The Climate of Southwest WA State

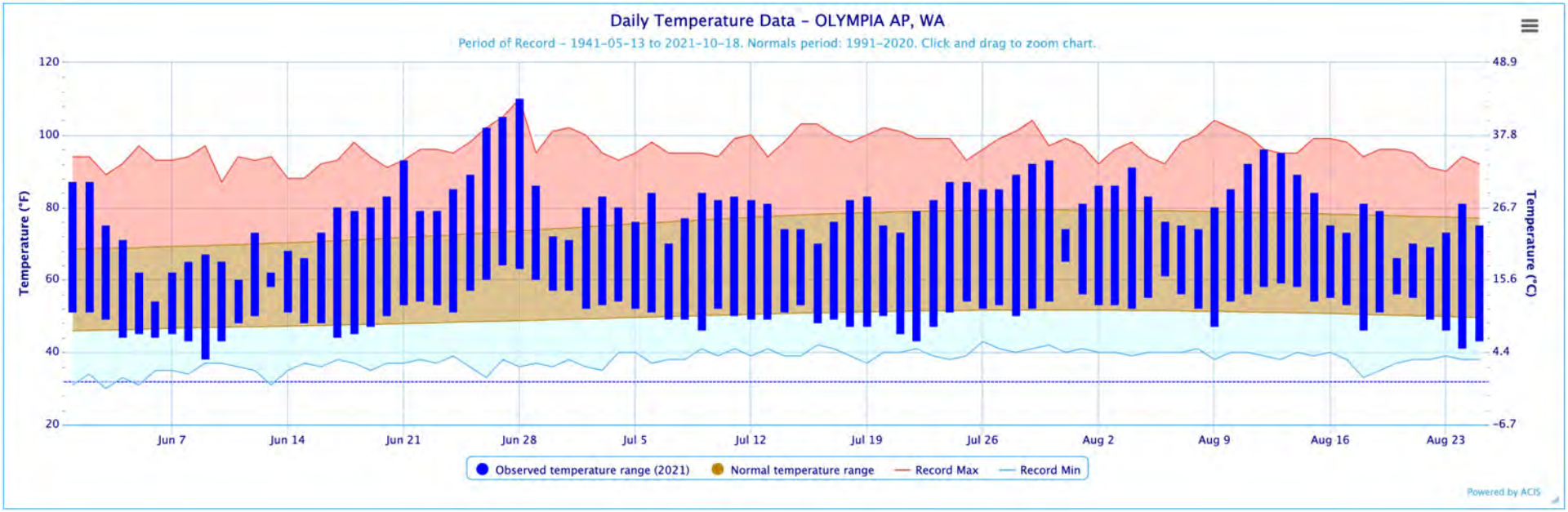
Nick Bond & Karin Bumbaco

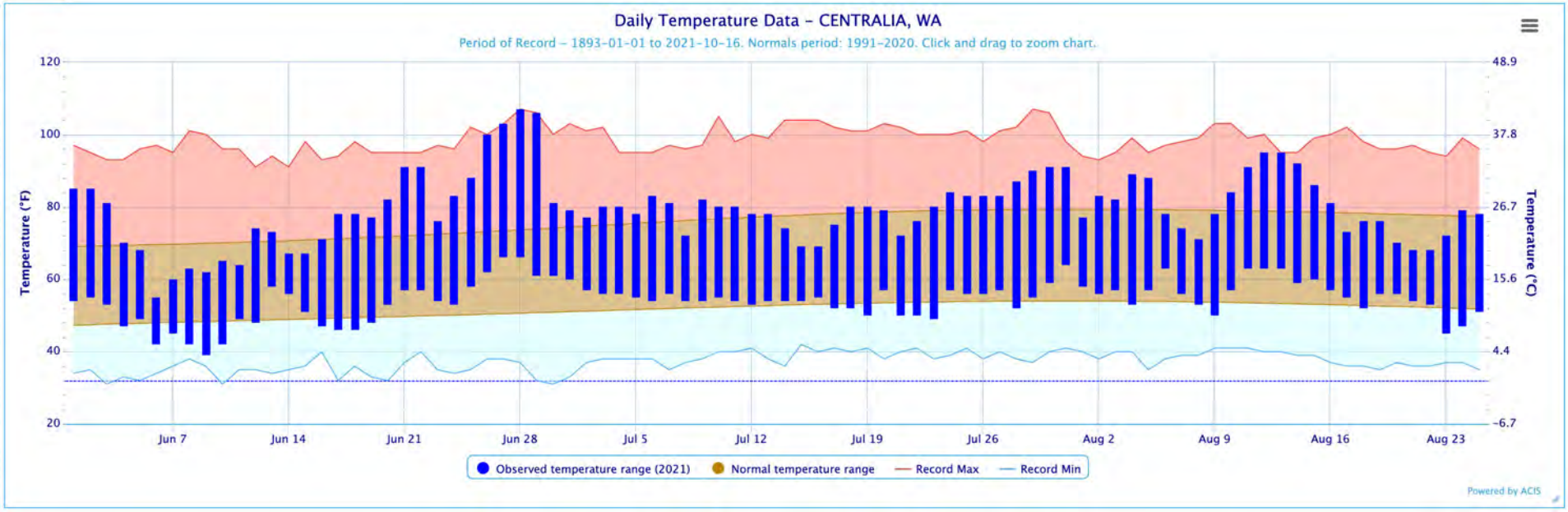
Historical Context & Future Projections

Implications for Summer Water Supplies

The Winter Ahead

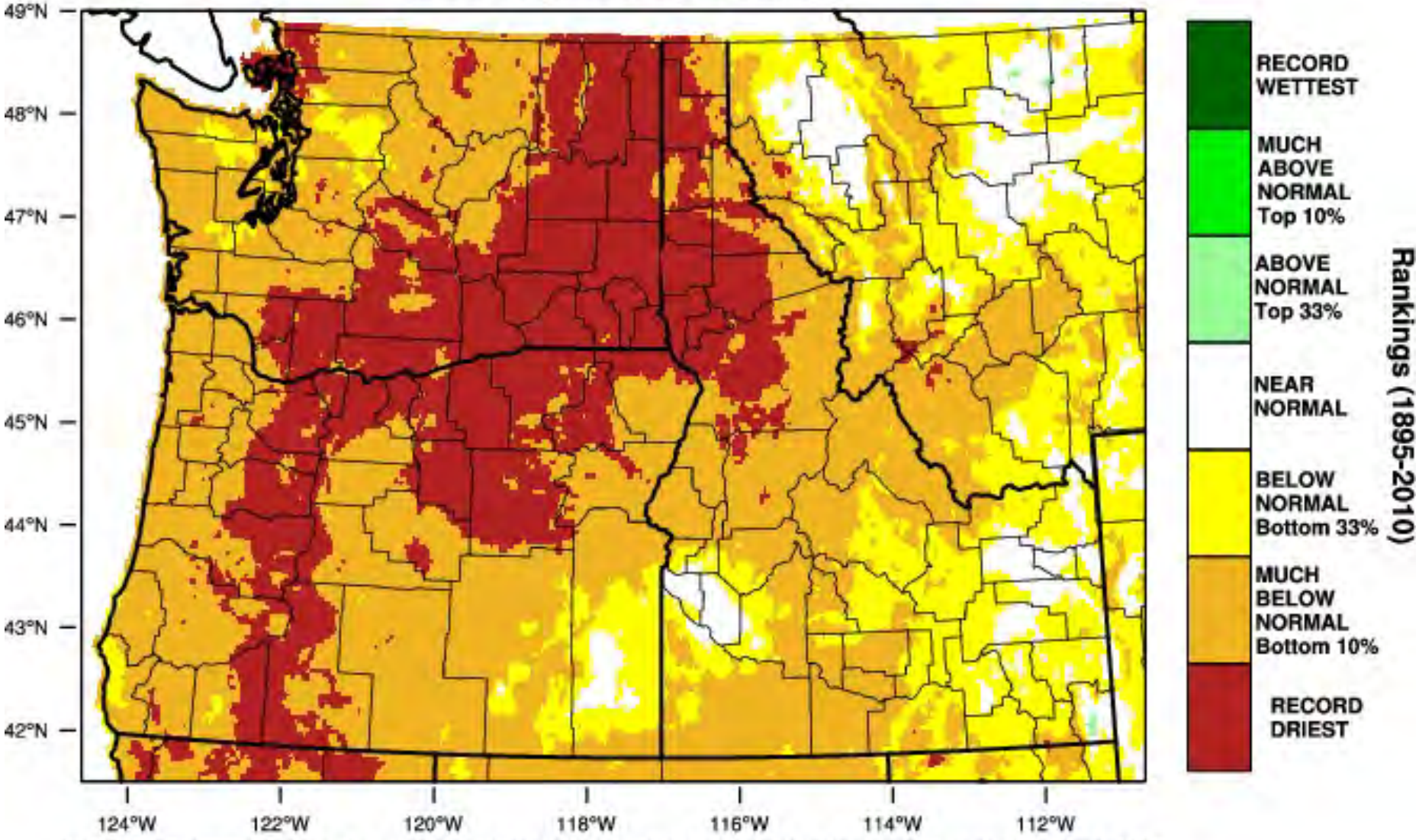

APPROUVE
APPROVED
Strange Passions!
Haunting Terror!
Guilty Love!
heat wave
starring
ALEX NICOL
HILLARY BROOKE
with SIDNEY JAMES • SUSAN STEPHEN • PAUL CARPENTER
Produced by Anthony Hinds • Directed by Ken Hughes
Screenplay by Ken Hughes • Based on his novel "High Wray"
A HAMMER PRODUCTION • A LIPPERT PICTURES PRESENTATION


Daily Temperature Data - OLYMPIA AP, WA
Period of Record - 1941-05-13 to 2021-10-18. Normals period: 1991-2020. Click and drag to zoom chart.
Temperature (°F)
Temperature (°C)
120
100
80
60
40
20
48.9
37.8
26.7
15.6
4.4
-6.7
Jun 7
Jun 14
Jun 21
Jun 28
Jul 5
Jul 12
Jul 19
Jul 26
Aug 2
Aug 9
Aug 16
Aug 23
Observed temperature range (2021)
Normal temperature range
Record Max
Record Min
Powered by ACIS

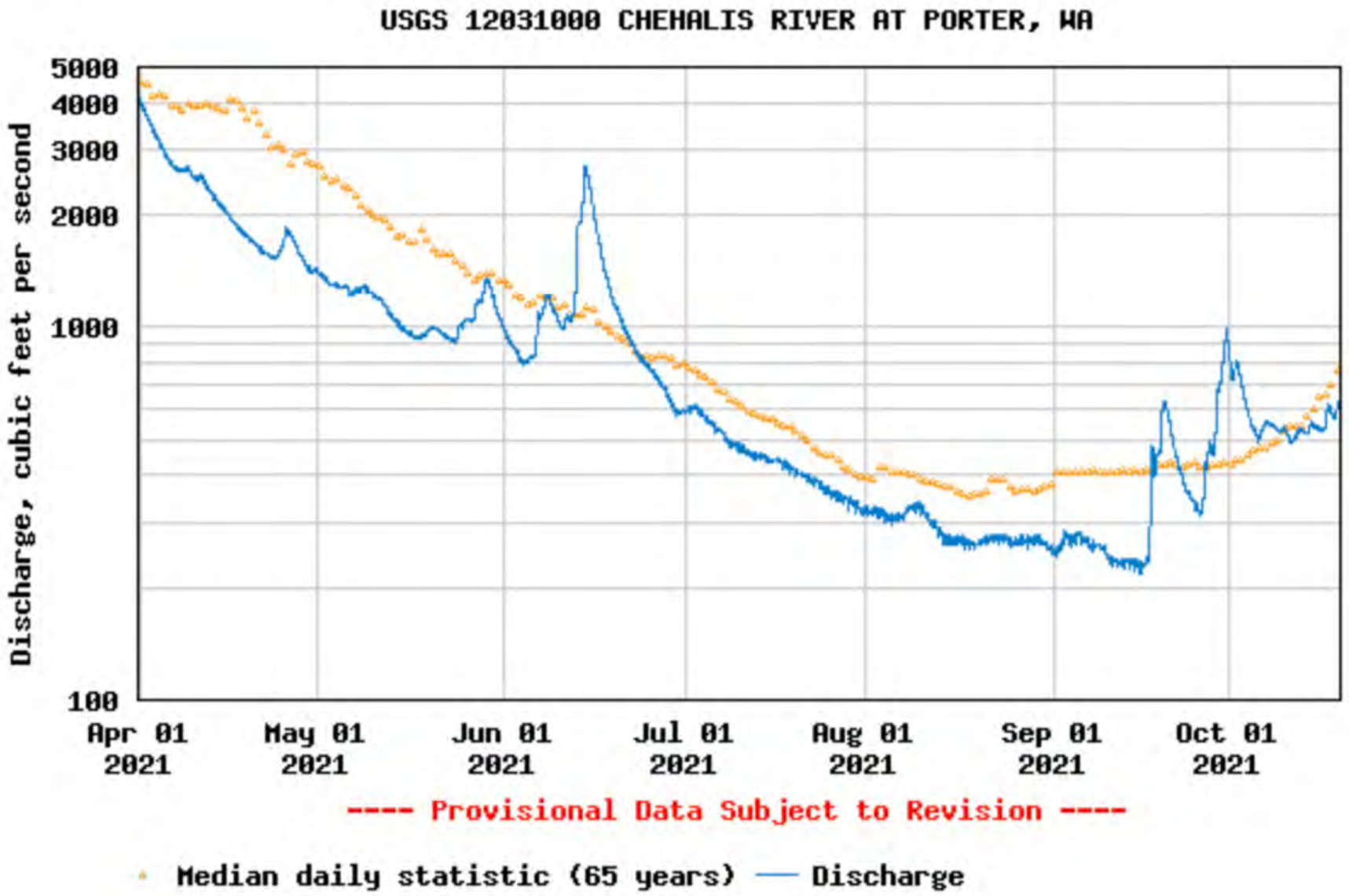

Daily Temperature Data - CENTRALIA, WA
Period of Record - 1893-01-01 to 2021-10-16. Normals period: 1991-2020. Click and drag to zoom chart.
Temperature (°F)
Temperature (°C)
120
100
80
60
40
20
48.9
37.8
26.7
15.6
4.4
-6.7
Jun 7
Jun 14
Jun 21
Jun 28
Jul 5
Jul 12
Jul 19
Jul 26
Aug 2
Aug 9
Aug 16
Aug 23
Observed temperature range (2021)
Normal temperature range
Record Max
Record Min
Powered by ACIS

Pacific Northwest - Precipitation

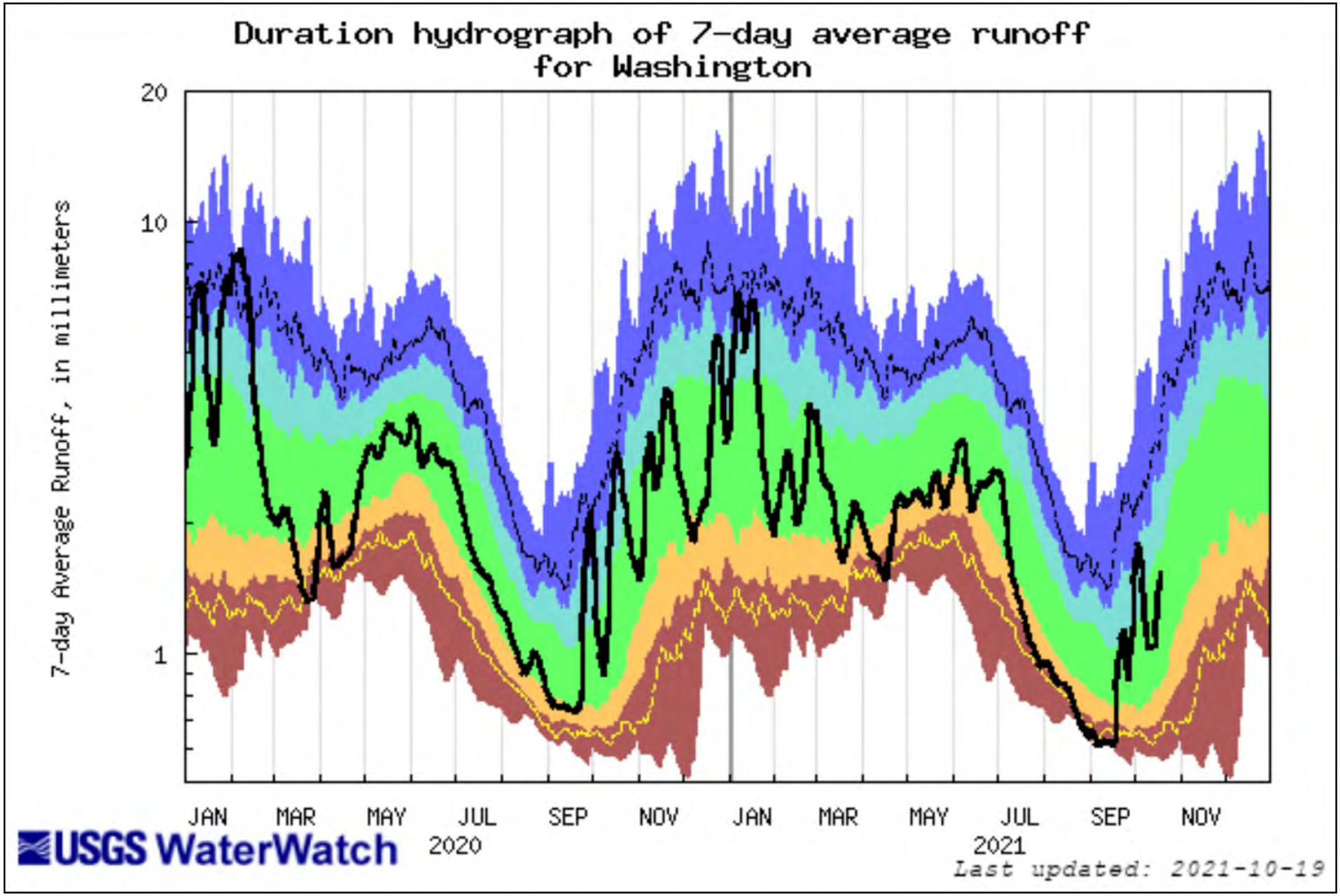
March-August 2021 Percentile



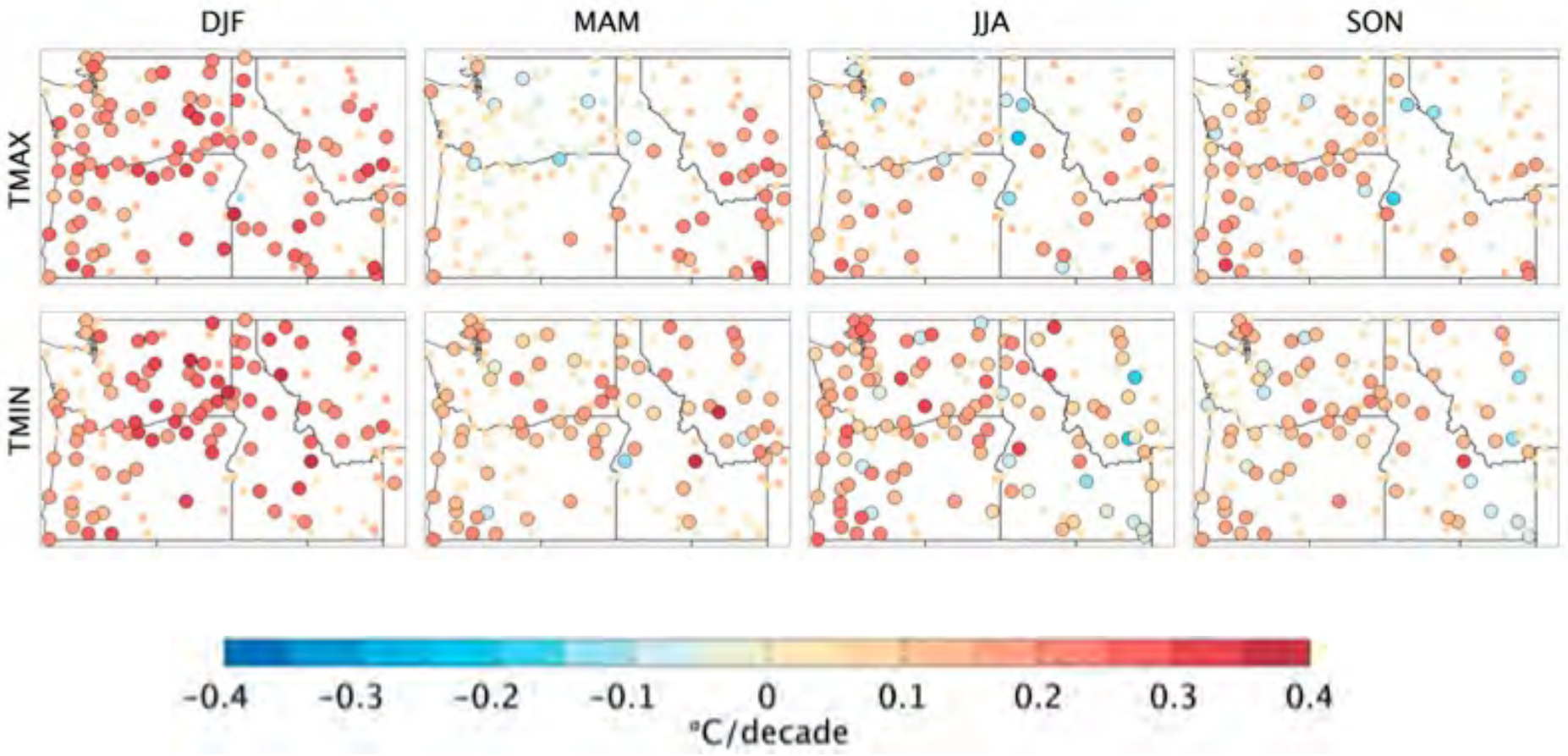
WestWide Drought Tracker - U Idaho/WRCC Data Source - PRISM (Prelim), created 16 SEP 2021


USGS 12031000 CHEHALIS RIVER AT PORTER, WA
Discharge, cubic feet per second
5000
4000
3000
2000
1000
100
Apr 01 2021
May 01 2021
Jun 01 2021
Jul 01 2021
Aug 01 2021
Sep 01 2021
Oct 01 2021
---- Provisional Data Subject to Revision ----
Median daily statistic (65 years)
Discharge

Streamflow


Duration hydrograph of 7-day average runoff
for Washington
7-day Average Runoff, in millimeters
20
10
1
JAN
MAR
MAY
JUL
SEP
NOV
JAN
MAR
MAY
JUL
SEP
NOV
2020
2021
USGS WaterWatch
Last updated: 2021-10-19

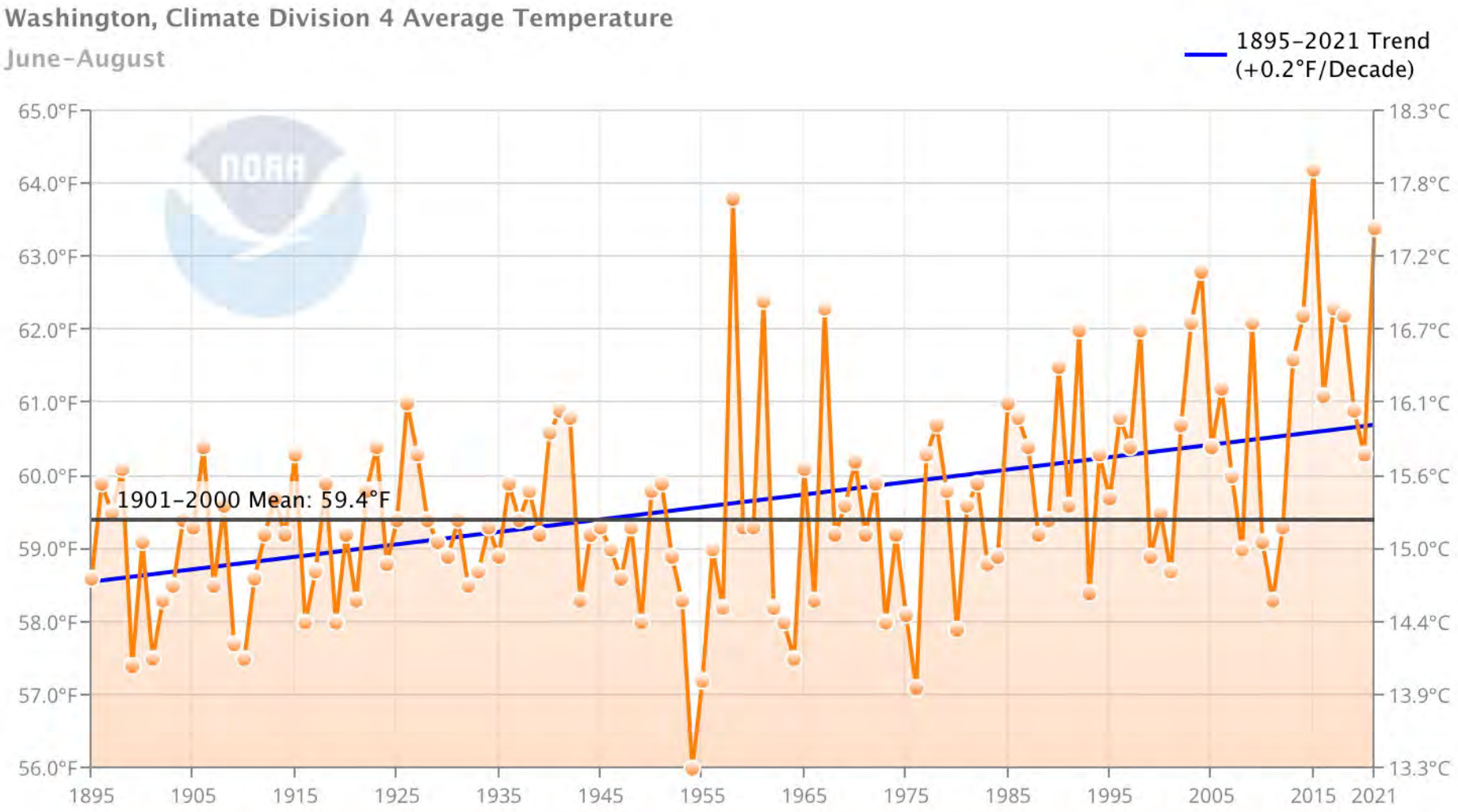
1920-2012 Temperature Trends



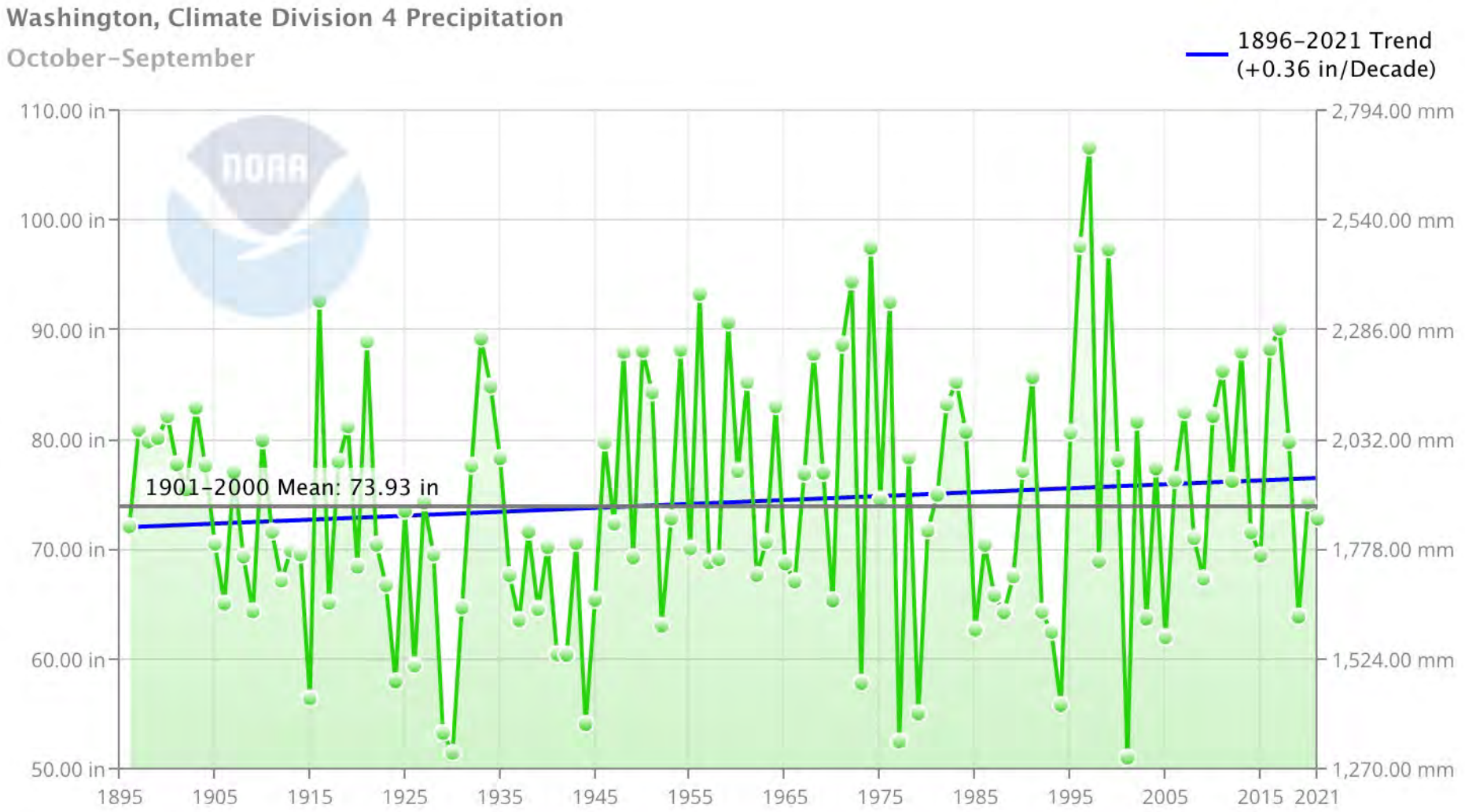
Squares aren't significant linear trends; circles are significant at 95%

Abatzoglou et al. 2014 (J. Climate)

Summer Temperatures: East Olympic Cascade Foothills



Water Year Precipitation:
East Olympic Cascade Foothills



Trends in Cascade Mountain Snow Water Equivalent (SWE)

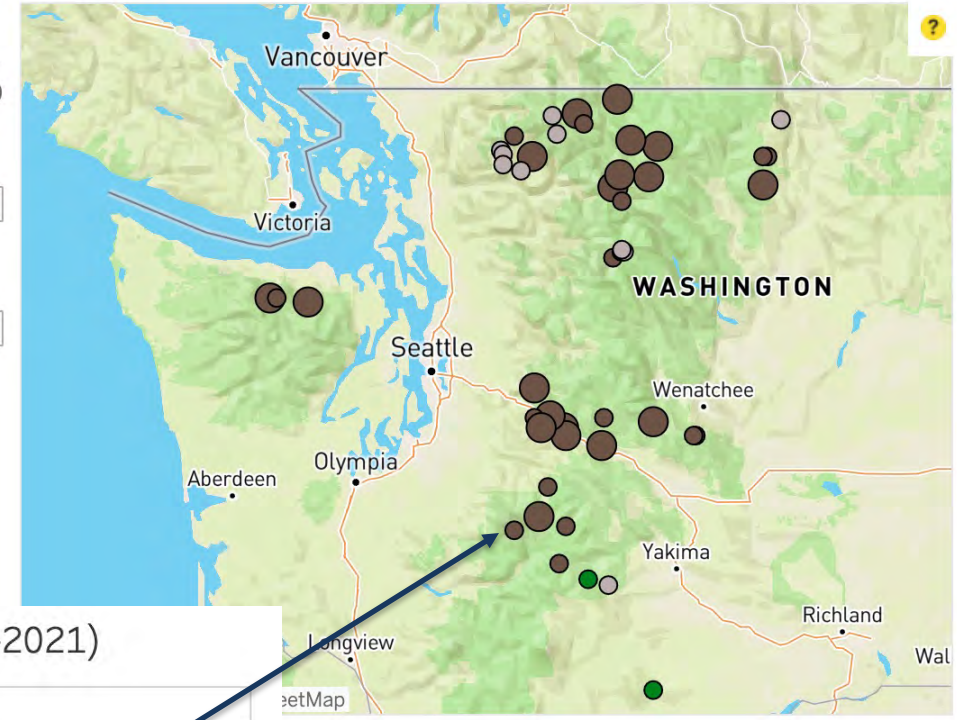
Temperature | Precipitation | Snow Water Equivalent

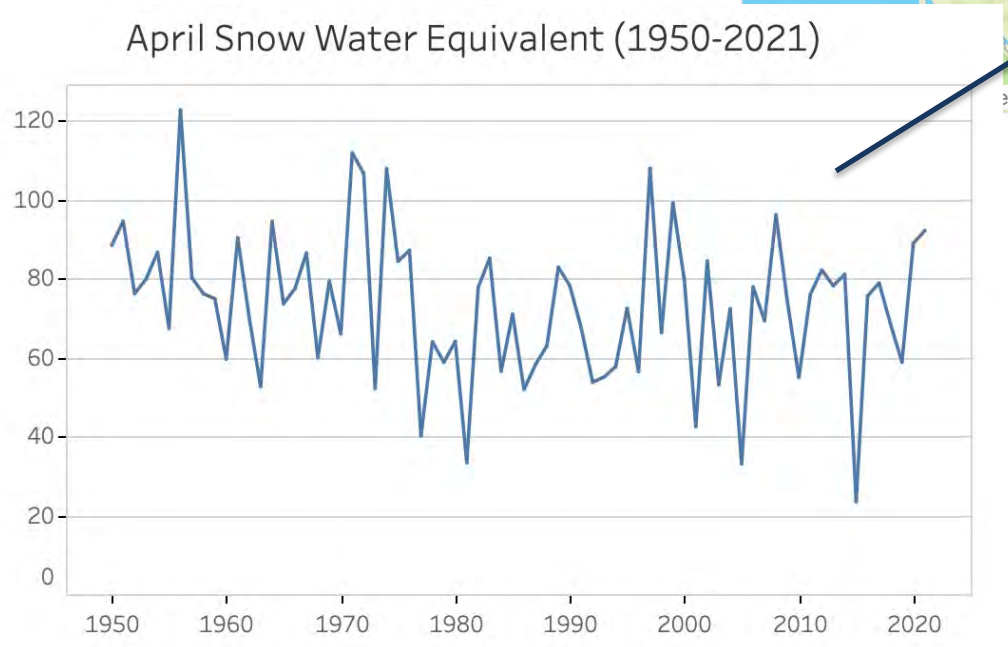
Year Range
1950 2021

Time Frame
April

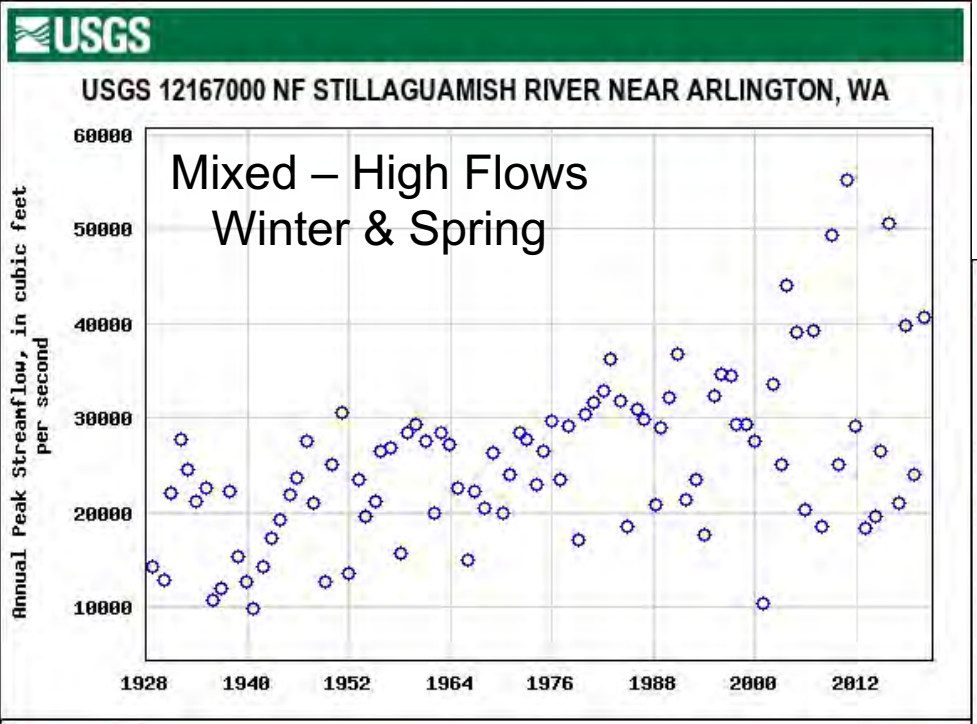
Trend Range
Per Decade

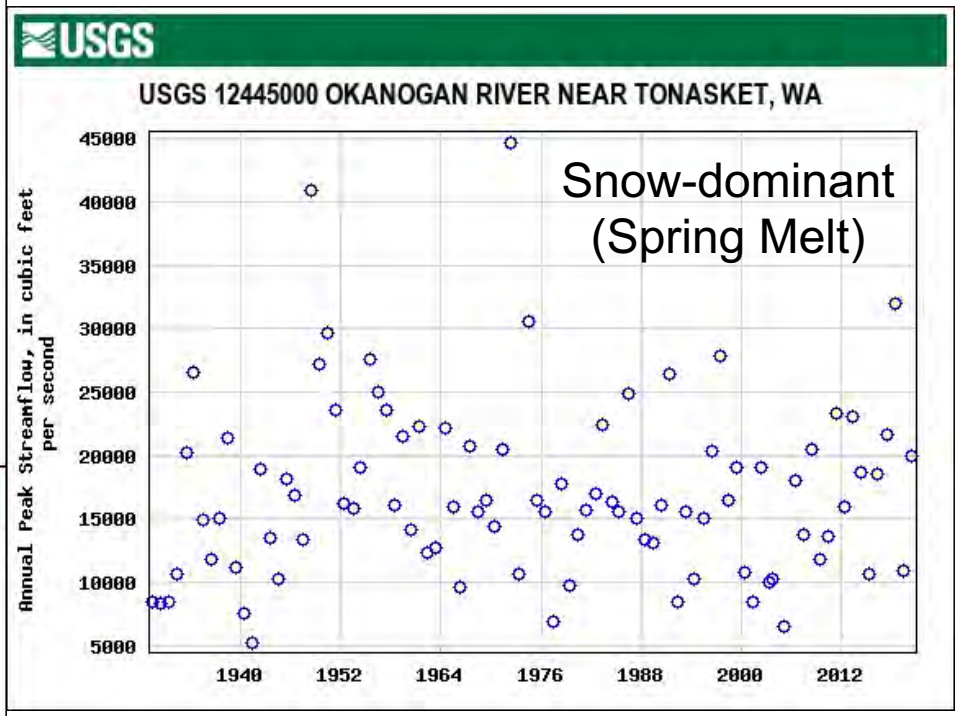
Trend	-	0	+
Significant (S)			
Not Significant (NS)			
Insufficient Data (I)			

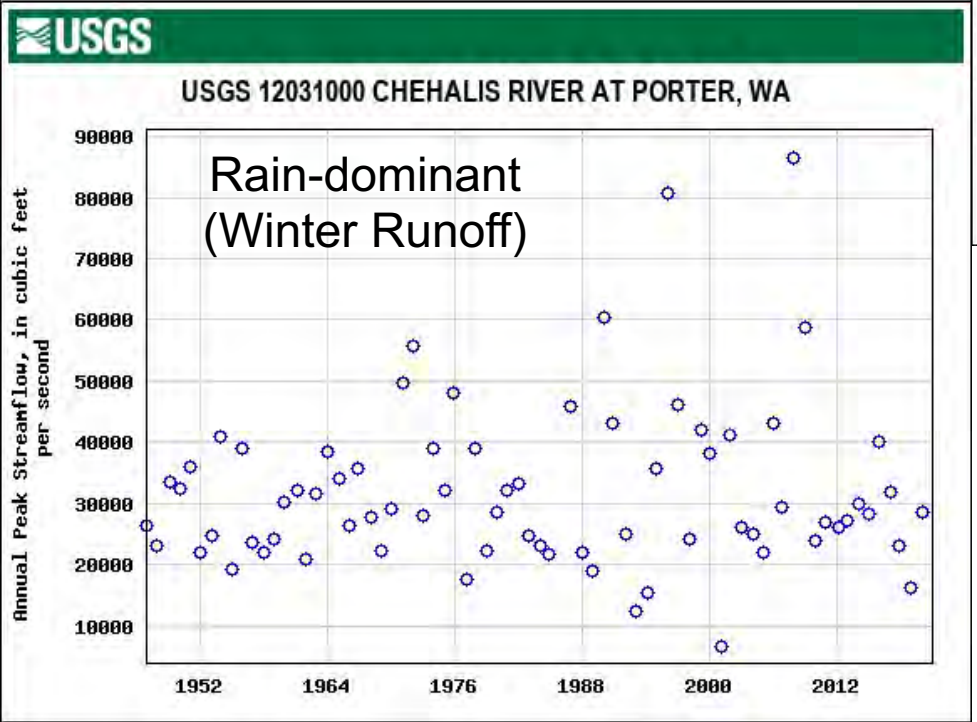




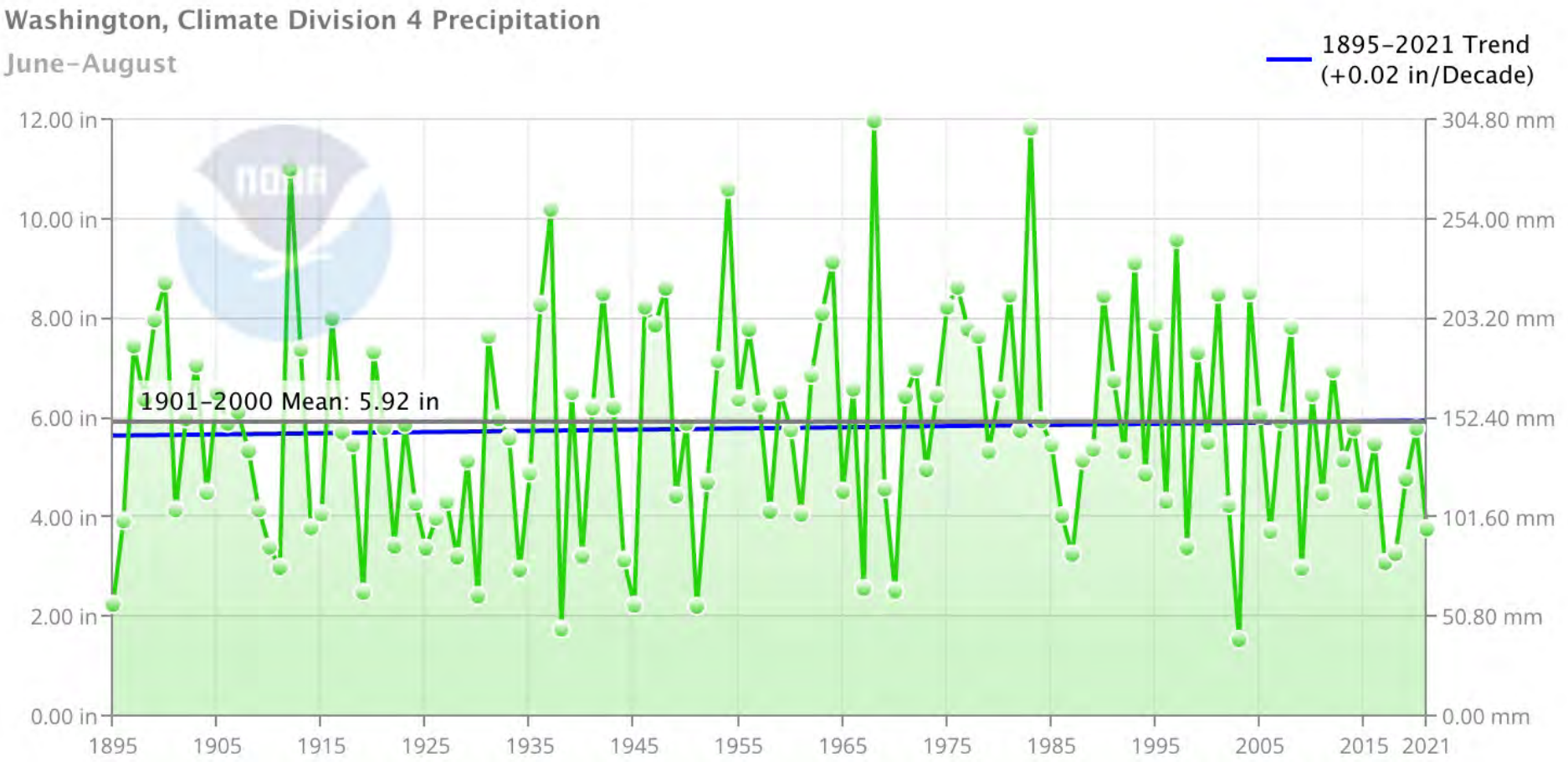
Magnitudes of Greatest 1-Day Streamflows





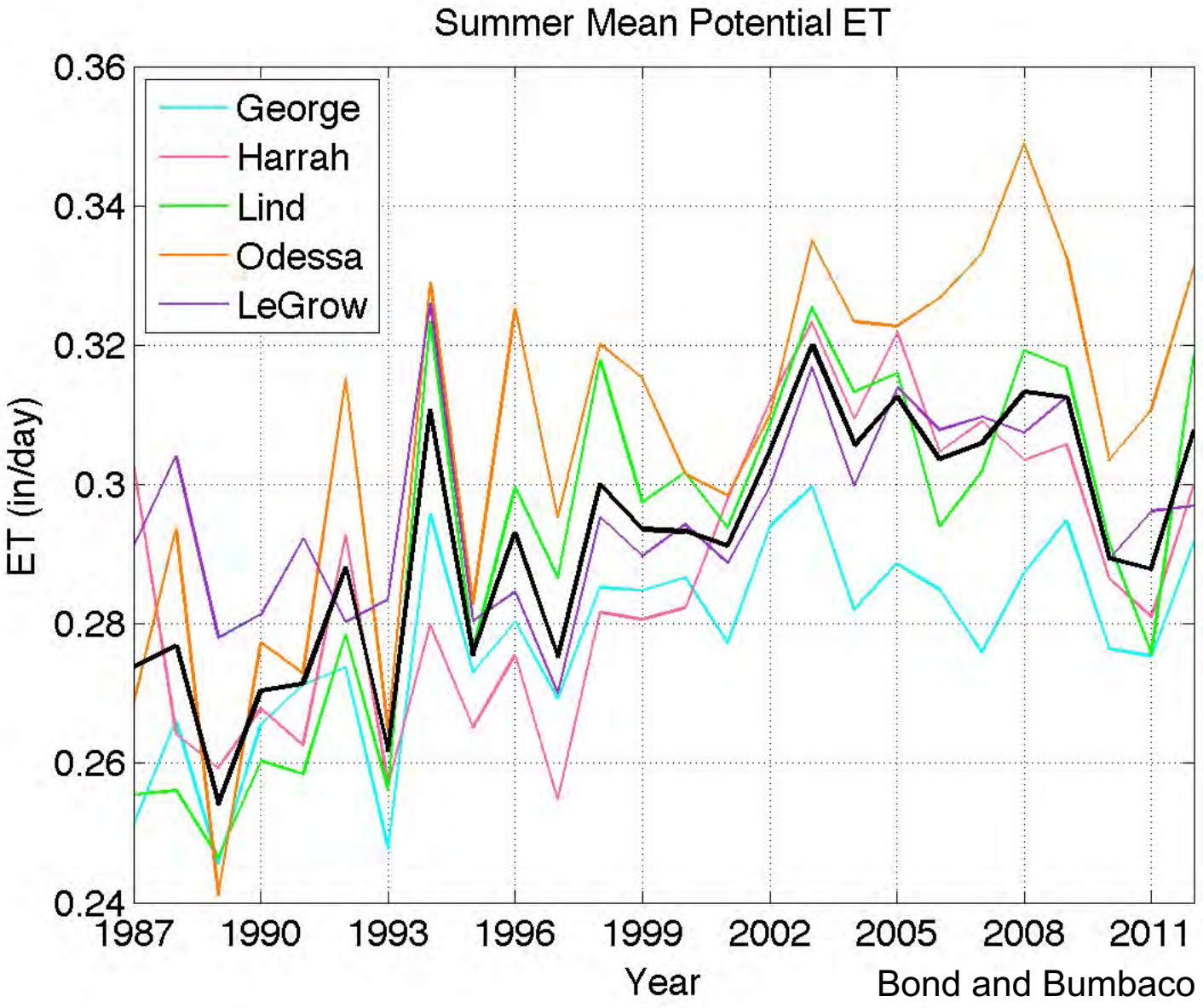


Summer (Jun-Aug) Precipitation



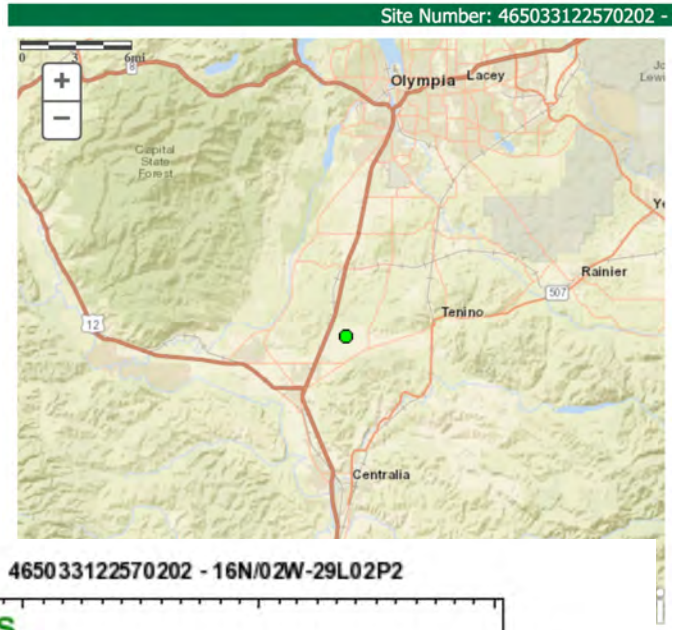
Note overall decline during last 30 years

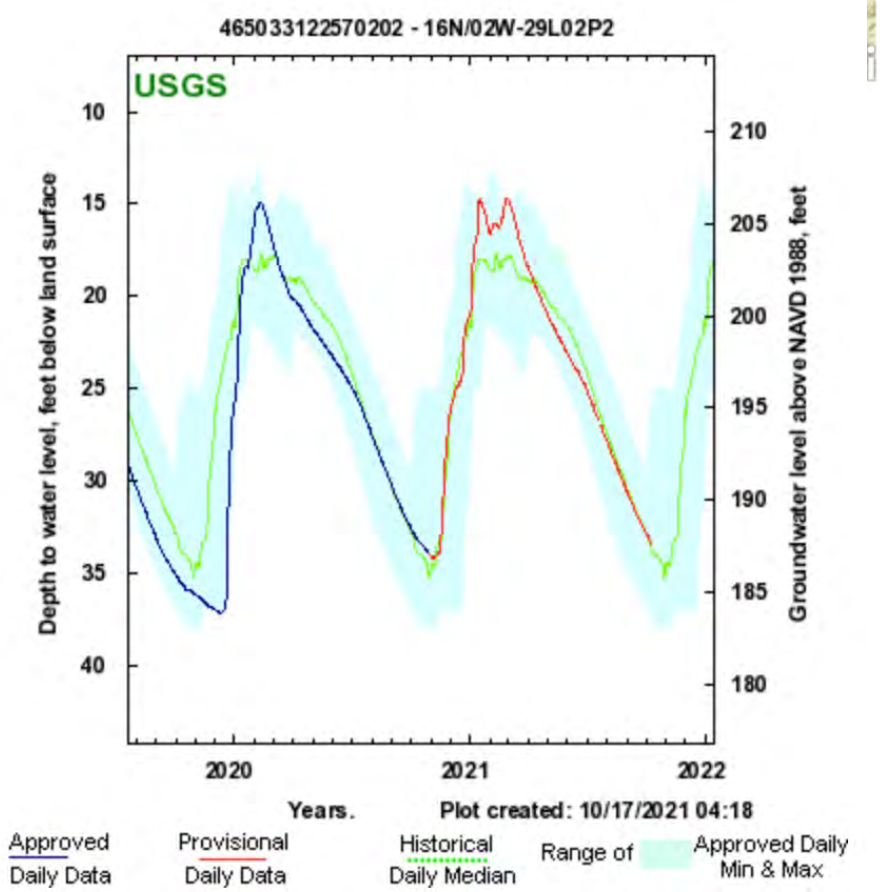
Potential Evapotranspiration (pET)

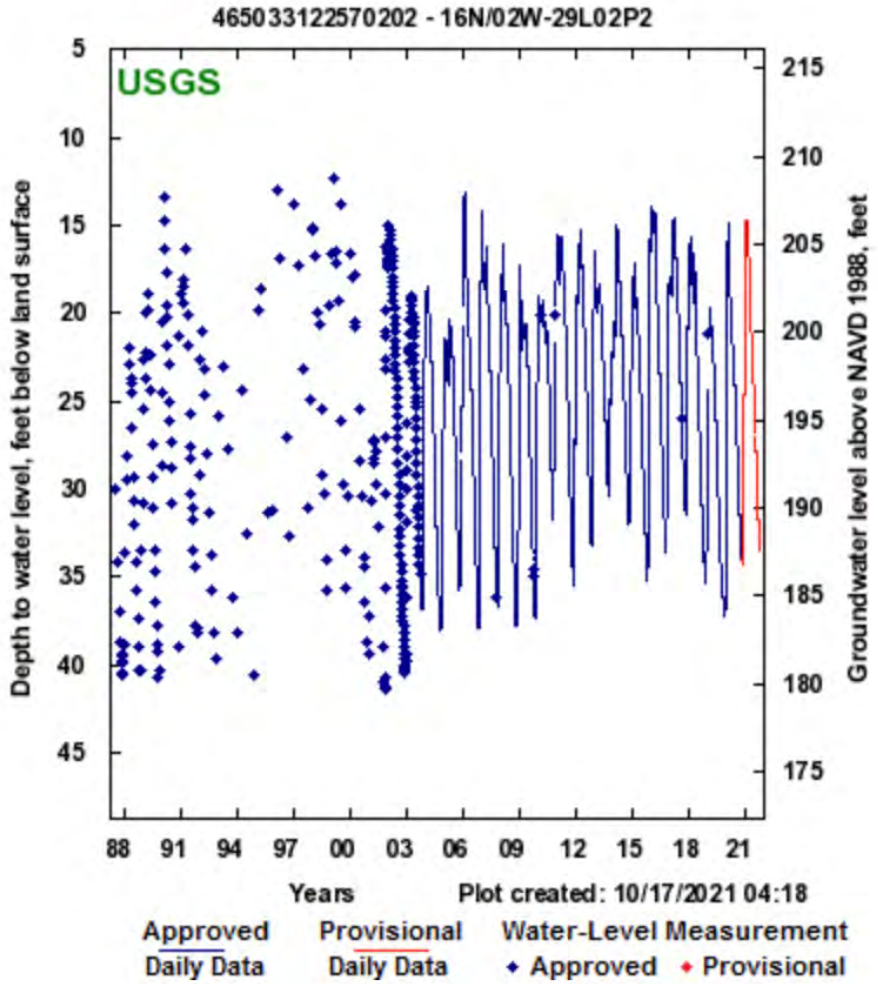


Bond and Bumbaco (2015)

Groundwater Level in South Thurston County





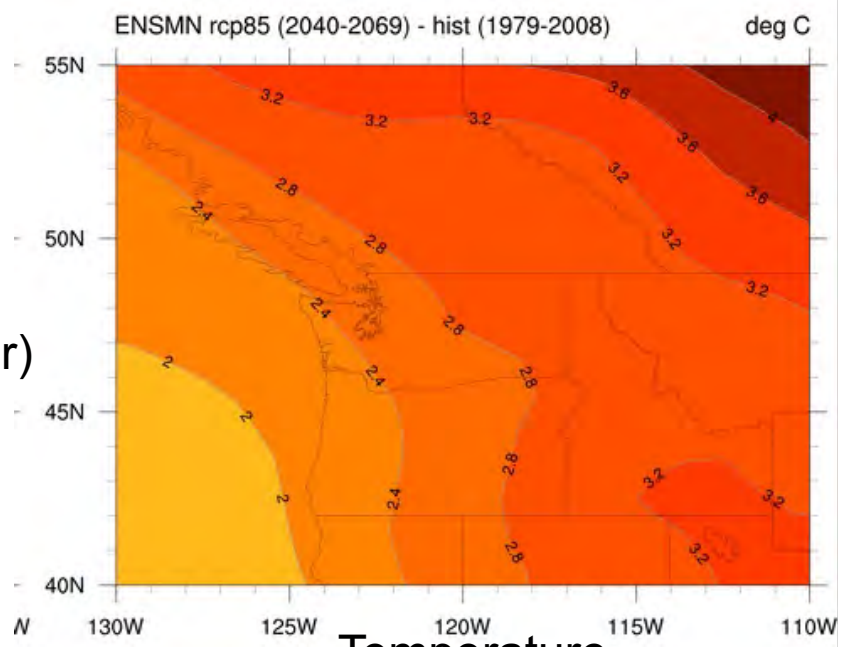


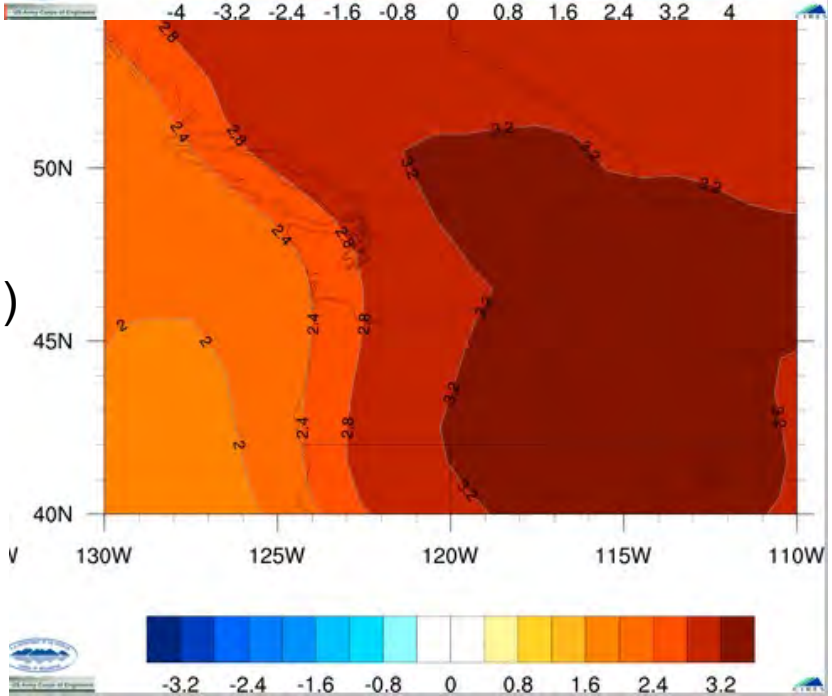

Positive proof of global warming.
18th Century
1900
1950
1970
1980
1990
2021

Winter (Nov-Mar)

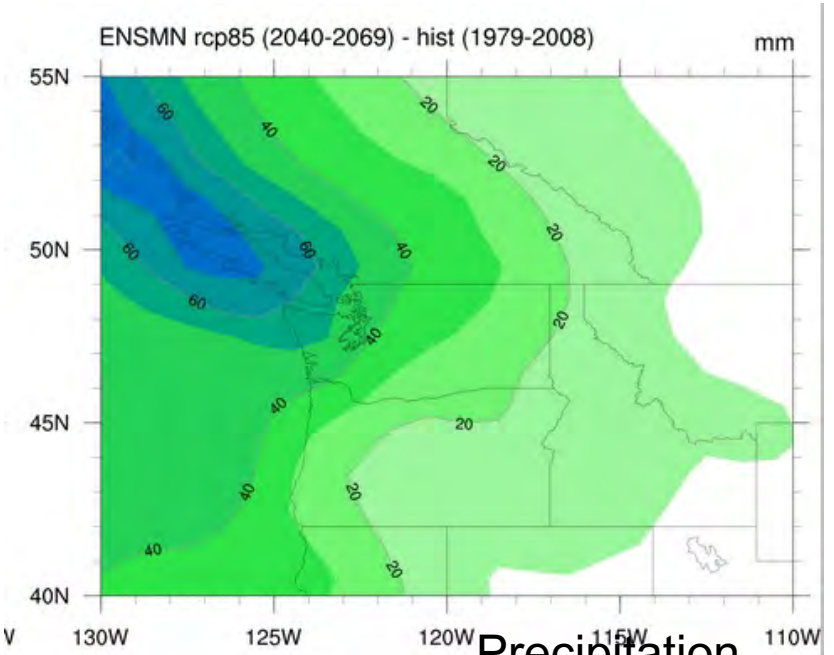
Summer (Jun-Aug)

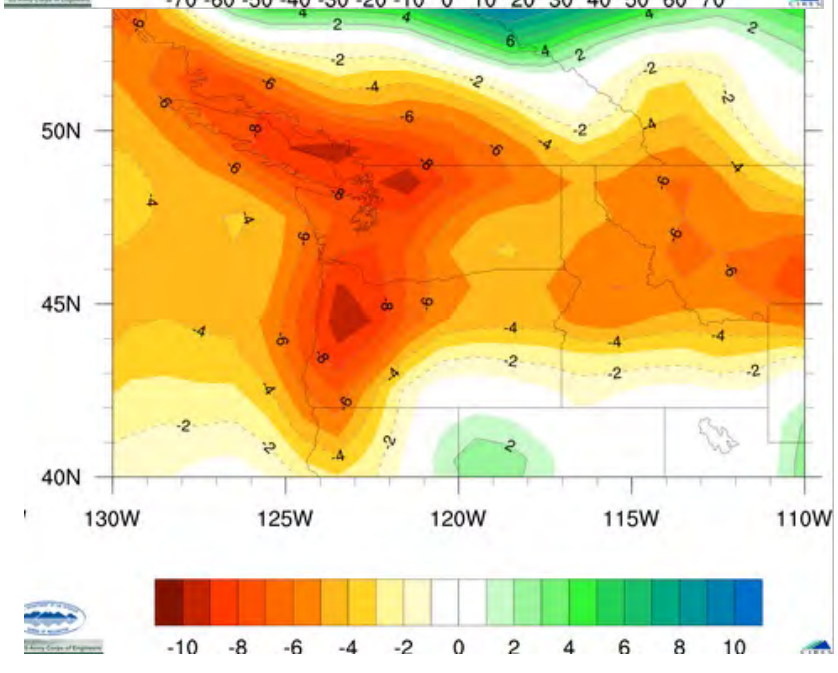
Temperature

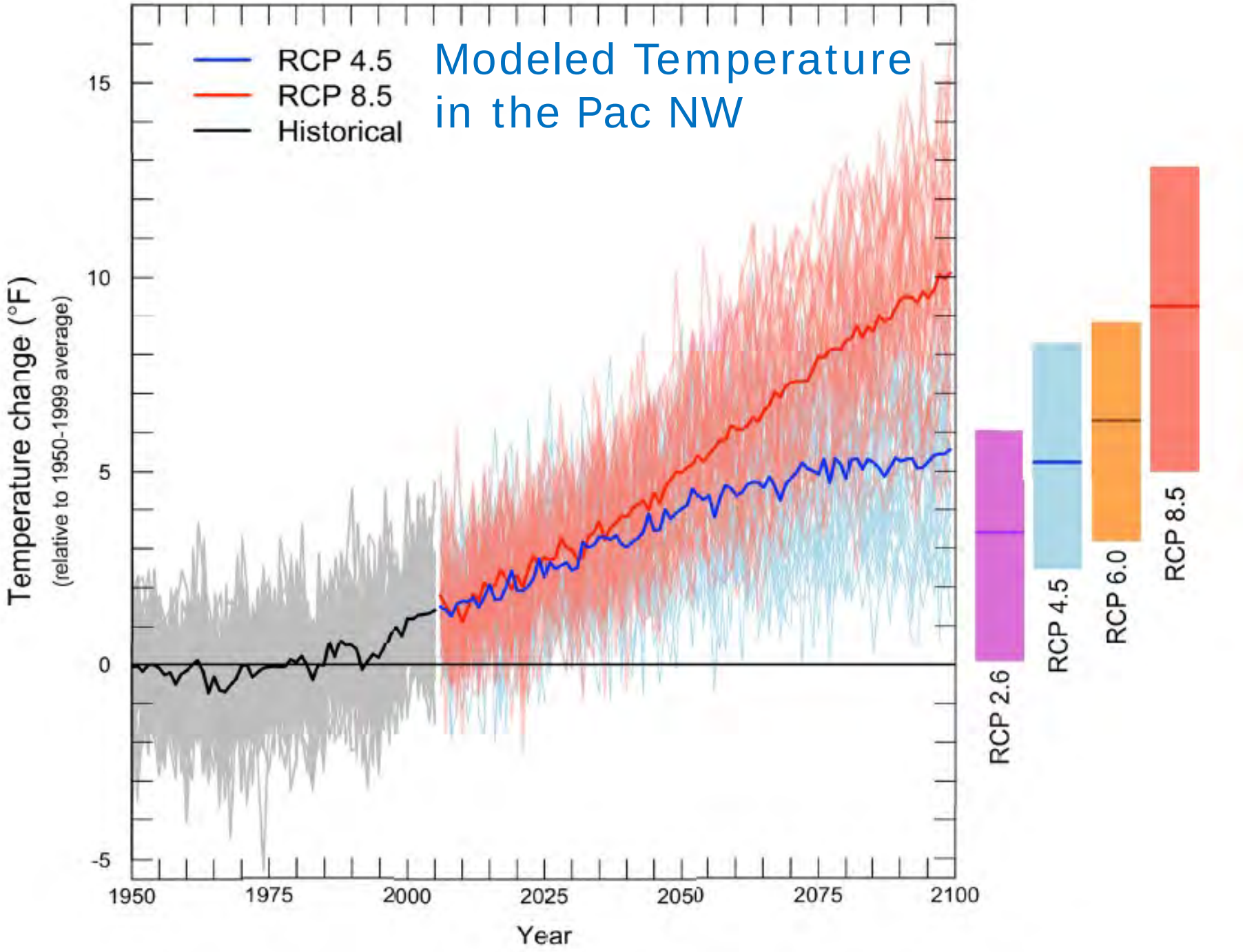




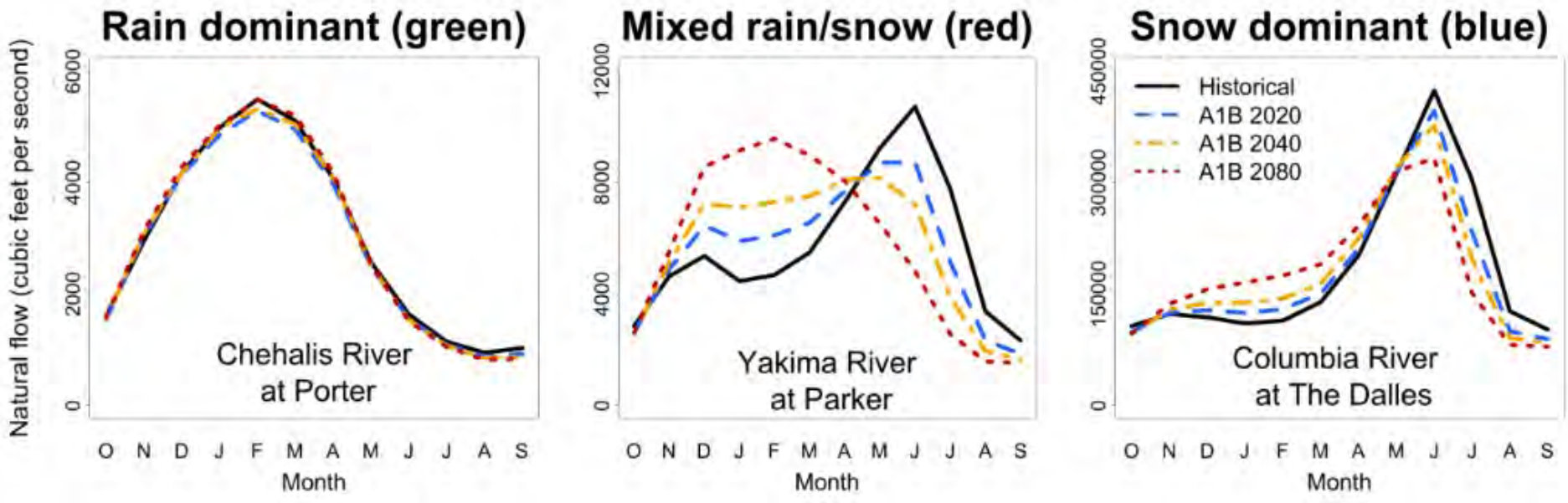
Precipitation



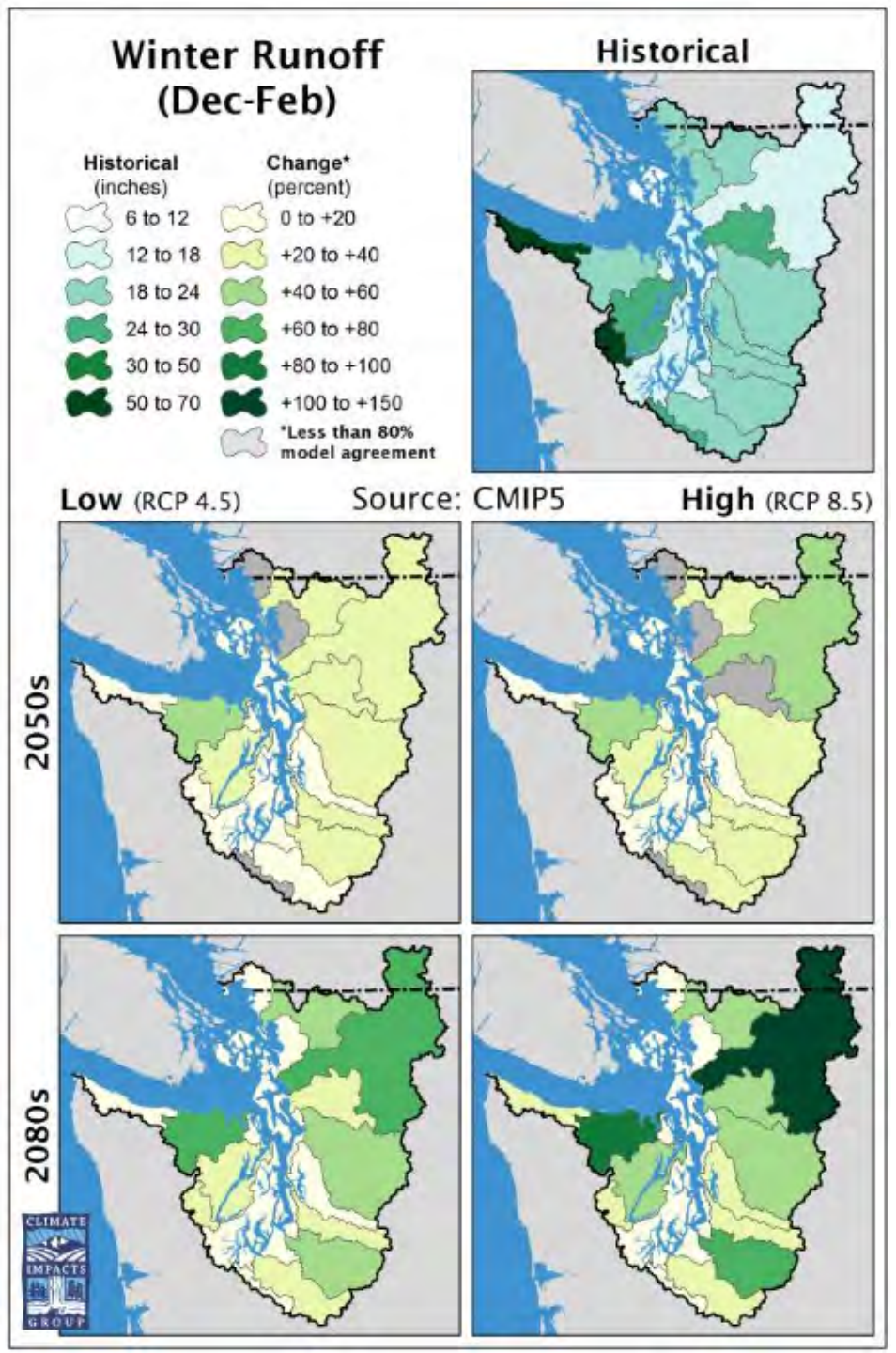


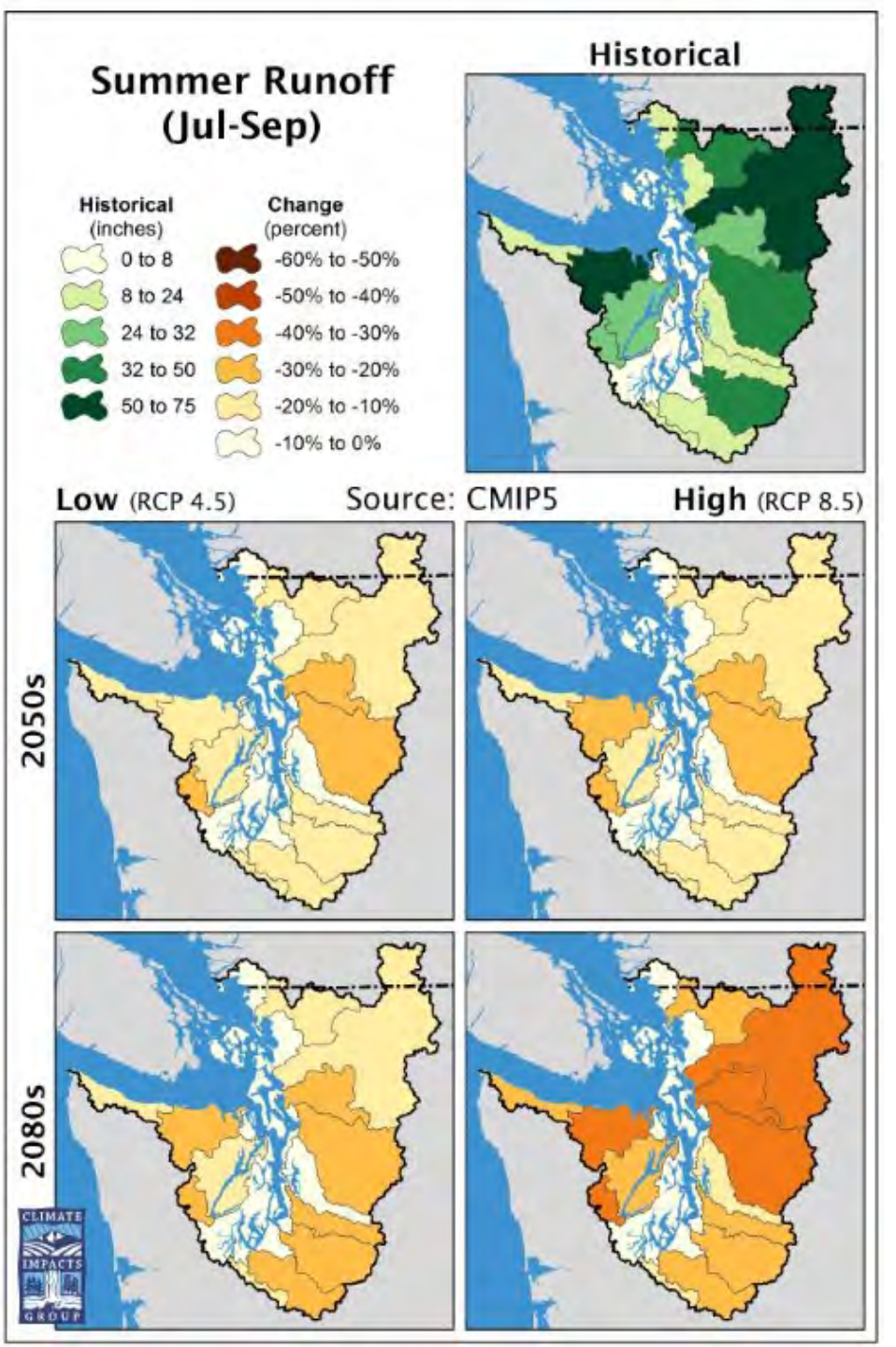

Modeled Temperature in the Pac NW
RCP 4.5
RCP 8.5
Historical
Temperature change (°F)
(relative to 1950-1999 average)
15
10
5
0
-5
1950
1975
2000
2025
2050
2075
2100
Year
RCP 2.6
RCP 4.5
RCP 6.0
RCP 8.5

Expected Transitions in Watershed Types



Climate Impacts Group/UW
Hamlet et al. 2013


Winter Runoff
(Dec-Feb)
Historical
Historical (inches)
6 to 12
12 to 18
18 to 24
24 to 30
30 to 50
50 to 70
Change* (percent)
0 to +20
+20 to +40
+40 to +60
+60 to +80
+80 to +100
+100 to +150
*Less than 80% model agreement
Low (RCP 4.5)
Source: CMIP5
High (RCP 8.5)
2050s
2080s
CLIMATE IMPACTS GROUP


Summer Runoff
(Jul-Sep)
Historical
Historical (inches)
0 to 8
8 to 24
24 to 32
32 to 50
50 to 75
Change (percent)
-60% to -50%
-50% to -40%
-40% to -30%
-30% to -20%
-20% to -10%
-10% to 0%
Low (RCP 4.5)
Source: CMIP5
High (RCP 8.5)
2050s
2080s
CLIMATE IMPACTS GROUP

Challenges for Water Managers

- Summer Demand versus Winter Floods
- Infrastructure (e.g., Reservoirs)
- Legal Issues
- Hydropower
- Ecosystems (e.g., Fish Habitats & Migrations)
- Recreation/Tourism
- Groundwater Withdrawals

INDESCRIBABLE...

INDESTRUCTIBLE!

NOTHING CAN STOP IT!

THE BLOB

STEVEN McQUEEN

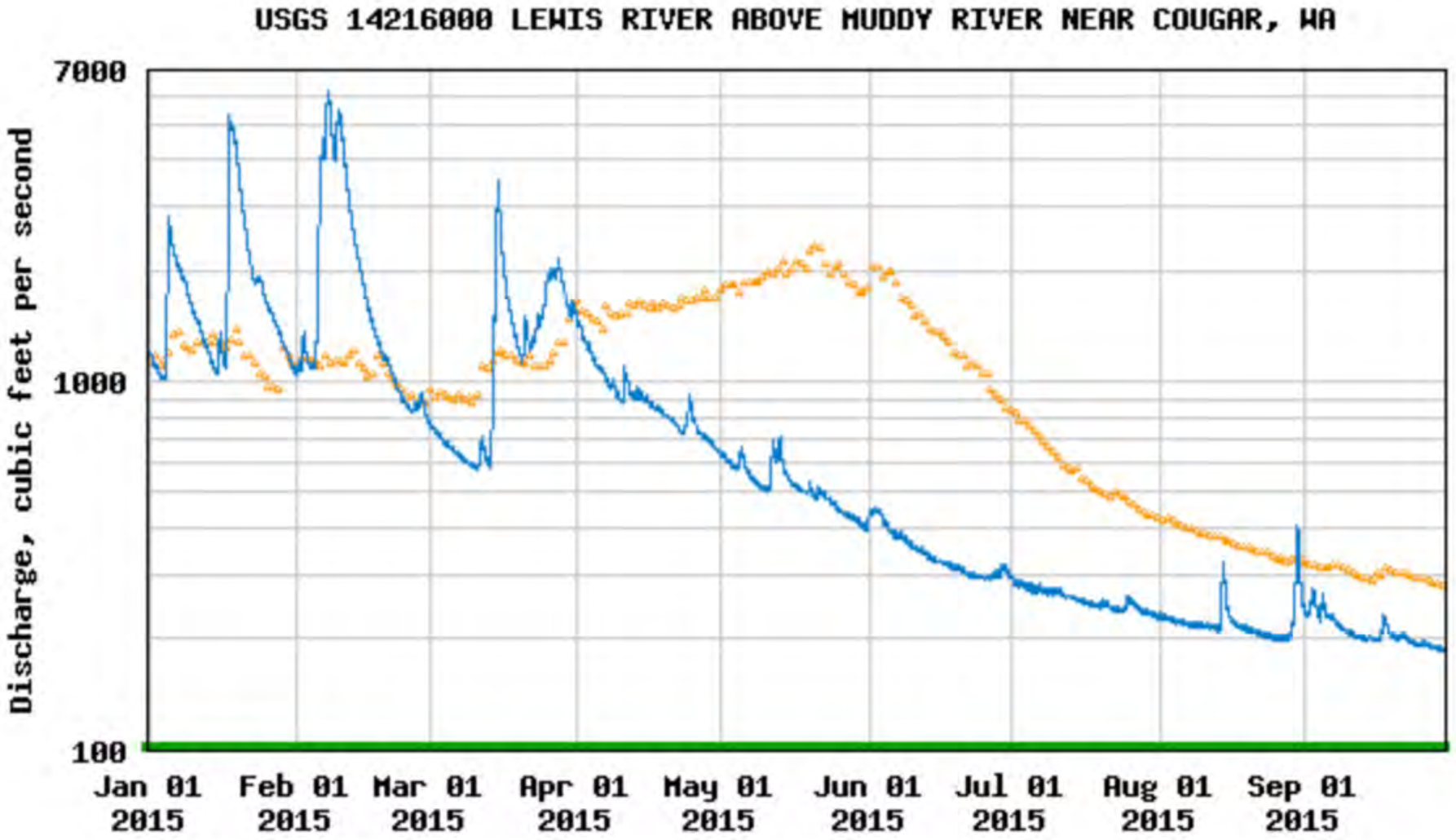
ANITA CORSEAUT · EARL ROWE

PRODUCED BY JACK H. HARRIS · DIRECTED BY IRVIN S. YEAWORTH, JR. · SCREENPLAY BY THEODORE SIMONSON AND KATE PHILLIPS

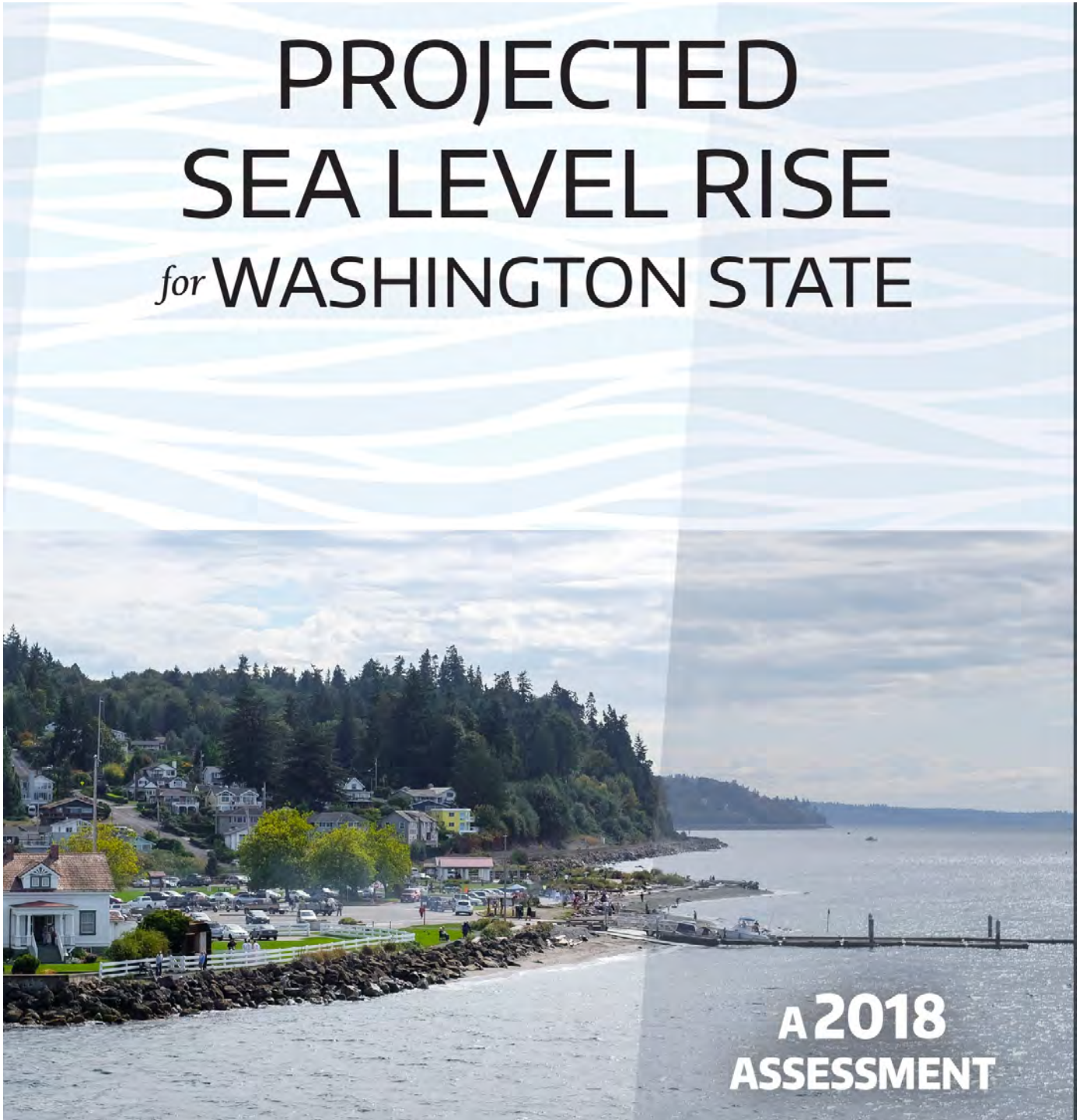
FROM AN IDEA BY KENNETH A. RUSSELL

A TONWYN PRODUCTION

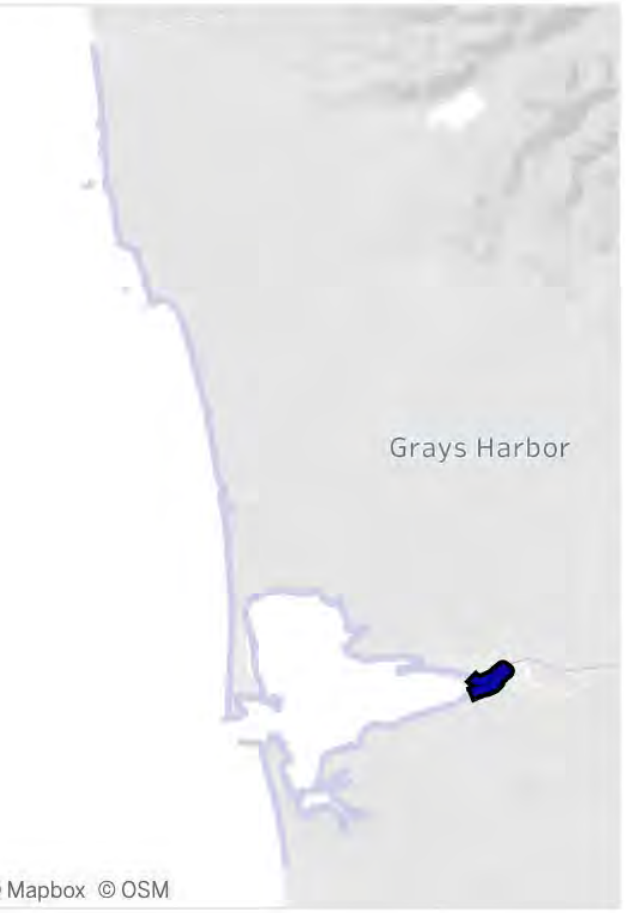
Capital Press – March 2015

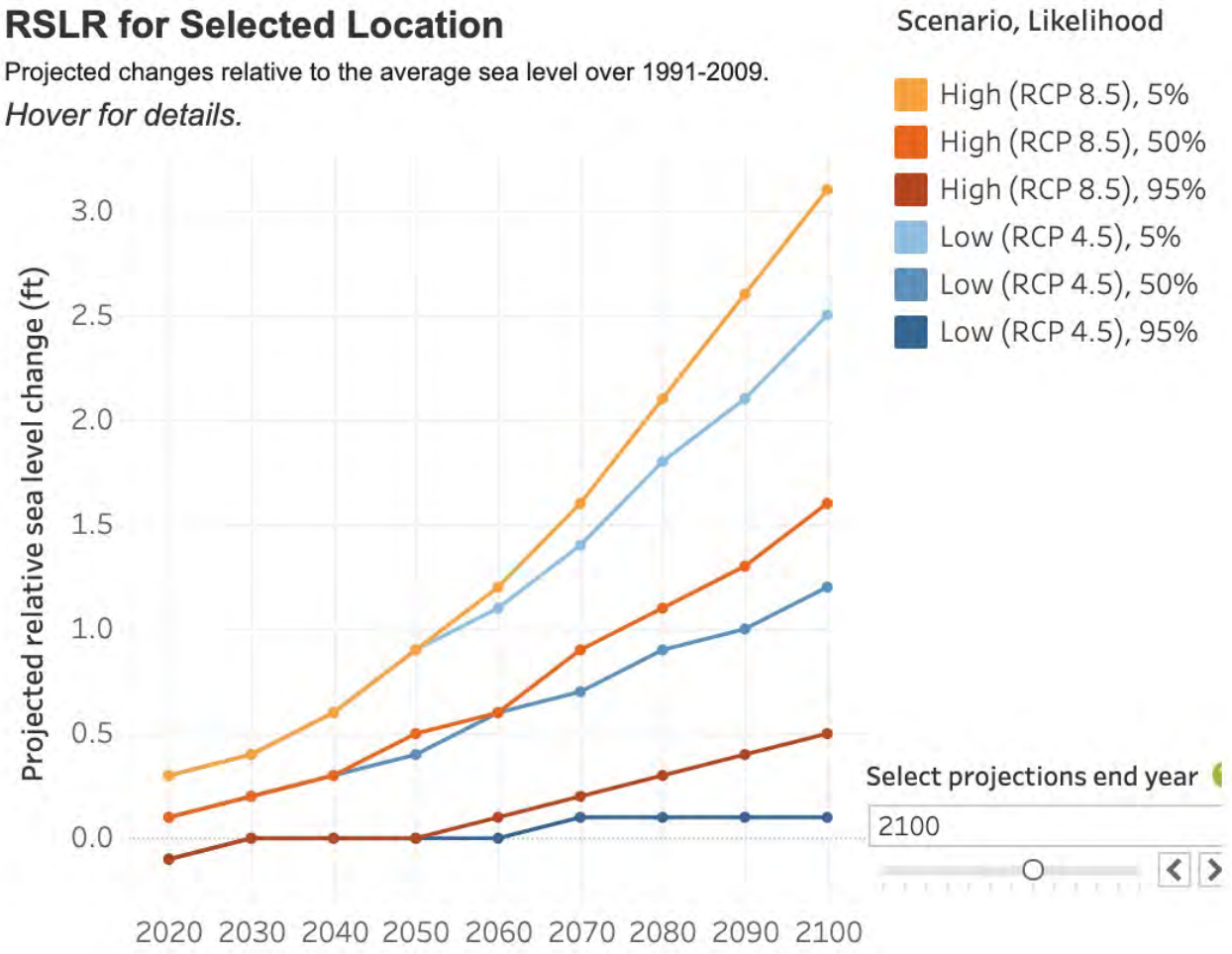

USGS 14216000 LEWIS RIVER ABOVE MUDDY RIVER NEAR COUGAR, WA
Discharge, cubic feet per second
7000
1000
100
Jan 01 2015
Feb 01 2015
Mar 01 2015
Apr 01 2015
May 01 2015
Jun 01 2015
Jul 01 2015
Aug 01 2015
Sep 01 2015

The mouth of the White Salmon River in July 2015



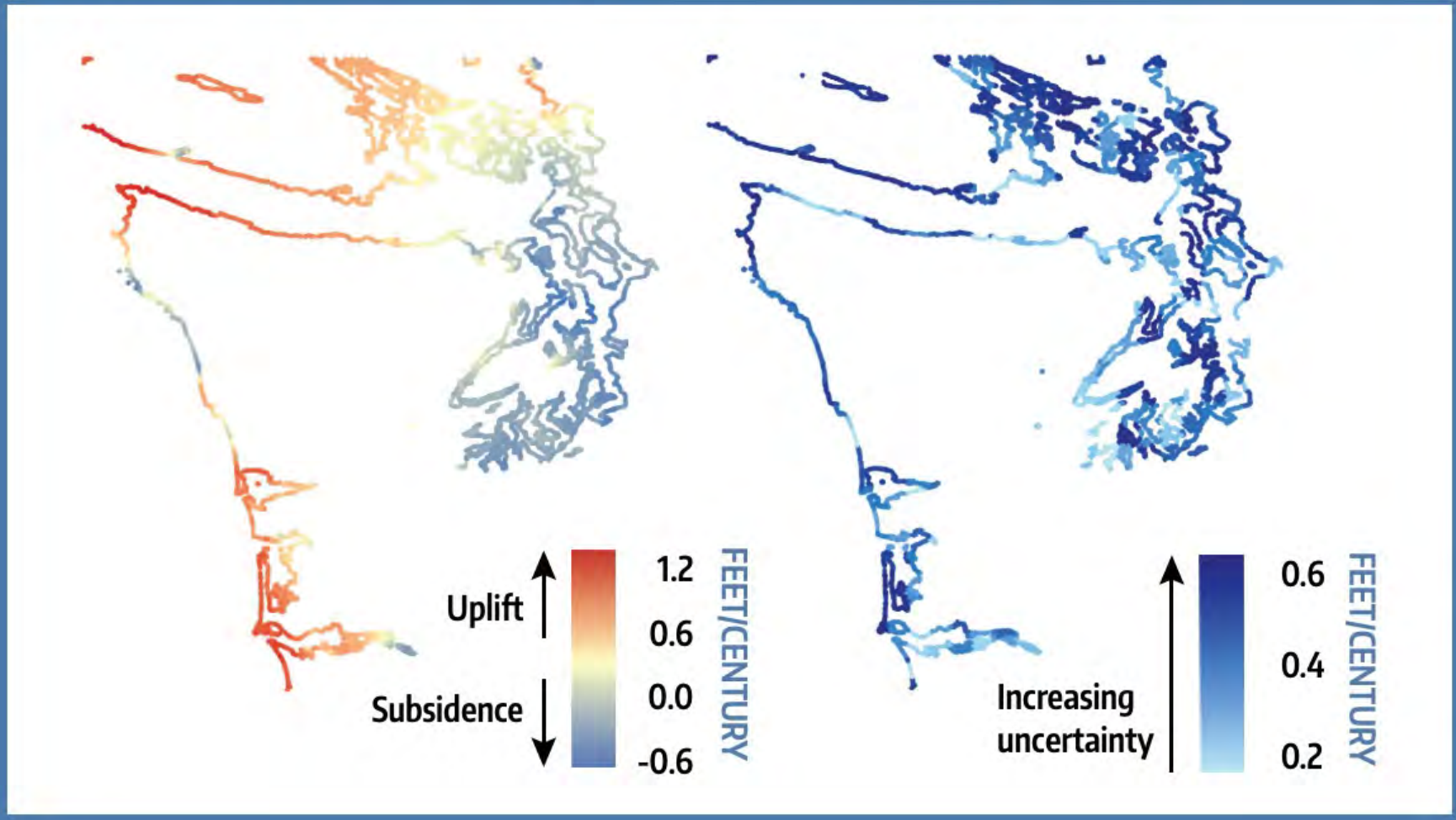
The Washington Coastal Resilience Project (WCRP)

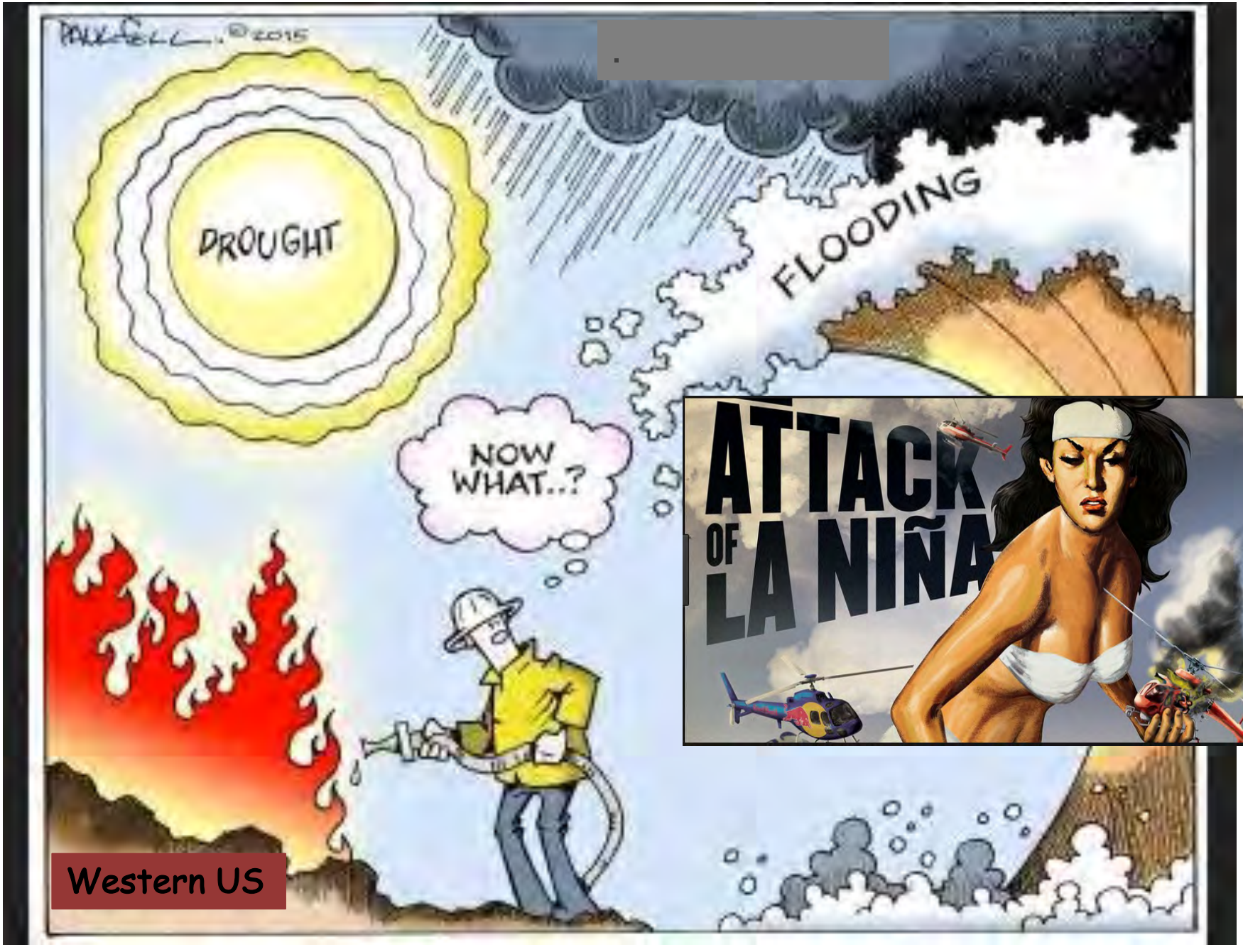




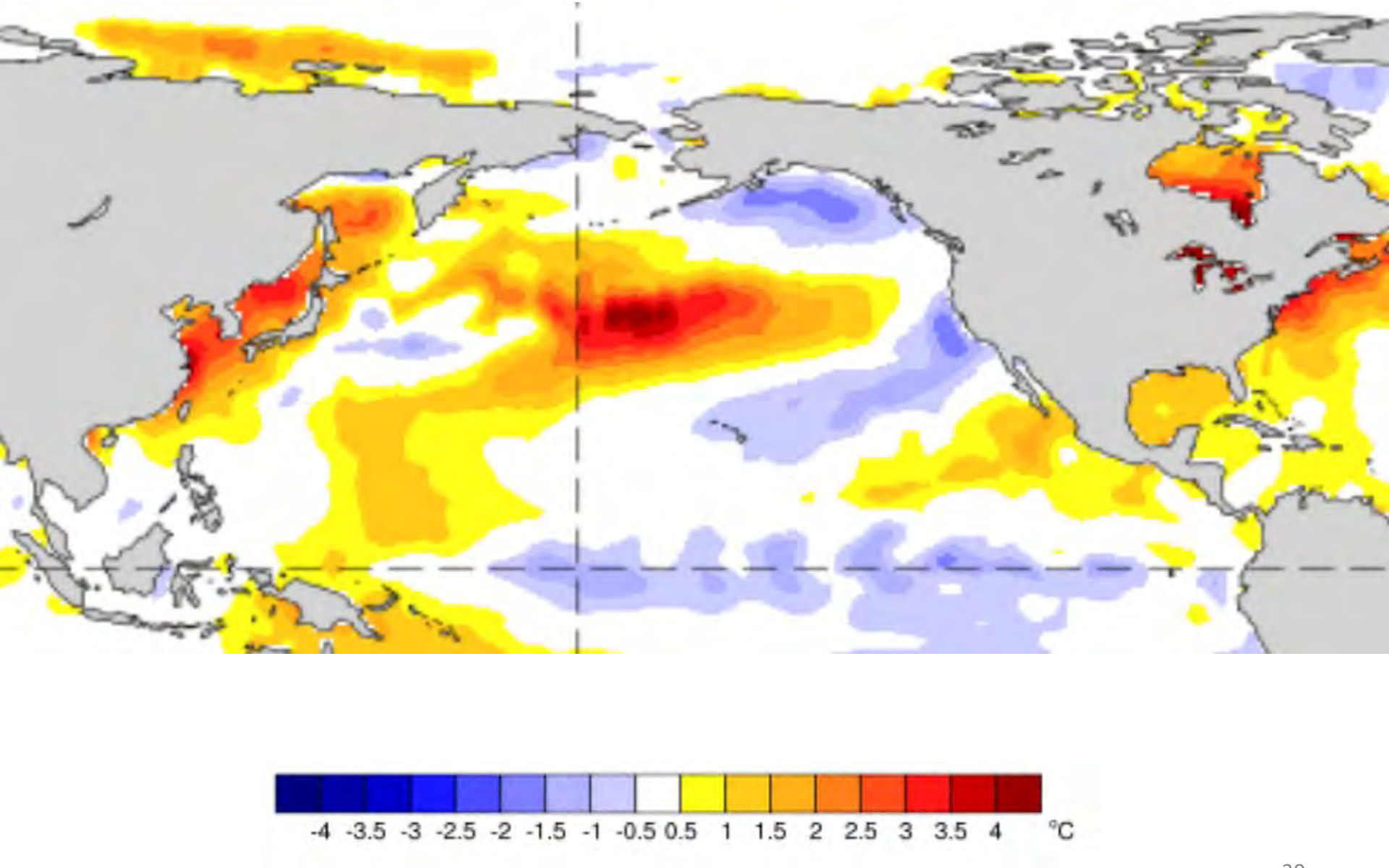
Assuming uplift of 0.4 feet/century; note that a subduction earthquake is expected to produce a land level change at this location of -2.5 to -6.0 feet!

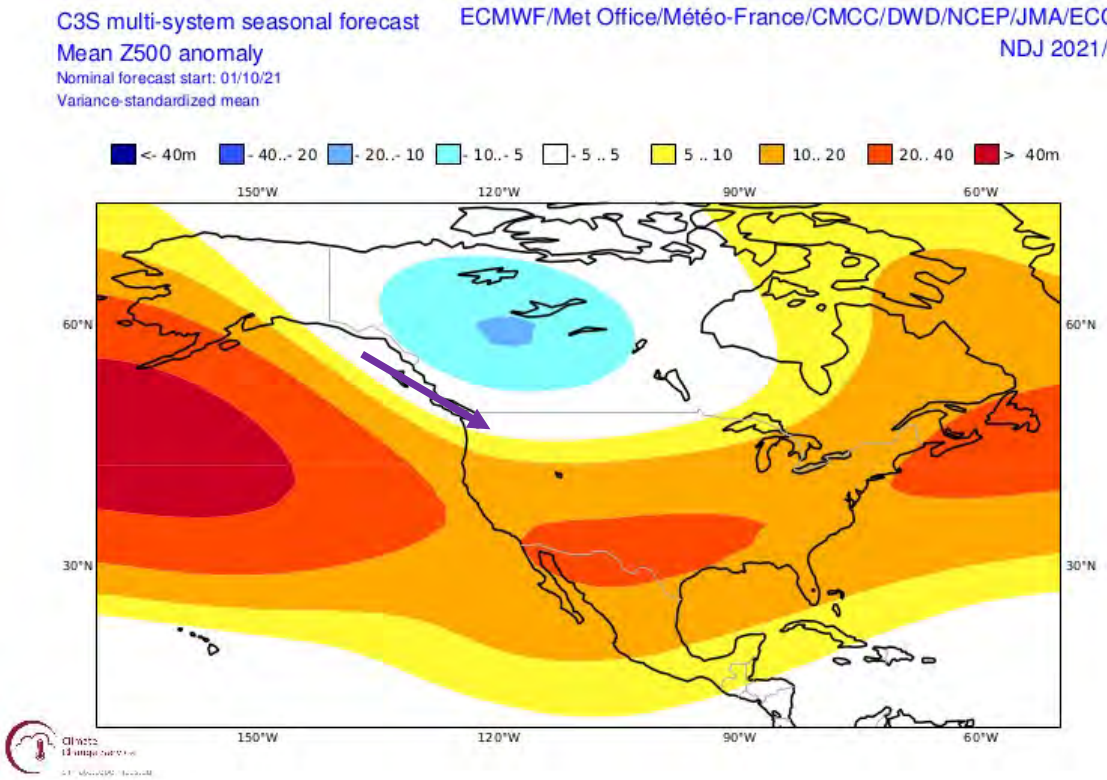
FIGURE 3: Vertical land movement best estimate rates (left) expressed in rates of feet/century, and their uncertainties (1 standard deviation, right) as estimated for Washington's coastline.



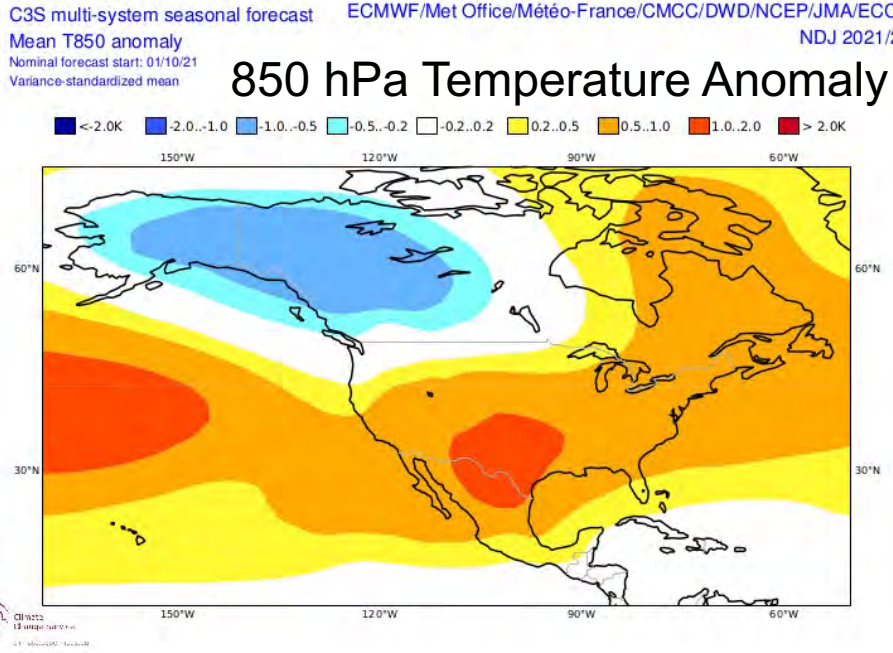

DROUGHT
FLOODING
NOW WHAT..?
ATTACK OF LA NIÑA
Western US

SST Anomalies: 10-16 Oct 2021

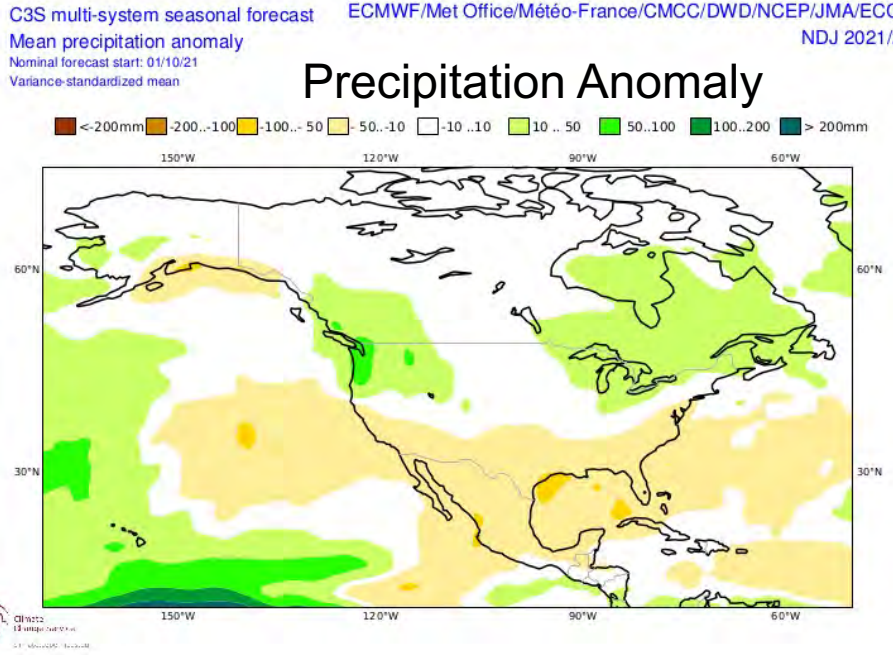




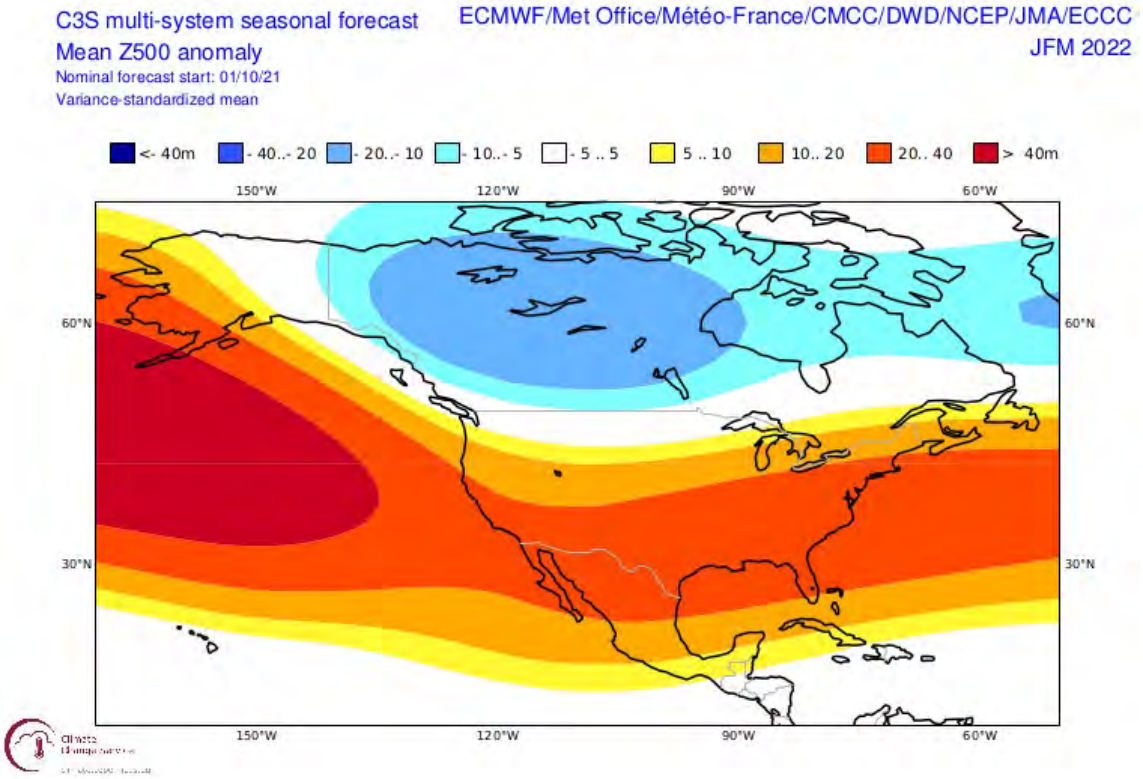
500 hPa
Z Anomaly
Nov-Jan



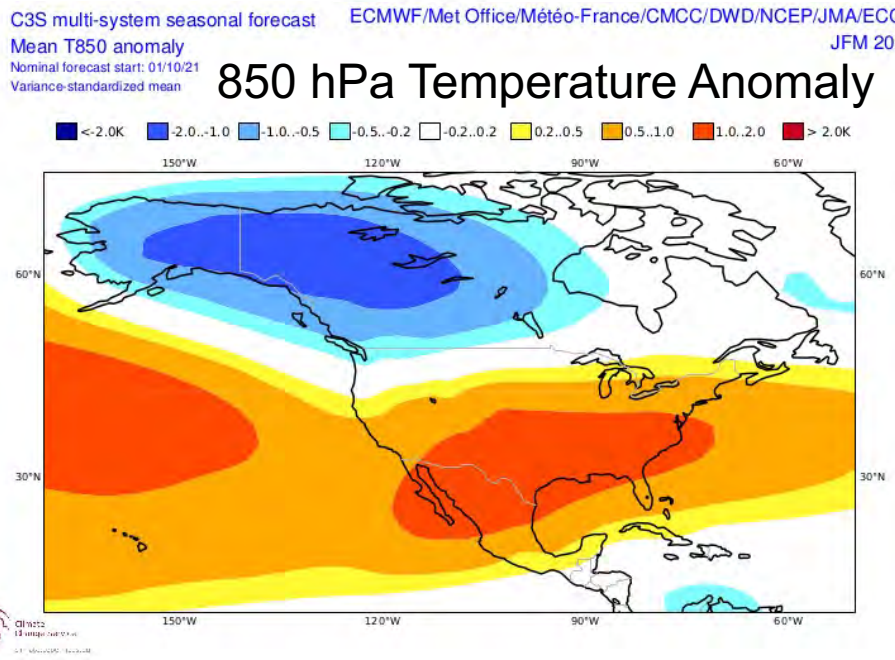
850 hPa Temperature Anomaly

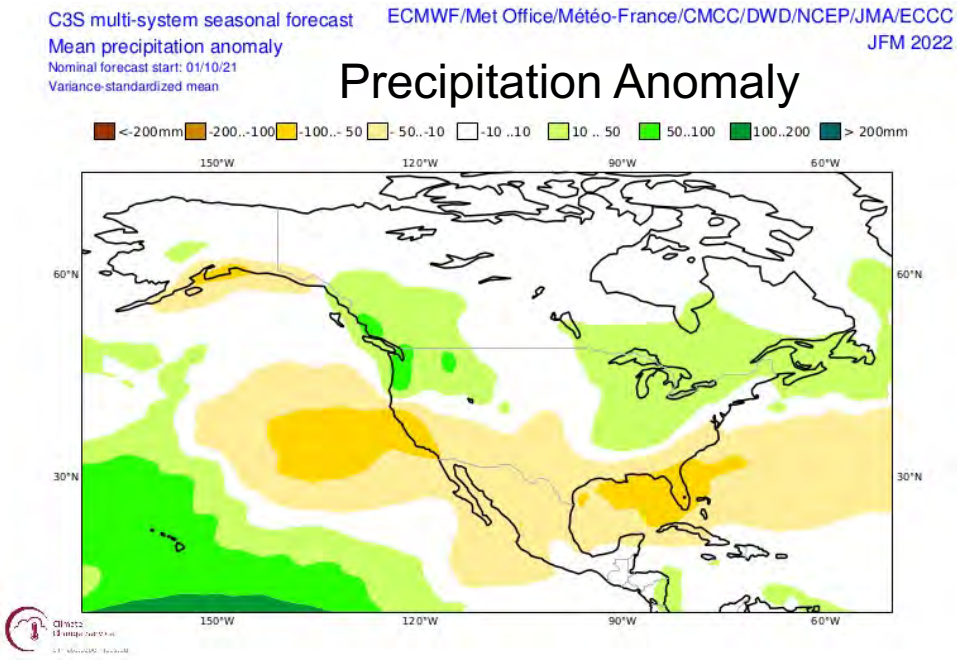


Precipitation Anomaly



500 hPa
Z Anomaly
Jan-Mar



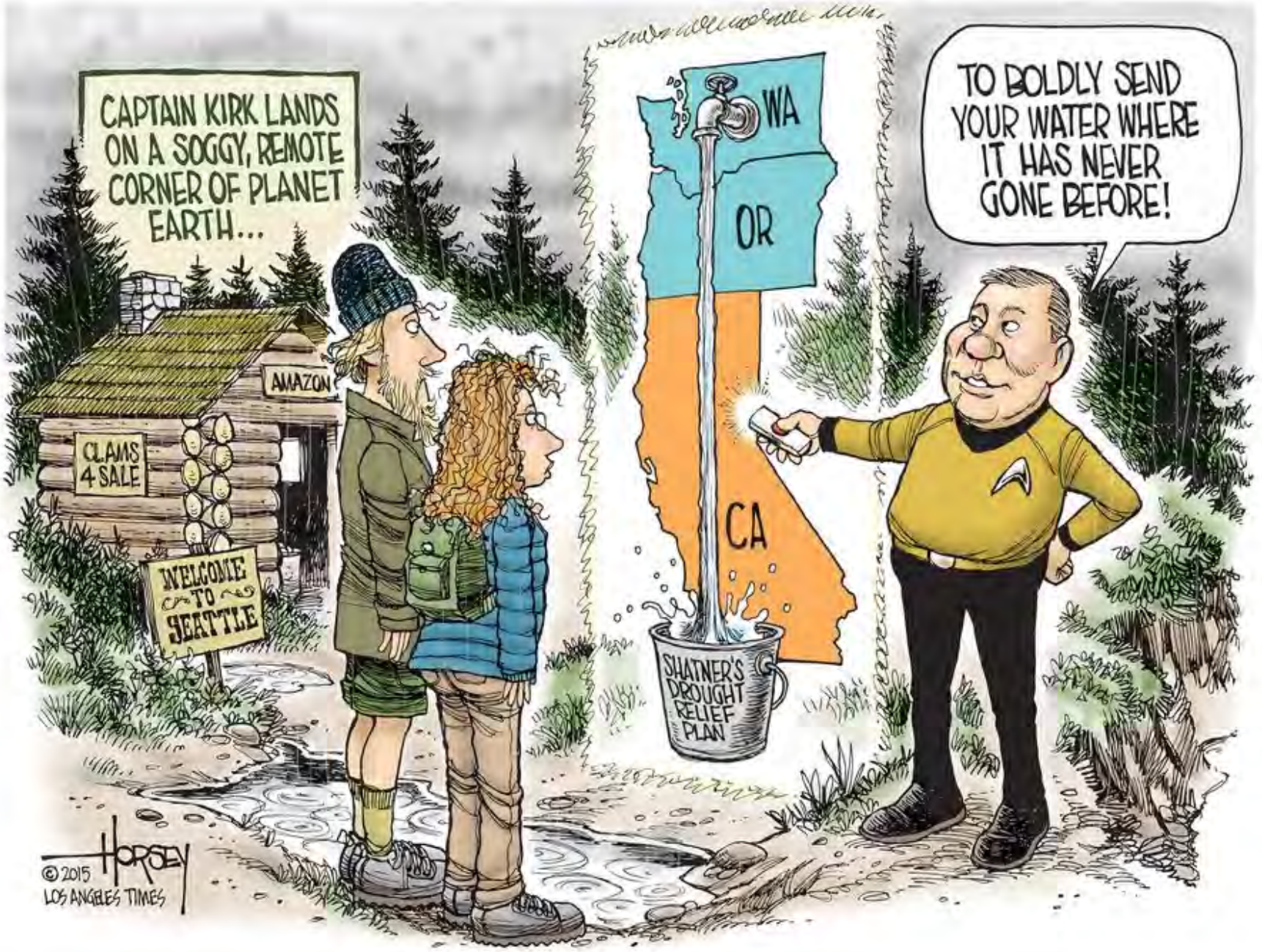


How are the upcoming fall and winter seasons liable to play out?

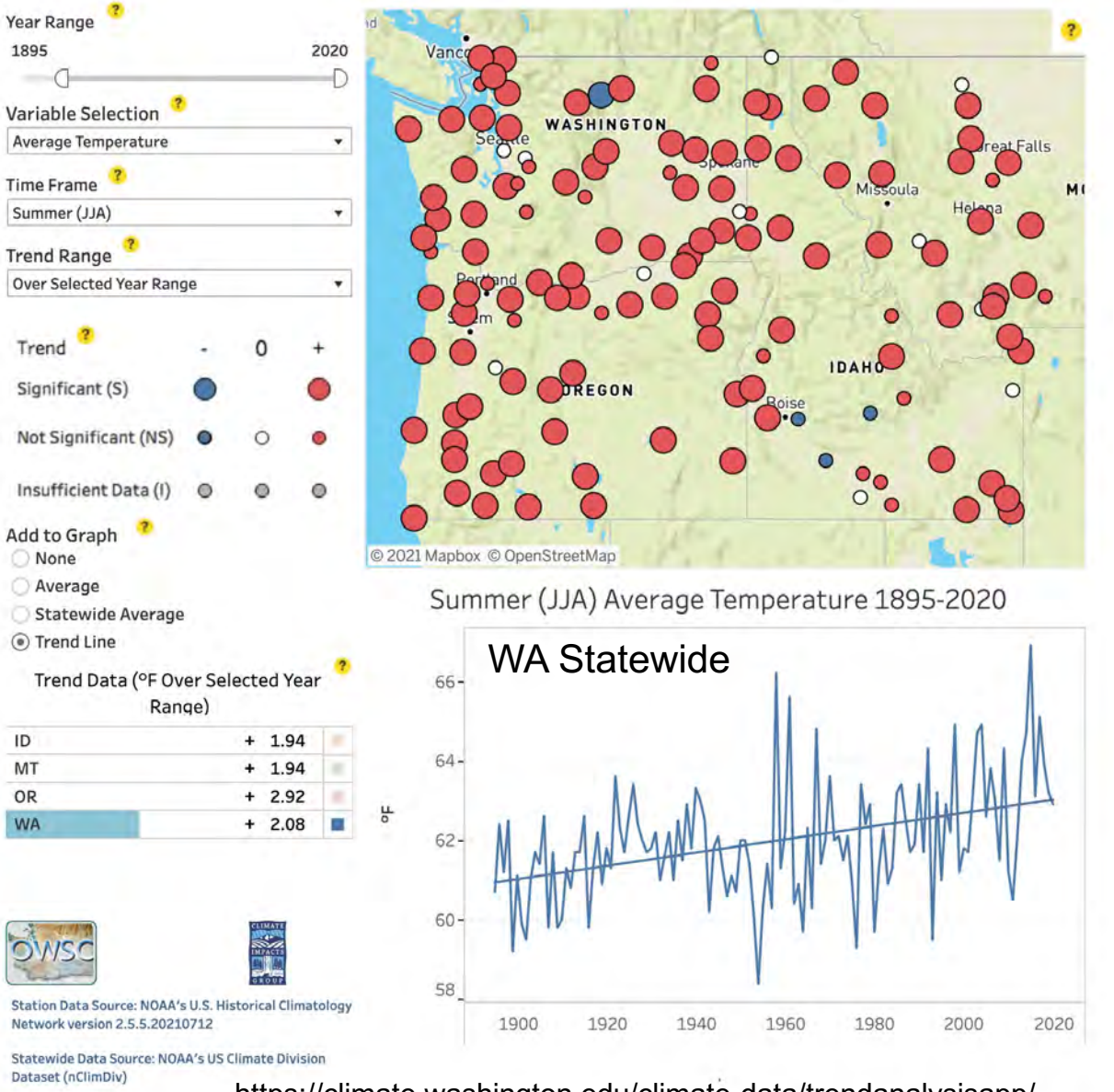
- Floods – High probability of moderate to major flooding in watersheds with west and northwest facing slopes
- Windstorms – Slightly higher odds than usual (there always is the ***possibility of an intense storm***)
- Cold-air Outbreaks – More likely than in the historical record; extremely low temperatures are not expected
- Fog/Air Pollution – Decreasing long-term trend, but pollution events occur virtually every winter
- End of Season Snowpack – Probably more than in most years during the last decade or two

Final Remarks

- By one measure, the heat wave of 2021 was on the order of a 1000-year event for the Pacific NW, and based on accepted methods involving extreme events, it was made much more likely by climate change.
- Low minimum temperatures in winter are becoming less severe and frequent; minimum temperatures in summer are rising
- Winter precipitation is liable to increase (but is not yet evident in the observations); flooding from many mountain watersheds appears to be increasing
- Summer rainfall has declined over the last few decades, which may represent a harbinger of climate change
- Our challenges are liable to be associated with the timing versus the overall amounts of available water in the Pacific NW as a whole and SW WA in particular.


CAPTAIN KIRK LANDS ON A SOGGY, REMOTE CORNER OF PLANET EARTH...
AMAZON
CLAMS 4 SALE
WELCOME TO SEATTLE
WA
OR
CA
SHATNER'S DROUGHT RELIEF PLAN
TO BOLDLY SEND YOUR WATER WHERE IT HAS NEVER GONE BEFORE!
HORSEY
© 2015 LOS ANGELES TIMES

Summer Temperature Trends



https://climate.washington.edu/climate-data/trendanalysisapp/

Questions?

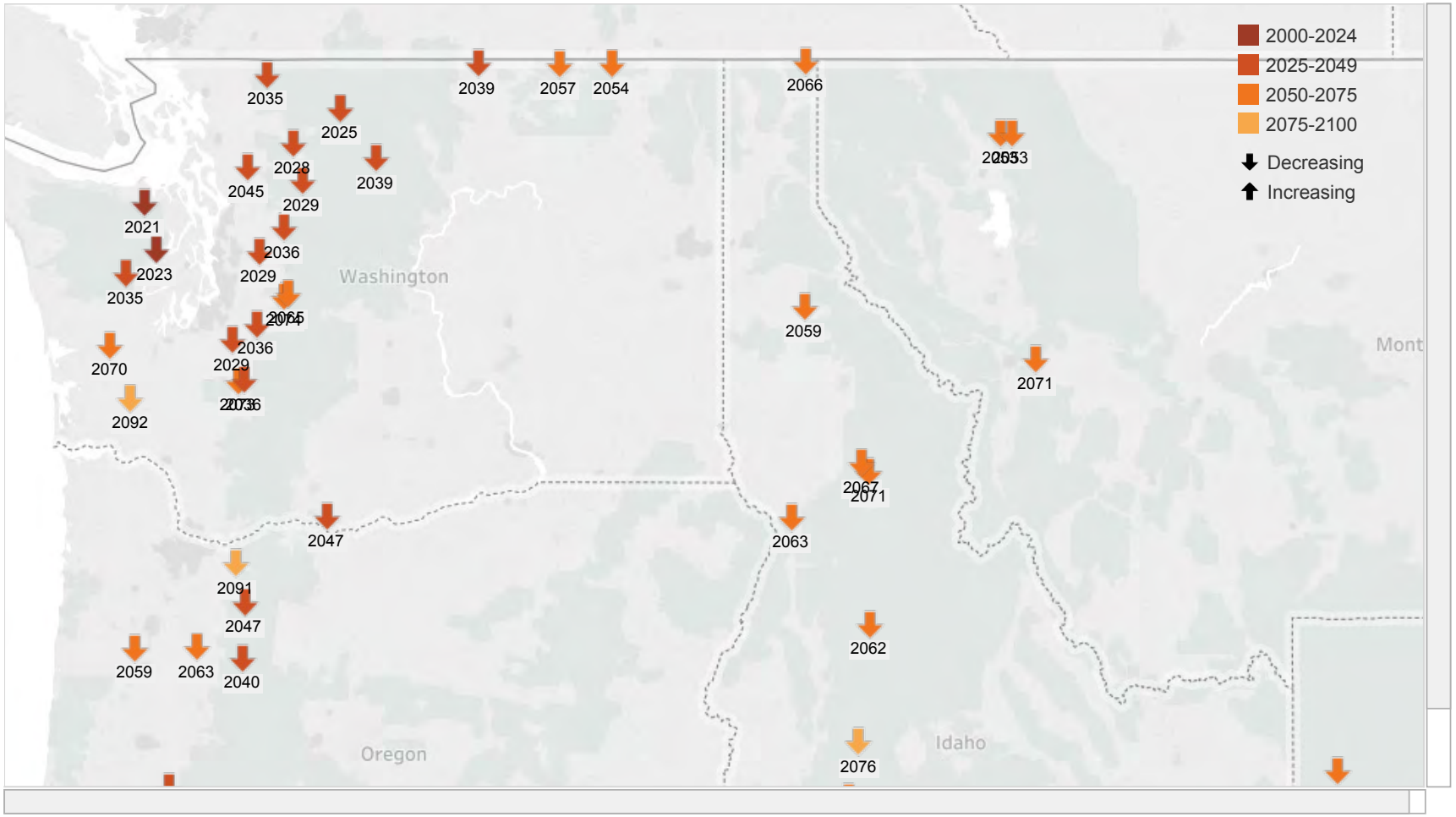
- OWSC website: www.climate.washington.edu
- email: climate@atmos.washington.edu
- Newsletter: www.climate.washington.edu/newsletter

- phone: 206-543-3145 (Karin)
- phone: 206-525-7363 (Nick)

Climate Change Time of Emergence for the Pacific Northwest

When is the earliest change expected for monthly streamflow metrics?

Total Streamflow



Choose Streamflow Metric:
- ○ Maximum Daily Streamflow
- ◉ Total Streamflow

Dataset
- ○ CMIP3
- ◉ CMIP5

Emissions Scenario
- ◉ High Emissions
- ○ Low Emissions

Resilience
- ◉ Less resilient
- ○ More resilient

Model Agreement
- ○ 25%
- ◉ 50%
- ○ 75%

Month
July
☐ Show history

When will the climate change signal in July streamflow exceed the interannual variability?

CLIMATE IMPACTS GROUP

The 'heat dome'

Occurs when the atmosphere traps hot ocean air like a lid or cap

1 In summer, the **jet stream** (which moves the air) shifts northward

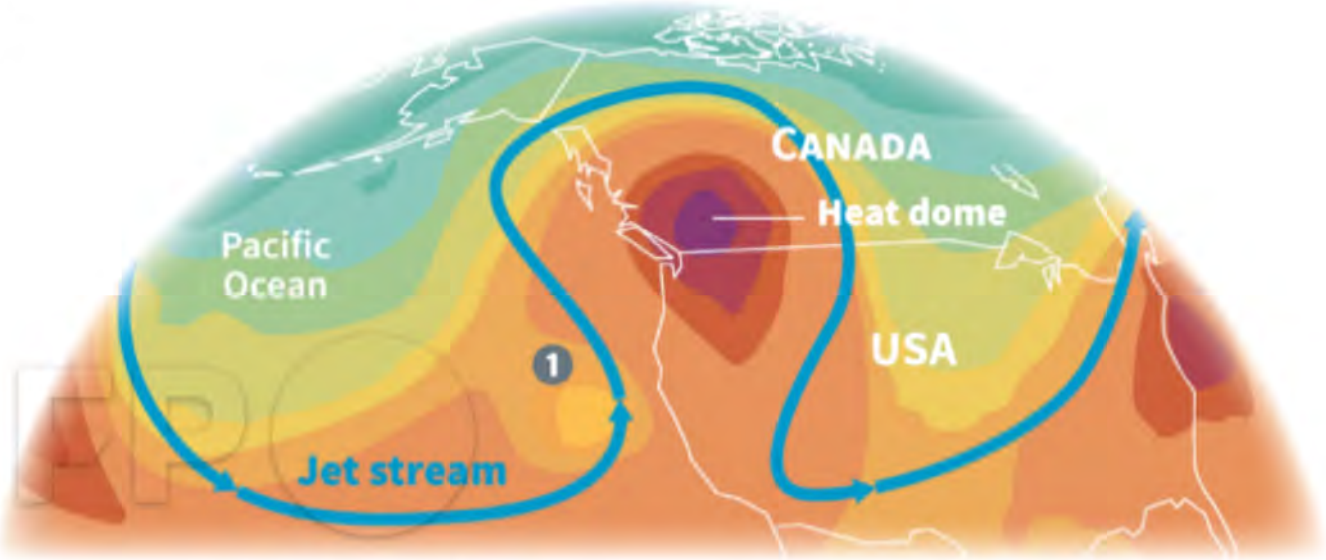
2 **Hot** and stagnant **air expands** upwards

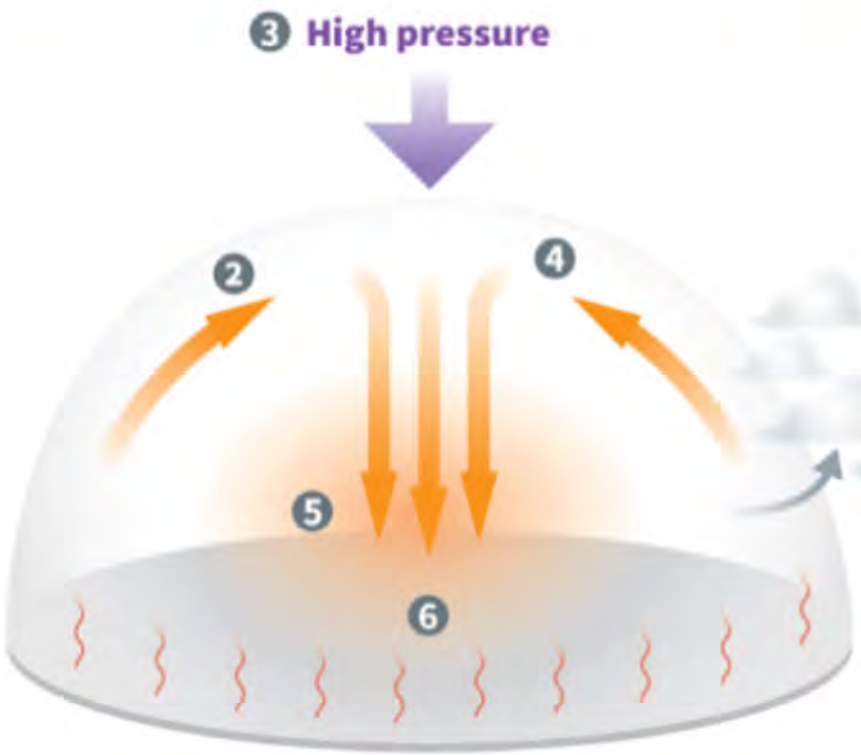
3 Strong and **high-pressure** atmospheric conditions combine with influences from La Nina act like a dome or cap

4 In a process known as **convection,** hot air attempts to escape but high pressure pushes it back down

5 Under the dome, the air sinks and **compresses,** releasing more heat

6 As winds move the hot air east, the jet stream traps the air where it sinks, resulting in **heat waves**





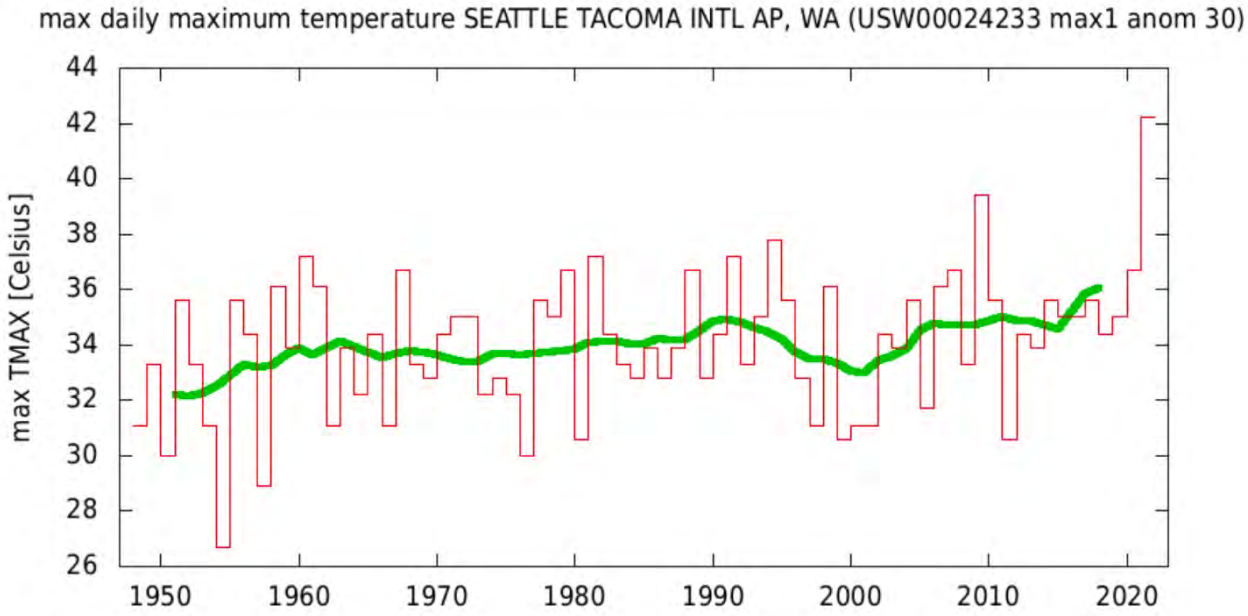
Temperature forecasts (darker color = hotter)

Heat dome also blocks out clouds, which provide some relief from the sun's heat

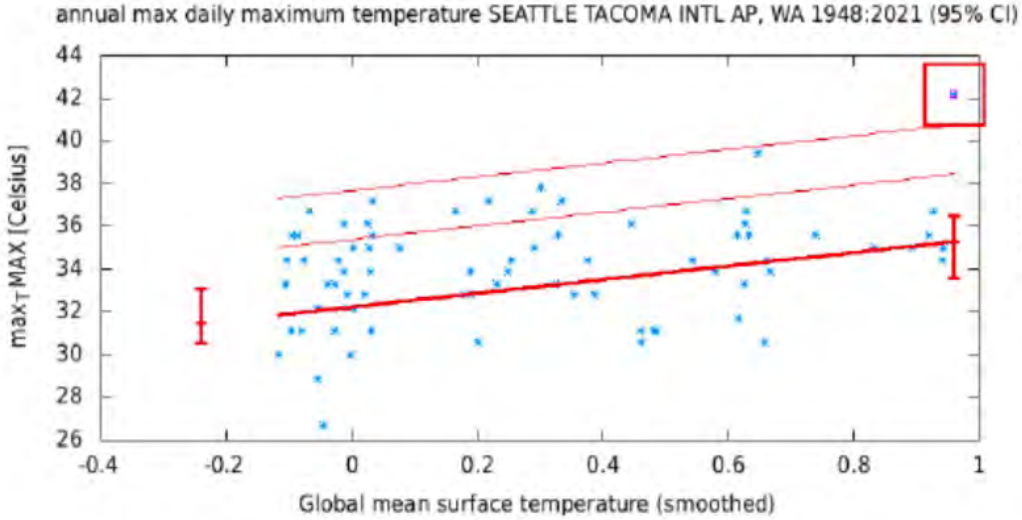
The hotter the temperature is, the stronger the heat dome gets, and vice versa

Source: NOAA/US/Canada medias, experts

AFP



World Weather Attribution
Philip et al. (2021)



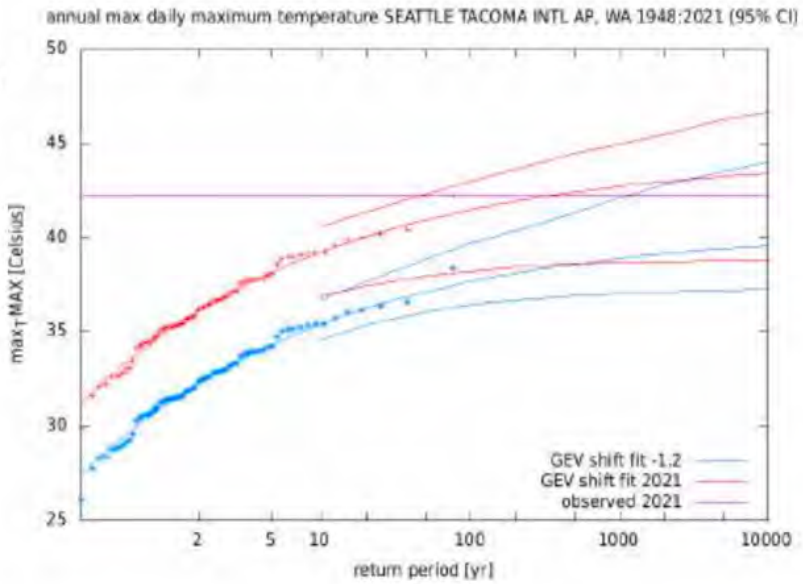
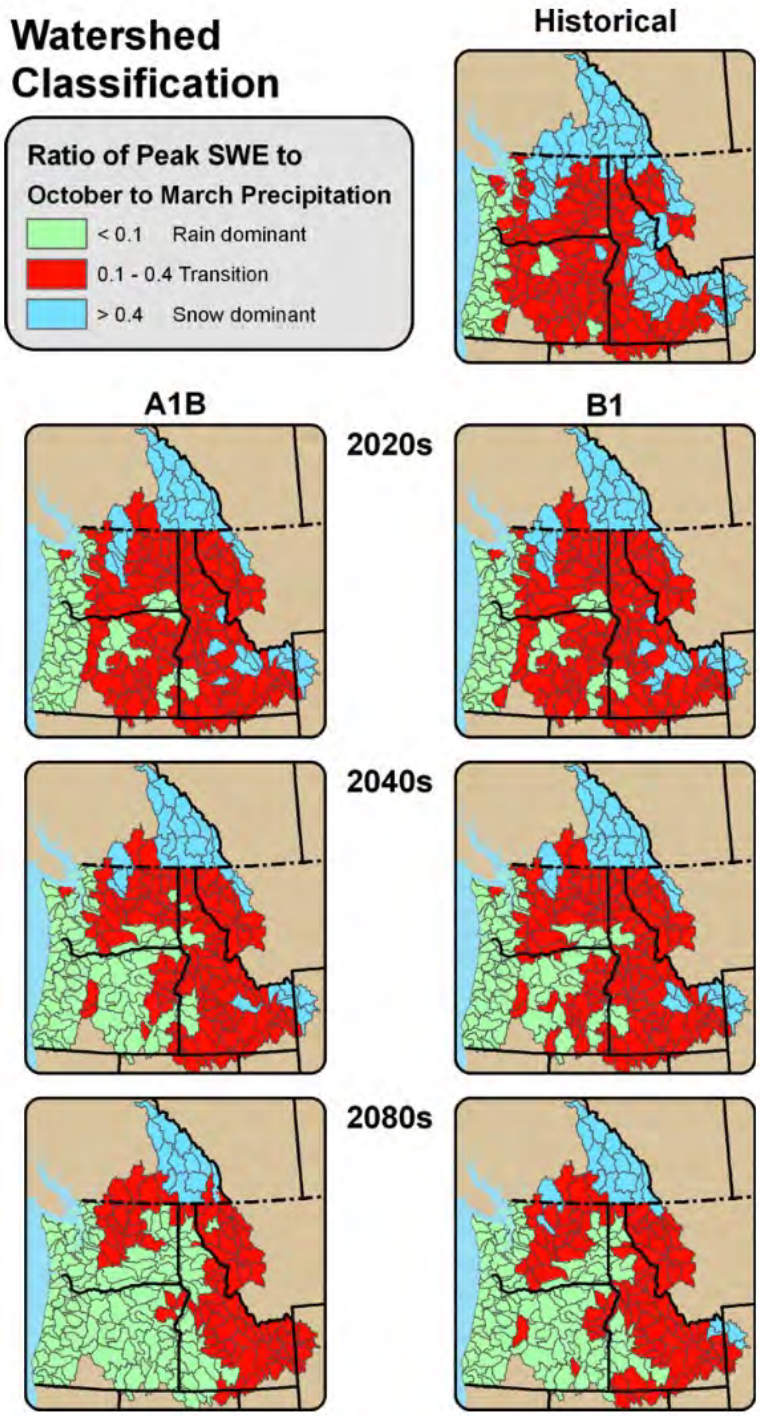


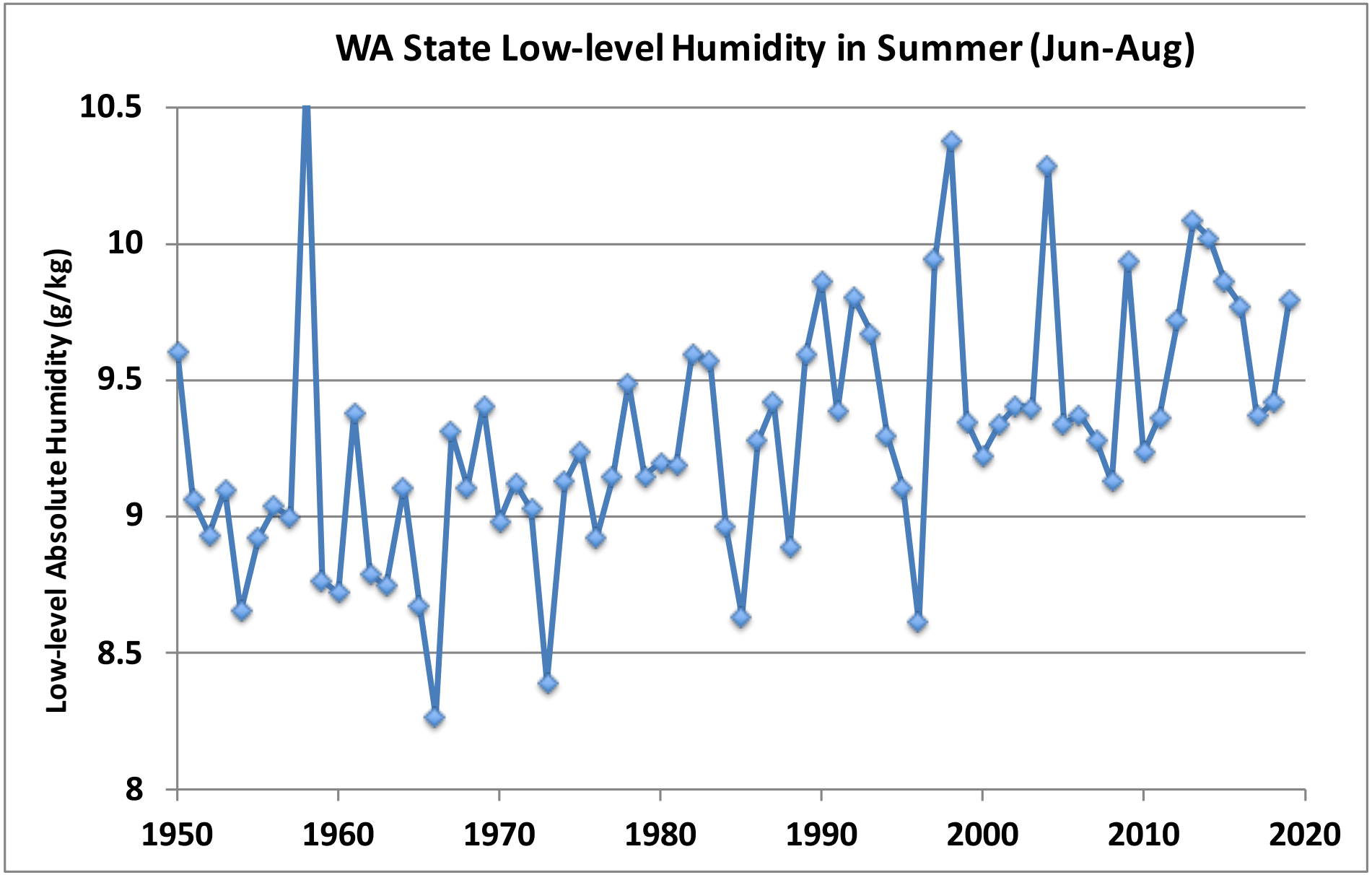
Figure 10: as Figure 9 but for the station data at Seattle-Tacoma International Airport. Source: data GHCN-D, fit: KNMI Climate Explorer.

Excerpt from the “Main Findings” of Philip et al. (2021)

- With this assumption and combining the results from the analysis of climate models and weather observations, an event, defined as daily maximum temperatures (TXx) in the heatwave region, as rare as 1 in a 1000 years would have been at least 150 times rarer without human-induced climate change.
- Also, this heatwave was about 2°C hotter than it would have been if it had occurred at the beginning of the industrial revolution (when global mean temperatures were 1.2°C cooler than today).
- Looking into the future, in a world with 2°C of global warming (0.8°C warmer than today which at current emission levels would be reached as early as the 2040s), this event would have been another degree hotter. An event like this – currently estimated to occur only once every 1000 years, would occur roughly every 5 to 10 years in that future world with 2°C of global warming.



Tohver et al. 2014


WA State Low-level Humidity in Summer (Jun-Aug)
Low-level Absolute Humidity (g/kg)
10.5
10
9.5
9
8.5
8
1950
1960
1970
1980
1990
2000
2010
2020

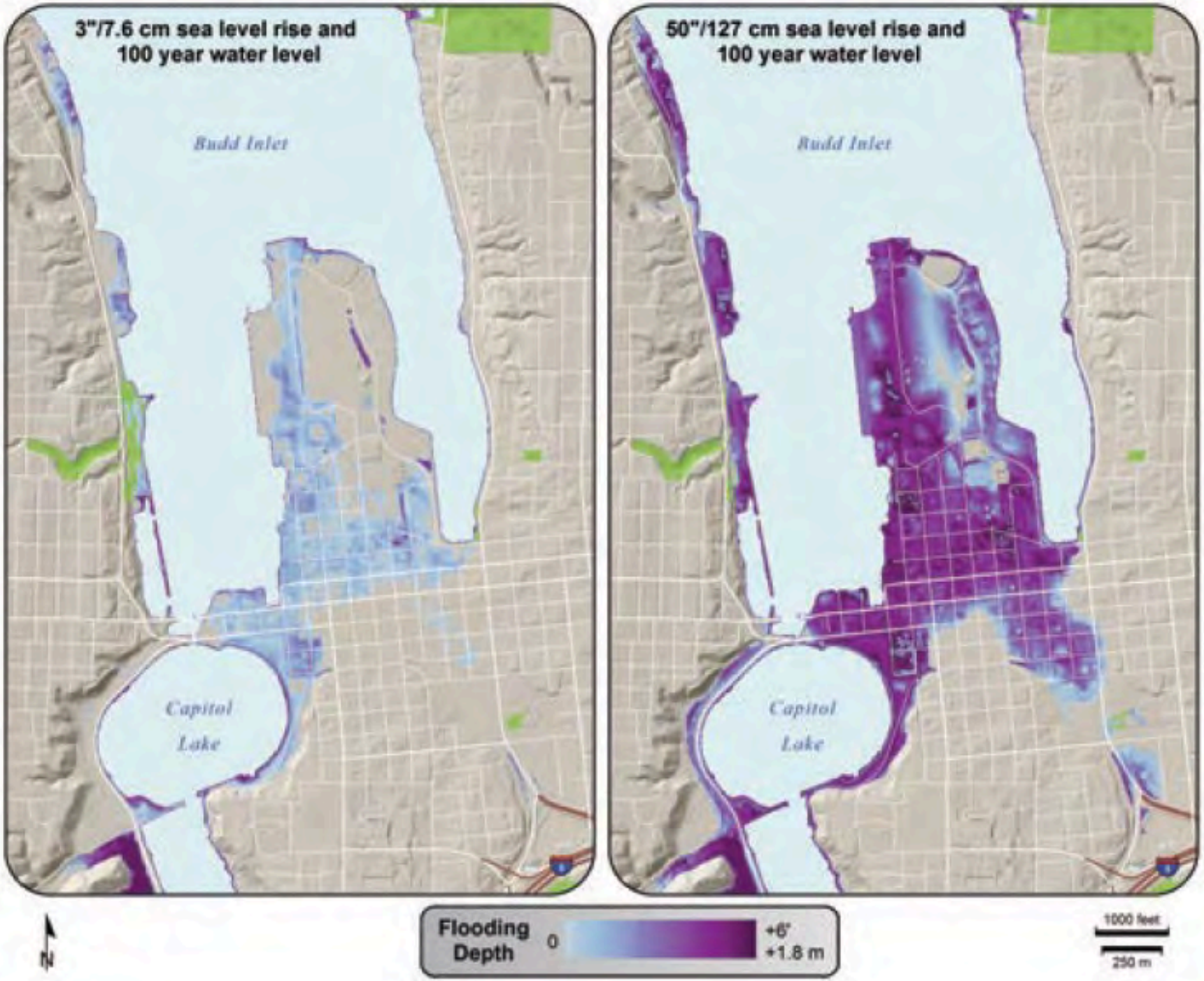
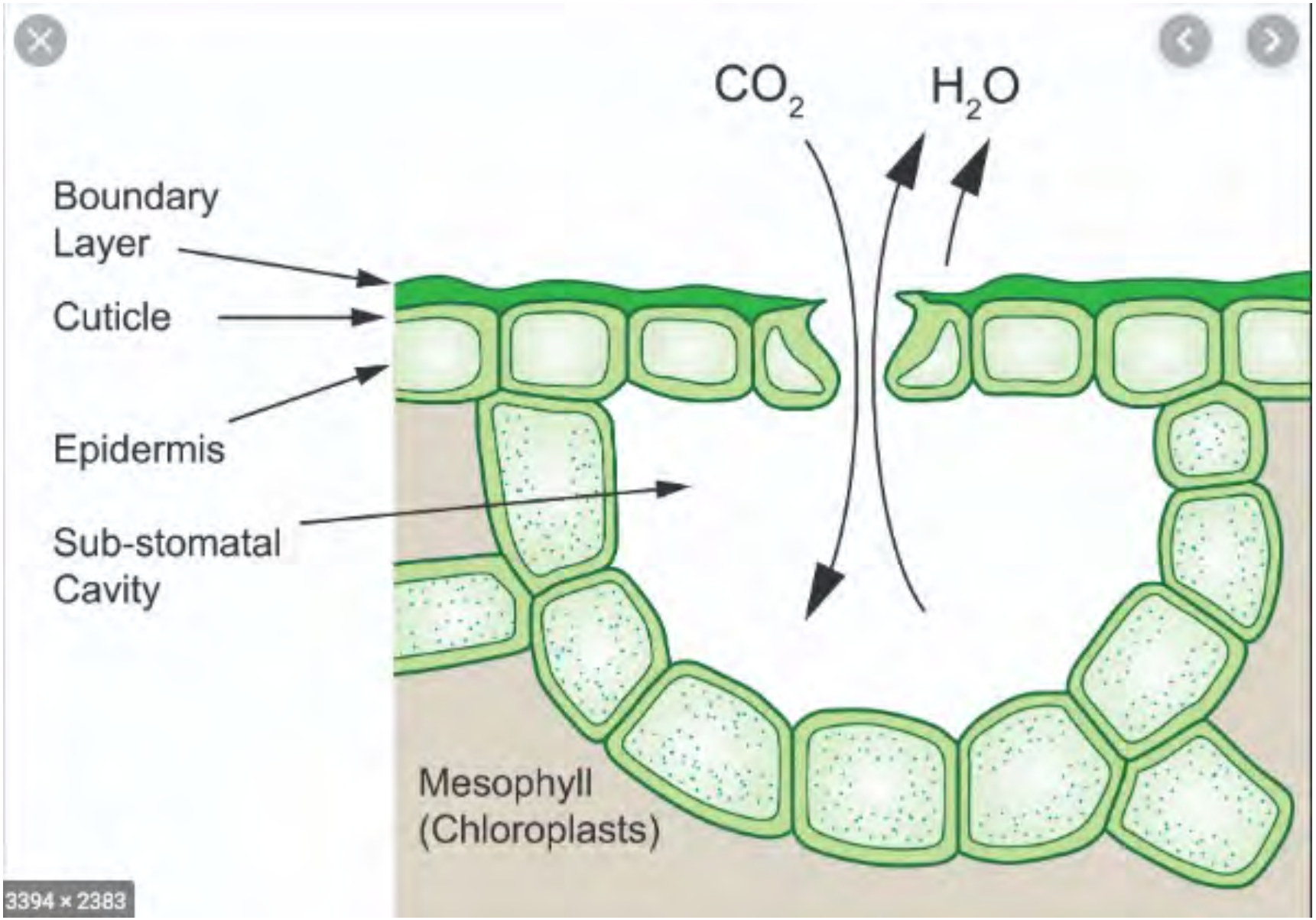

3"/7.6 cm sea level rise and
100 year water level
Budd Inlet
Capitol
Lake
50"/127 cm sea level rise and
100 year water level
Budd Inlet
Capitol
Lake
Flooding
Depth
0
+6'
+1.8 m
N
1000 feet
250 m

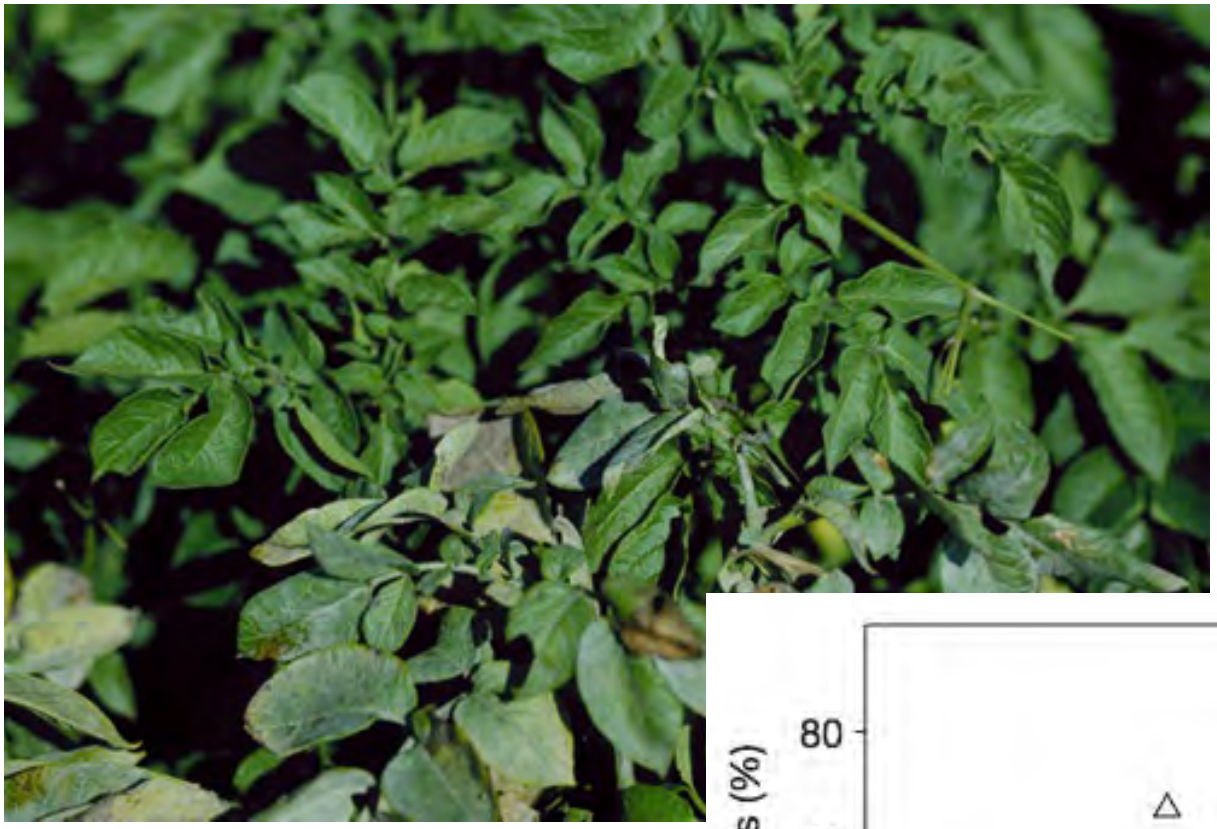
Table 2–1. Factors, Including Changes in Climate and Atmospheric Conditions, Potentially Affecting Future Agricultural Water Demands

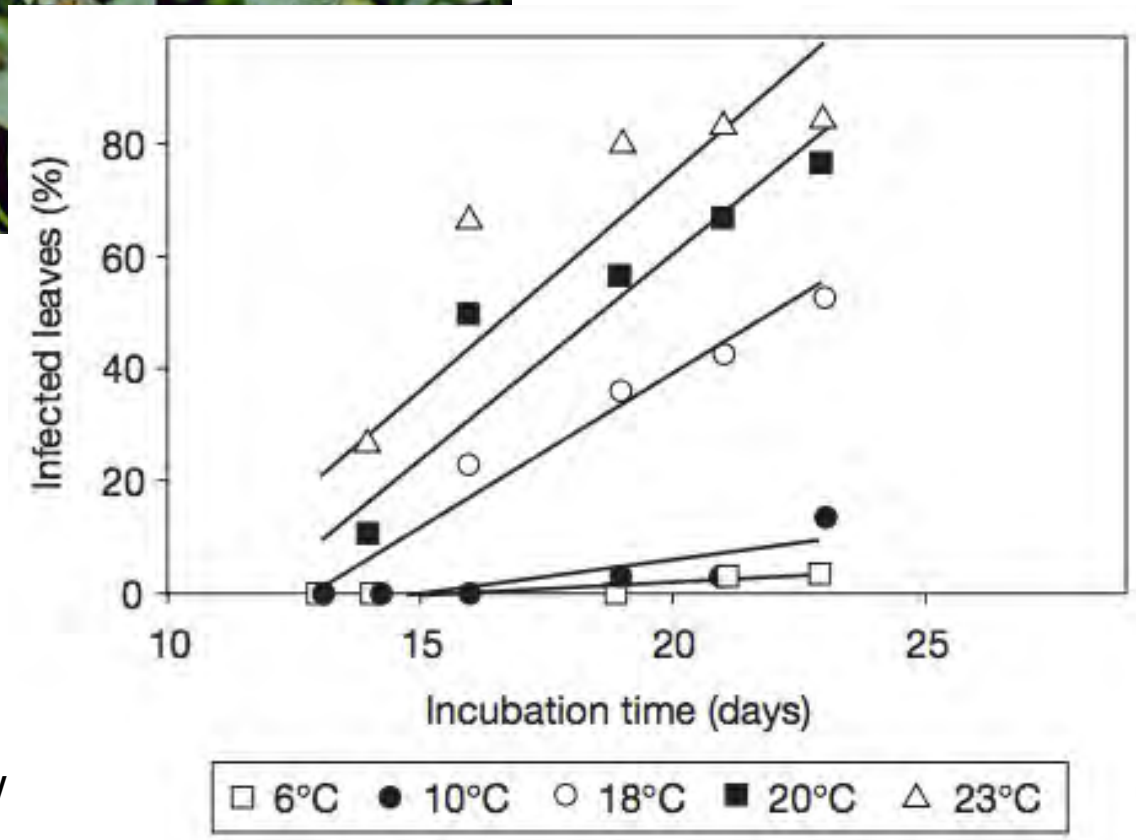
Factors Increasing Demand	Factors Reducing Demand	Factors With Unknown Effects
Increased evaporation and evapotranspiration due to temperature increase.	Reduced losses of agricultural water through improvements to delivery practices and facilities.	Changes in the types and characteristics of crops grown.
Increased evapotranspiration due to extended growing seasons.	Less per-unit crop water use associated with increased atmospheric CO_2 and ozone.	Changes in agricultural management practices (e.g., more dry-year fallowing or deficit-irrigation cropping).
Increase in lands requiring supplemental irrigation to remain viable.	Increased crop failure due to increased pests, diseases, etc.	Transfers of water between different uses.
Increase in irrigated lands due to northward warming.	Conversion of irrigated cropland to other less water-intensive uses.	Effects on the surface energy balance from factors other than temperature.
Increased livestock water demands.		
Increased total crop yield associated with increased atmospheric CO_2.		

Stomata closing with higher CO2 concentrations means less water loss (transpiration) from some kinds of plants



Powdery Mildew

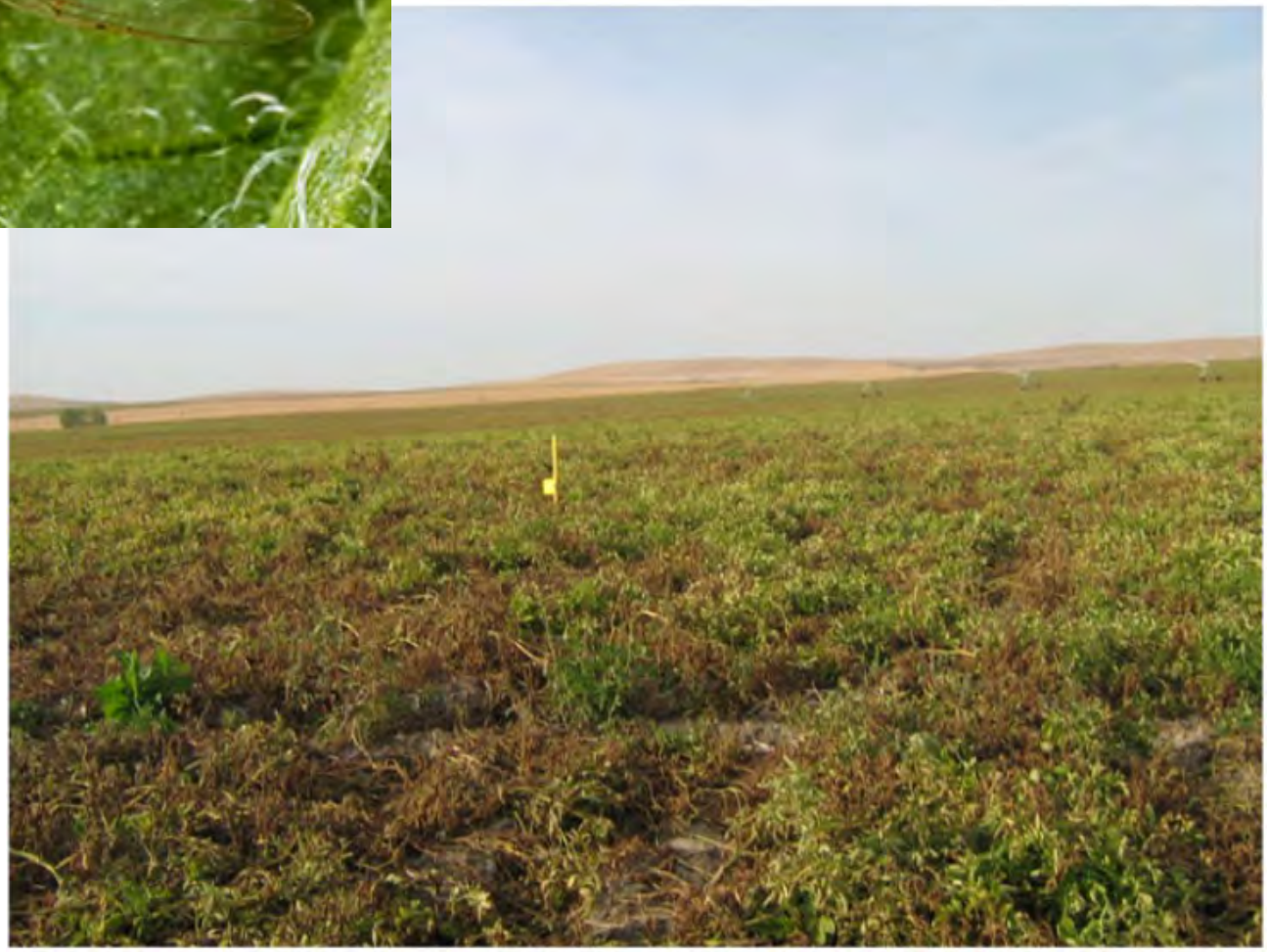




Infection Rates for Grapevine Powdery Mildew

Potato Psyllids and Zebra Chip

Survival of psyllids reduced during cold winters – Will changes in climate allow them to extend their range?



Implications for Growers

- Longer growing season and fewer winter freezes will benefit many crops (but could increase pests, weeds, diseases)
- Increasing CO_2 may increase productivity in some crops
- **Key**: water supply

- "Projections for potatoes indicate significant yield declines due to warming, with losses of 9%, 15%, and 22% for the 2020, 2040, and 2080 scenarios respectively... with elevated CO2 assumed to have a low beneficial impact on growth and yields, compensating for losses only at temperature increases of 2.5 C or lower."
  – Stockle et al. (2010)