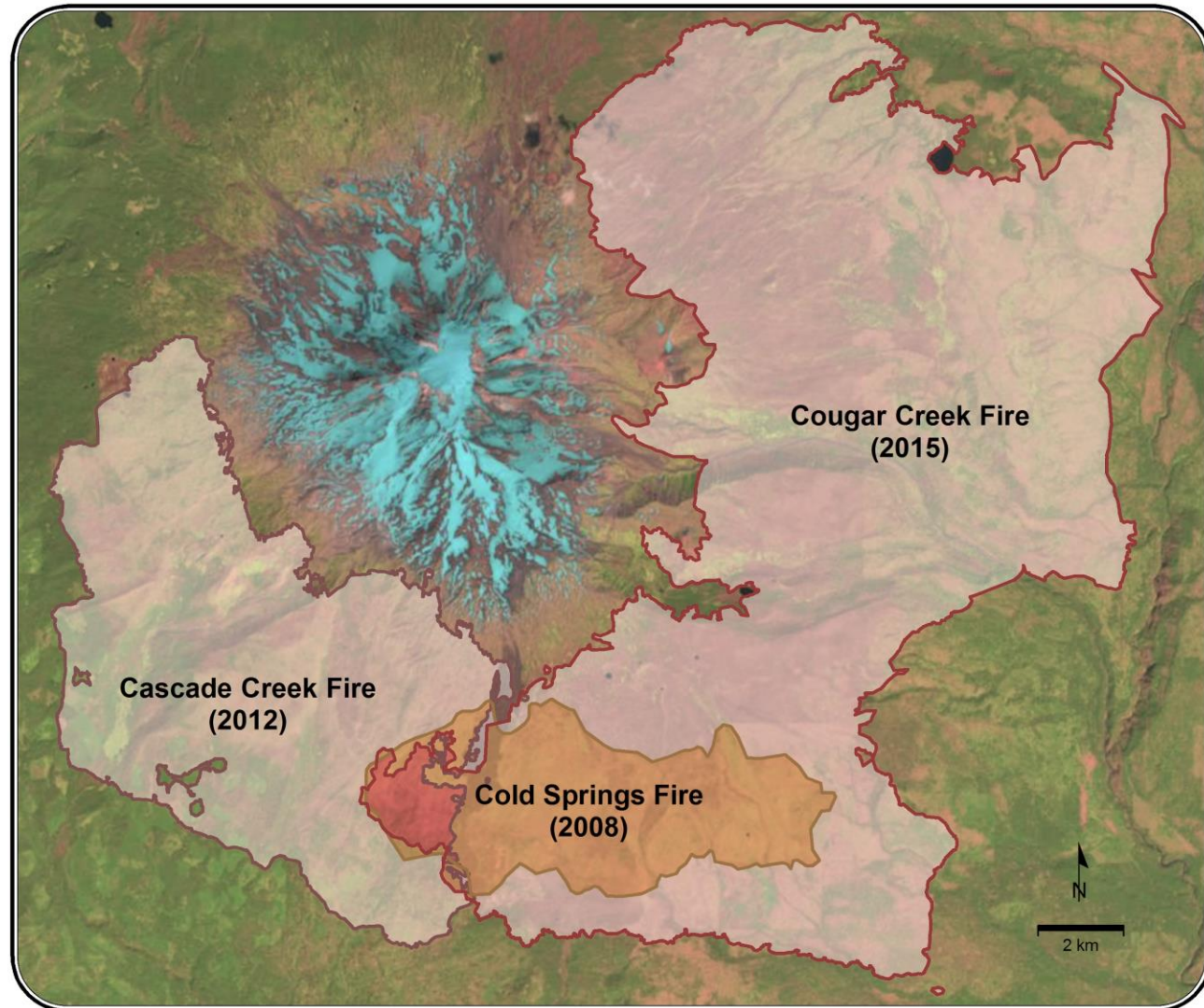


Seattle (August 2018)

Wildfires are colliding

Southwest Washington

Fires have
burned some
areas 3 times
since 2008



Map by R. Norheim

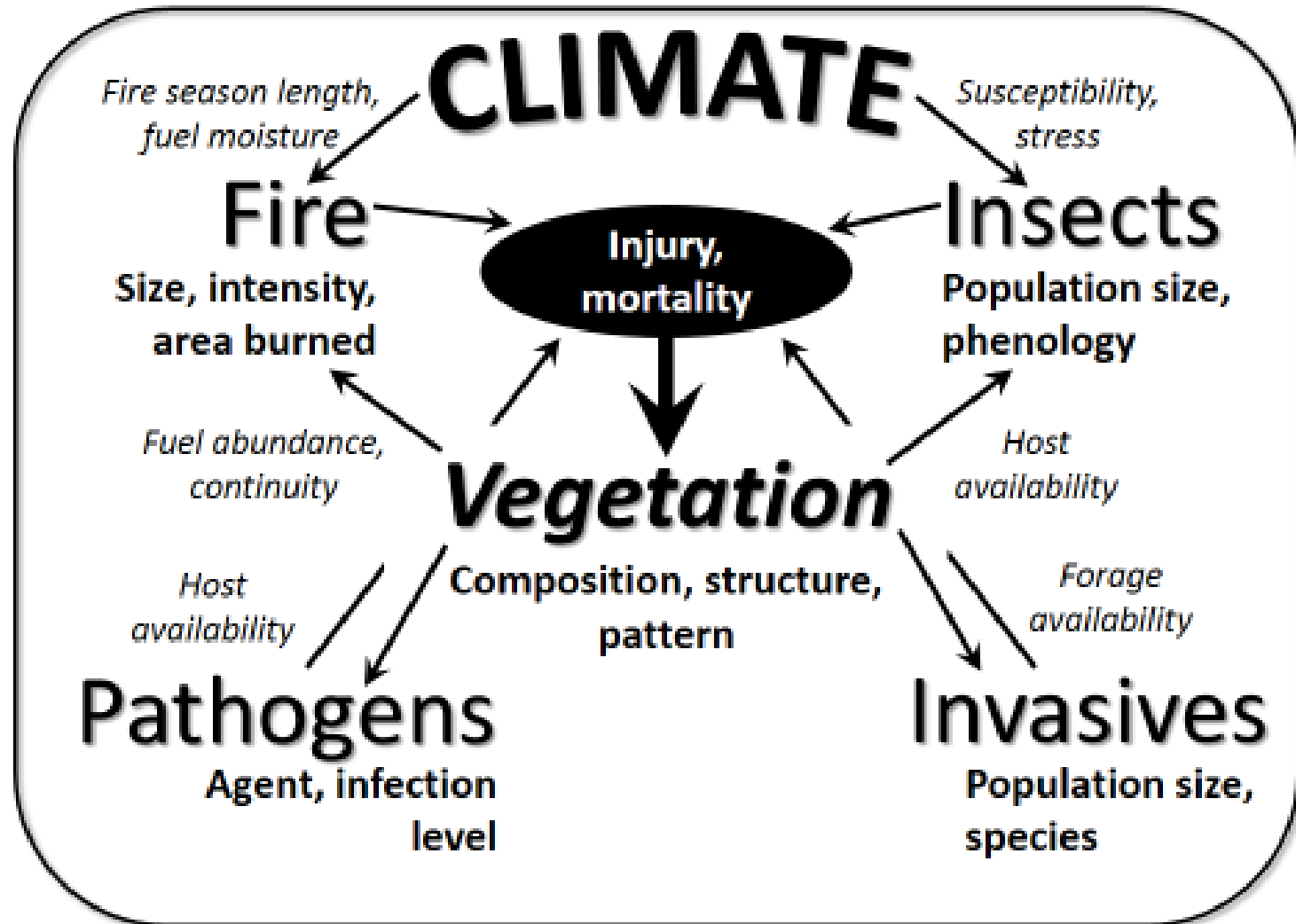
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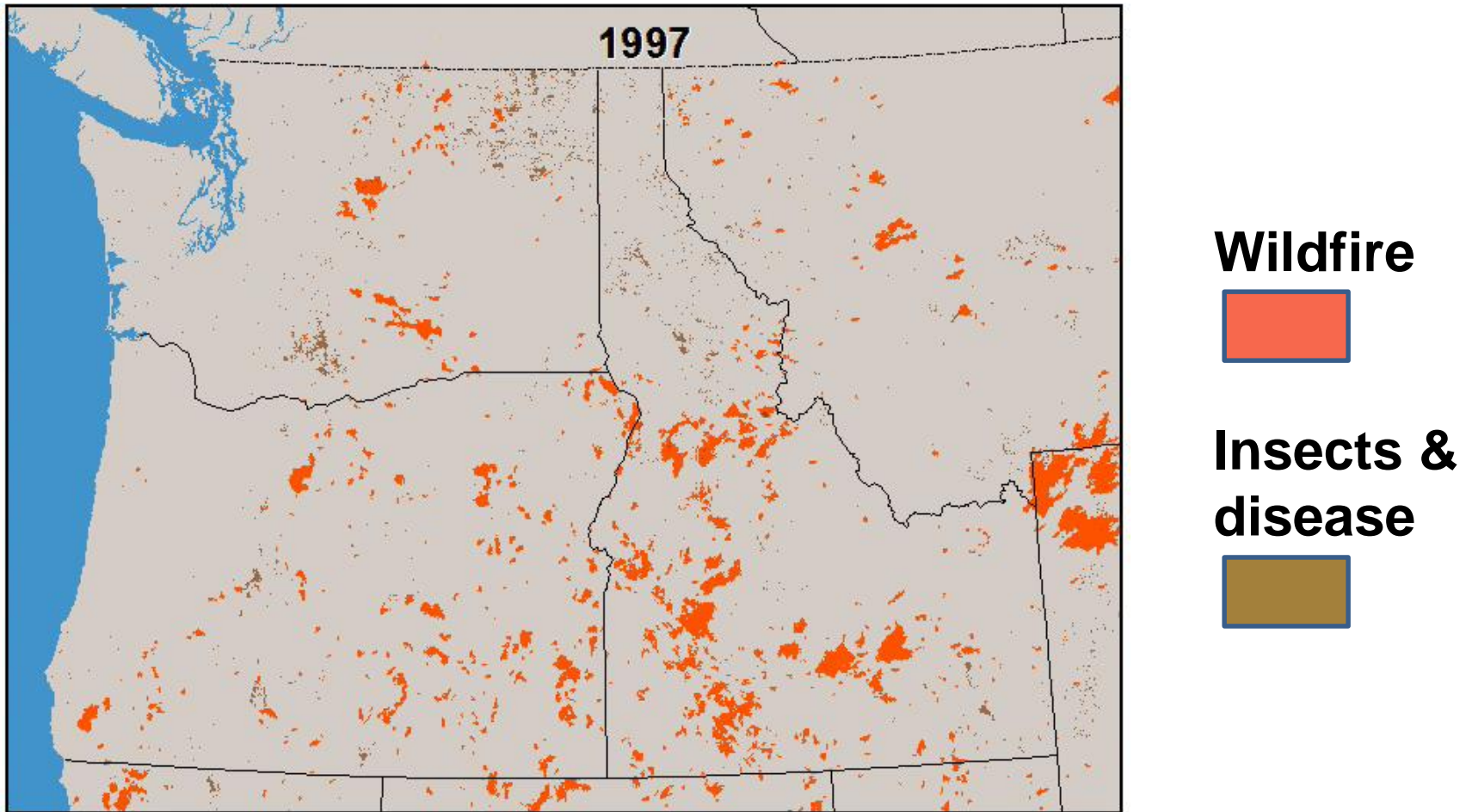
Fires have
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Disturbances will interact

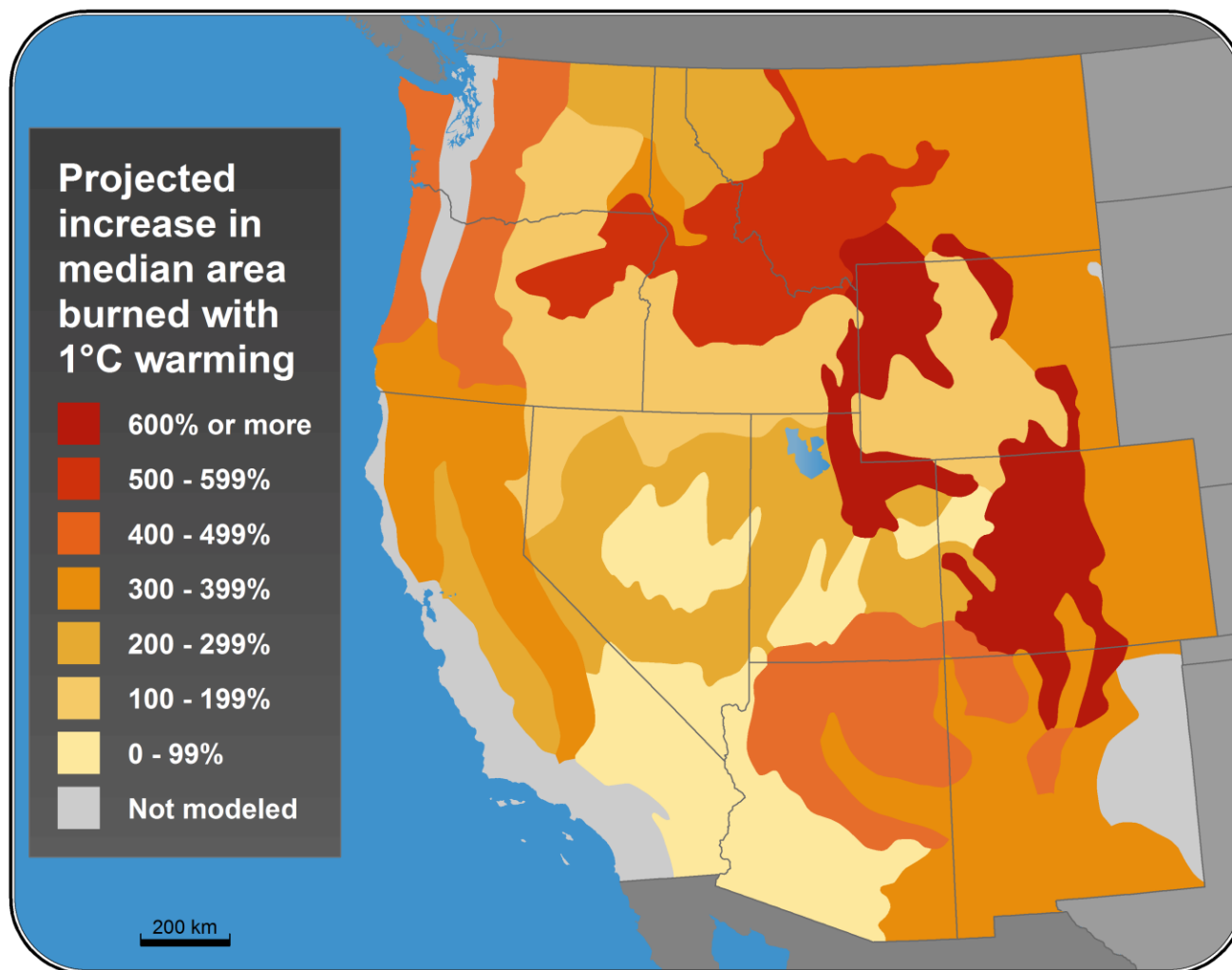


Interacting disturbances

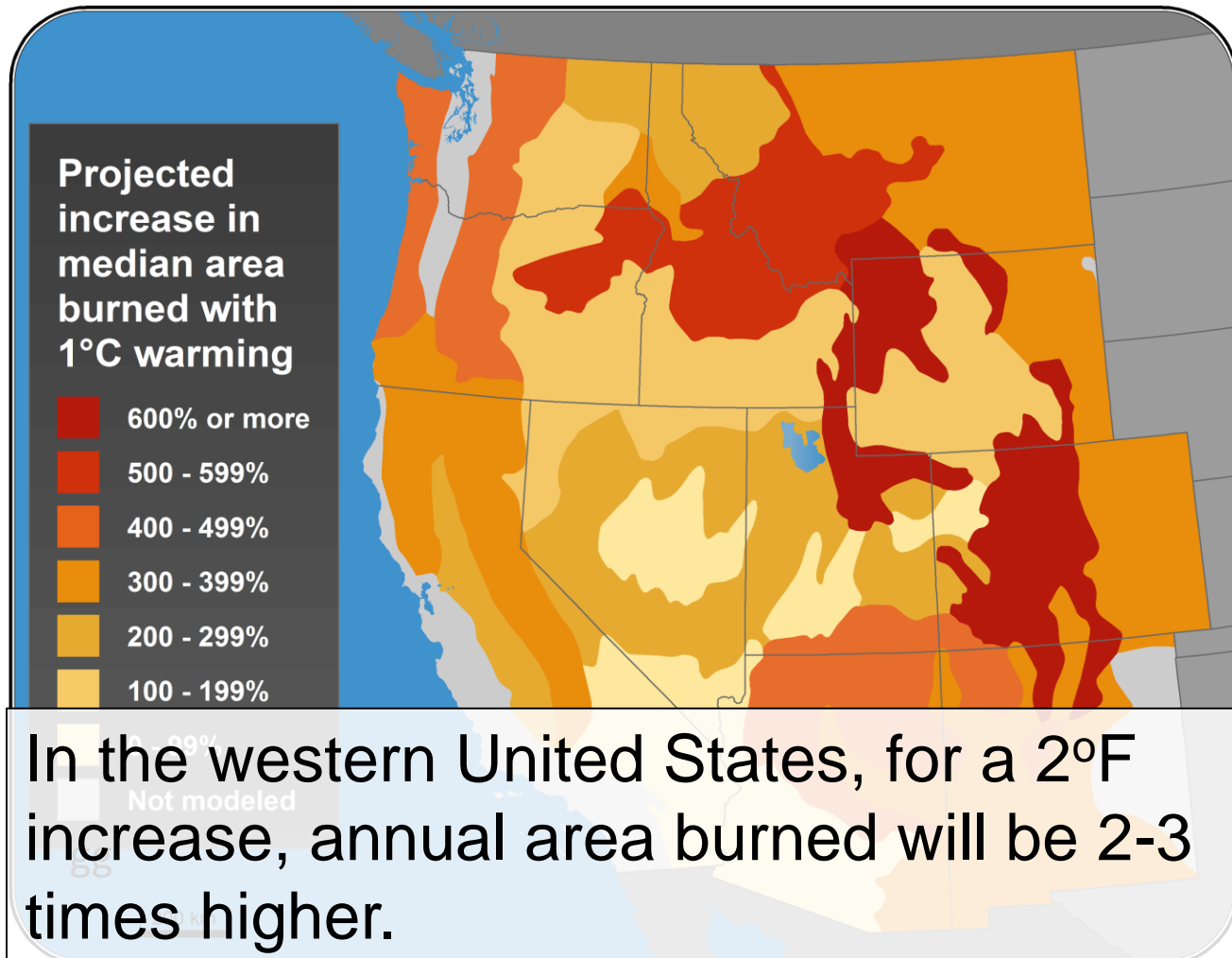


Map by R. Norheim

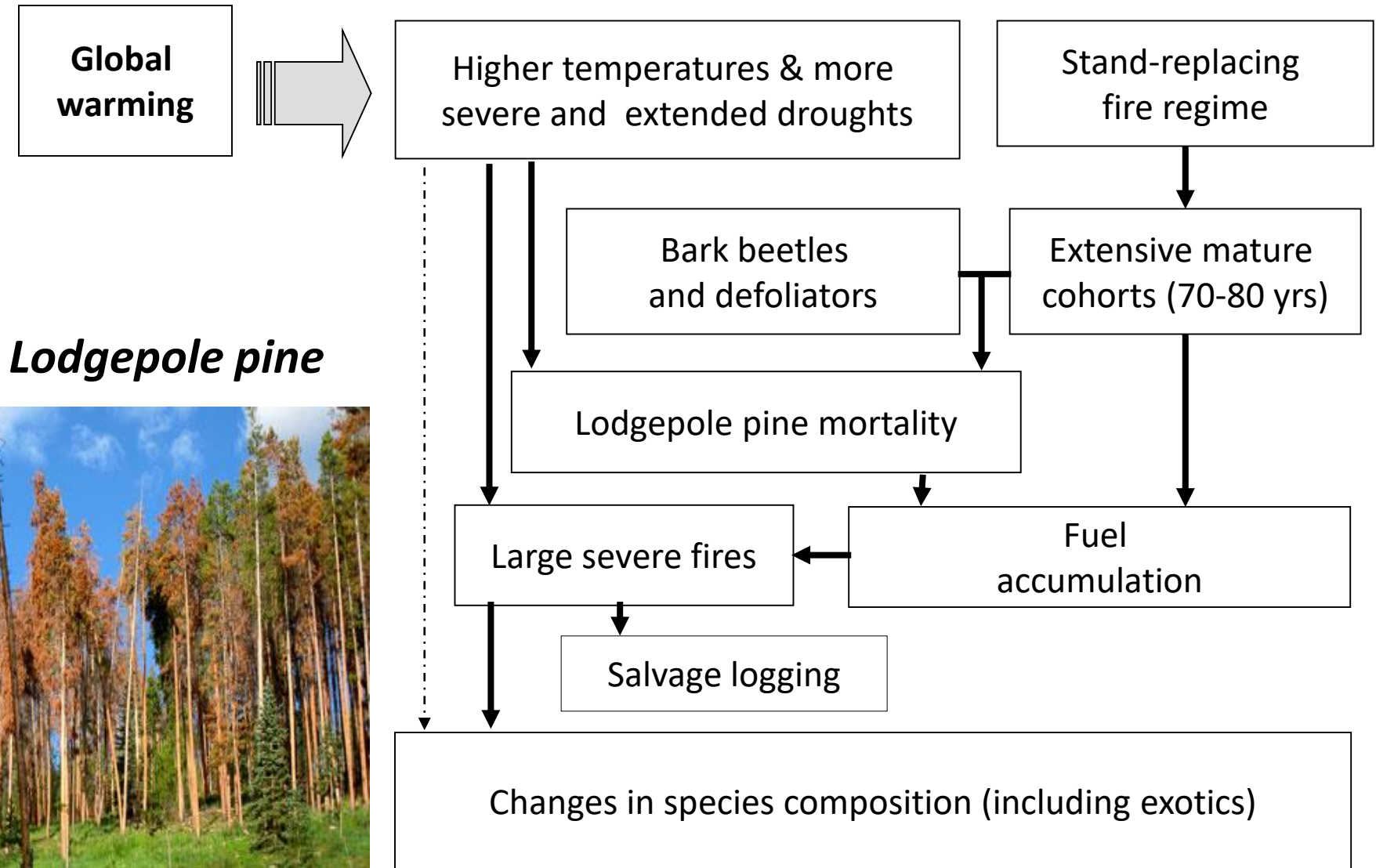
Wildfire area burned, 2050



Wildfire area burned, 2050



Warming affects stress complexes



In summary — What to expect

- High certainty: Higher temperature, more wildfire, less snowpack, less water in summer
- Less certainty: Precipitation
- Extreme events (drought, wildfire, insects) will have the biggest effects on ecosystems.
- Things may change quickly after 2050.
- There will be surprises.

Thank you

For more information:
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www.adaptationpartners.org

