General Overview of Climate Projections and their consequences

Dr. Dominique Bachelet, Dept of Biological and Ecological Engineering, OSU



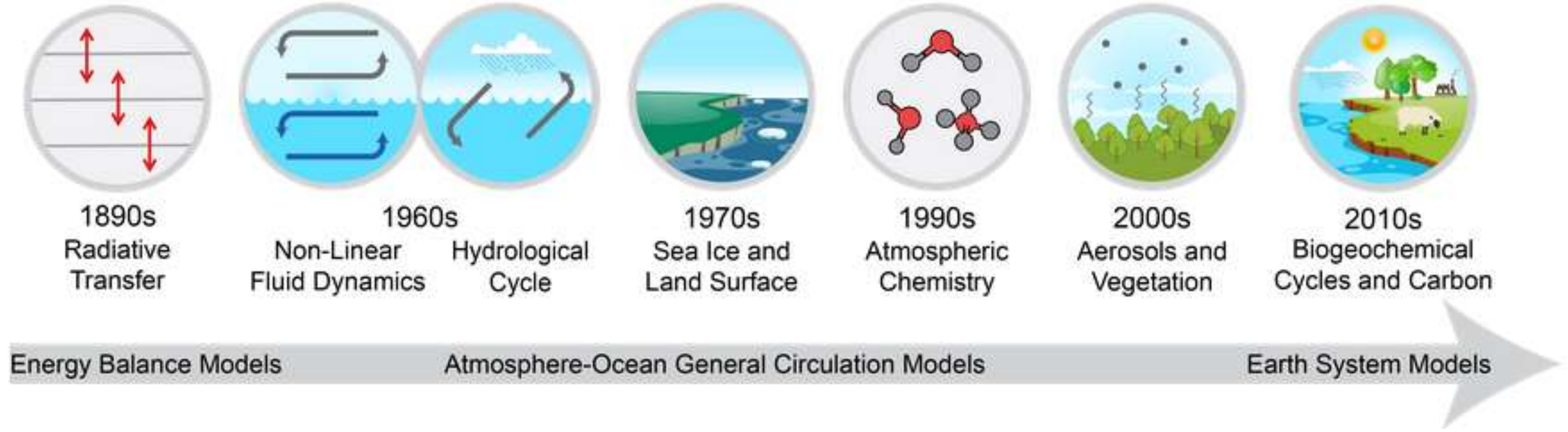


Maintaining a Healthy Forest in an Uncertain Climate

Roseburg, OR – 12 March 2020

Climate Model Evolution

Source: 4th National Climate Assessment Report i.e. AR4 (2017)

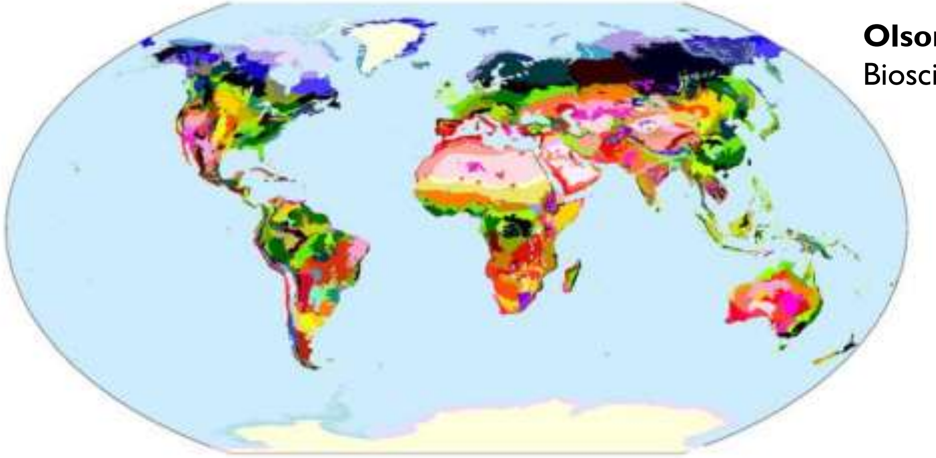


1990 1995 2001 2007

Source: IPCC 4th Assessment Report i.e. AR4 (2018)

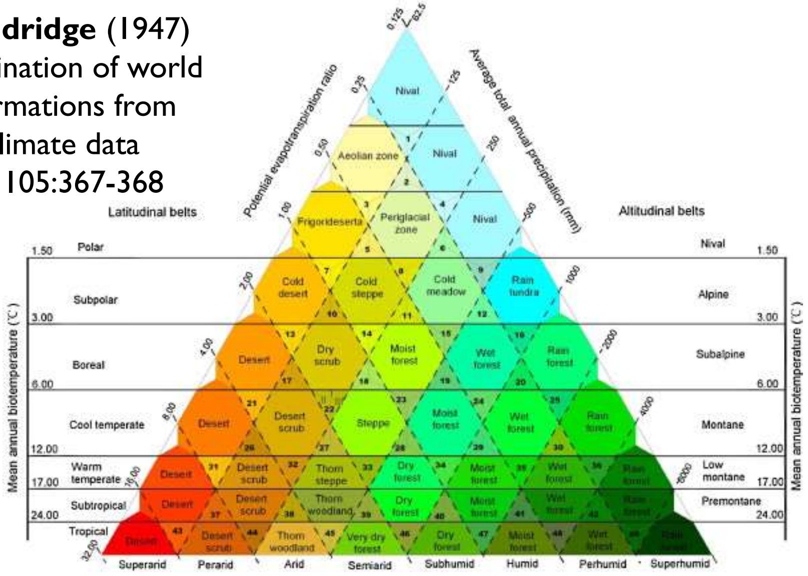
Vegetation Model Evolution

BIOGEOGRAPHY MODELS

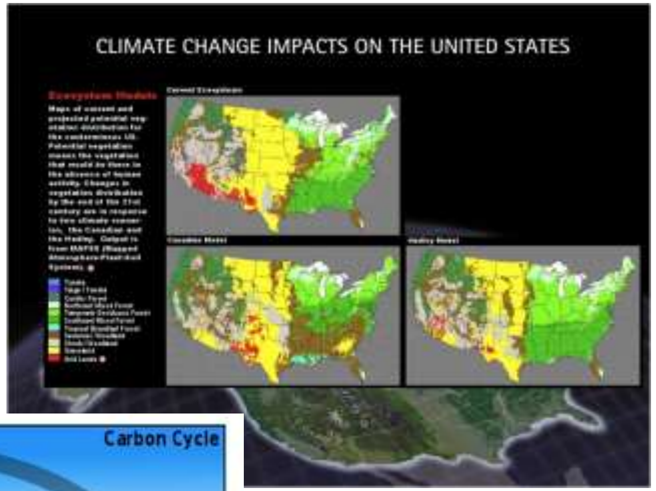


Olson et al. 2001.
Bioscience 51:933-938

L.R. **Holdridge** (1947)
Determination of world plant formations from simple climate data
Science, 105:367-368



DYNAMIC VEGETATION MODELS



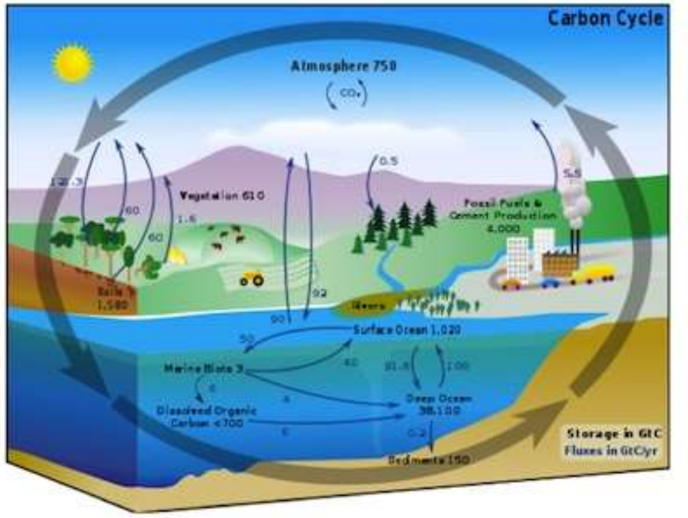
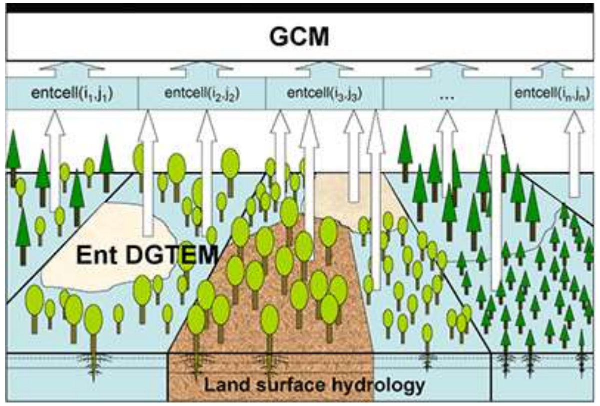
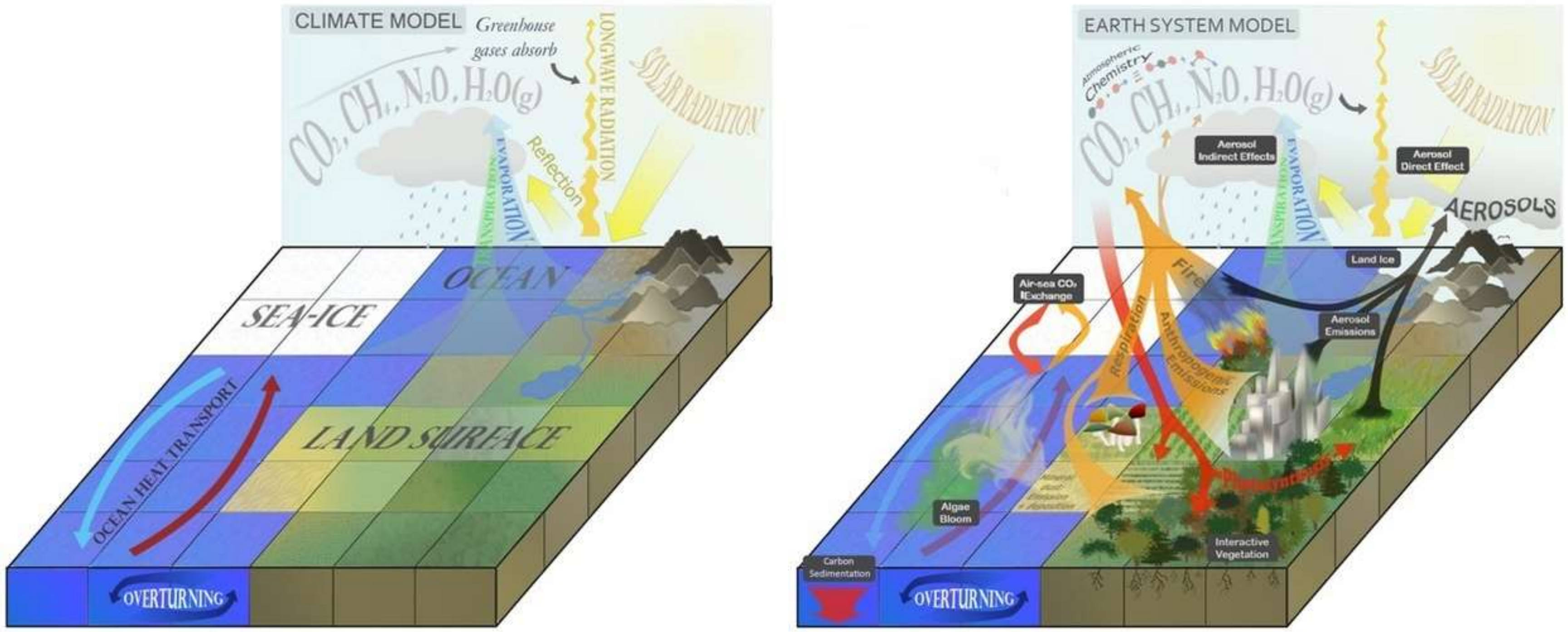


Image courtesy of earthobservatory.nasa.gov



Increased complexity - Earth System Models

AR5 in 2014 – AR6 in 2022 (AR=assessment report)



Source: Heavens, N. G., Ward, D. S. & Natalie, M. M. (2013) Studying and Projecting Climate Change with Earth System Models. *Nature Education Knowledge* 4(5):4

NEEDS MORE WORK!

Salt Intrusion
Storm surges

IS92 (IPCC scenarios): 1992
SRES (Special Report on Emission Scenarios): 2000
RCPs (Representative Concentration Pathways): 2014
SSP (Shared Socioeconomic Pathways): 2020

QUIZ

True or false:

Compared to other greenhouse gases, **carbon dioxide** is the most effective at trapping heat near the Earth's surface.

Answer to QUIZ

Answer: **Water vapor** has more heat-trapping power than carbon dioxide. It is also more abundant.

But carbon dioxide and water vapor interact in crucial ways: more carbon dioxide means the atmosphere gets warmer, which then creates more water vapor, which traps heat and warms the atmosphere even more.

Thunder over Ancona, Italy by A.Serresi

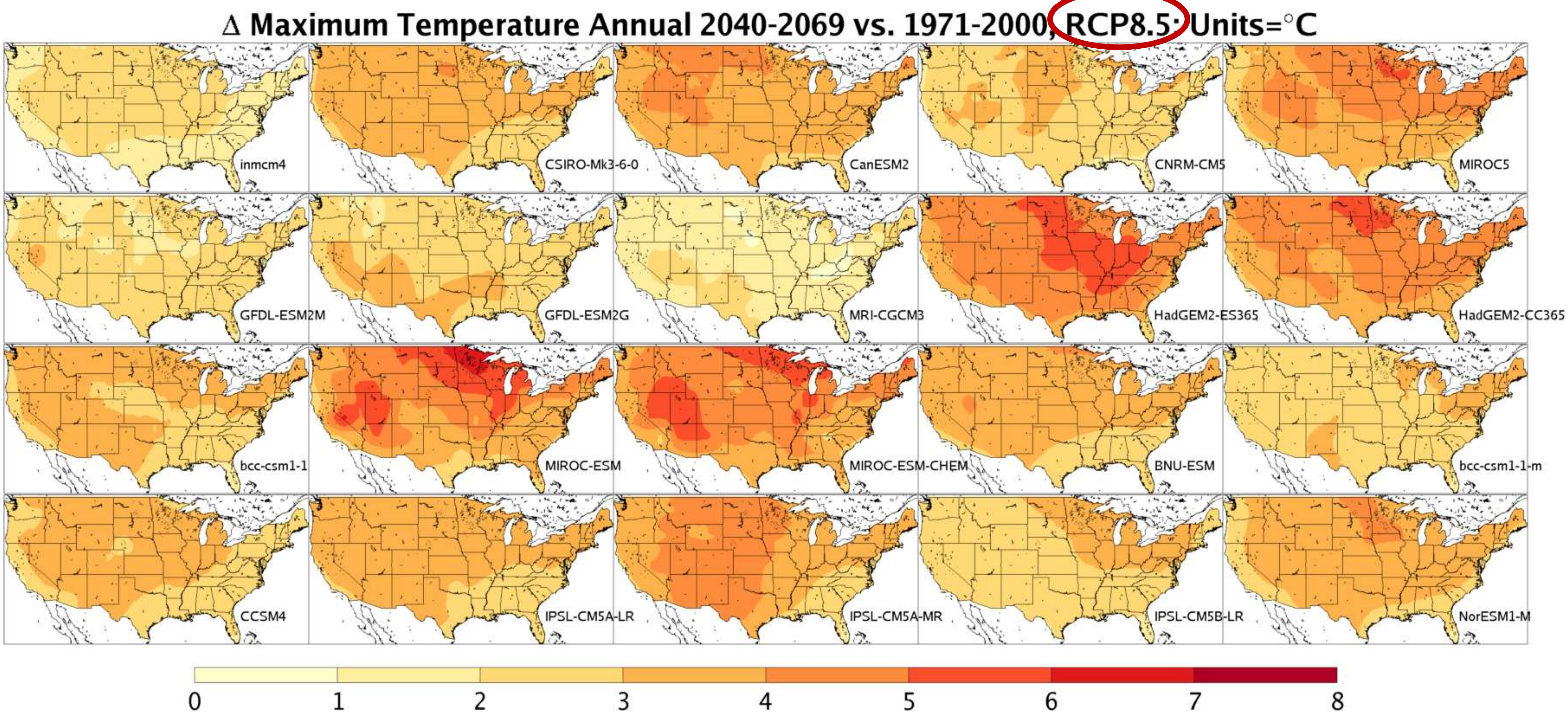
What do models project for the rest of the century?

The purpose of models is not to fit the data but to sharpen the questions.
Samuel Karlin (1924-2007)

Photo credit: U of Oregon

Temperature projections

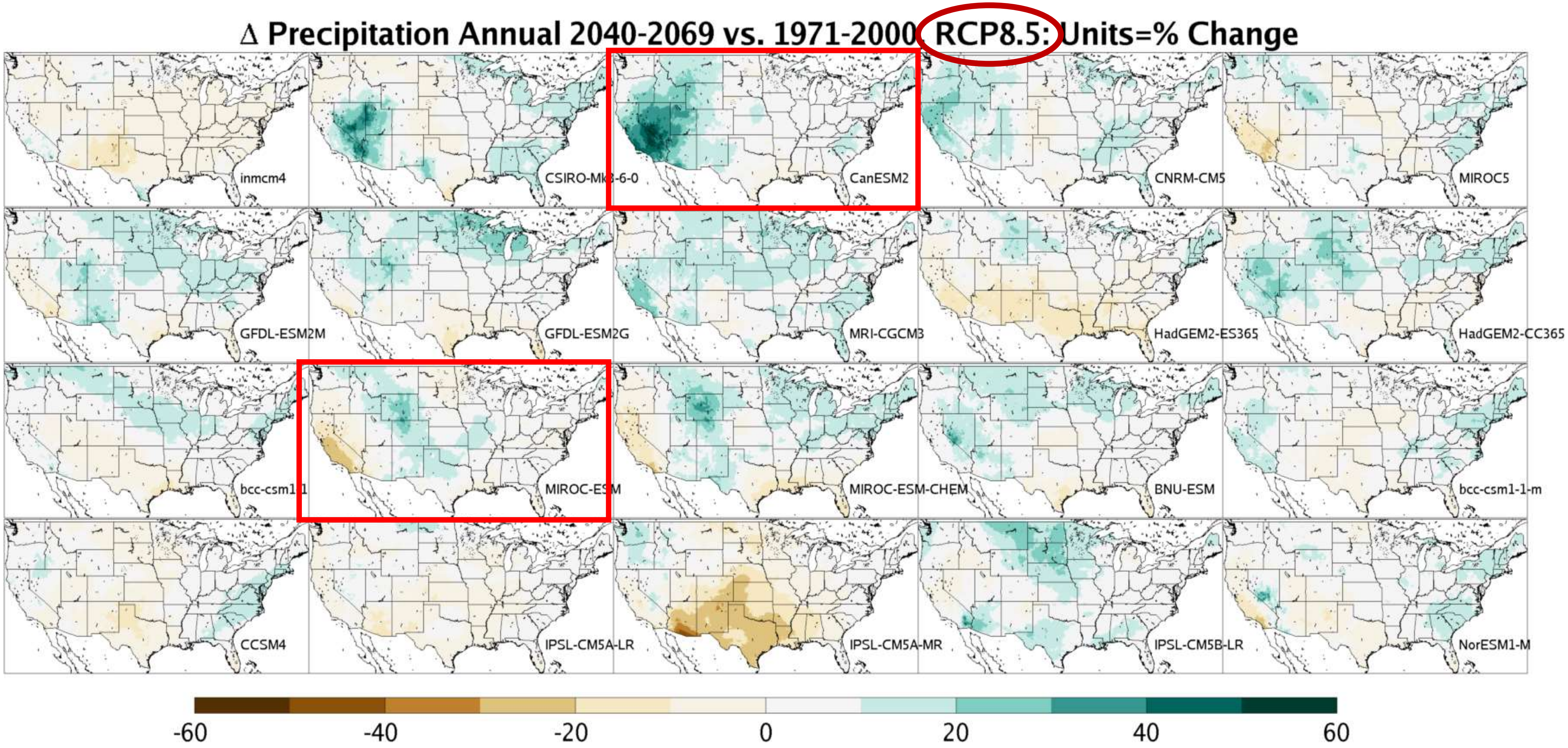
spatial variability but identical trend of warming



Source: https://climate.northwestknowledge.net/MACA/tool_projectionmaps.php

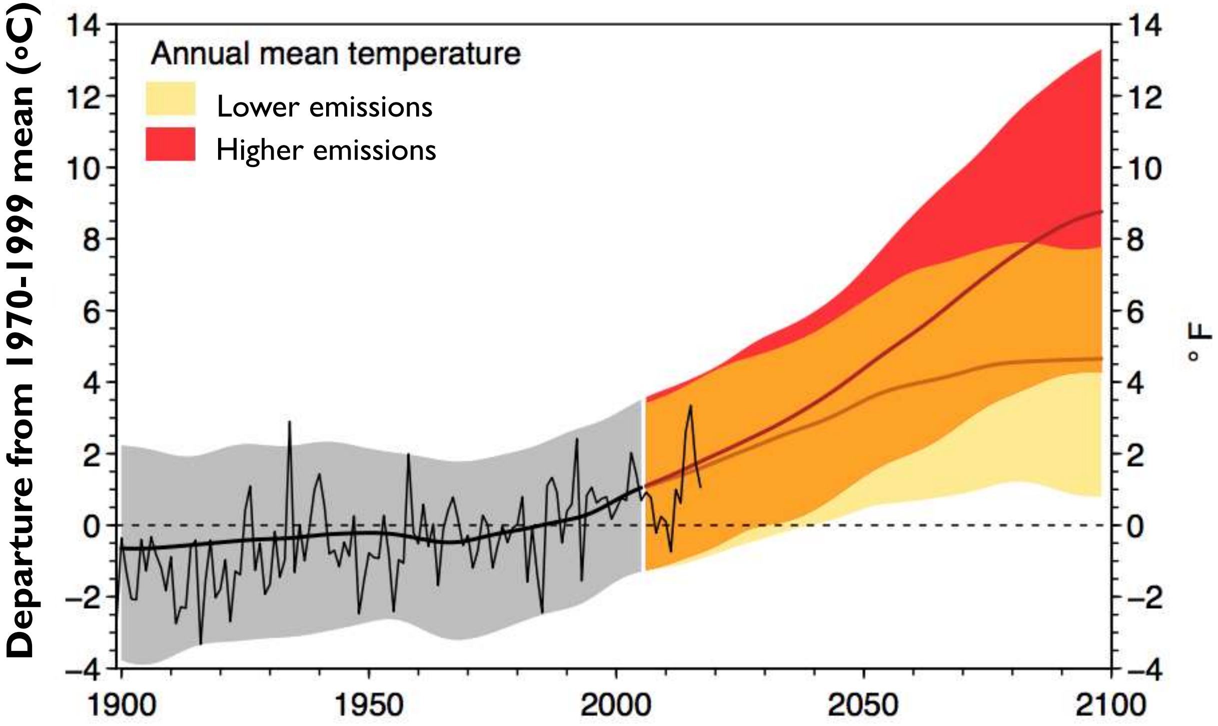
Precipitation projections

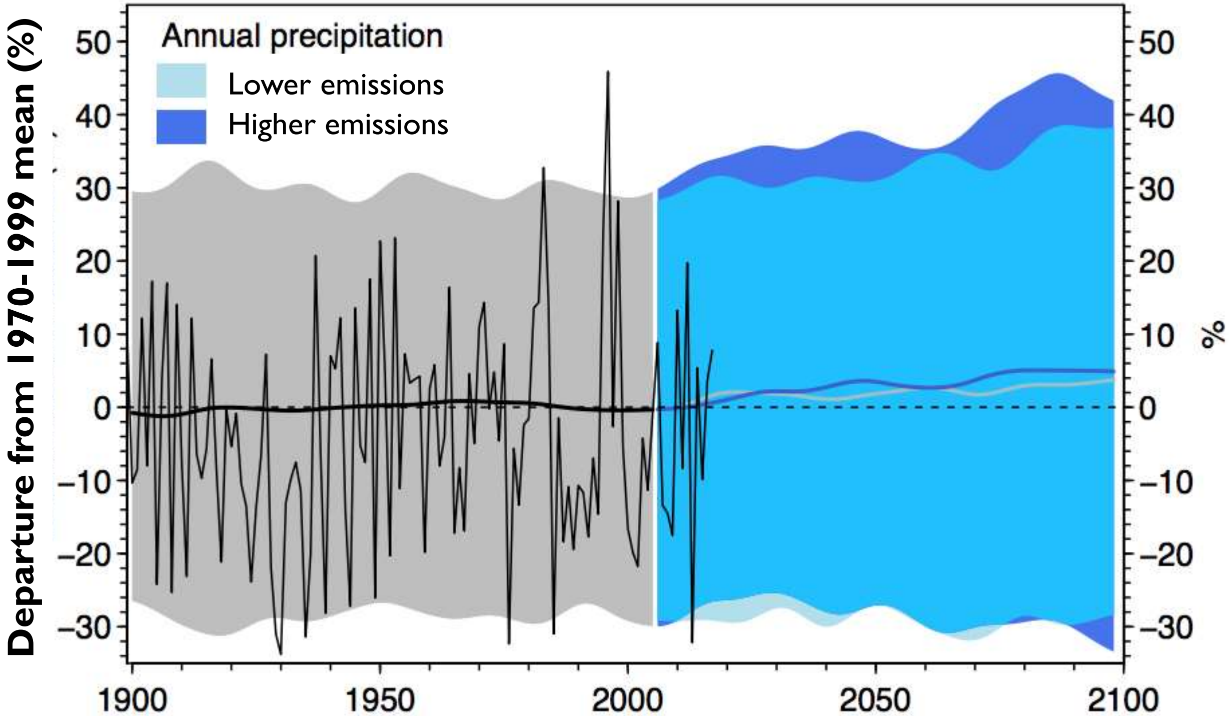
spatial variability with little agreement



Source: https://climate.northwestknowledge.net/MACA/tool_projectionmaps.php

CMIP5 Projections and Observations for Oregon – RCP 4.5-8.5

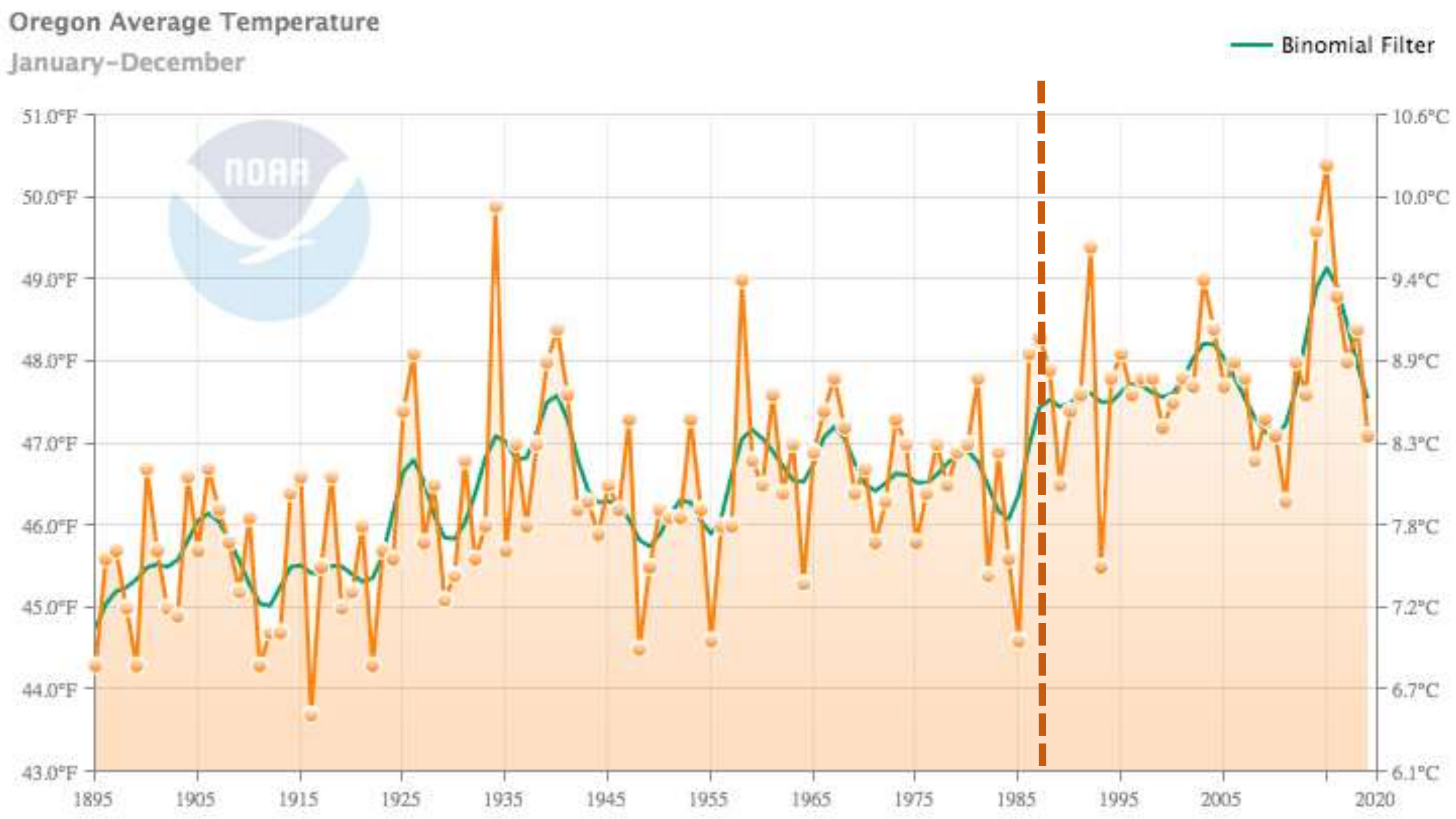




From: OR Clim. Ass. Report 4, 2019

What have we observed …

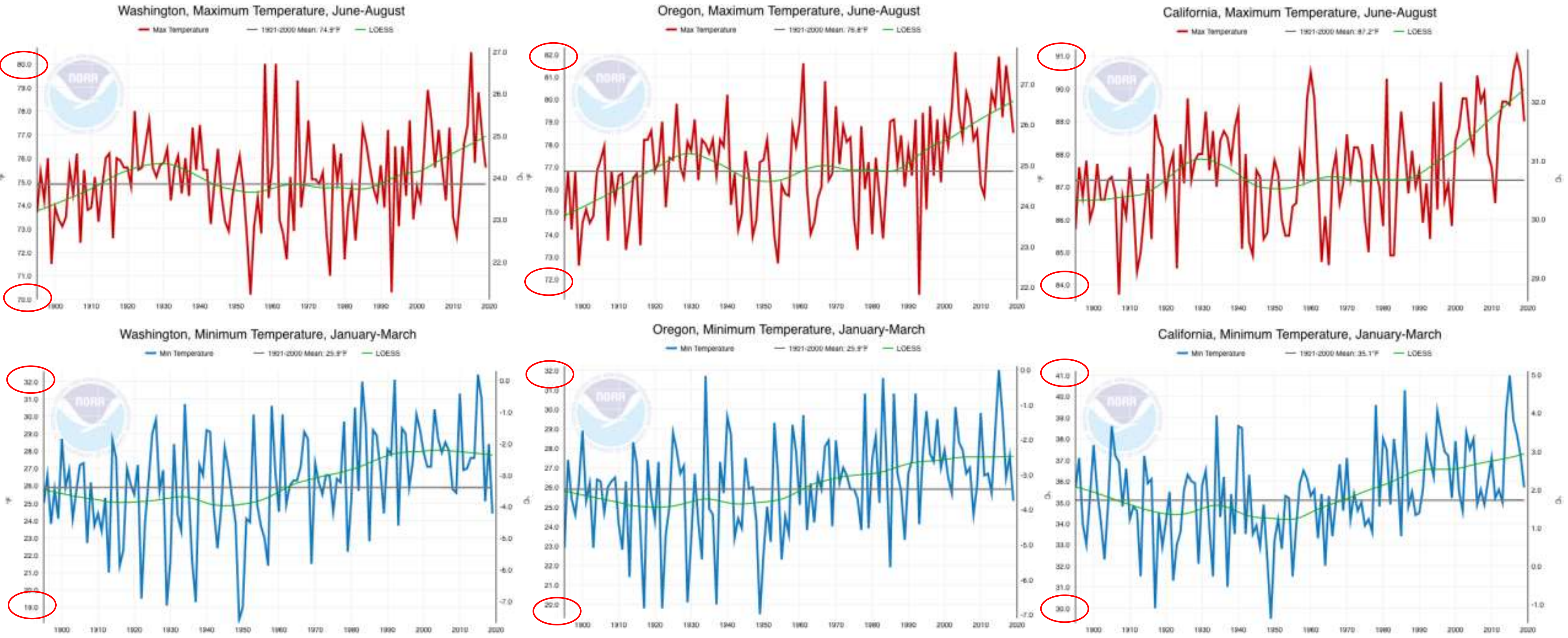
Observations: Warming has been accelerating



Warming trend
1895-2019: +0.10°C
1950-2019: +0.17°C
1980-2019 : +0.23°C

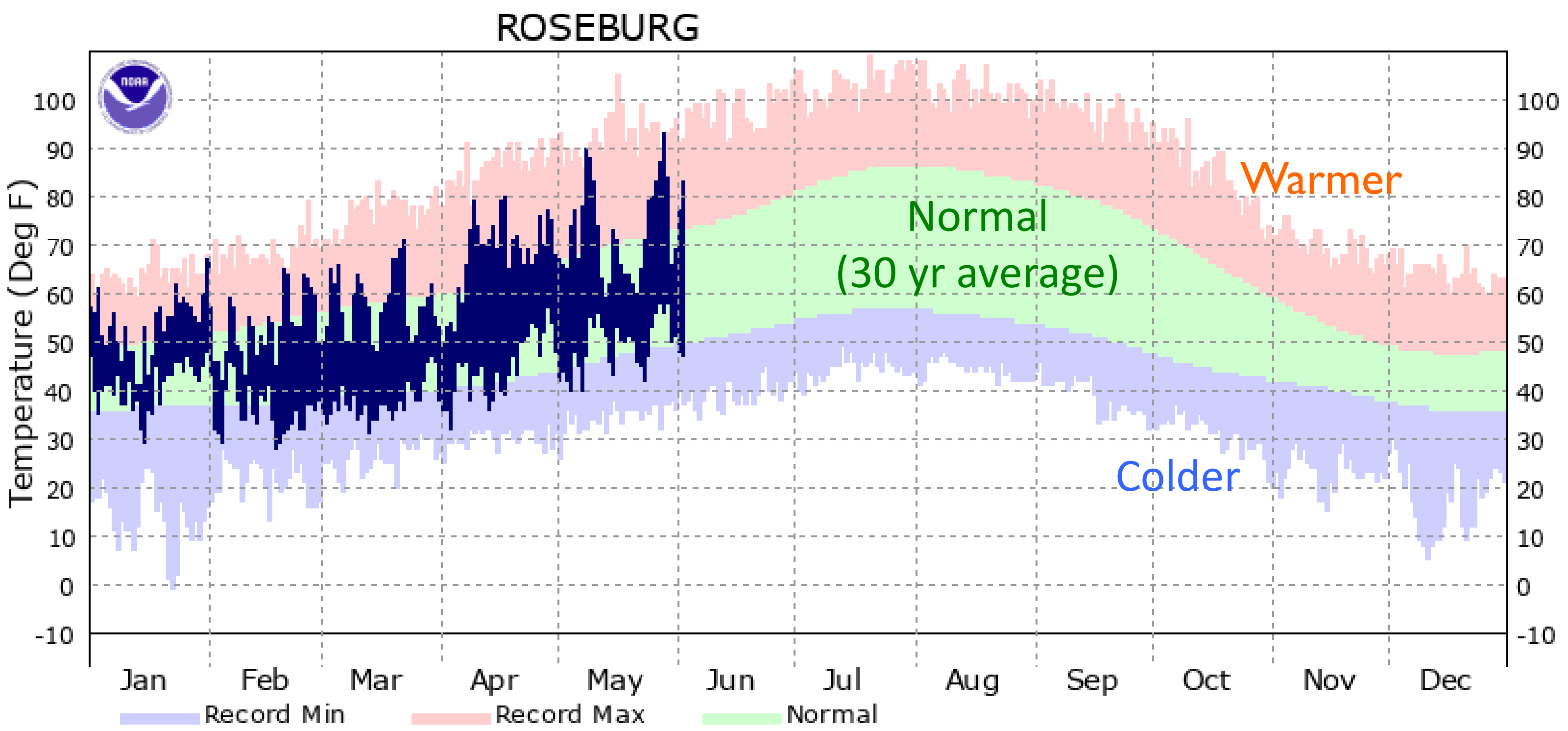
Data Source: National Center for Environmental Information, NOAA (https://www.ncdc.noaa.gov/cag/)

Same trend along entire West coast



https://www.ncdc.noaa.gov/cag/statewide/time-series/35/tmin/3/3/1895-2019?base_prd=true&begbaseyear=1901&endbaseyear=2000&filter=true&filterType=loess

ROSEBURG, Oregon
Observed daily temperatures (2020)

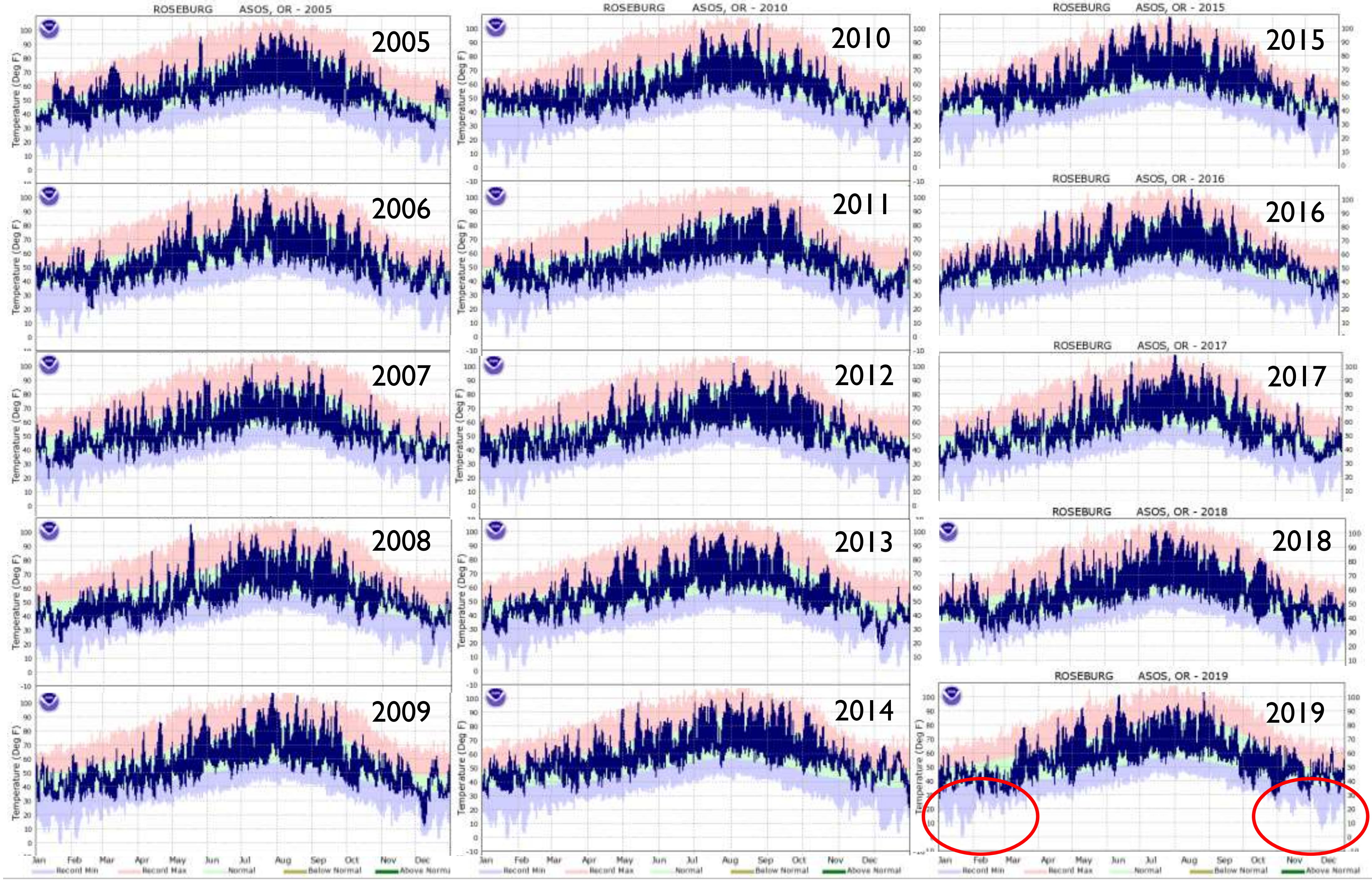


https://www.wrh.noaa.gov/climate/yeardisp.php?stn=KRBG&wfo=mfr&year=2020&span=Calendar+Year

Normal = 30 year average (1981-2010)

ROSEBURG, Oregon

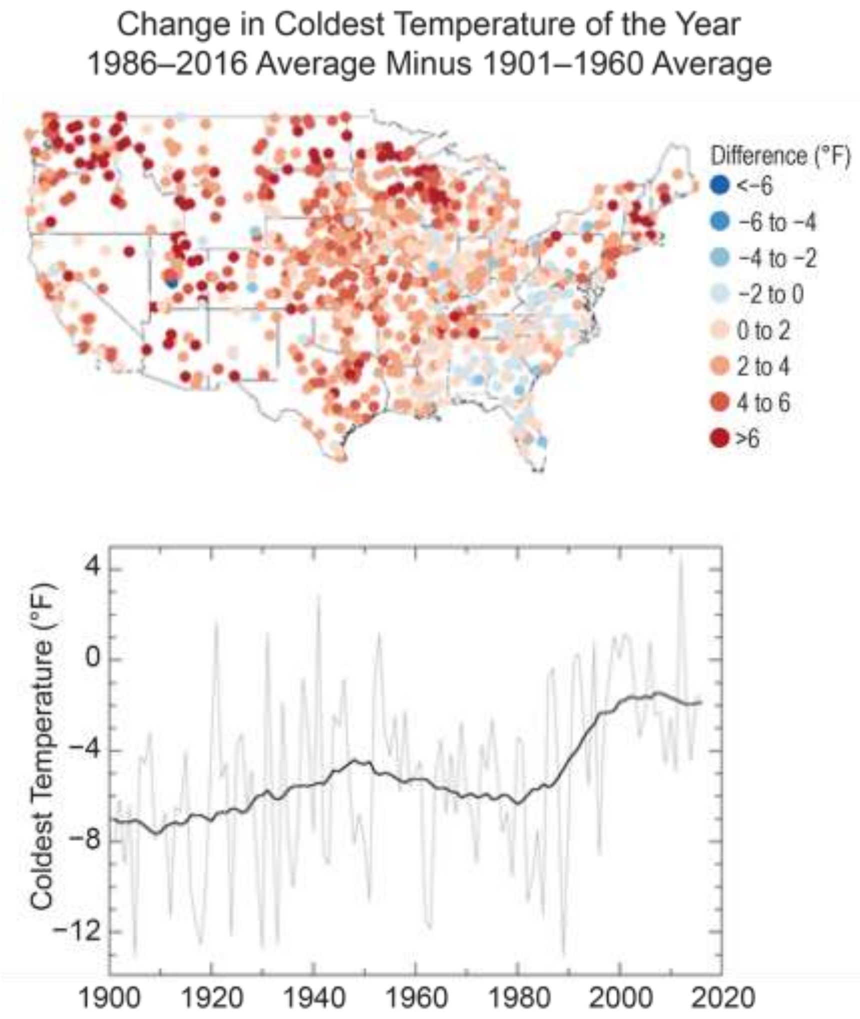
Observed daily temperatures



Record Min
Record Max
Normal

Seasonal Temperature change: Warmer Winters

e.g. Harrington and Gould 2015



Life cycle extended

Source: USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I,* Wuebbles, D.J. et al. (eds.) U.S. Global Change Research Program, Washington, DC, USA.

QUIZ

When was the last year with below average <u>global</u> temperatures?

1960, 1976, 1997 or 2003

Answer to QUIZ

1976

was the last year the planet had below-average temperatures in more than 130 years of recordkeeping. The global average temperature that year was 0.1°F below the long-term average.

Heat Waves

Antarctica logs hottest temperature on record with a reading of 18.3C

A new record set so soon after the previous record of 17.5C in March 2015 is a sign warming in Antarctica is happening much faster than global average

The New York Times

It's a Disgrace! Moscow's Warmest January in 100 Years

By Esther B. Fein, Special To the New York Times

Jan. 18, 1989

January 2020 was Earth's hottest January on record

The long-term trend of above-average temperatures continues

February 13, 2020 — In the span of 141 years of climate records, there has never been a warmer January than last month, according to scientists at NOAA's National Centers for Environmental Information.

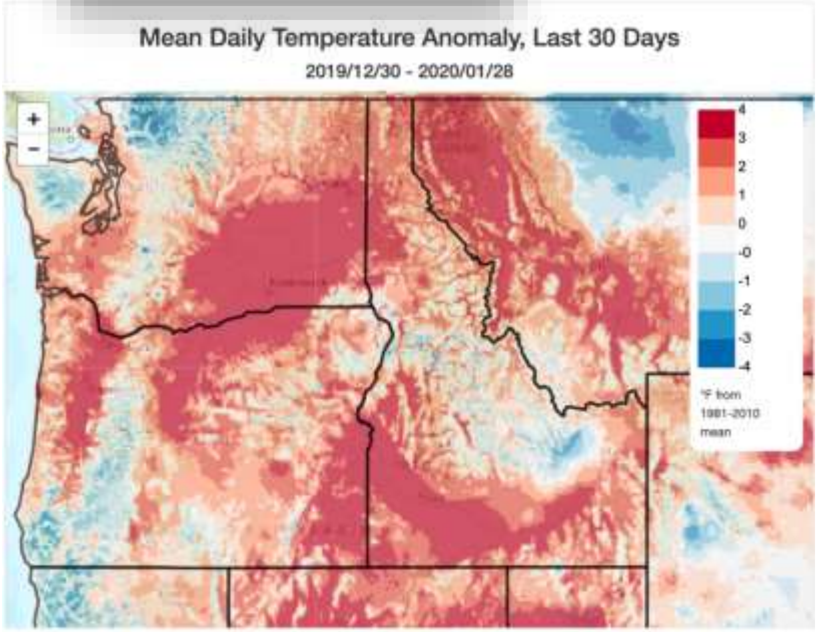
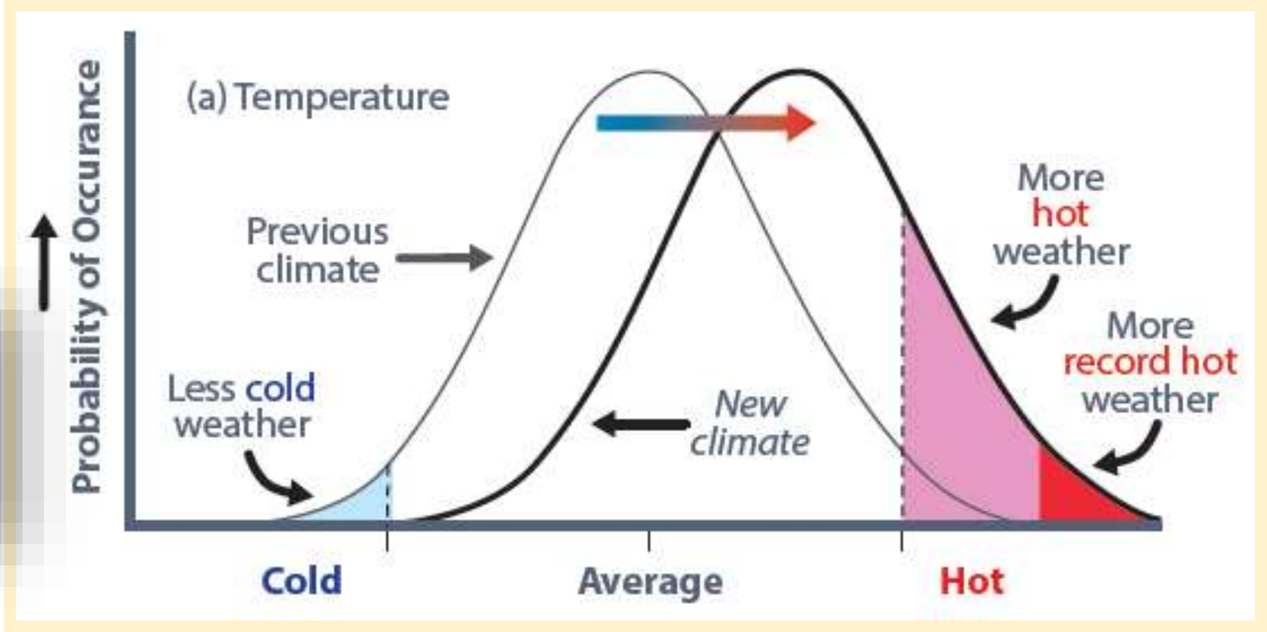
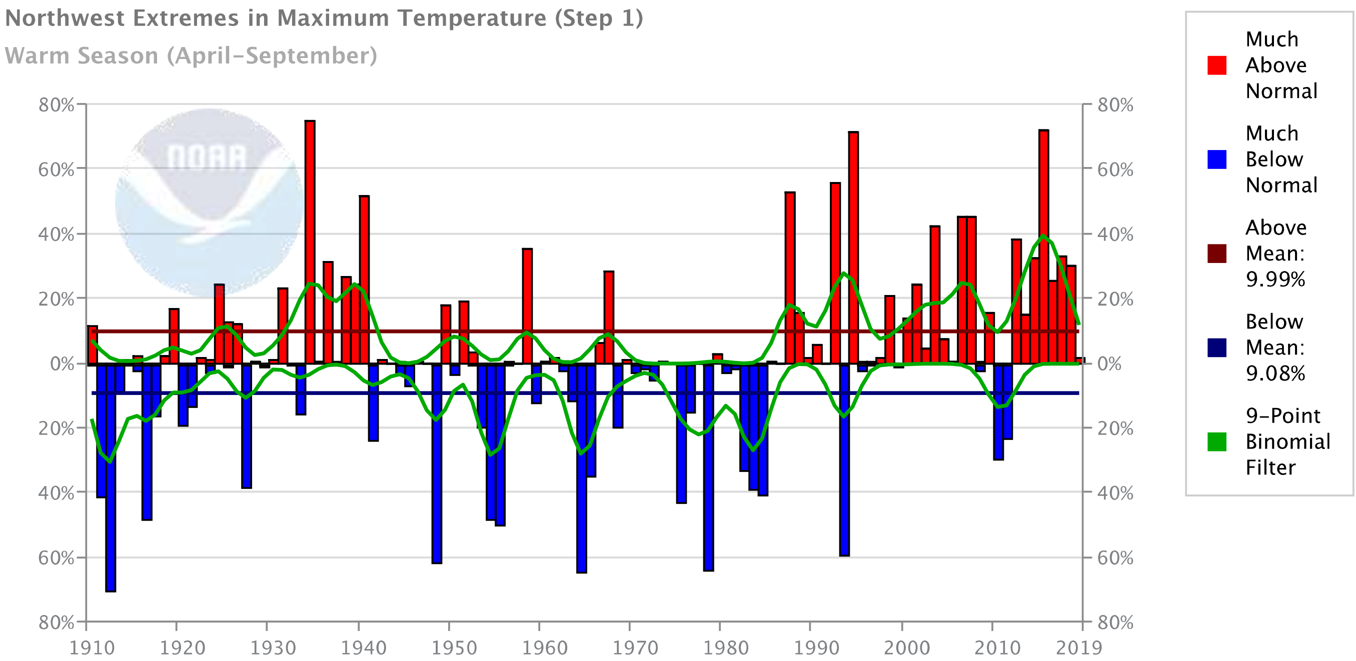


Figure 4: Daily mean temperature anomalies for the 30 day period between December 30, 2019 and January 28, 2020. (Image Credit: The Climate Mapper Tool—The Climate Toolbox.)





https://www.ncdc.noaa.gov/extremes/cei/graph/nw/04-09/1

Physiological mechanisms of drought-induced tree die-off in relation to carbon, hydraulic and respiratory stress in a drought-tolerant woody plant

Shin-Taro Saiki[1], Atsushi Ishida[1], Kenichi Yoshimura[2] & Kenichi Yazaki[3]

Sc. Reports 2017

nature climate change LETTERS
PUBLISHED ONLINE: 5 SEPTEMBER 2016 | DOI: 10.1038/NCLIMATE3114

The increasing importance of atmospheric demand for ecosystem water and carbon fluxes

Kimberly A. Novick[1*], Darren L. Ficklin[2], Paul C. Stoy[3], Christopher A. Williams[4], Gil Bohrer[5], A. Christopher Oishi[6], Shirley A. Papuga[7], Peter D. Blanken[8], Asko Noormets[9], Benjamin N. Sulman[10], Russell L. Scott[11], Lixin Wang[12] and Richard P. Phillips[13]

PNAS
CrossMark

Increased water deficit decreases Douglas fir growth throughout western US forests

Christina M. Restaino[a,1], David L. Peterson[b], and Jeremy Littell[c]

[a]Department of Environmental Science and Policy, University of California, Davis, CA 95616; [b]Pacific Northwest Research Station, US Forest Service, Seattle, WA 98103; and [c]Department of the Interior Alaska Climate Science Center, Anchorage, AK 99508

Edited by Monica G. Turner, University of Wisconsin-Madison, Madison, WI, and approved June 28, 2016 (received for review February 11, 2016)

Changes in tree growth rates can affect tree mortality and forest feedbacks to the global carbon cycle. As air temperature increases, evaporative demand also increases, increasing effective drought in forest ecosystems. Using a spatially comprehensive network of Douglas fir (*Pseudotsuga menziesii*) chronologies from 122 locations that represent distinct climate environments in the western United States, we show that increased temperature decreases growth via vapor pressure deficit (VPD) across all latitudes. Using an ensemble of global circulation models, we project an increase in both the mean VPD associated with the lowest growth extremes and the probability of exceeding these VPD values. As temperature continues to increase in future decades, we can expect deficit-related stress to increase and consequently Douglas fir growth to decrease throughout its US range.

gradients or close stomata. DEF and VPD are variables that integrate water and energy and are sensitive to temperature increases (13).

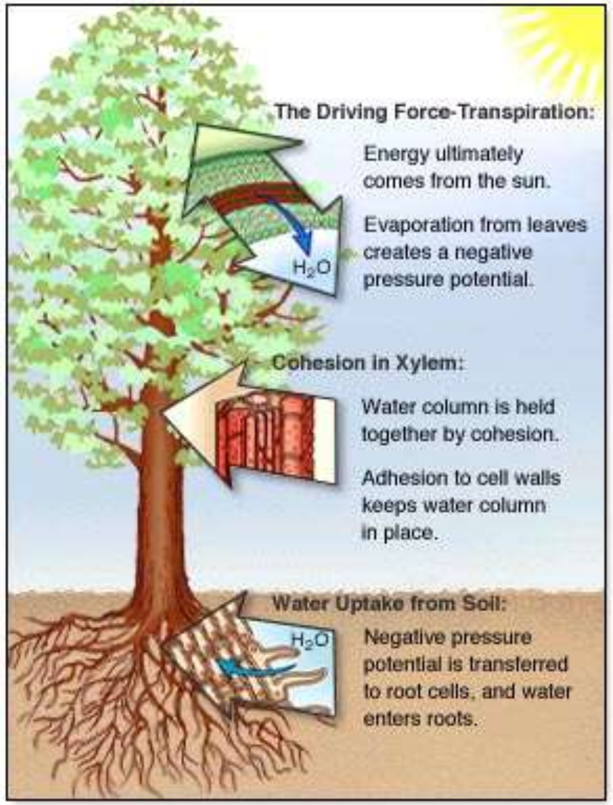
We quantified the relationship between climate and Douglas fir growth in forests throughout the western United States. Douglas fir, which occupies diverse landscapes from sea level to 3,300 m and a broad range of climate regimes (Fig. S1 and Table S1), is one of the most ecologically and economically important coniferous species in western US forests. Our network of 122 tree-ring-width chronologies represents tree growth in a breadth of growing environments and climates (Fig. 1 and Fig. S1). This work builds on previous efforts to assess climate-growth relationships at regional scales (9, 13, 16) but expands to the realized climatic niche of the species rather than using data from the

AUGUST 7, 2017

Drought-affected trees die from hydraulic failure and carbon starvation

by University of Sydney

Credit: Notnab82, Wikimedia Commons

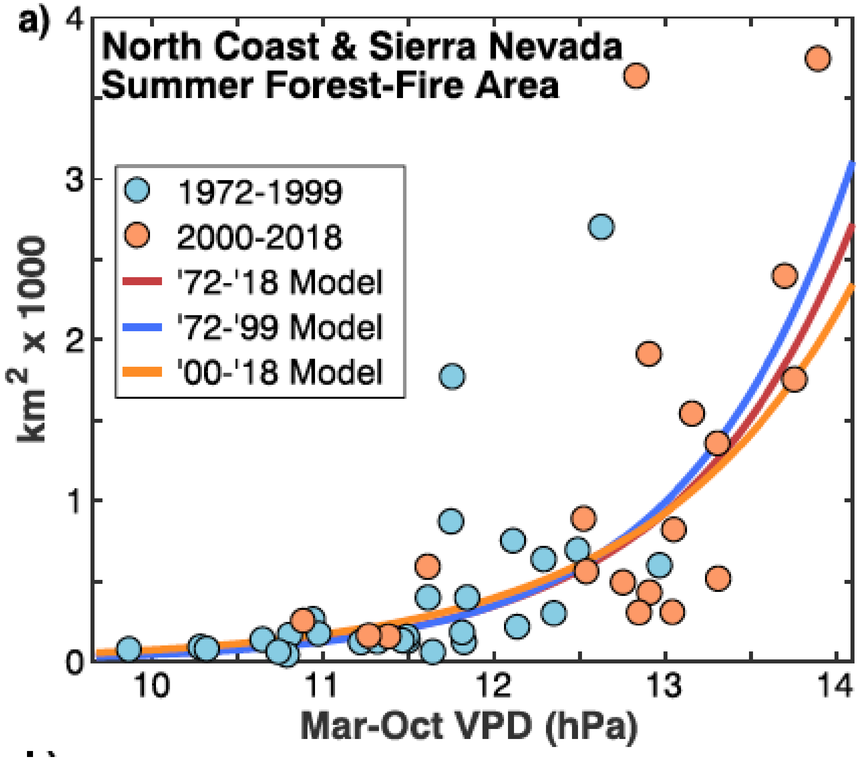


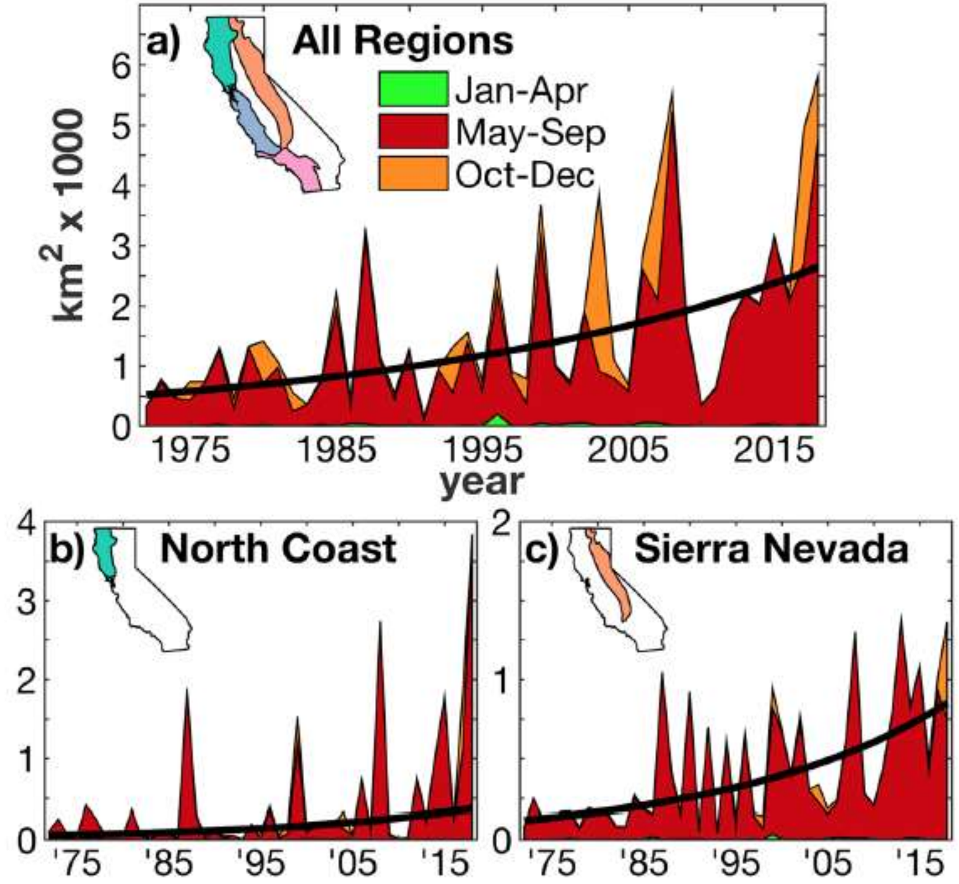
Heat Waves,
Vapor Pressure Deficit,
C starvation,
Embolism,
& Tall Tree Mortality

What does it mean for a forest manager?

- Extremely **dry air** drives stomatal closure to avoid **embolism** but it can cause **carbon starvation** and eventually mortality. This drought stress is **not due to competition for soil water** so **thinning will not help**.
- Moreover, in wet cool forests, **thinning can increase warm air circulation**, which increases **evaporative demand**, drying of understory and ladder fuels, while slash debris dry and act as kindling.

Response of CA forest-fire area to atmospheric aridity





Seasonal and annual burned areas in California 1972–2018

Earth's Future

RESEARCH ARTICLE

10.1029/2019EF001210

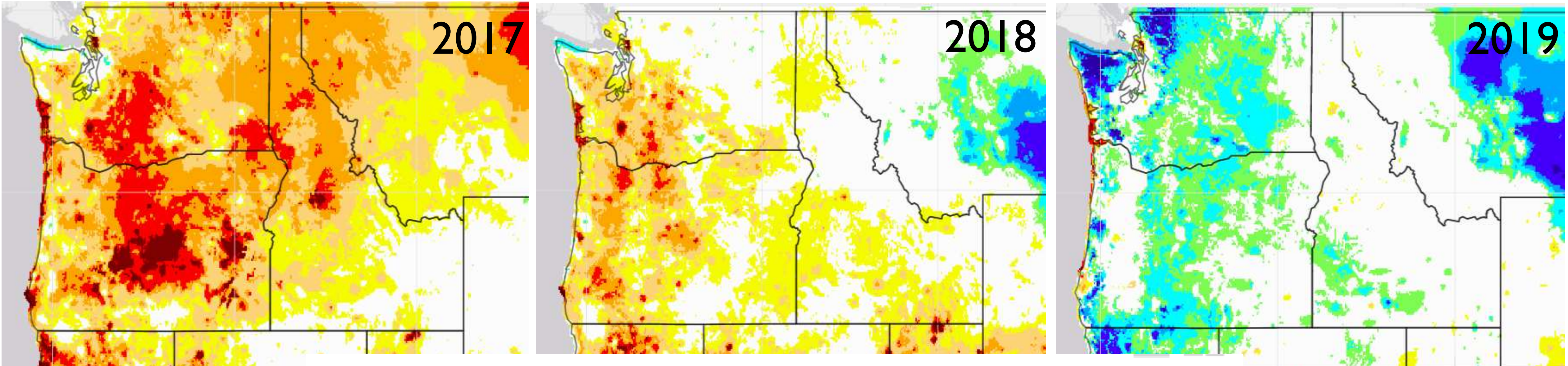
Observed Impacts of Anthropogenic Climate Change on Wildfire in California

A. Park Williams[1], John T. Abatzoglou[2], Alexander Gershunov[3], Janin Guzman-Morales[3], Daniel A. Bishop[1,4], Jennifer K. Balch[5], and Dennis P. Lettenmaier[6]

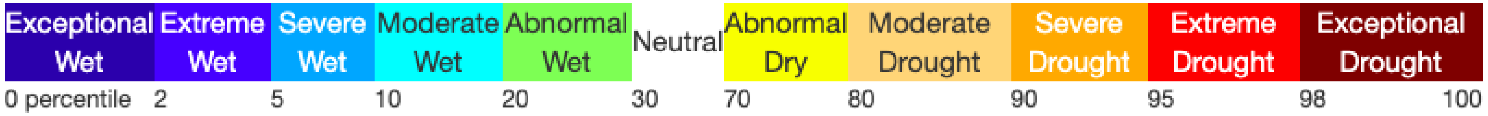
Key Points:

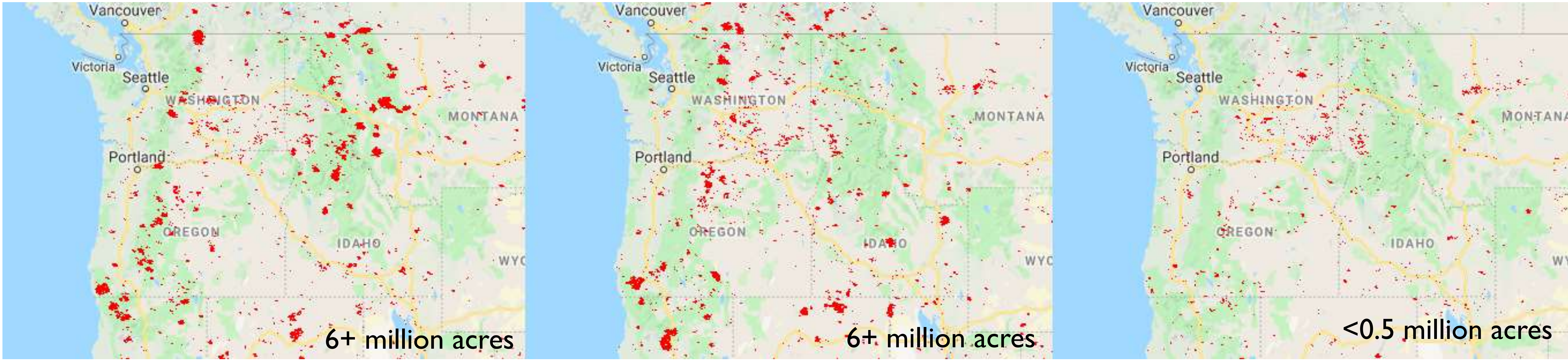
- Annual burned area in California increased fivefold during 1972–2018, mainly due to summer forest fire

Vapor Pressure Deficit (air dryness) during summer - June-August - and Wildfires



Source: J. Abatzoglou, U. Idaho

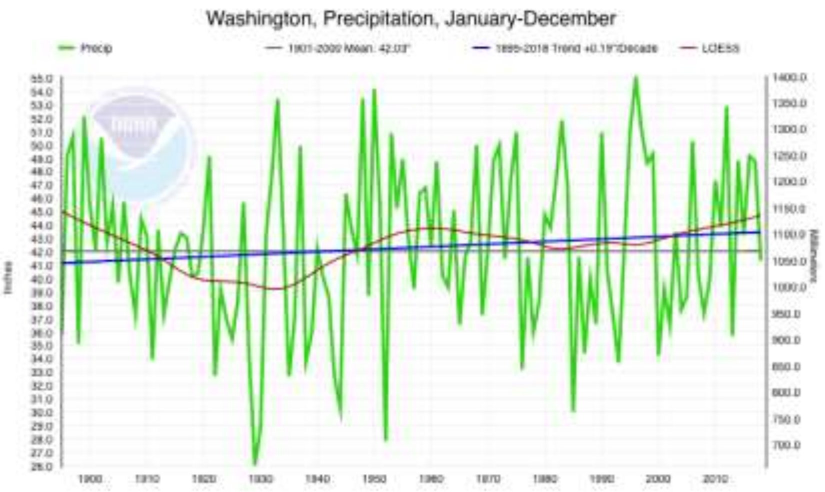


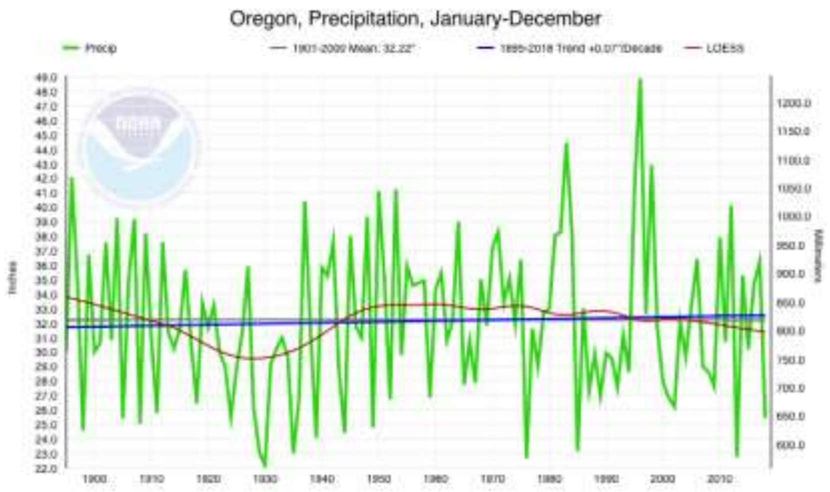


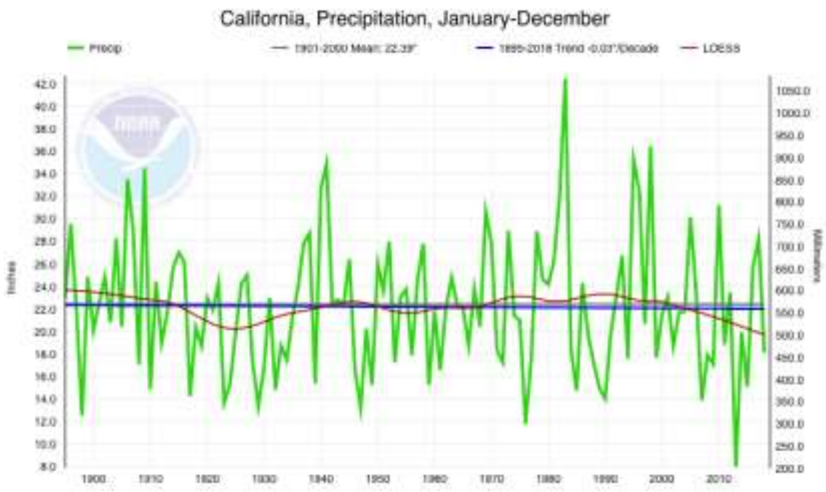
Source: FIRMS Active Fire Detection

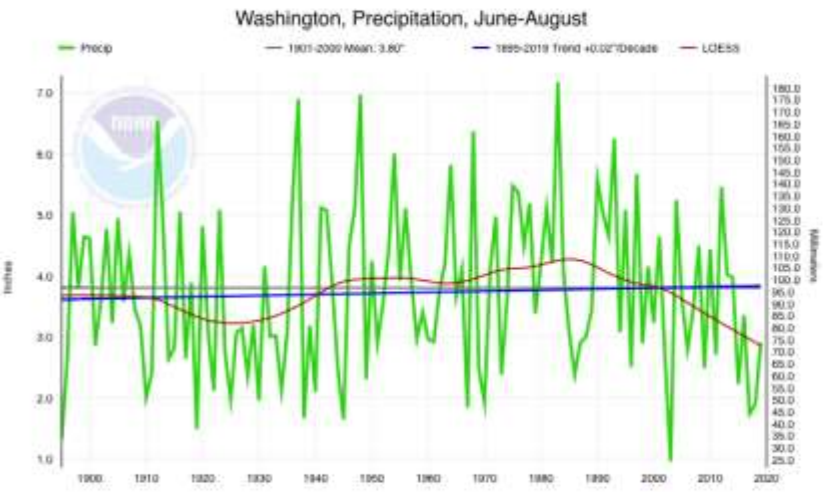
What about precipitation?

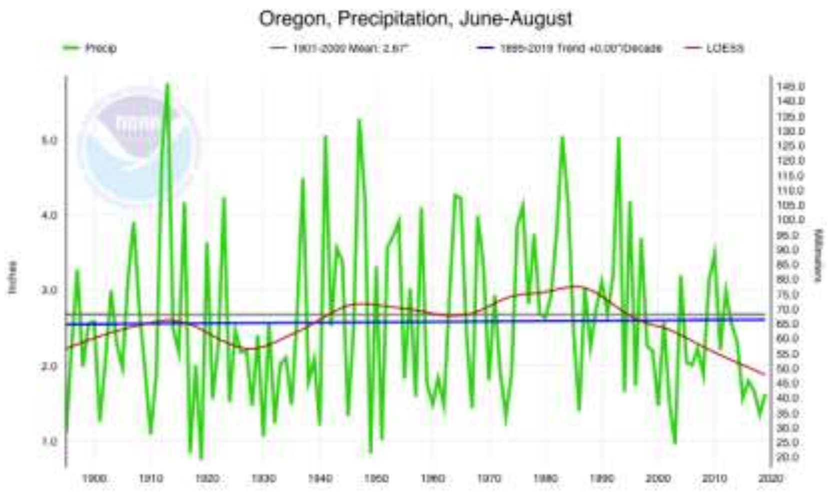
Precipitation – Much Variability and no Trend

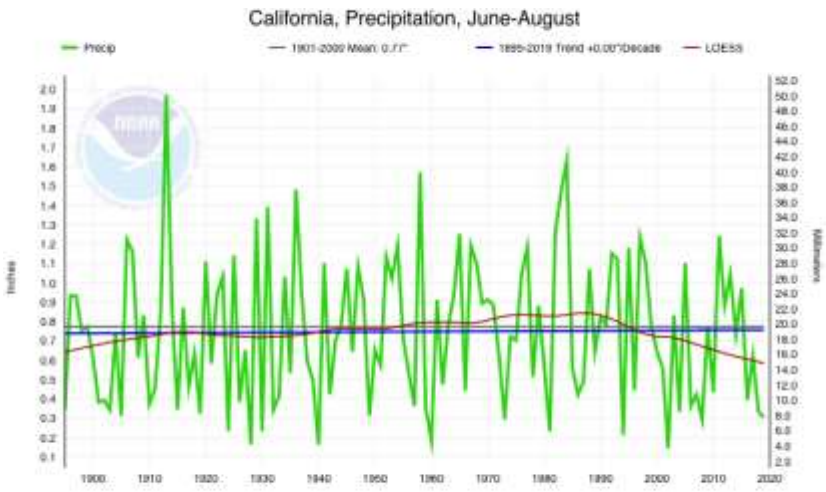






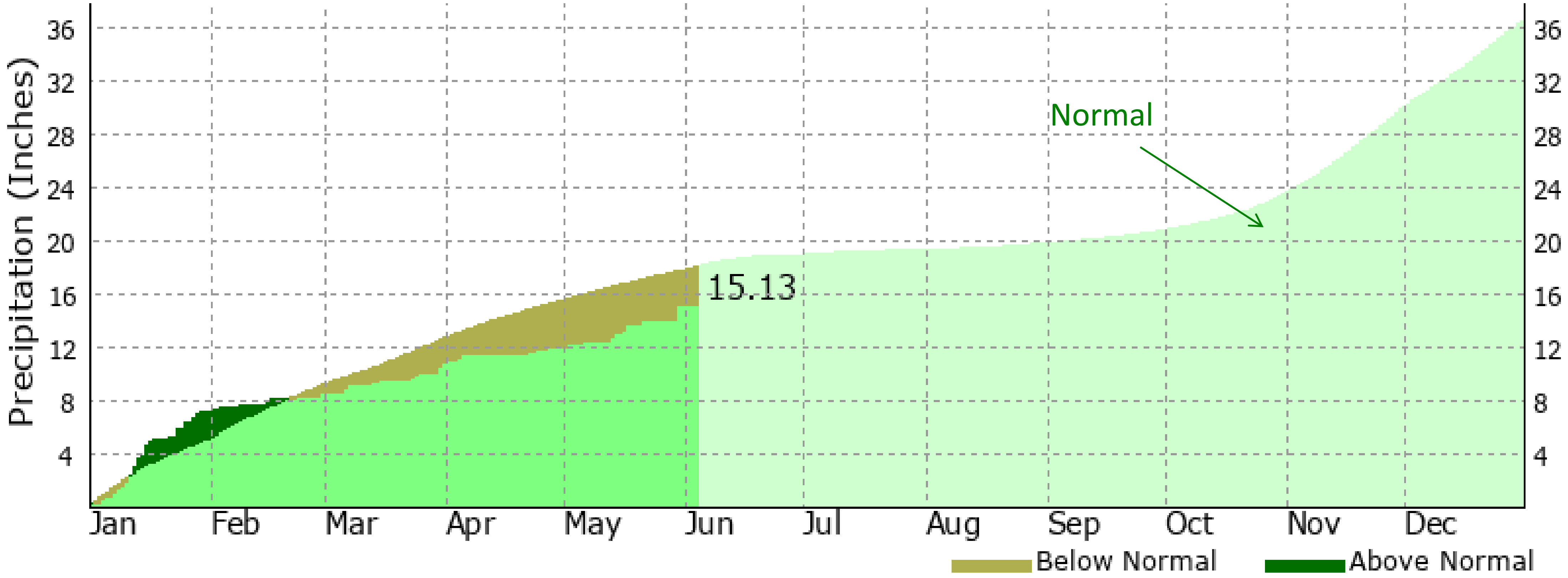






https://www.ncdc.noaa.gov/cag/statewide/time-series/4/pcp/3/8/1895-2019?base_prd=true&begbaseyear=1901&endbaseyear=2000&filter=true&filterType=loess

ROSEBURG, Oregon
Observed daily precipitation (2020)

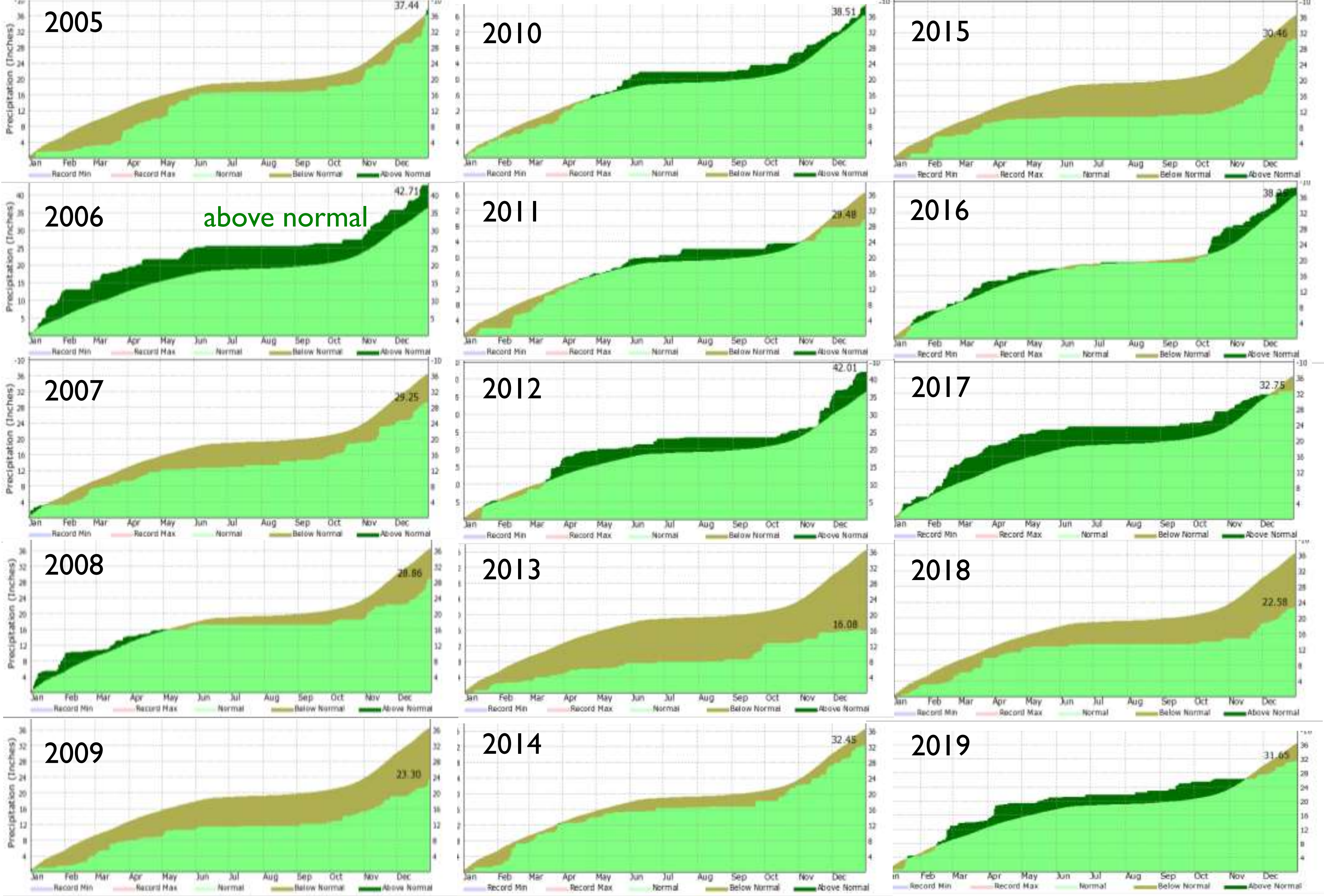


https://www.wrh.noaa.gov/climate/yeardisp.php?stn=KRBG&wfo=mfr&year=2020&span=Calendar+Year

Normal = 30 year average (1981-2010)

ROSEBURG, Oregon

Observed daily precipitation



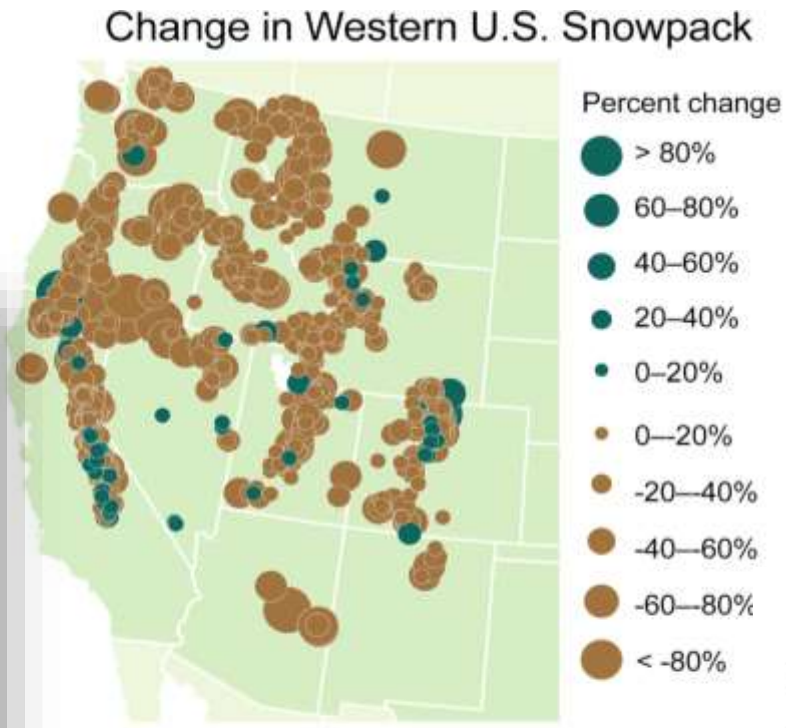
QUIZ

As average temperature rises, what happens to average precipitation?

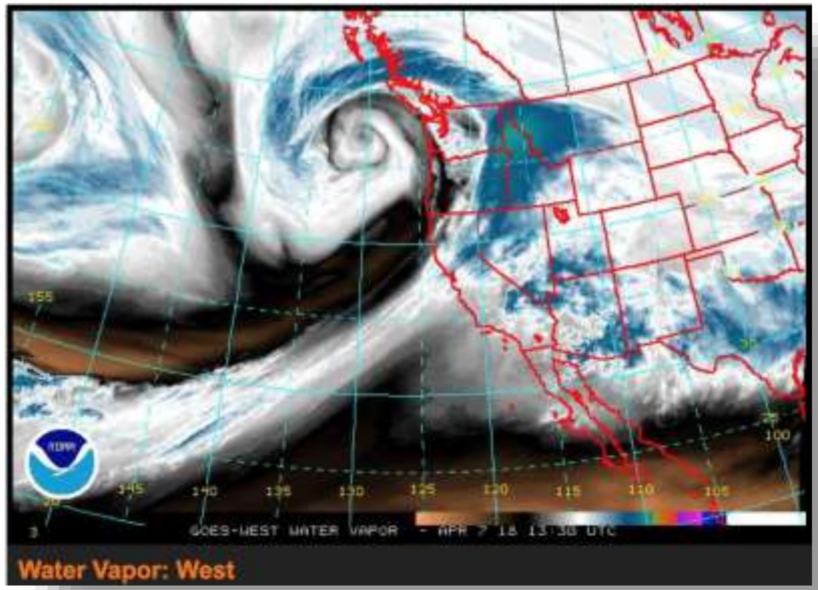
Answer to the QUIZ

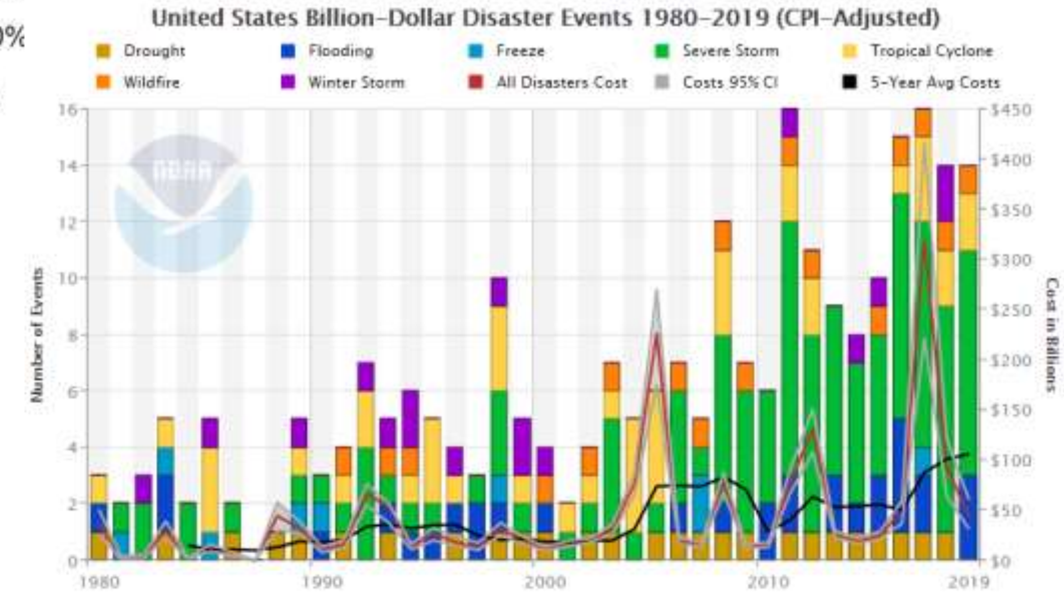
Higher temperatures give rise to a more active water cycle, which means faster and greater evaporation and precipitation and more extreme weather events.

Extremes: Floods

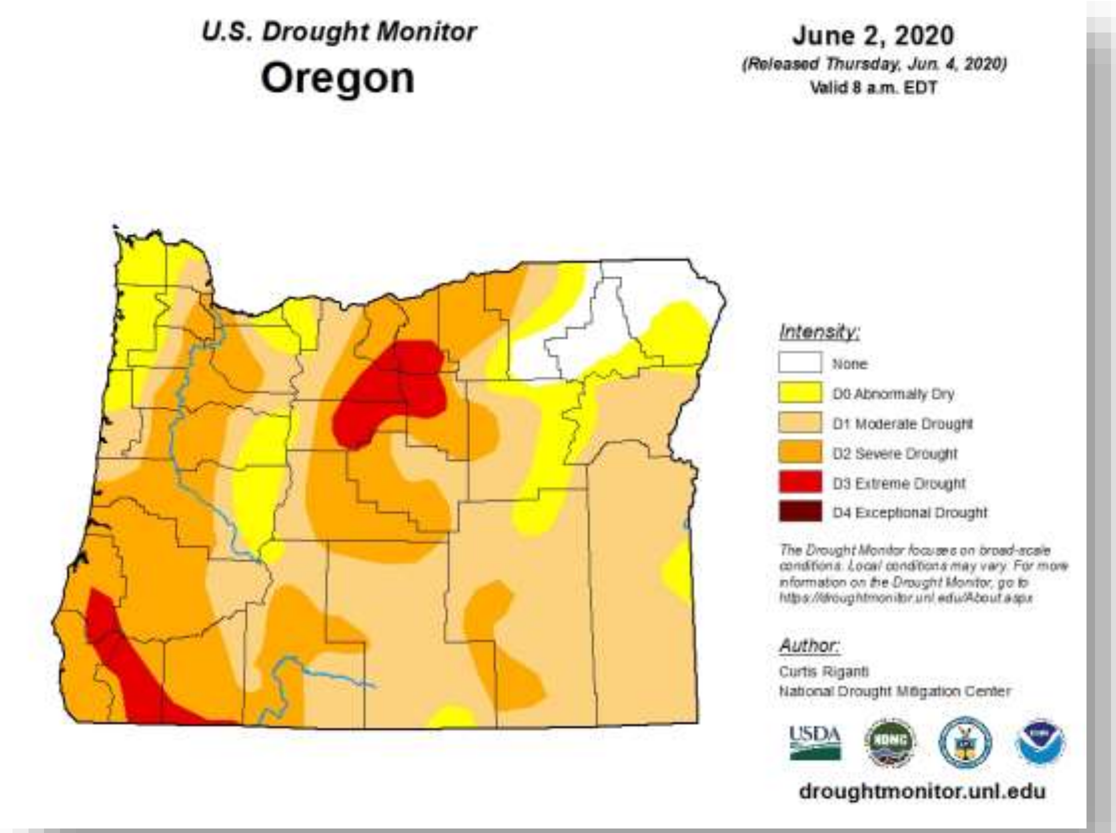


1955-2016

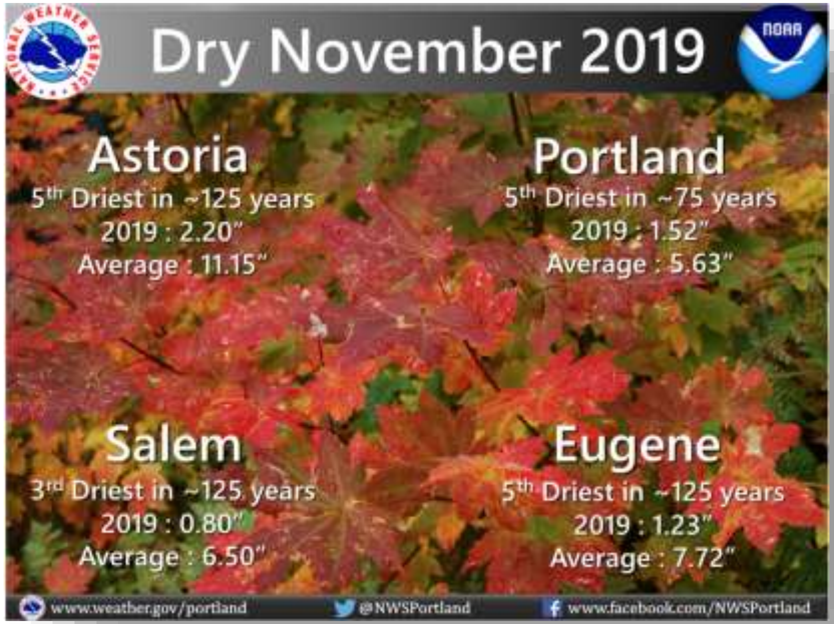




Extremes: Droughts



https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?OR




California

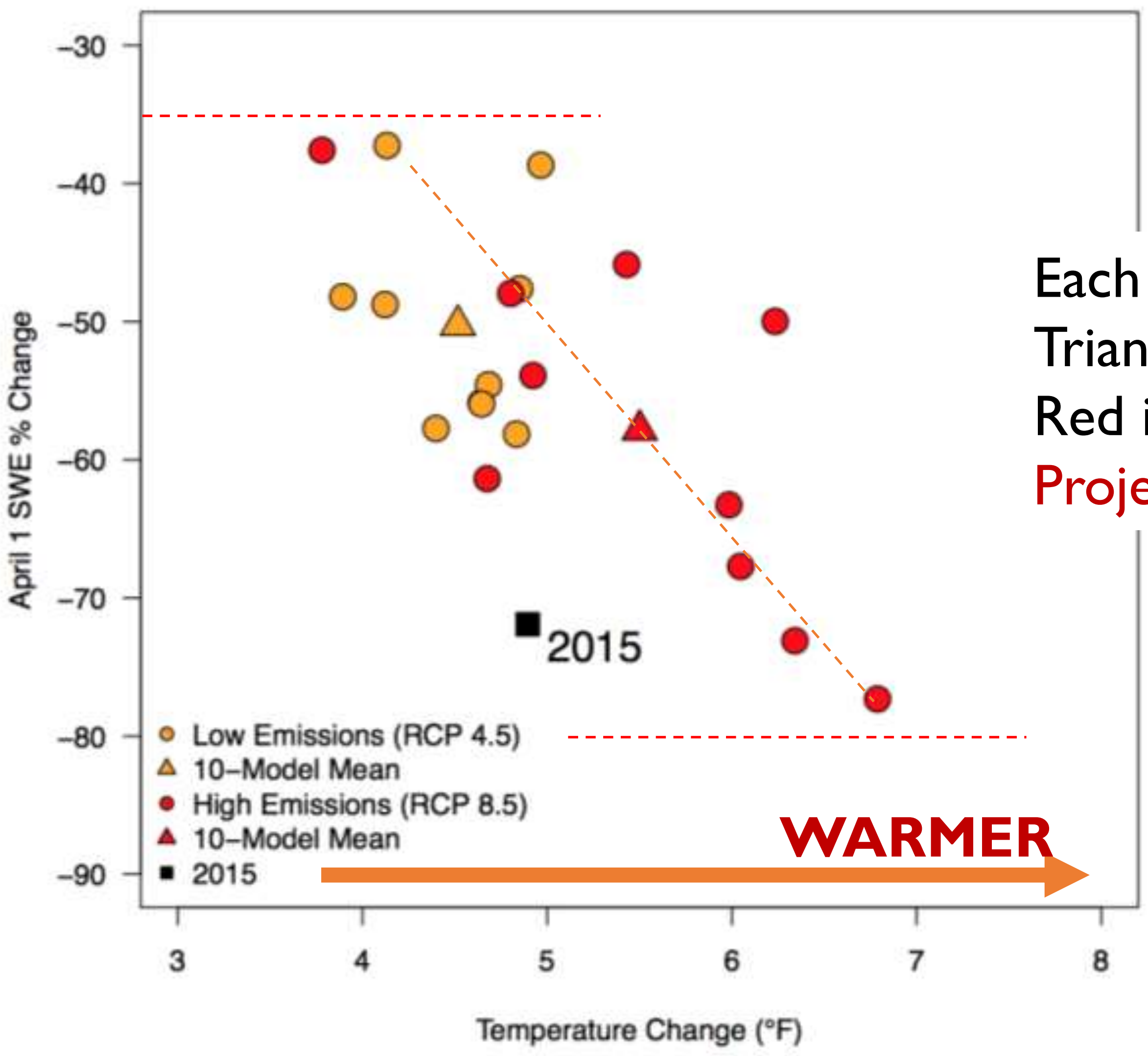
Dry February sends California back to drought: 'This hasn't happened in 150 years'

Susie Cagle

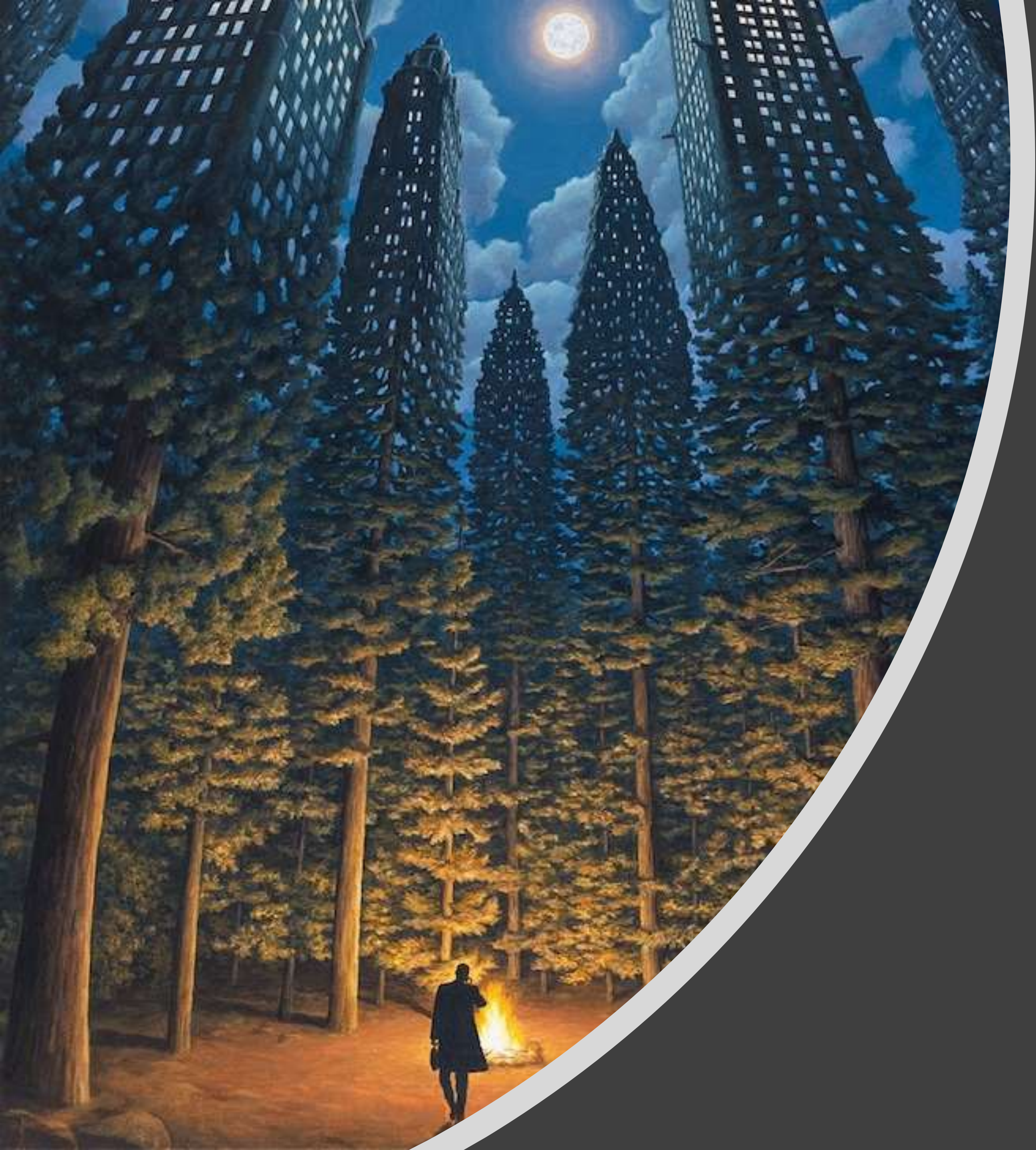
Projected change (2040-69 vs 1971-2000) in OR **winter mean temperature** and April 1 **Snow Water Equivalent** by 10 climate models compared to 2015 observations

Source: Dello et al. 2017, OCAR

LESS SNOW

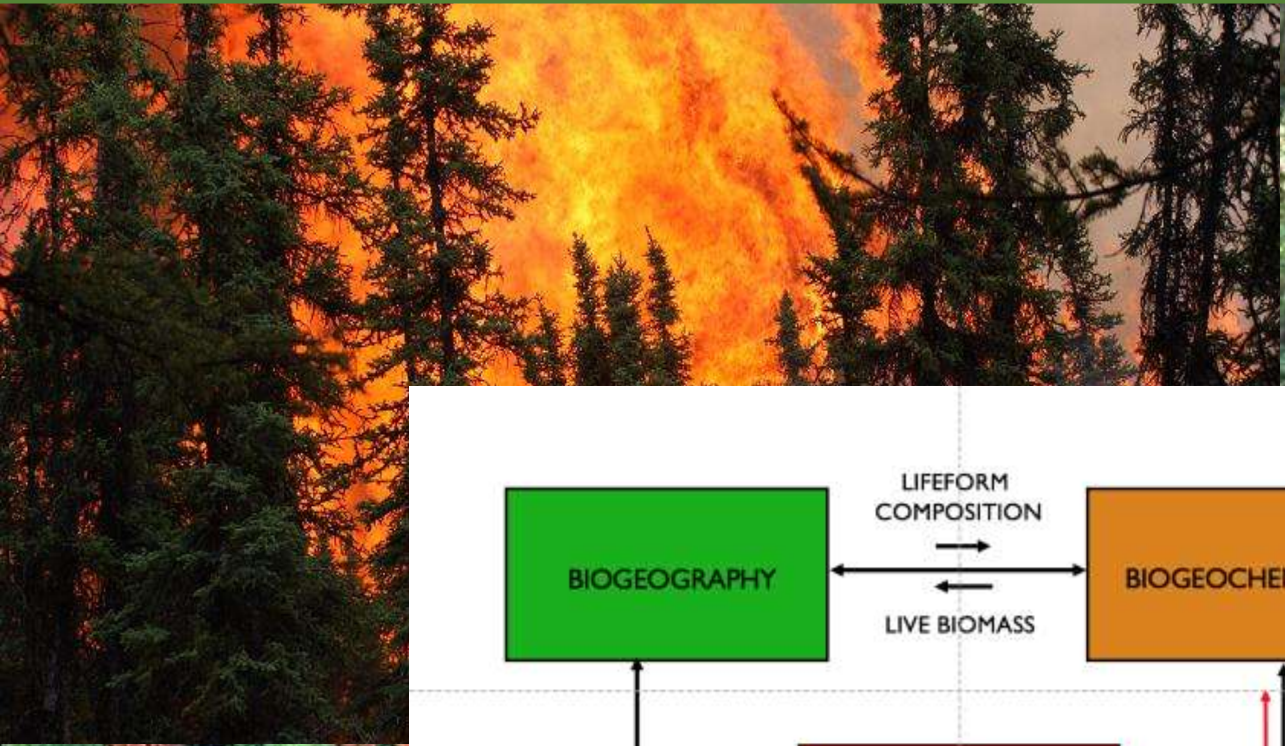


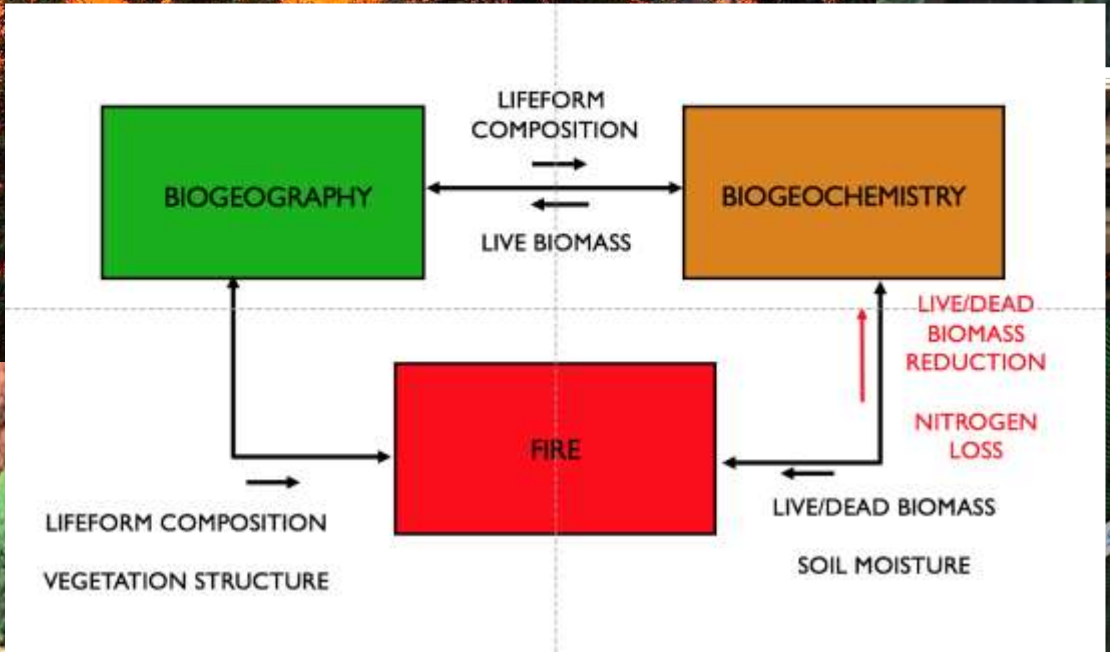
Each circle is a climate model (10)
Triangles are 10 models average
Red is business as usual
Projections are for mid century



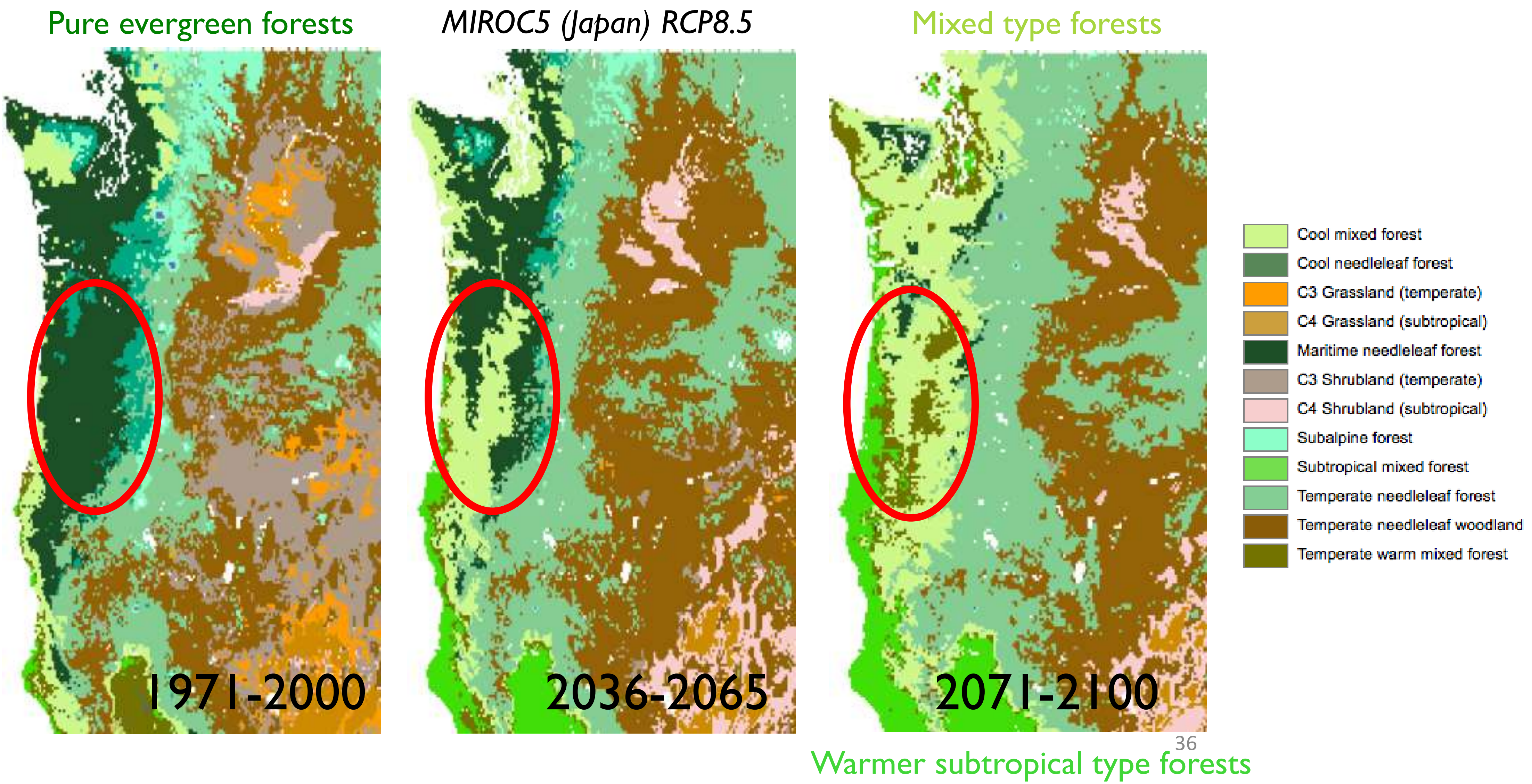
What might the future hold for the forest?

Modeling Climate Change Impacts





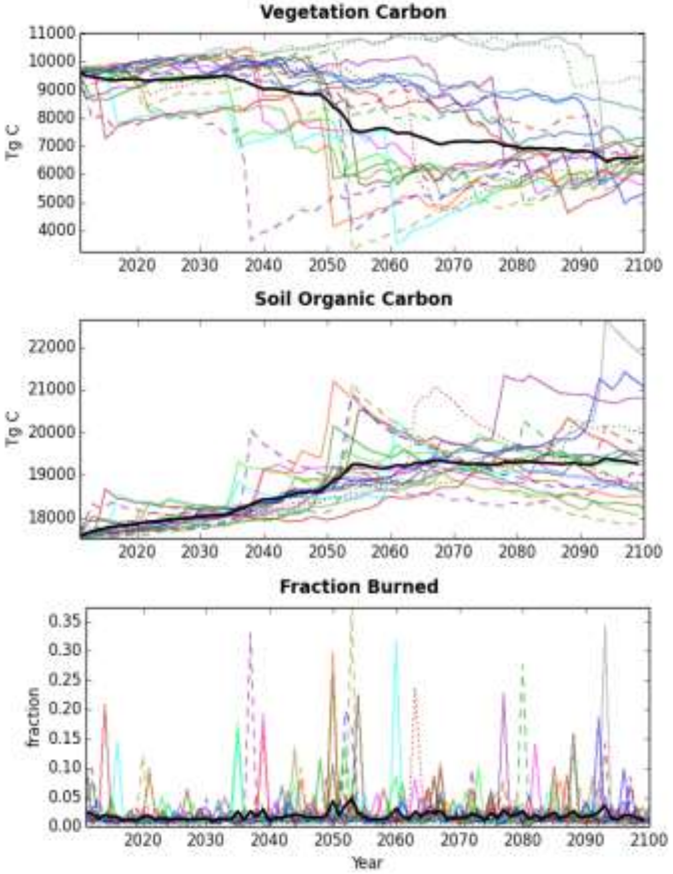
Simulating Vegetation Shifts by Mid-Century



Some changes mediated by fire

Simulation results - carbon implications

Cascades



National Geographic Photo - 2016

Sheehan et al. unpub.

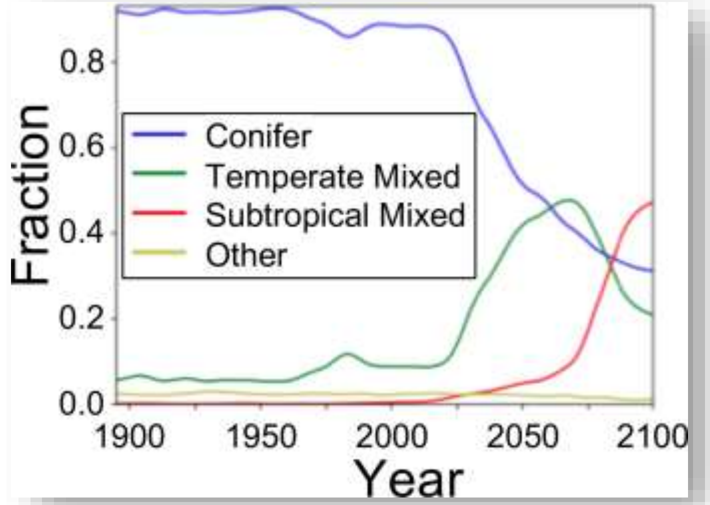
Some changes will just happen

Transition to new climatic conditions


PLOS | ONE

RESEARCH ARTICLE

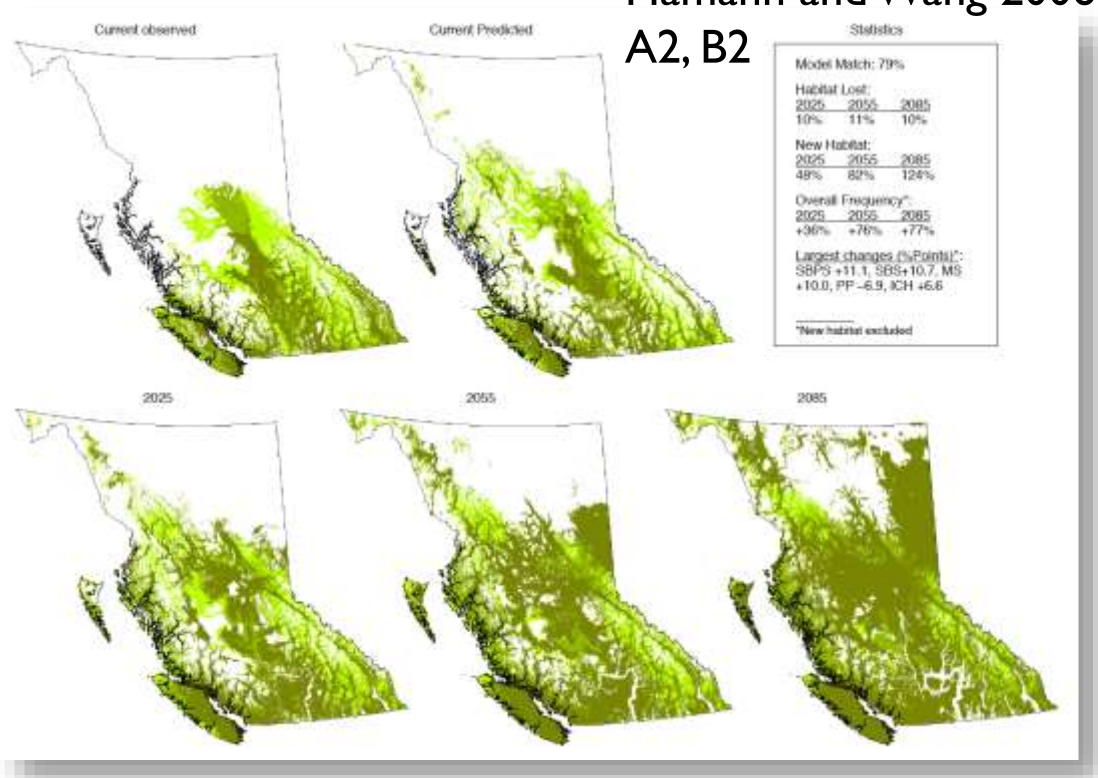
Fire, CO_2, and climate effects on modeled vegetation and carbon dynamics in western Oregon and Washington



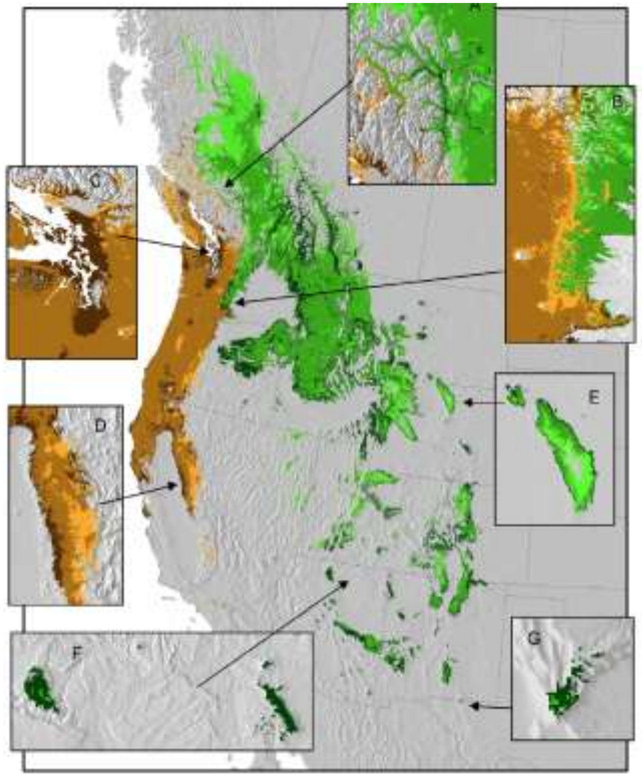
"**Vegetation is projected to change** from predominantly conifer to predominantly mixed conifer and hardwood forests, **regardless of CO_2 fertilization and fire effects**. With climate, not fire, driving vegetation change, much of the current vegetation can be expected to experience **mortality**. It is reasonable to anticipate that climate stress will make forests more susceptible to disease and pests"

Other approaches, similar results …

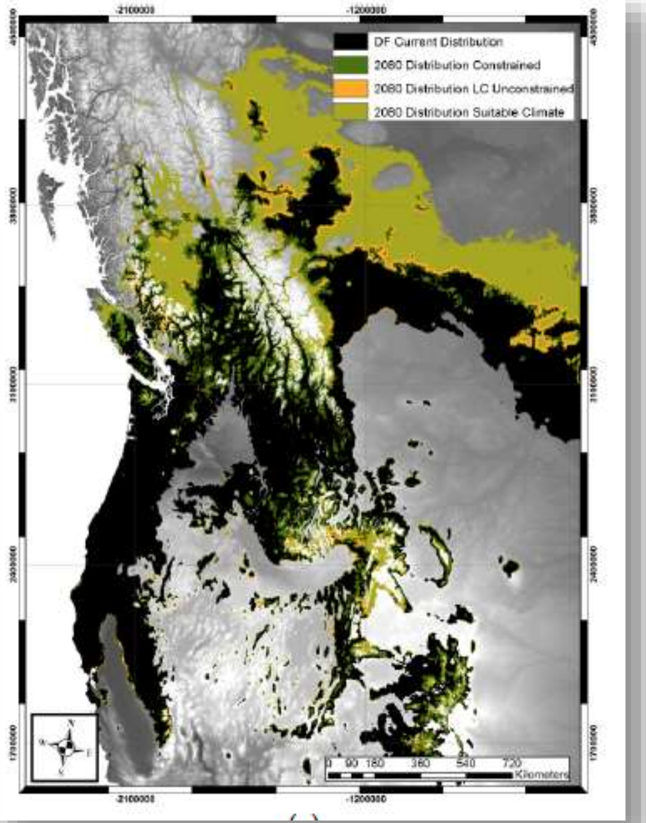
Hamann and Wang 2006
A2, B2



Douglas-fir will be less productive in the Pacific Northwest but will do well in Canada



Rehfeld et al. 2014
RCP 6.0



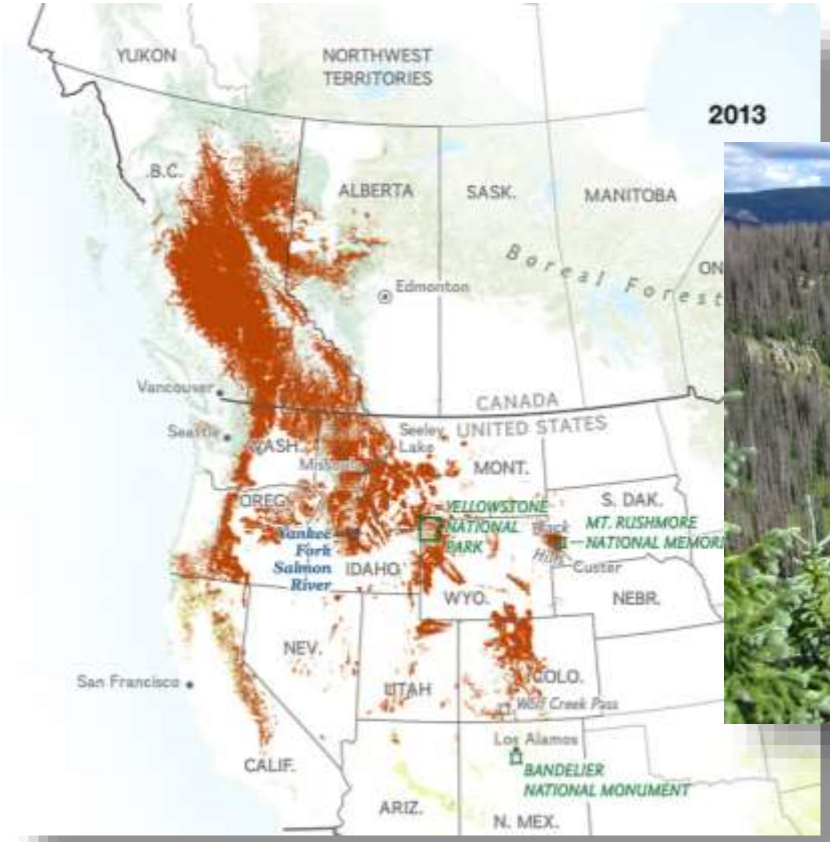
Coops, Waring et al. 2016
A2 scenario

Reality Check
Trees do not pick up their roots and move

Parke Harrison

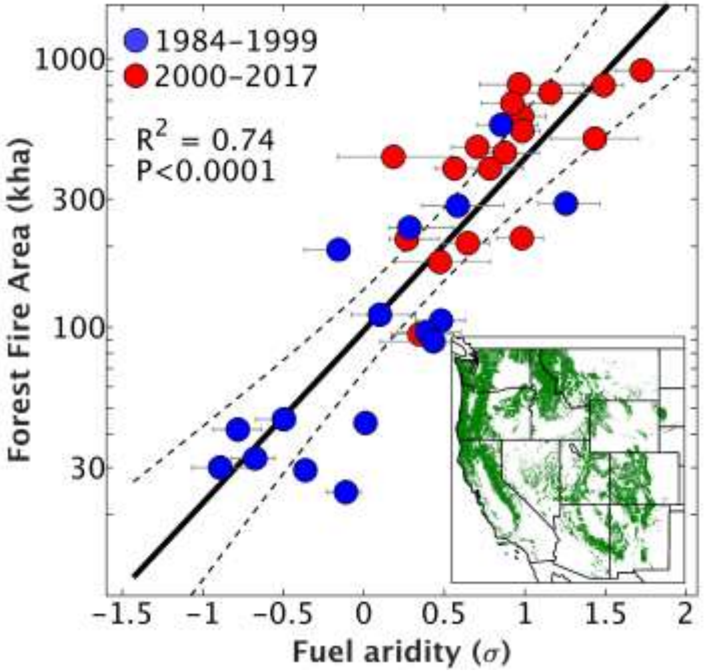
Signal for mal-adaptation to changing climate

Potential for abrupt changes mediated by disturbance



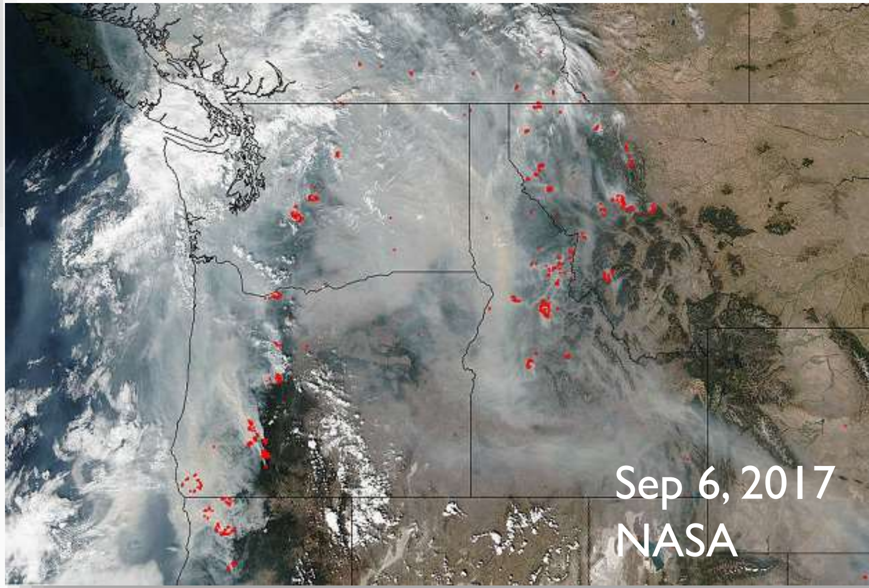
PEST OUTBREAK

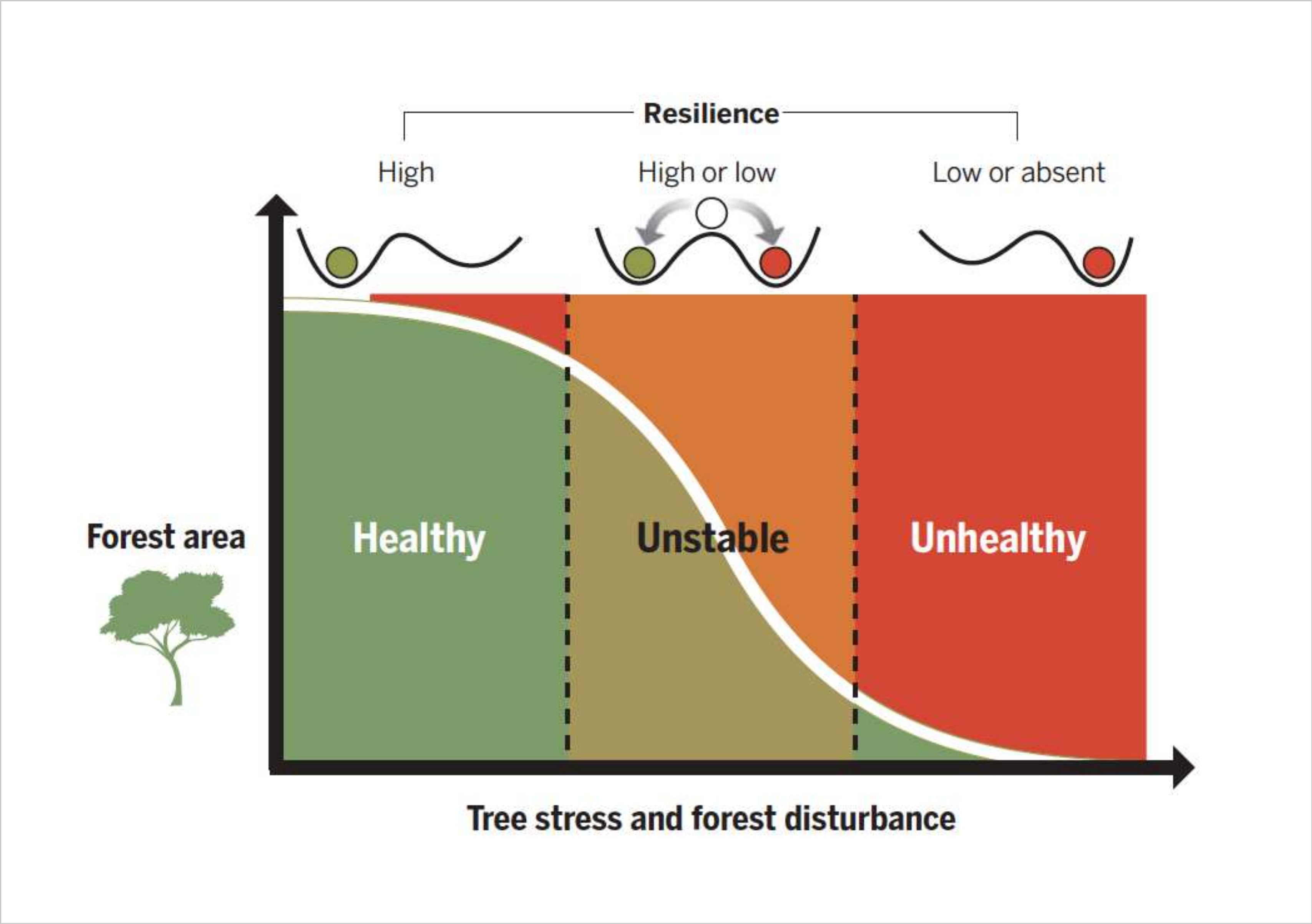
THE BEETLE AND ITS HOSTS
- Mountain pine beetle occurrence
- Lodgepole pine range
- Jack pine range
- Other pine species



Abatzoglou & Williams 2016

FIRE





Trumbore et al. 2015 Science

Maladaptation and Vulnerability

exposure, sensitivity and adaptive capacity

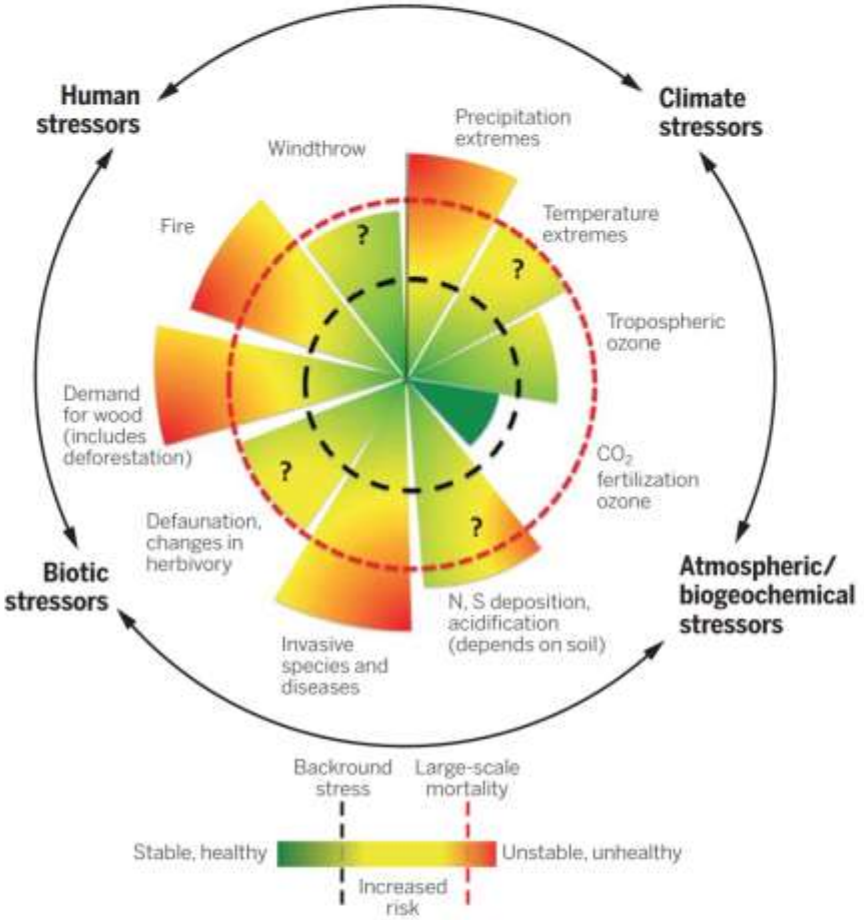


Fig. 4. Examples of different stresses and disturbances affecting forests and how they are expected to change in the future, compared with preindustrial background levels. We have adopted the ap-

Trumbore et al. 2015 Science

What does the future hold for forest?

Climate change is only one of the challenges

QUIZ

True of False: Deforestation is the 2nd leading cause of global warming.

Answer to QUIZ

True: Deforestation is the 2nd leading cause of global warming, responsible for ~24% of all greenhouse gas emissions

IN SUMMARY

- Climate models are complex, **earth system models** that link atmosphere, ocean, vegetation dynamics, disturbance and human activities are even more **complex**.
- Validation of climate and vegetation models is based on **20th century observations** but "*the future ain't what it used to be*".
- Model projections have been **conservative** – rate of warming is increasing; weather records are broken; physiological thresholds are exceeded.
- Vegetation models simulate **transitions before adaptation**. We are living it.
- Disturbances (pest outbreaks, diseases, wildfire) are hastening shifts in vegetation cover – **step changes**, not linear. **Monitoring** is critical.
- **Human actions** are hastening transitions (landscape fragmentation, introduction of invasives/plants & diseases, fuel build-up, fire ignition timing and location)

Thank you for your attention

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