Northwest **Power** and **Conservation** Council

October 8, 2019

MEMORANDUM

TO: **Council Members**

FROM: **Stacy Horton, Washington Policy Analyst/Biologist**

SUBJECT: **Water Resources in the Pacific Northwest as Related to Marine Heat Waves, El Nino, and Climate Change**

BACKGROUND:

Presenter: Washington State Climatologist Nick Bond is a senior research scientist with the Joint Institute for the Study of Atmosphere and Ocean (JISAO) at the University of Washington (UW) and also is an affiliate associate professor with the Department of Atmospheric Sciences at UW. His research is on a broad range of topics with a focus on the weather and climate of the Pacific Northwest, and the linkages between the climate and marine ecosystems of the North Pacific.

Summary: This presentation will review the precipitation, snowfall and streamflows that accompanied past climate fluctuations such as the Blob, and ENSO events. It will also include discussion of expected changes in streamflows with climate change. It will conclude with an outlook for the winter of 2019-20.

Relevance: The Council is interested in better understanding the effects of climate change. The Fish and Wildlife Program acknowledges the challenge of implementing actions to improve conditions for fish and wildlife while climate change is redefining the very environment around us. The Program recognizes the need to assess and, where necessary, respond to the impacts of climate change, which has the potential to threaten the program's past and ongoing investments in habitat improvements in the Columbia River Basin. The Council continues to encourage, monitor, and promote public awareness of pertinent climate change research and

information and to assess how it should influence program mitigation efforts.

Background: Projected future changes in temperature and precipitation will alter the snow pack, stream flow, and water quality in the Columbia Basin with anticipated impacts that warmer temperatures will result in more precipitation falling as rain rather than snow, with snowpack diminishing, particularly in lower-elevation watersheds, and stream flow timing will be altered. Peak river flows will likely shift to earlier in the spring, and water temperatures will continue to rise. These temperature and hydrologic changes are expected to have a variety of interrelated impacts on aquatic and terrestrial ecosystems in the Columbia River Basin.

February 2015

Water Resources in the Pacific NW as Related to Marine Heat Waves, El Nino and Climate Change

Regional Connections

Climate Change Projections

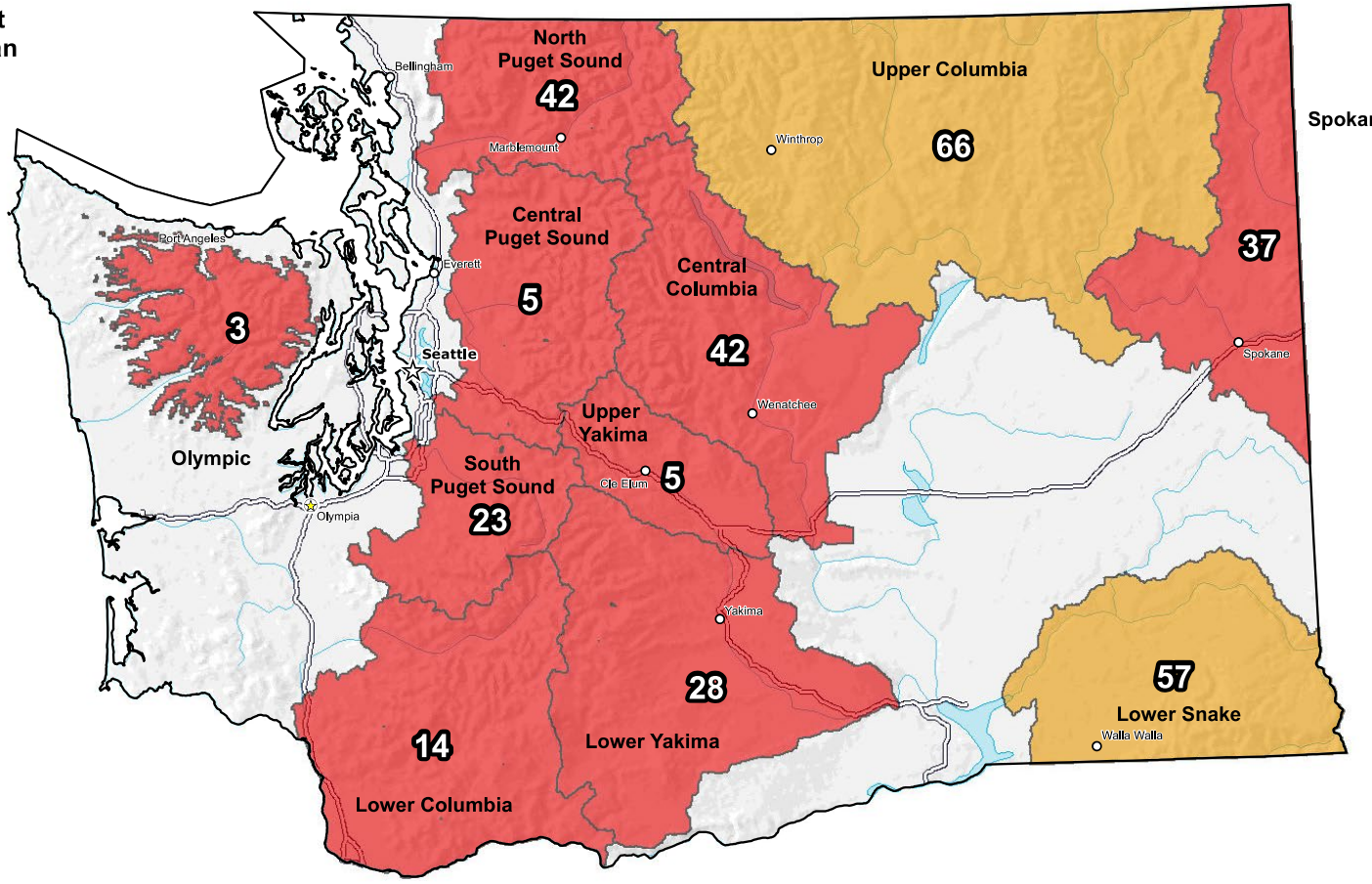
Apr 01, 2015

Snow Water
ent (SWE)
ride Percent
-2010 Median

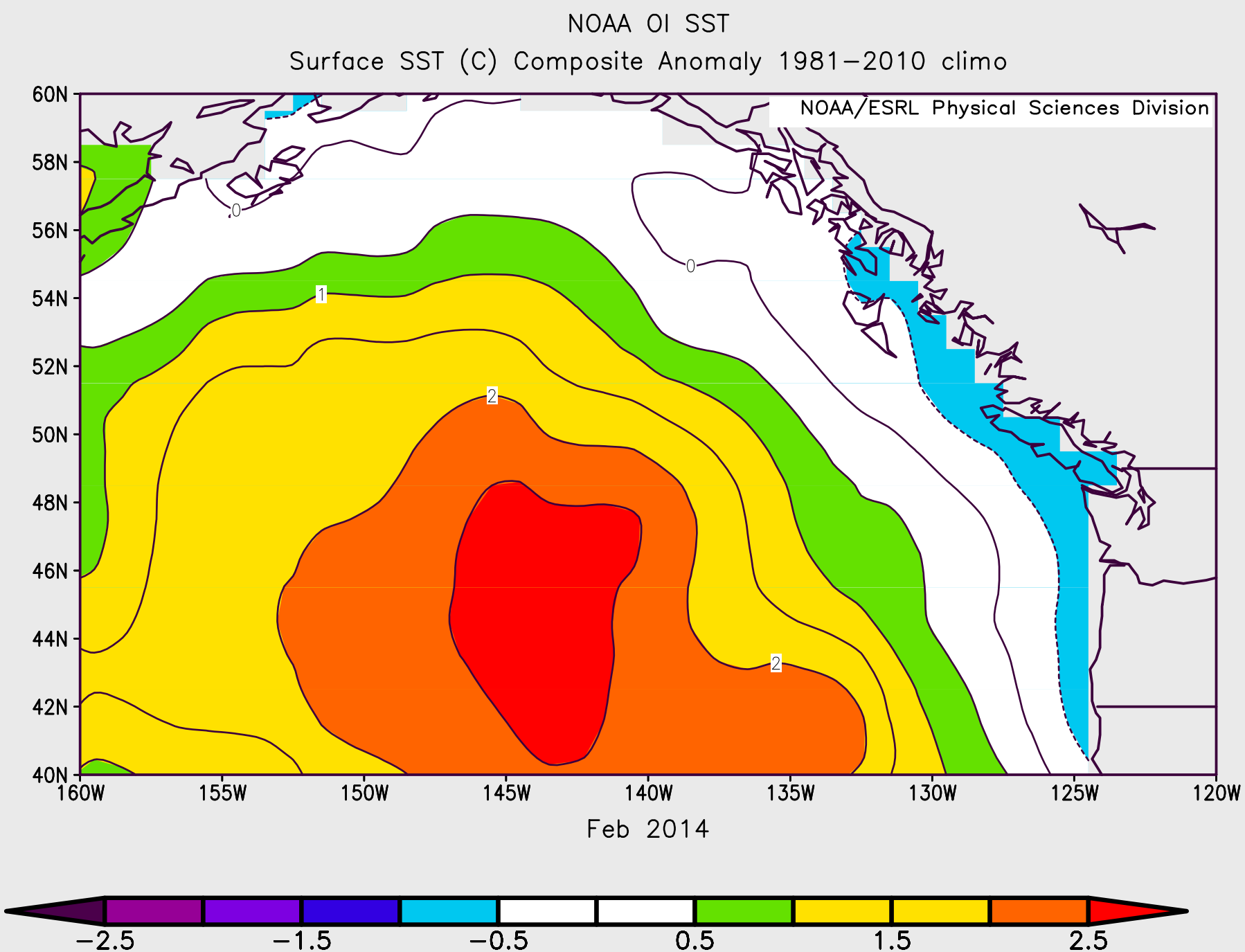
navailable *
50%
0 - 69%
0 - 89%
0 - 109%
10 - 129%
30 - 149%
=150%

ailable at time
or measurement
esentative at this
ar

al Data
o Revision



pared to the average value for those sites on this day. Data based on
the first reading of the day (typically 00:00).


NOAA OI SST
Surface SST (C) Composite Anomaly 1981–2010 climo
NOAA/ESRL Physical Sciences Division
60N
58N
56N
54N
52N
50N
48N
46N
44N
42N
40N
160W
155W
150W
145W
140W
135W
130W
125W
120W
0
1
2
2
0
Feb 2014
−2.5
−1.5
−0.5
0.5
1.5
2.5

INDESCRIBABLE... INDESTRUCTIBLE! NOTHING CAN STOP IT!

THE BLOB

STEVEN McQUEEN

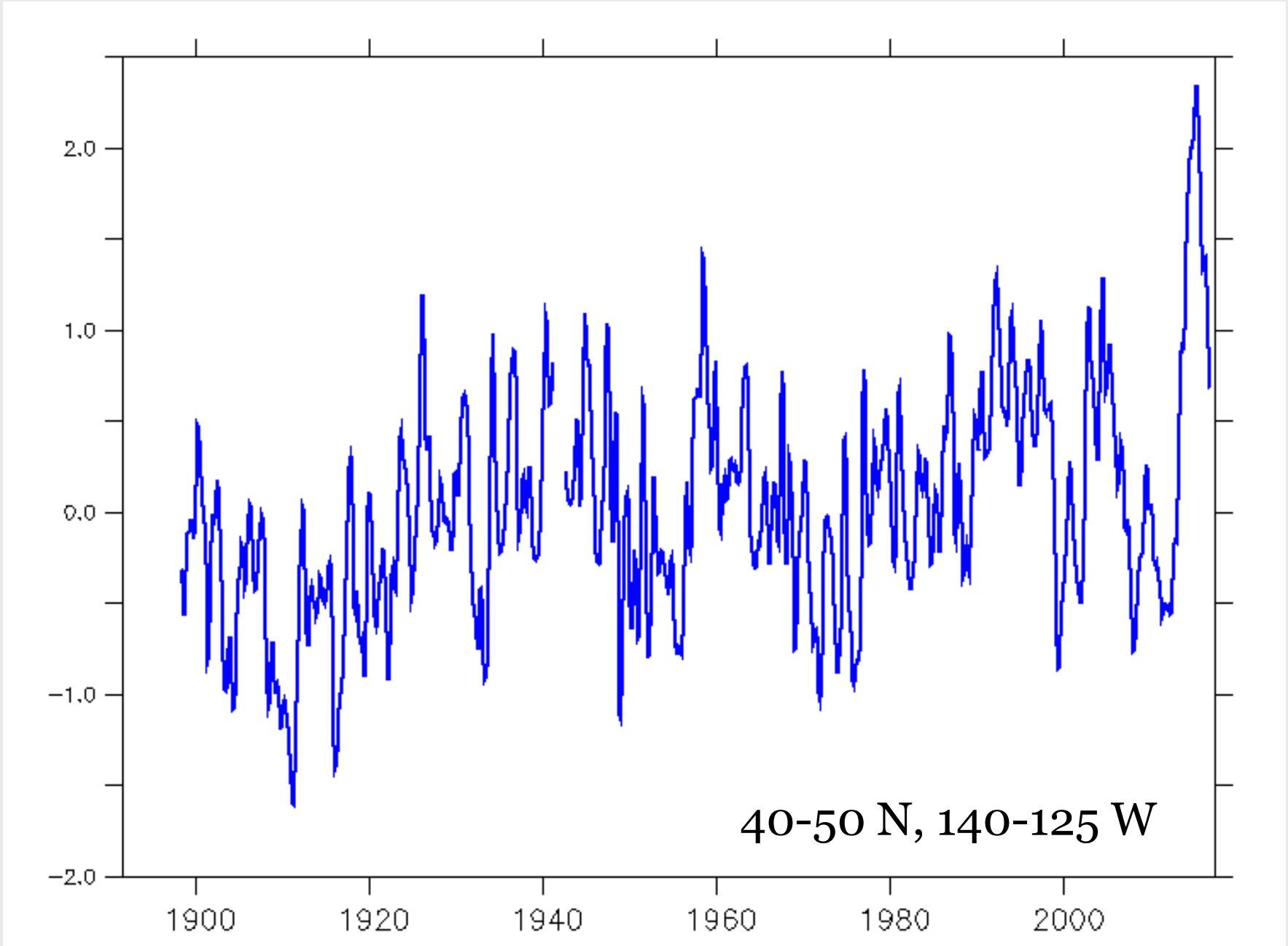
ANETA CORSEAUT · EARL ROWE

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

FROM AN IDEA BY IRVINE H. MILLIGAN

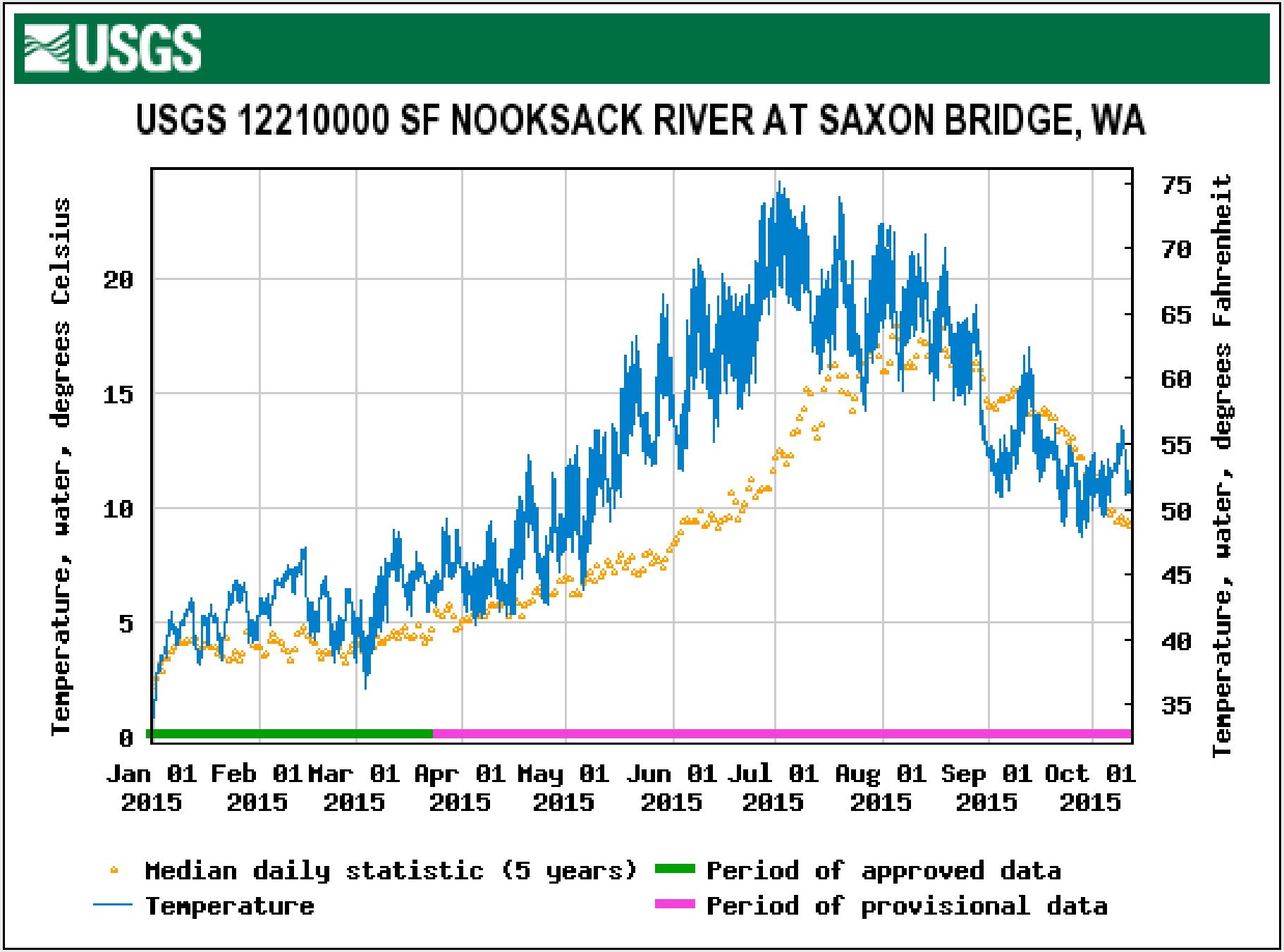
A TONWIN PRODUCTION · COLOR BY DE LUXE

Sea Surface Temperature (SST) Anomalies Offshore the Pacific NW



The Mouth of the White Salmon River in July 2015

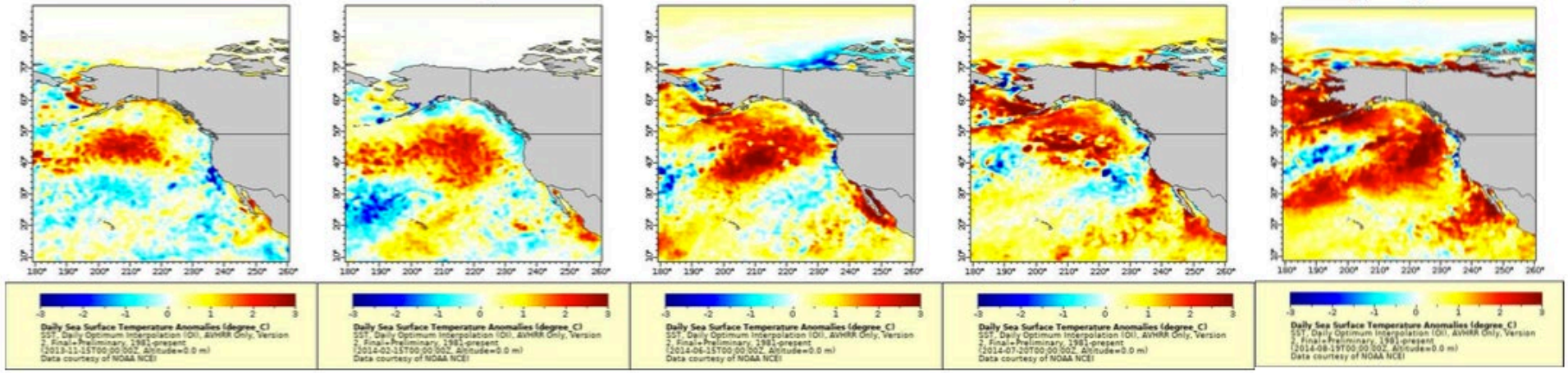
Northwest Power and Conservation Council


USGS
USGS 12210000 SF NOOKSACK RIVER AT SAXON BRIDGE, WA
Temperature, water, degrees Celsius
Temperature, water, degrees Fahrenheit
0
5
10
15
20
35
40
45
50
55
60
65
70
75
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
Oct 01 2015
Median daily statistic (5 years)
Temperature
Period of approved data
Period of provisional data

Current MHW vs. "The Blob": SST anomalies

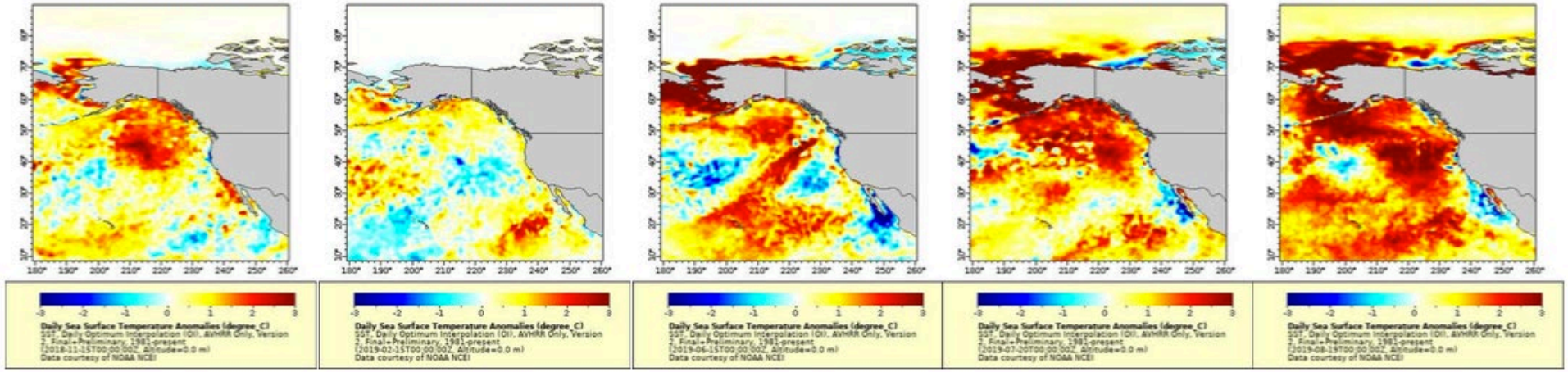
The Blob

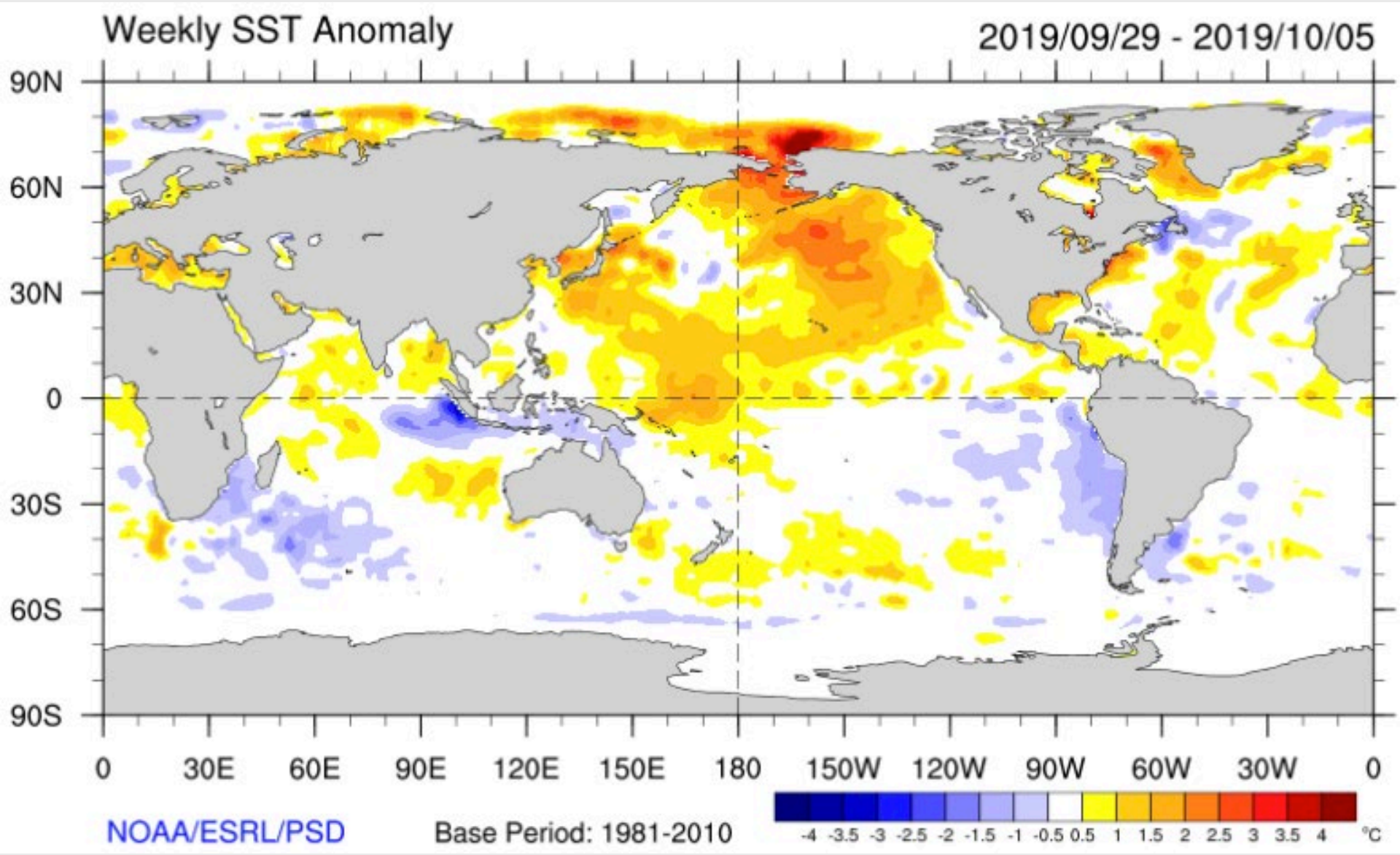
October 2013 | February 2014 | June 2014 | July 2014 | Aug 19, 2014

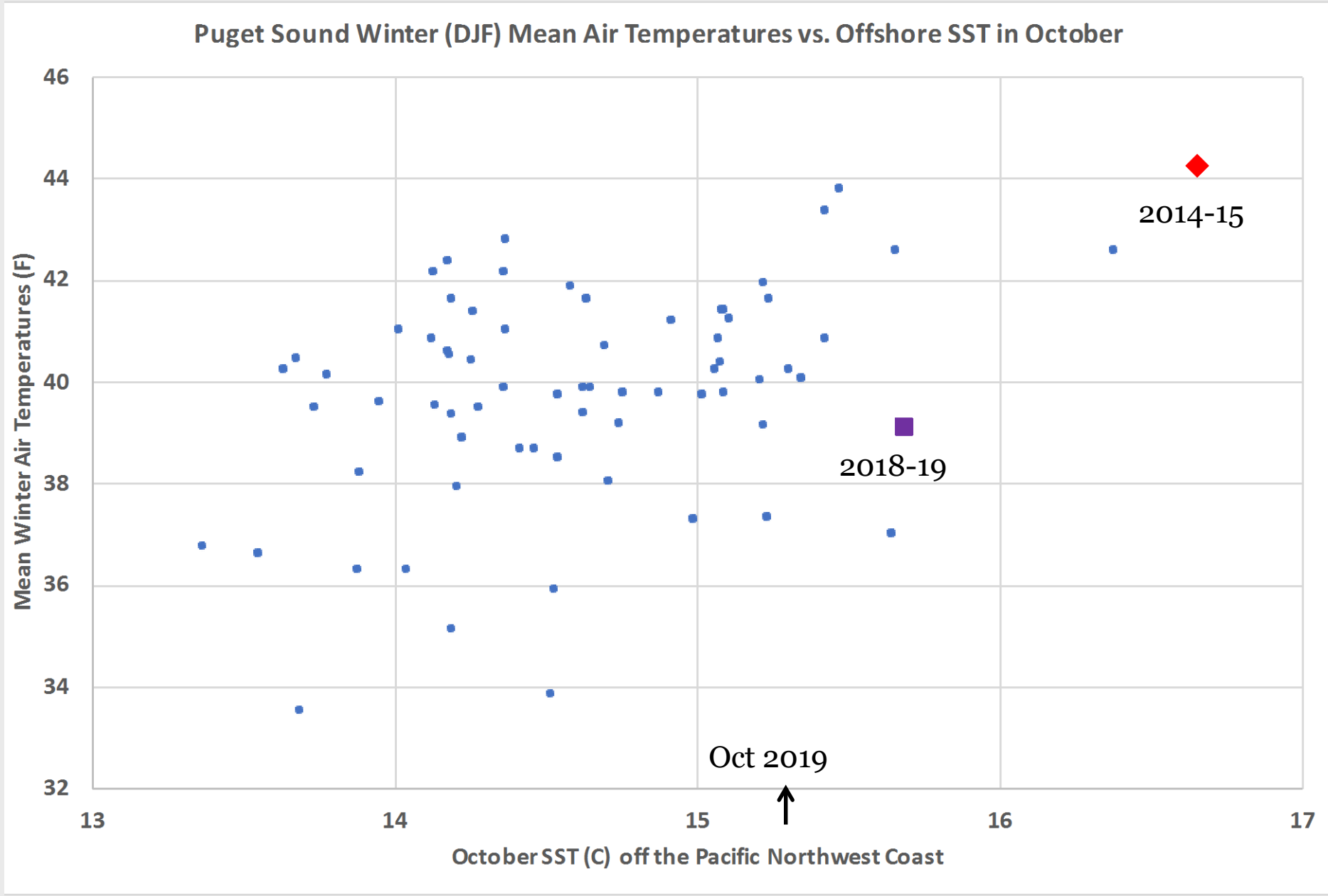


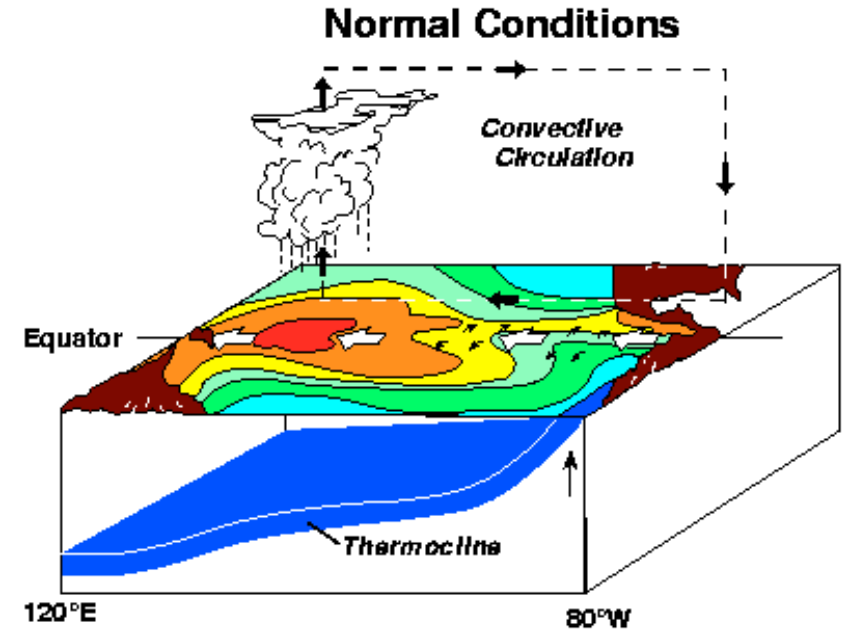
Current MHW

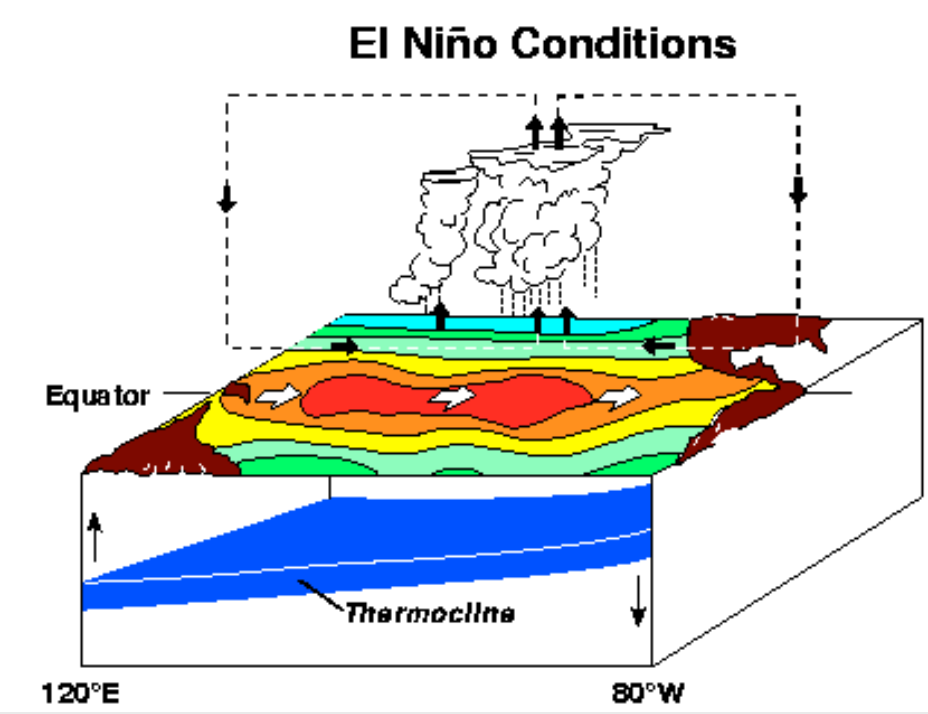
October 2018 | February 2019 | June 2019 | July 2019 | Aug 19, 2019

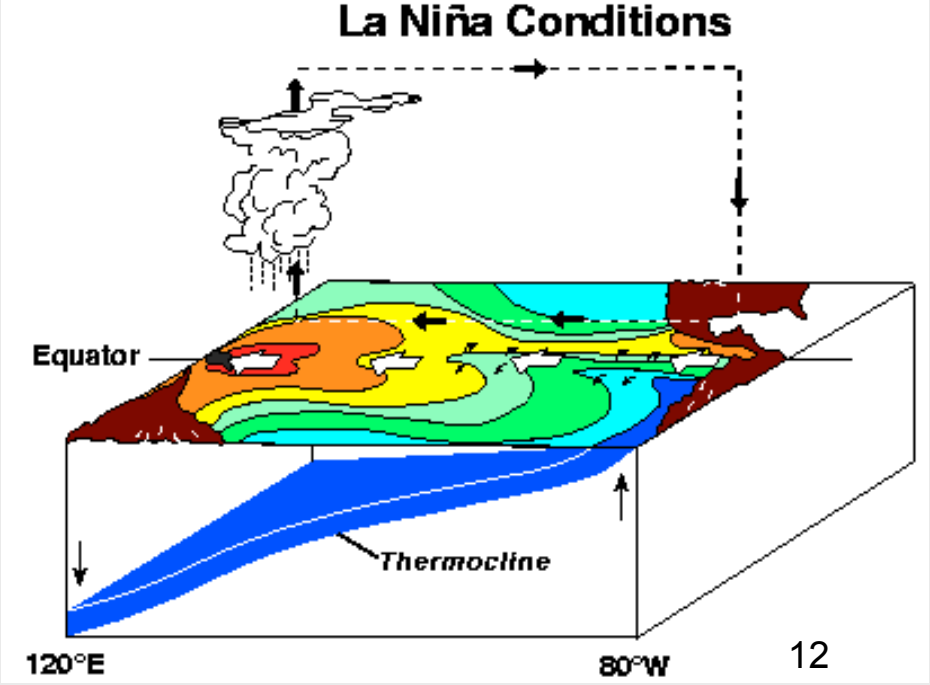


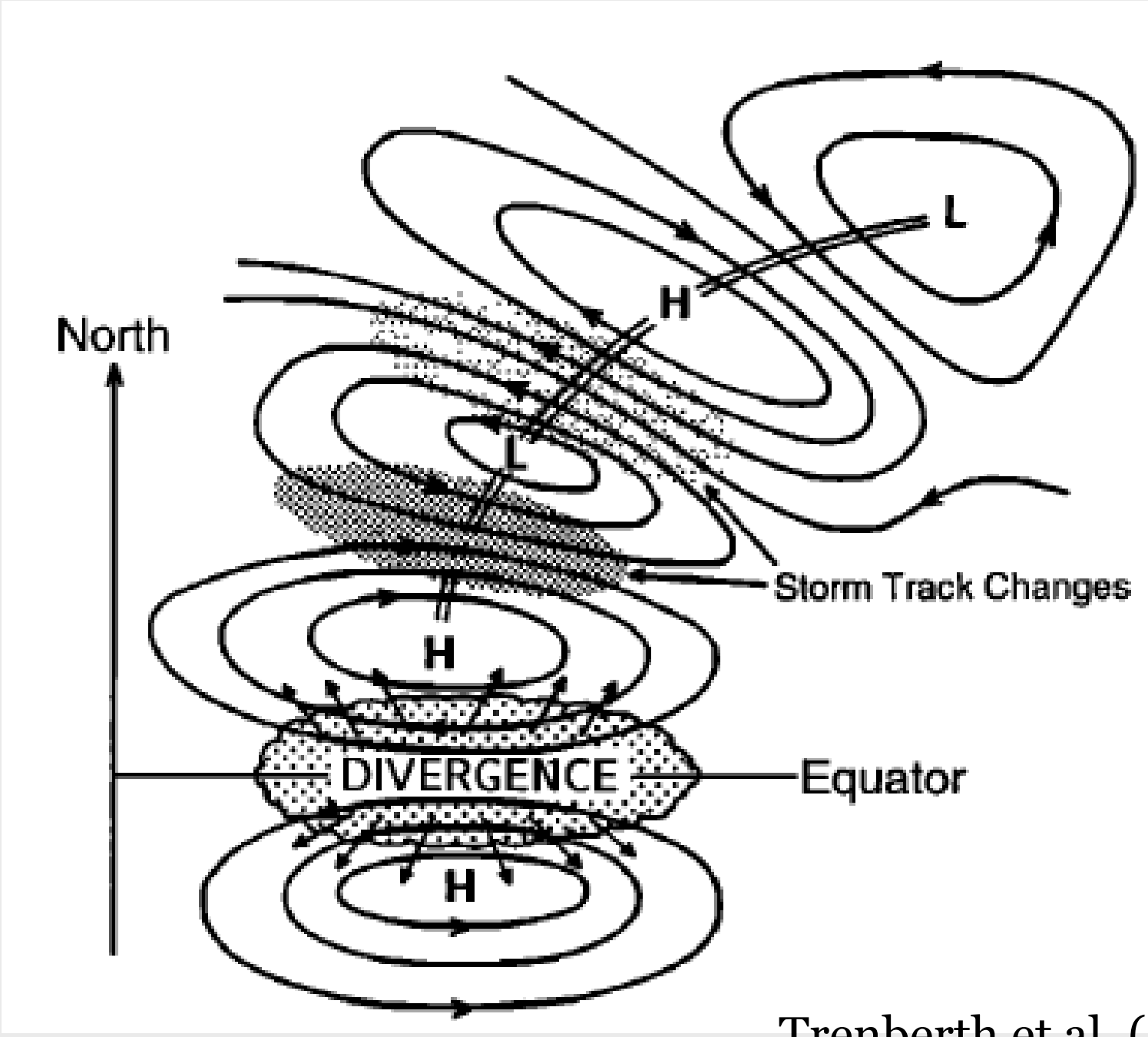

Weekly SST Anomaly
2019/09/29 - 2019/10/05
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
NOAA/ESRL/PSD
Base Period: 1981-2010
-4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0.5 1 1.5 2 2.5 3 3.5 4
°C


Puget Sound Winter (DJF) Mean Air Temperatures vs. Offshore SST in October
Mean Winter Air Temperatures (F)
46
44
42
40
38
36
34
32
13
14
15
16
17
October SST (C) off the Pacific Northwest Coast
2014-15
2018-19
Oct 2019


Normal Conditions
Convective Circulation
Equator
Thermocline
120°E
80°W

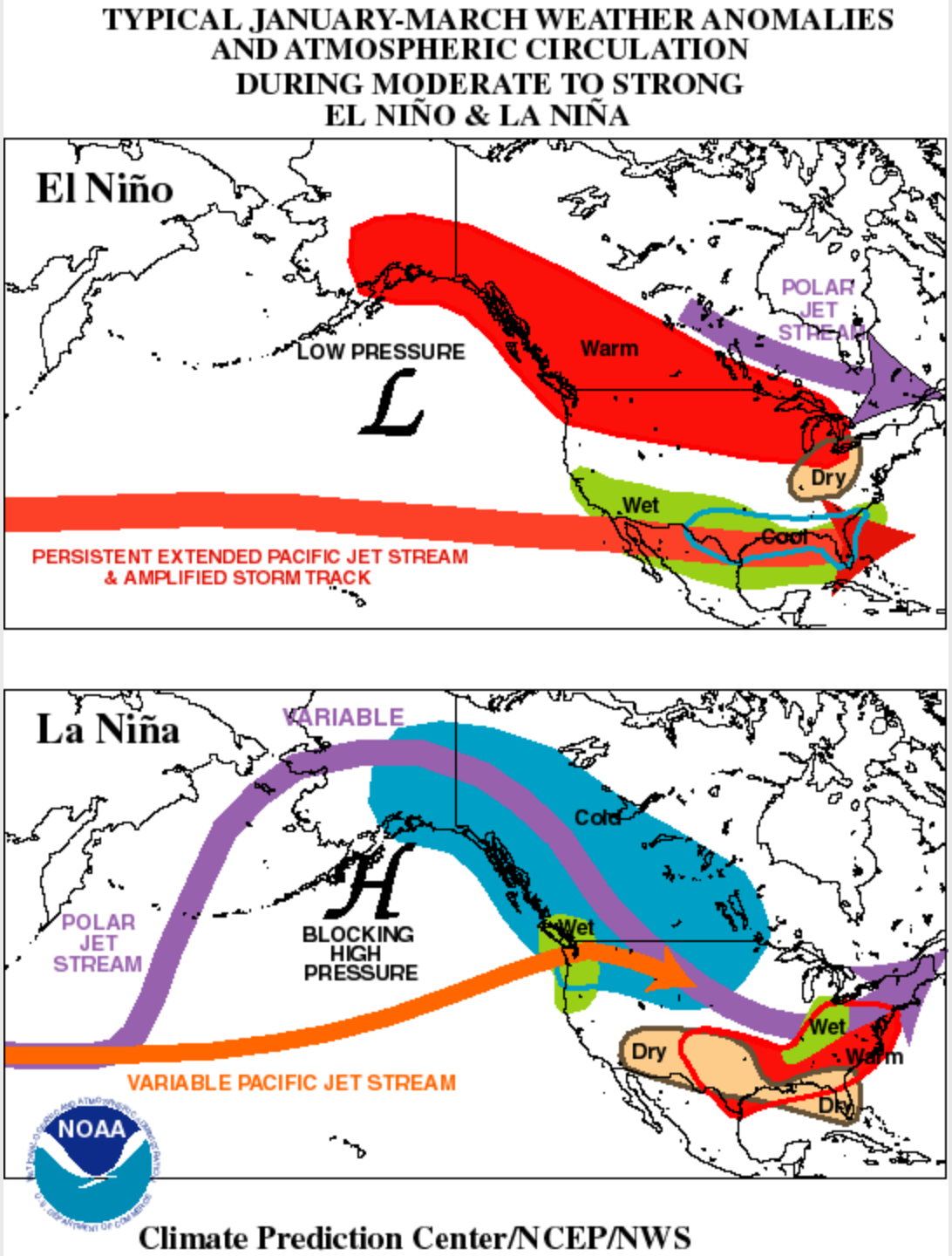

El Niño Conditions
Equator
Thermocline
120°E
80°W


La Niña Conditions
Equator
Thermocline
120°E
80°W

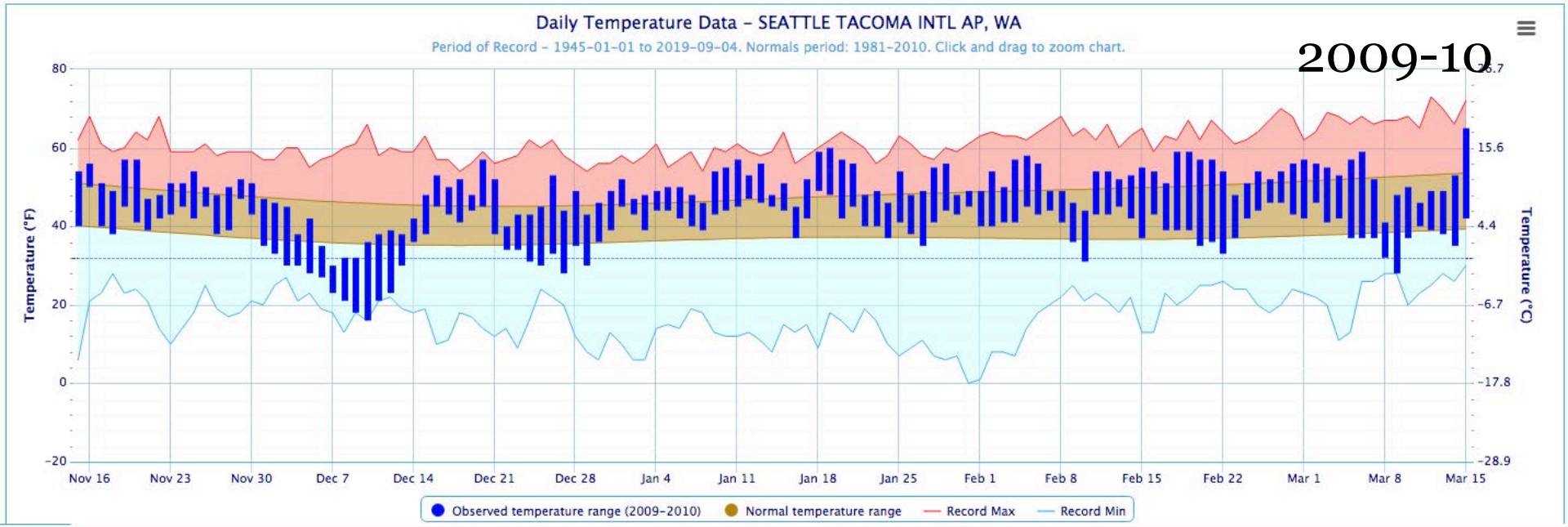


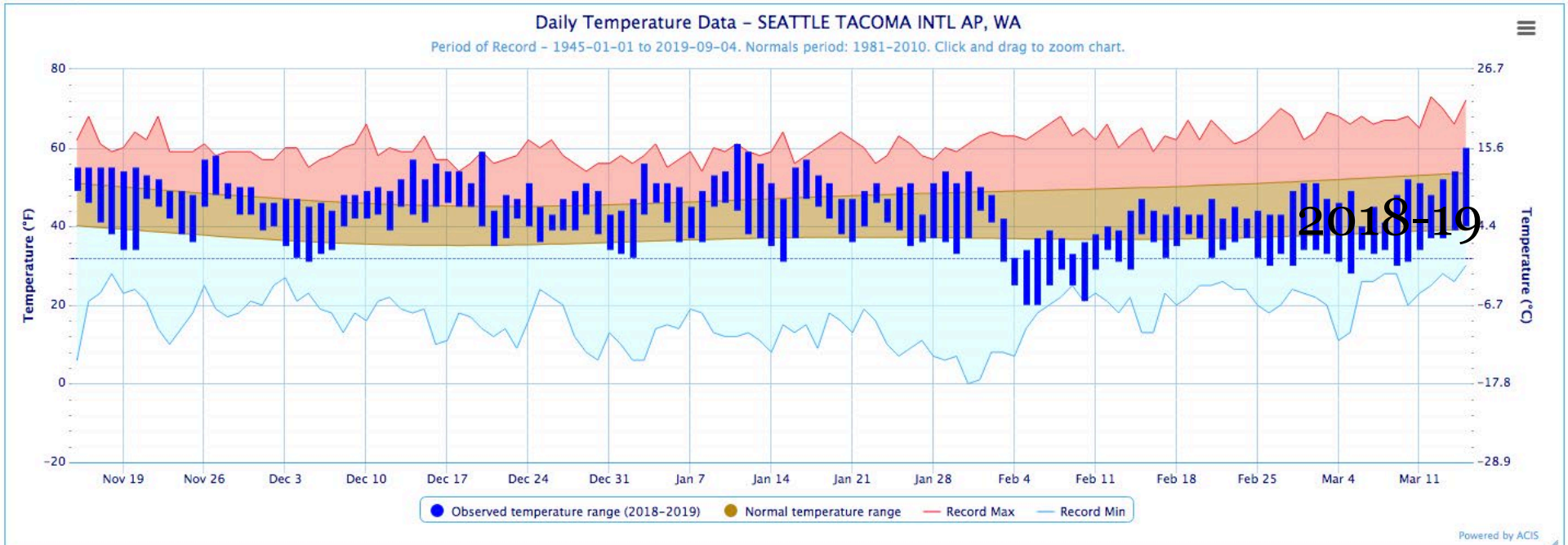
Trenberth et al. (1998)

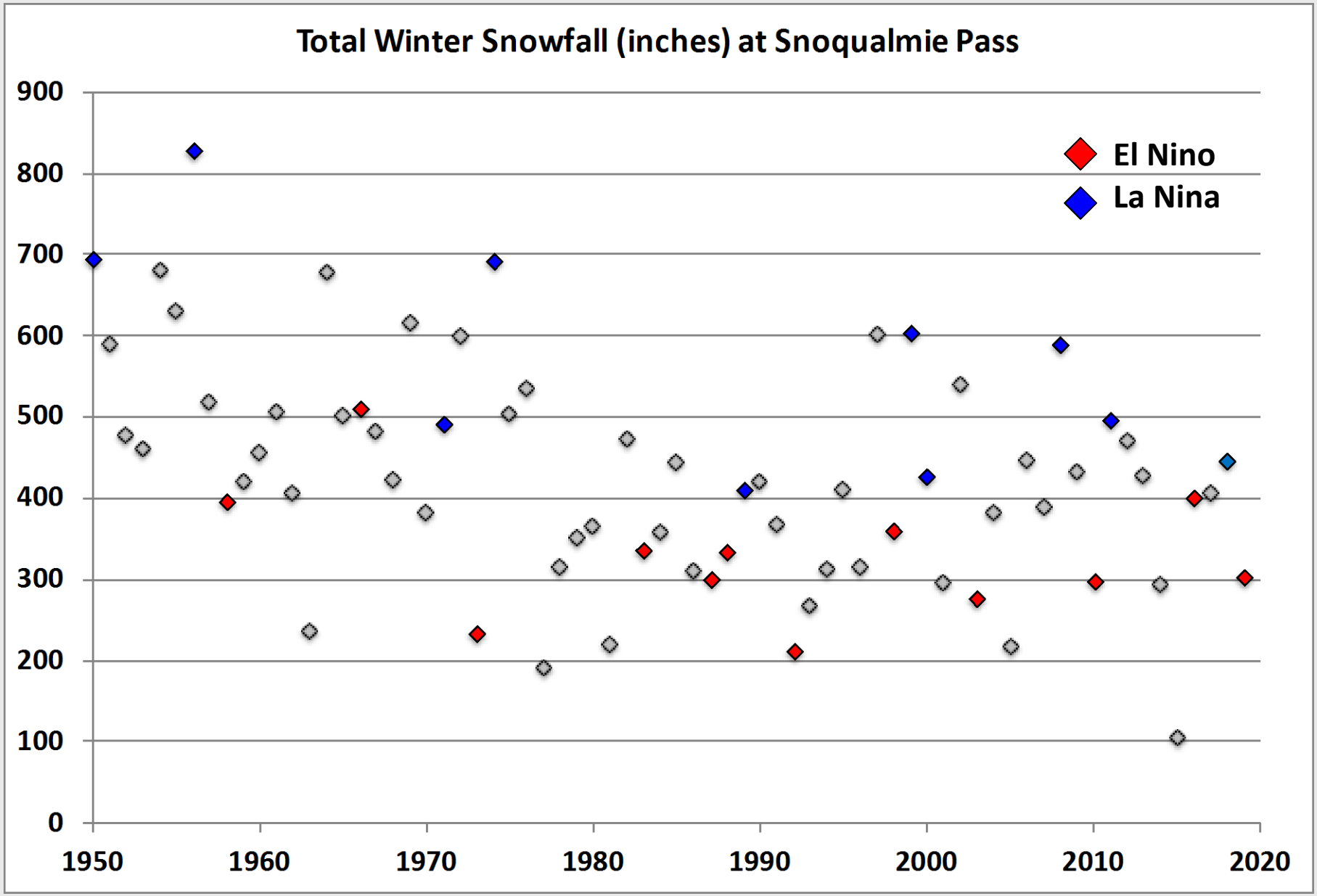
El Niño-Southern Oscillation (ENSO)



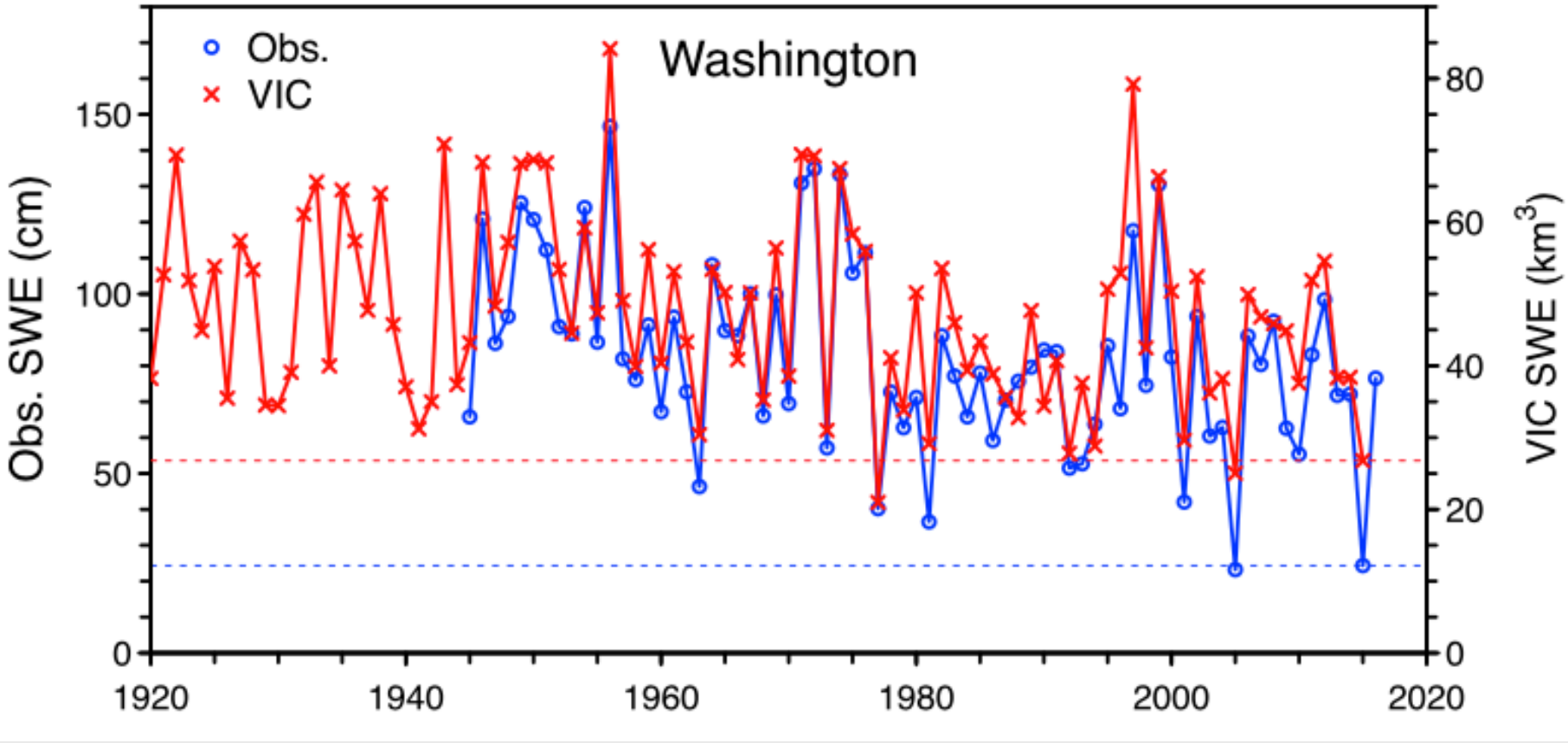
Daily Air Temperatures in Seattle during 2 El Nino Winters



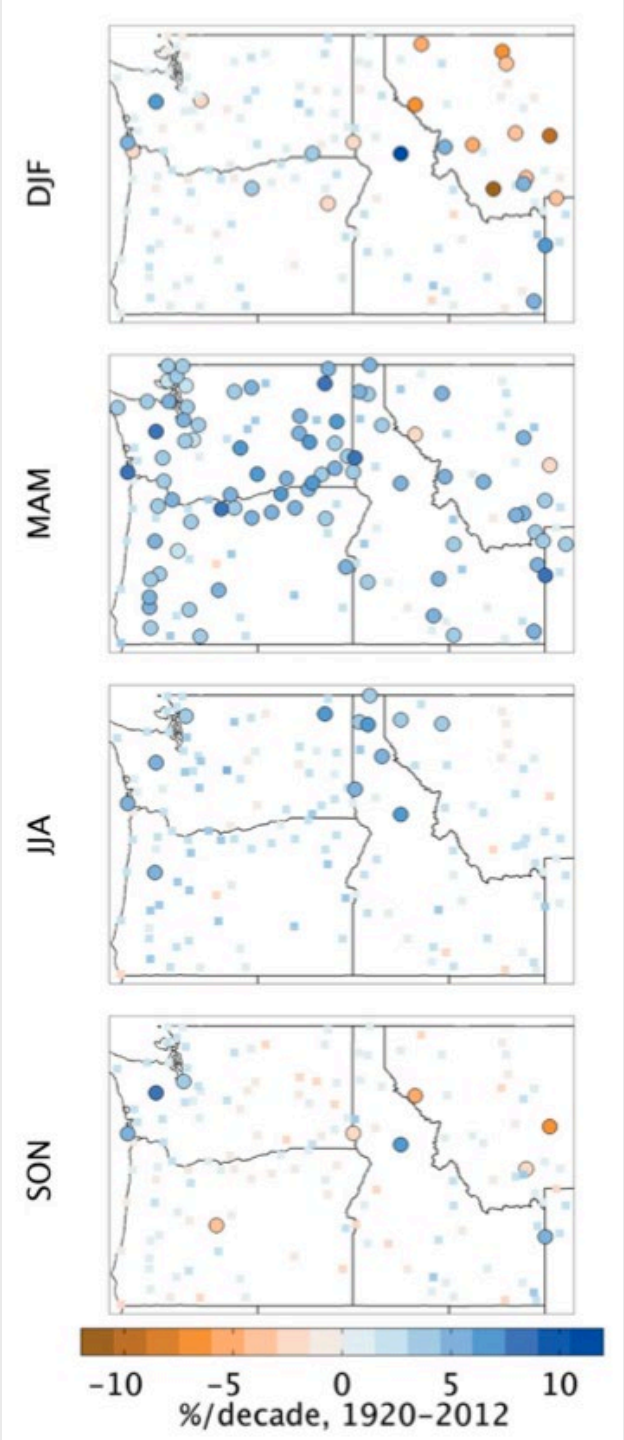



Total Winter Snowfall (inches) at Snoqualmie Pass
900
800
700
600
500
400
300
200
100
0
1950
1960
1970
1980
1990
2000
2010
2020
El Nino
La Nina

Snow Water Equivalent (SWE) for 1 April



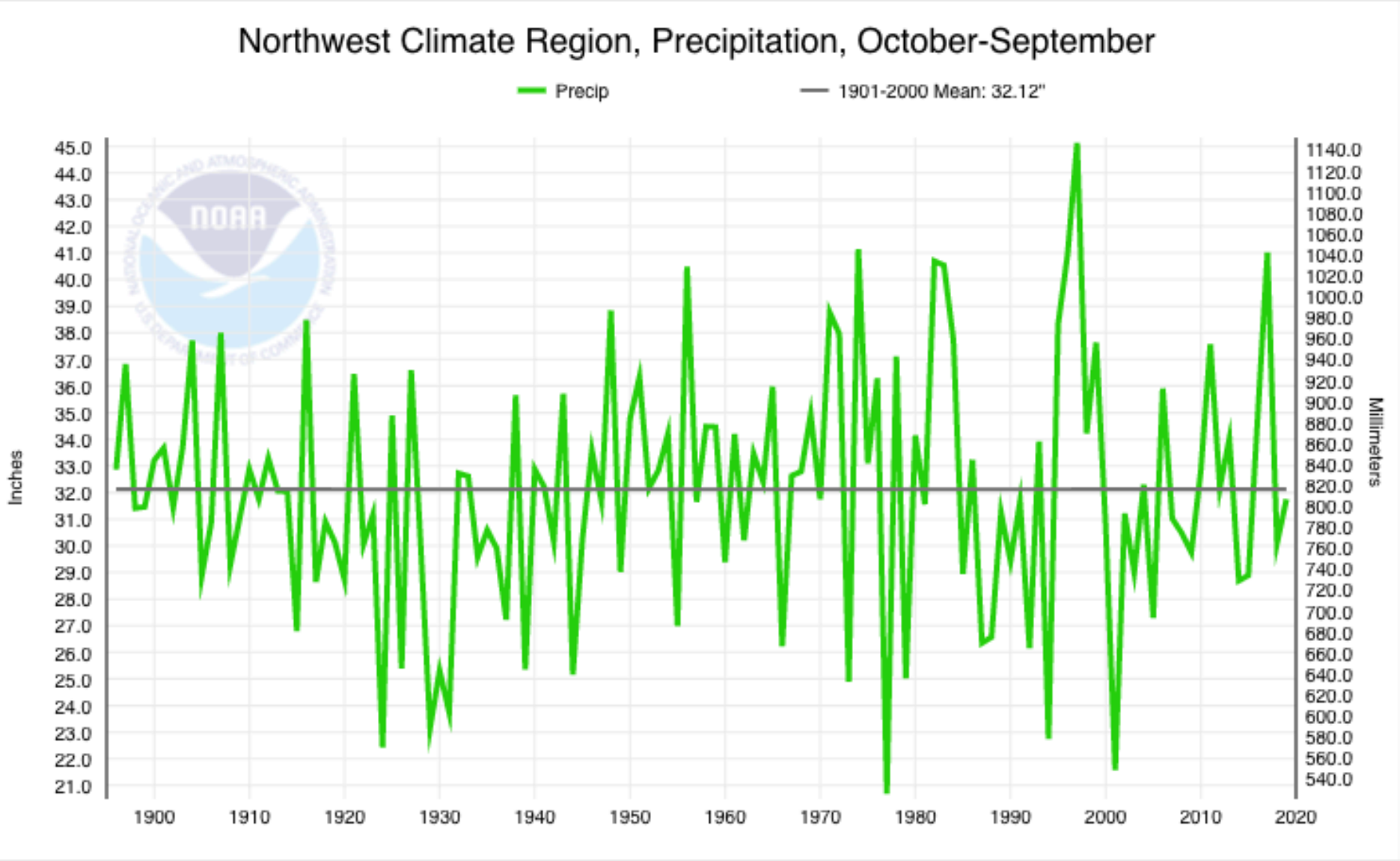
Mote et al. (2016)



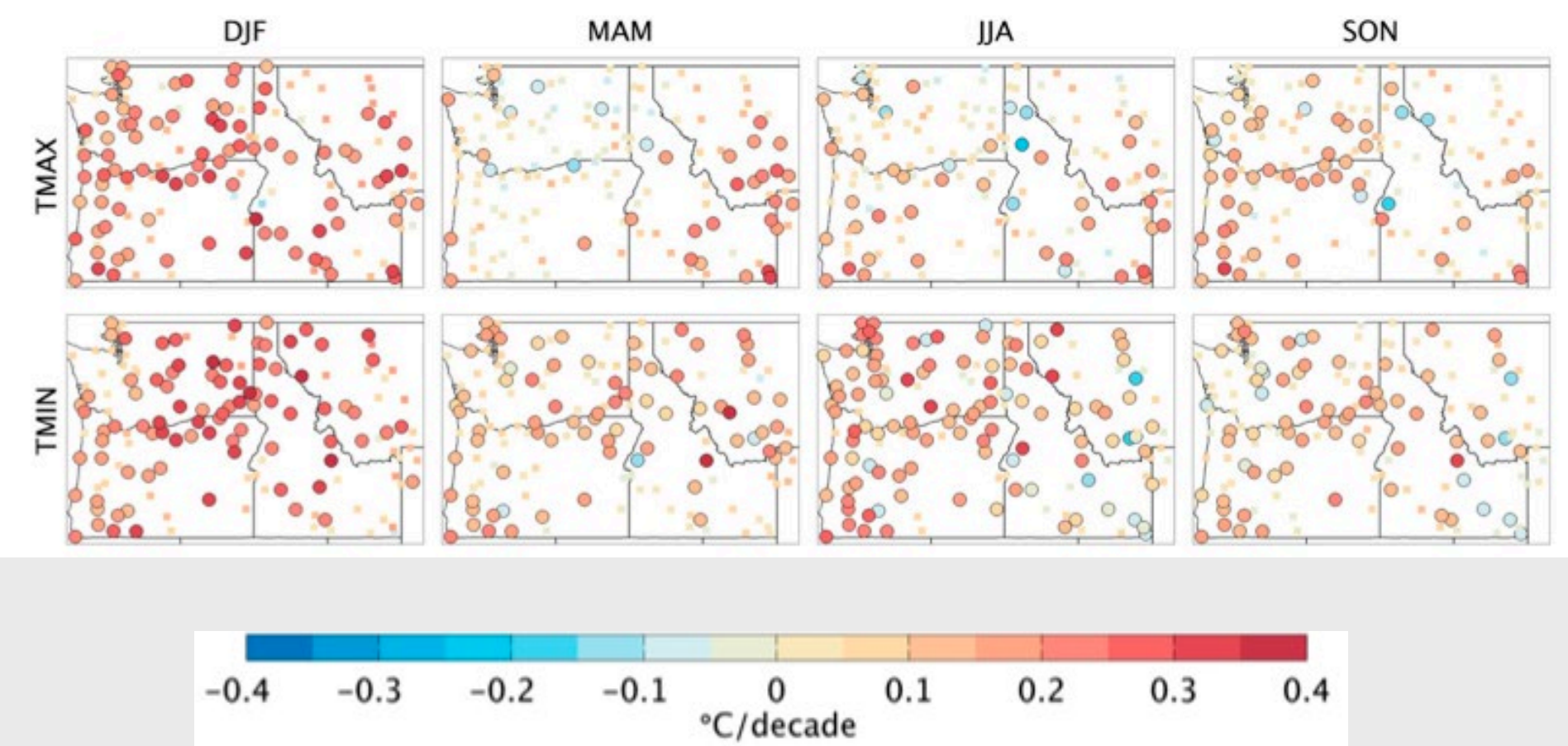
Precipitation Trends (1920-2012)

Squares indicate lack of significant linear trends; circles are significant at 95%

Abatzoglou et al. 2014 (J. Climate)


Northwest Climate Region, Precipitation, October-September
Precip
1901-2000 Mean: 32.12"
Inches
Millimeters
45.0
44.0
43.0
42.0
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
29.0
28.0
27.0
26.0
25.0
24.0
23.0
22.0
21.0
1140.0
1120.0
1100.0
1080.0
1060.0
1040.0
1020.0
1000.0
980.0
960.0
940.0
920.0
900.0
880.0
860.0
840.0
820.0
800.0
780.0
760.0
740.0
720.0
700.0
680.0
660.0
640.0
620.0
600.0
580.0
560.0
540.0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020

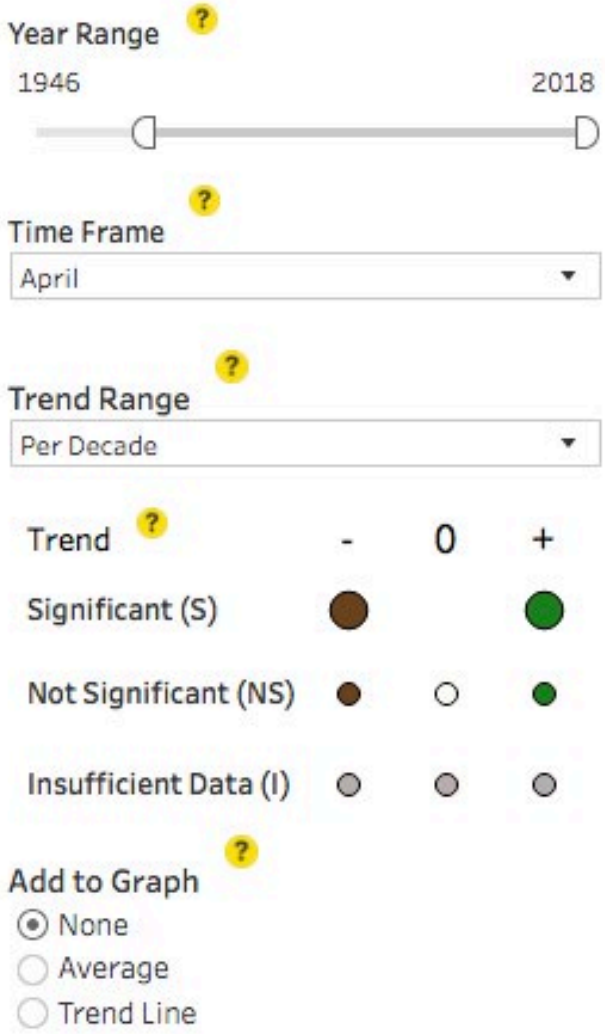
1920-2012 Temperature Trends

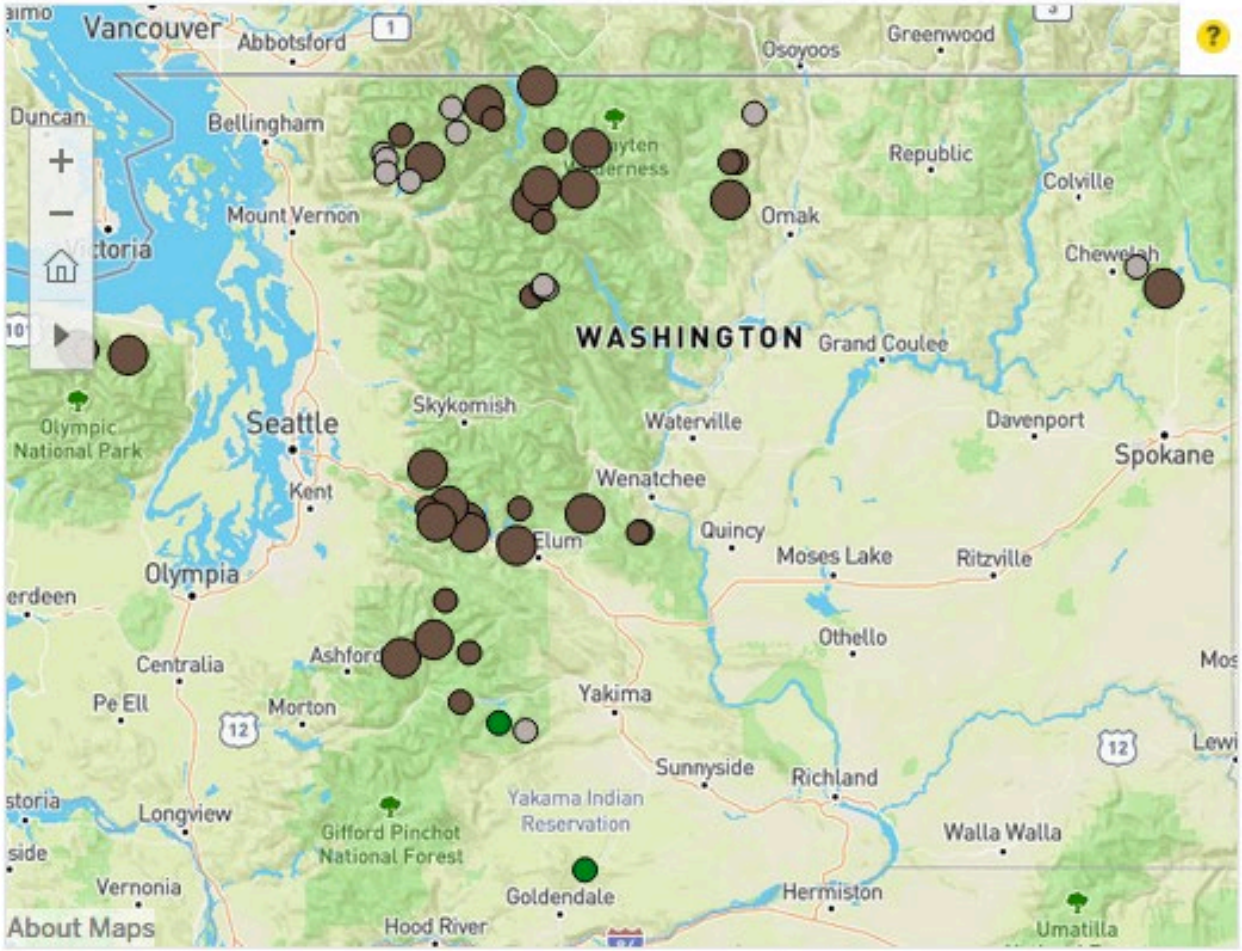


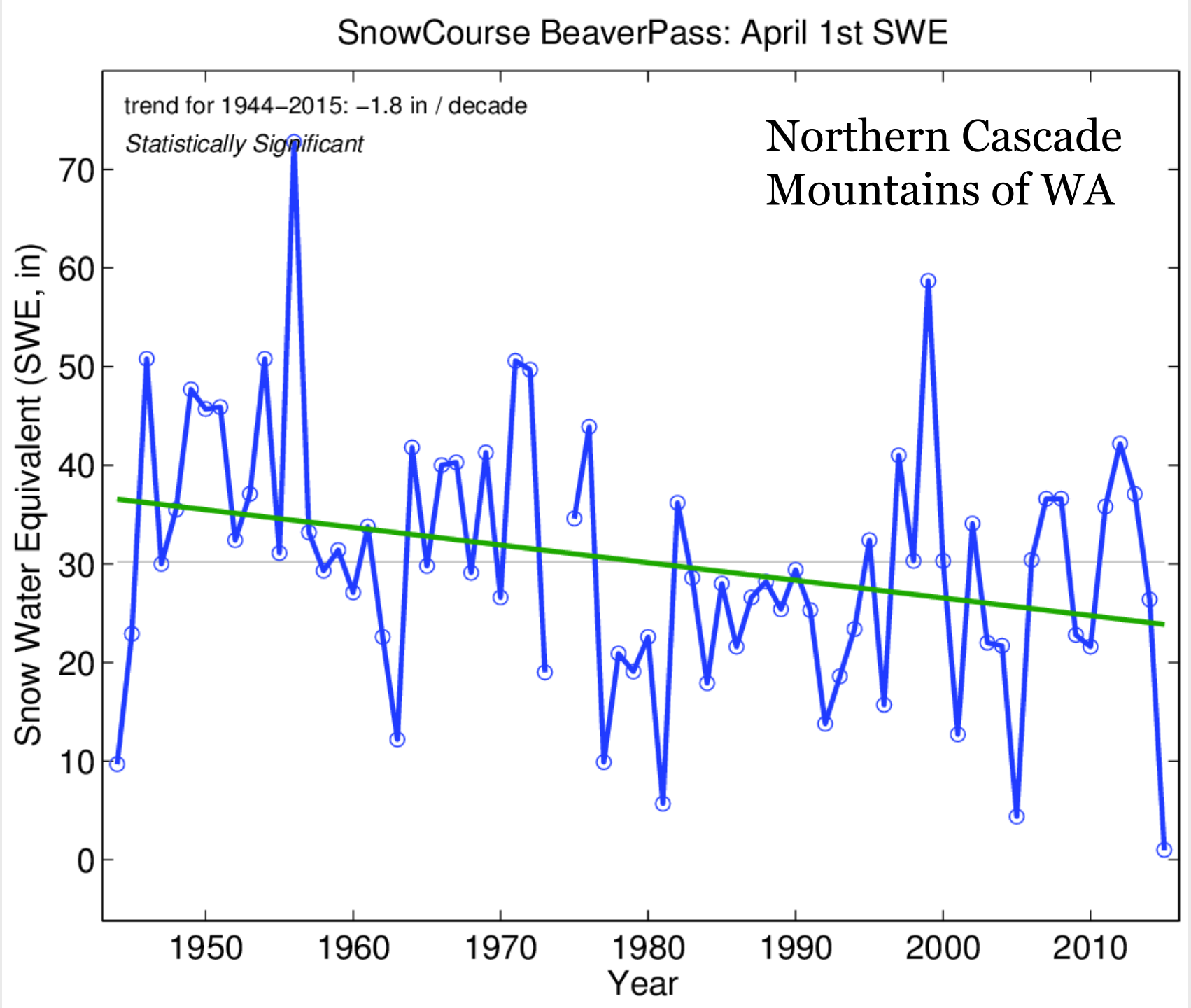
Squares aren't significant linear trends; circles are significant at 95%

Abatzoglou et al. 2014 (J. Climate)

Check out the new trend analysis tool: www.climate.washington.edu.trends






SnowCourse BeaverPass: April 1st SWE
trend for 1944–2015: –1.8 in / decade
Statistically Significant
Northern Cascade Mountains of WA
Snow Water Equivalent (SWE, in)
0
10
20
30
40
50
60
70
1950
1960
1970
1980
1990
2000
2010
Year

Snow Course Stations Reporting Snow Water Equivalent (SWE) on April 1st

Linear Trend Magnitude

0.33
1.00
2.00
3.28

(absolute value of the longest valid trend

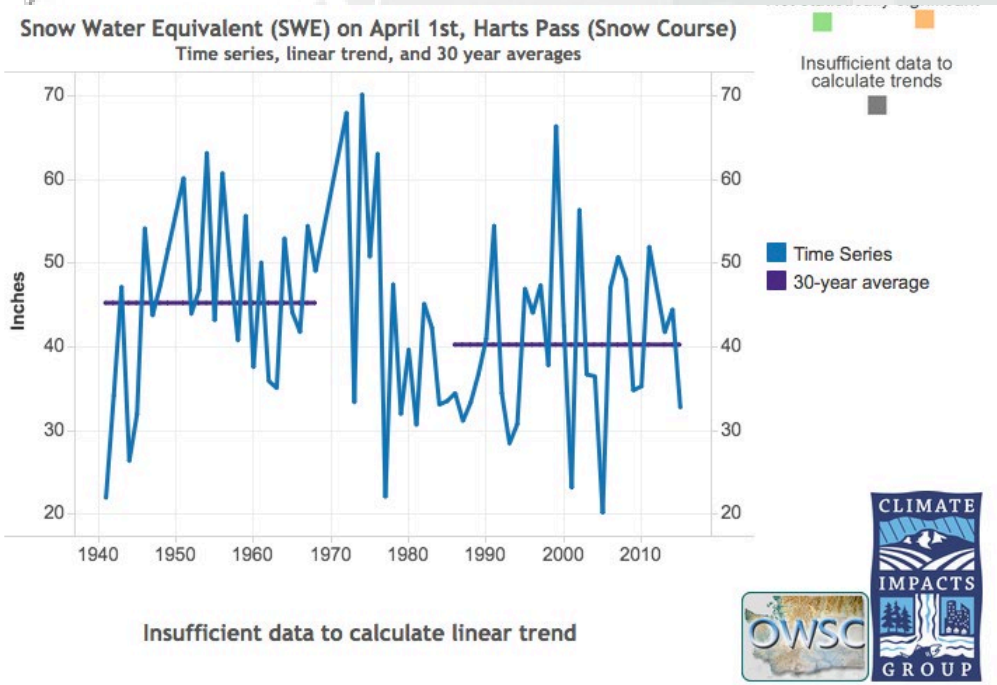
Significance

Positive trend | Negative trend

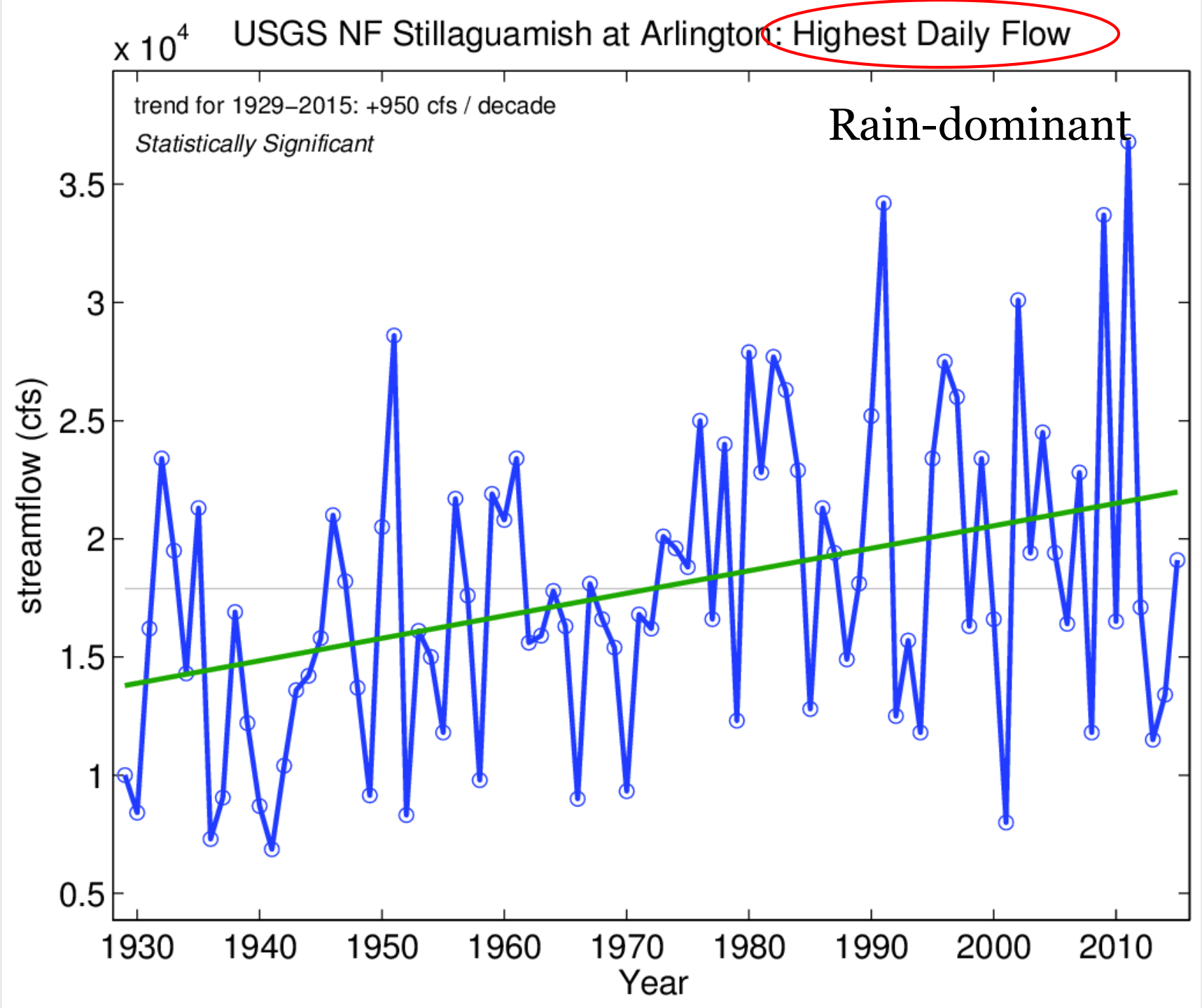
Statistically significant

Not statistically significant

Insufficient data to calculate trends

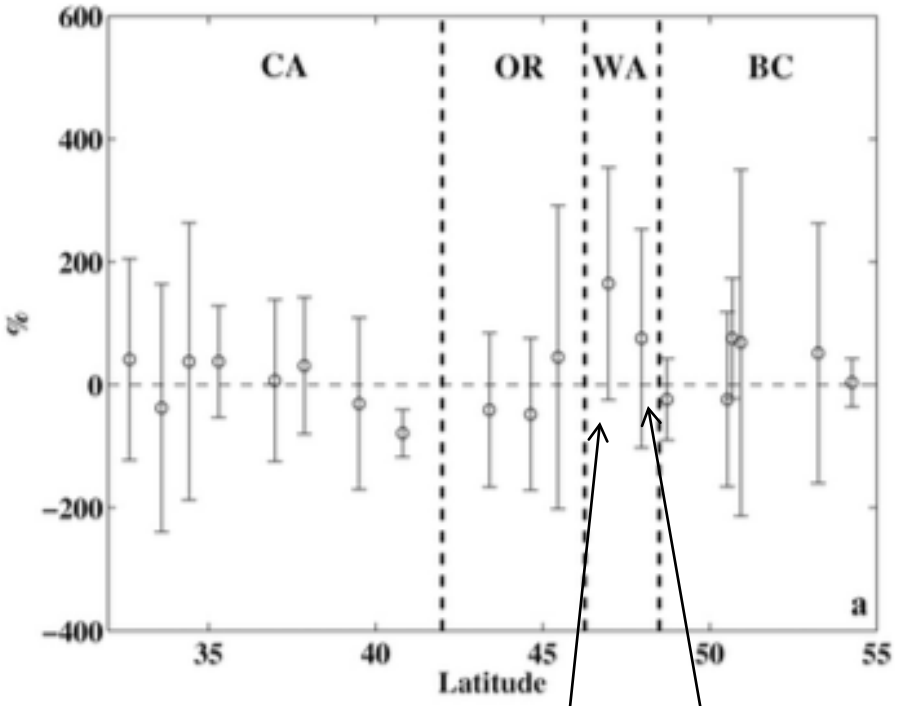


G. Mauger
K. Bumbaco

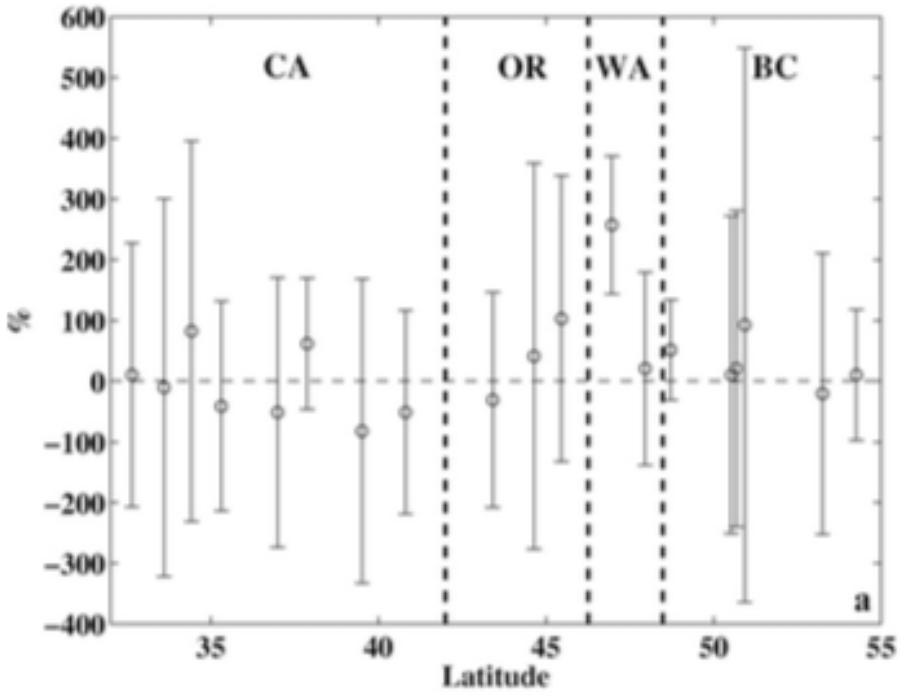

x 10^4
USGS NF Stillaguamish at Arlington: Highest Daily Flow
trend for 1929–2015: +950 cfs / decade
Statistically Significant
Rain-dominant
streamflow (cfs)
3.5
3
2.5
2
1.5
1
0.5
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year

60-Year Trends for the Top Precipitation Events along the West Coast of North America

Top 60



Top 20

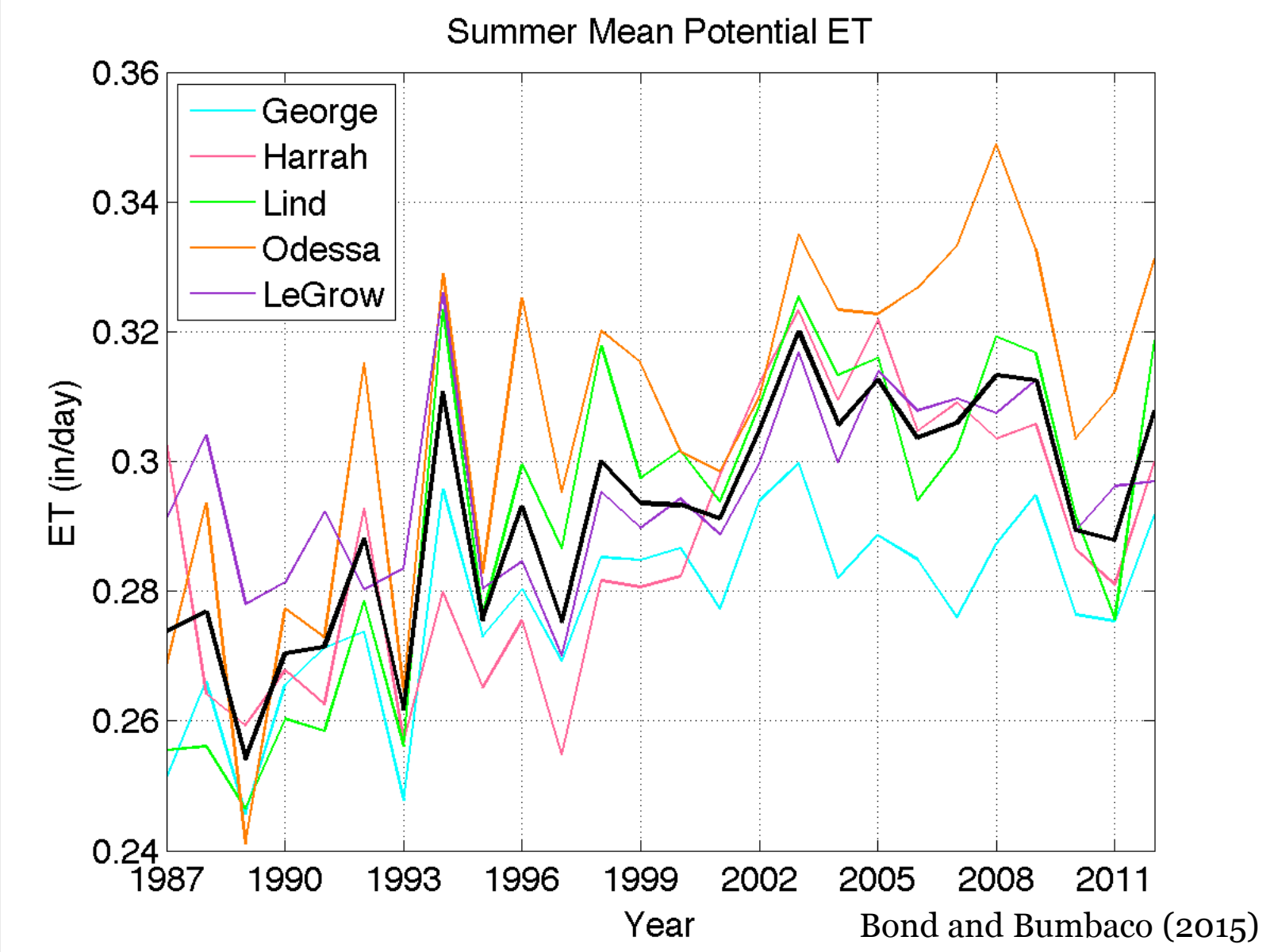


Aberdeen

Forks

Mass et al. (2011)

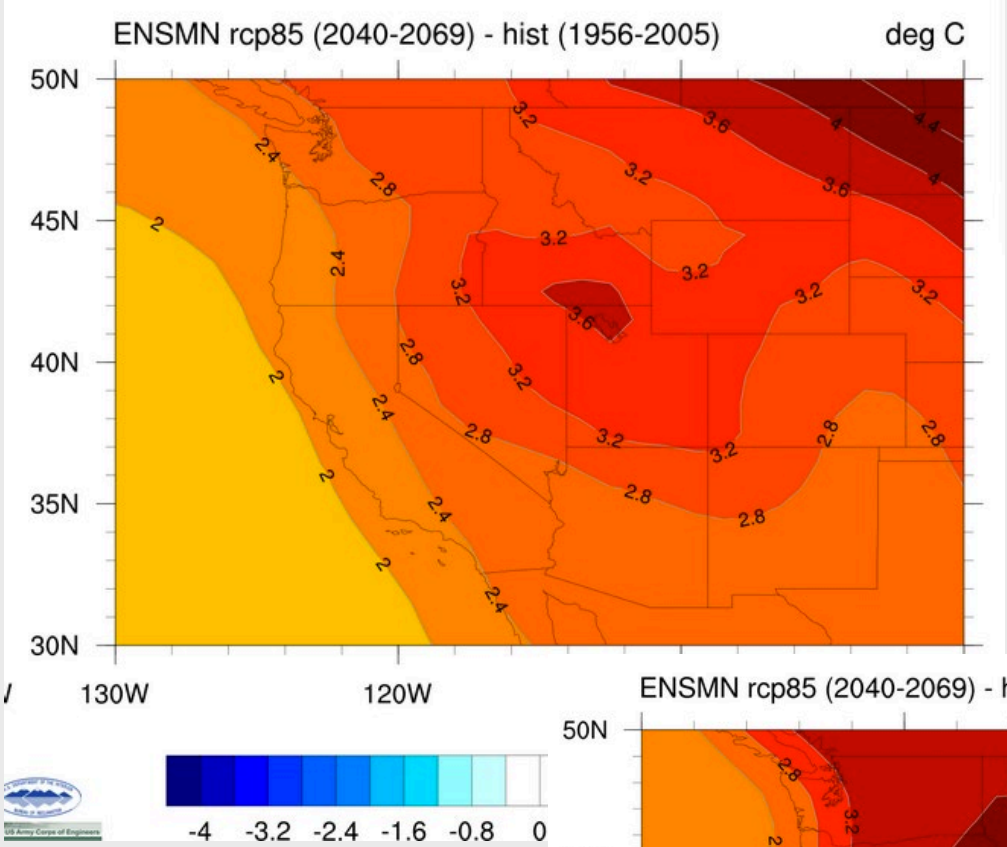
Potential Evapotranspiration (pET)



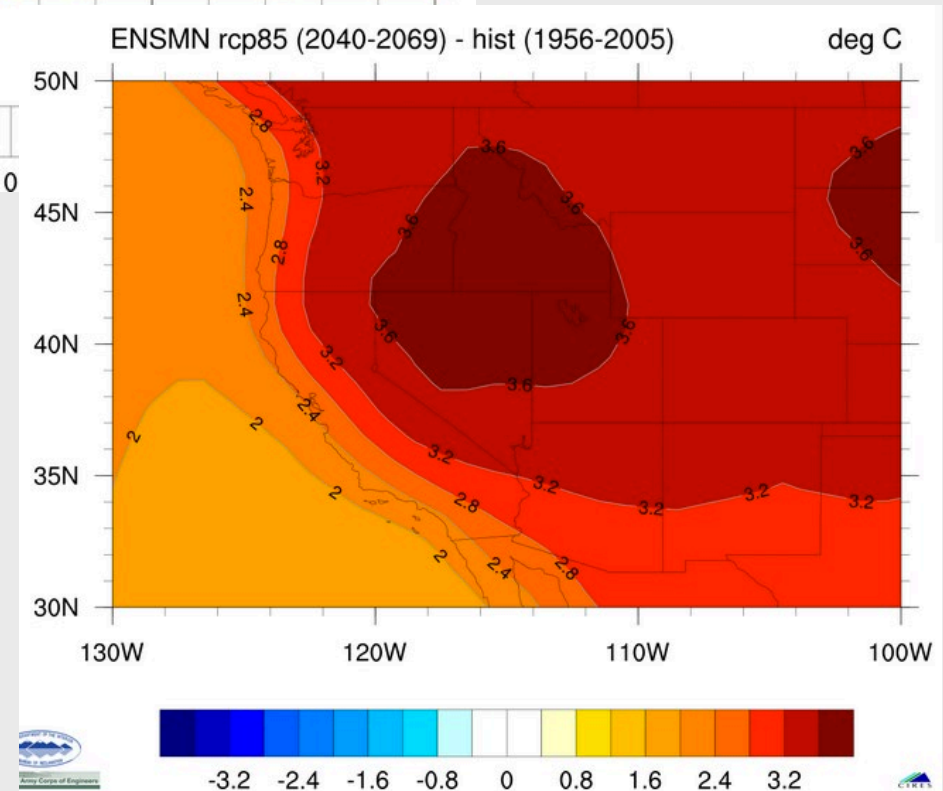
Bond and Bumbaco (2015)


January 2053...
I DON'T CARE WHAT THEY SAY, THIS GLOBAL WARMING SCARE IS JUST A BUNCH OF LOONY LEFT-WING ENVIRONMENTAL ANTI-GROWTH HYPE!
SO, IS THIS YOUR FIRST WINTER HERE IN SEATTLE?
Horsey

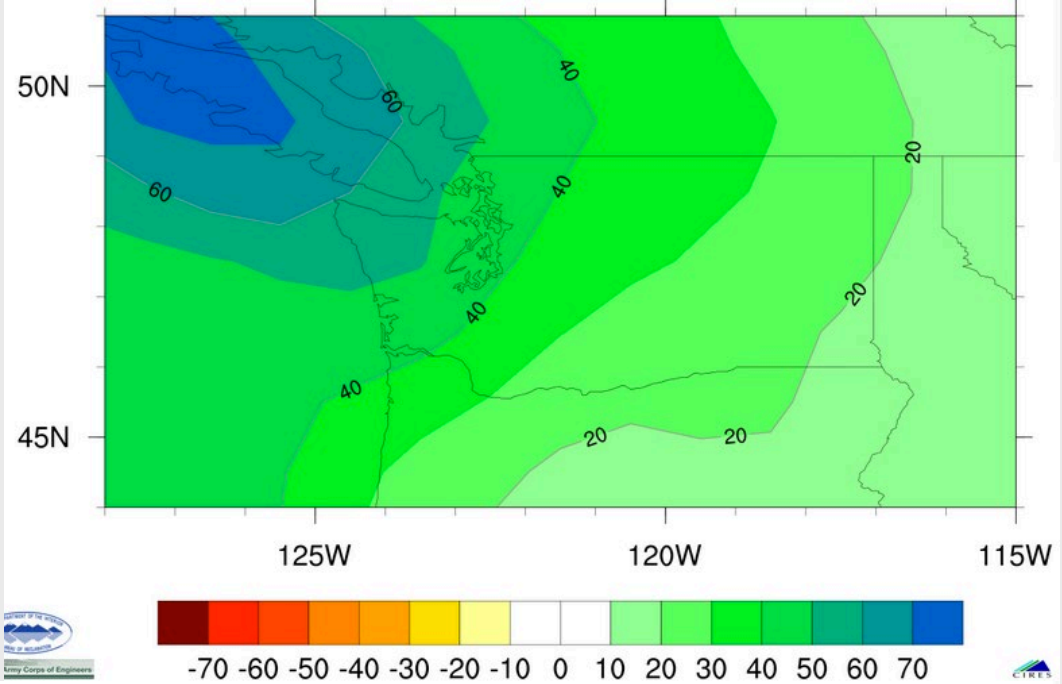
Modeled Change in Temperature by the Middle of the 21st Century



Dec-Jan-Feb

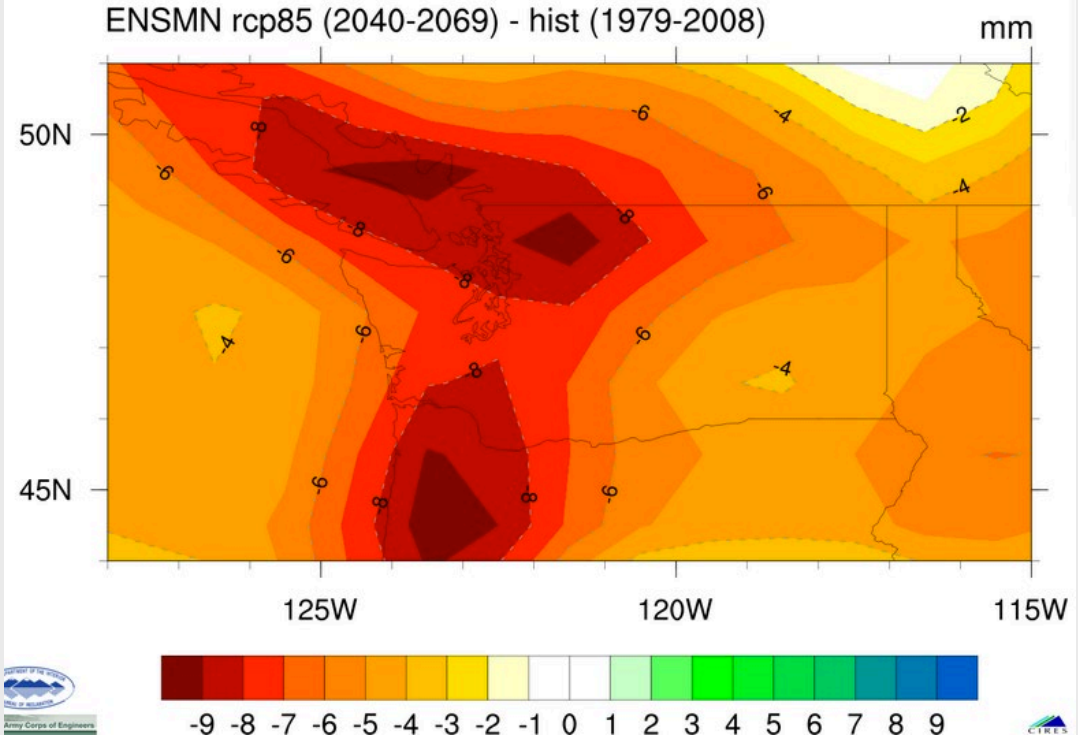


Jun-Jul-Aug

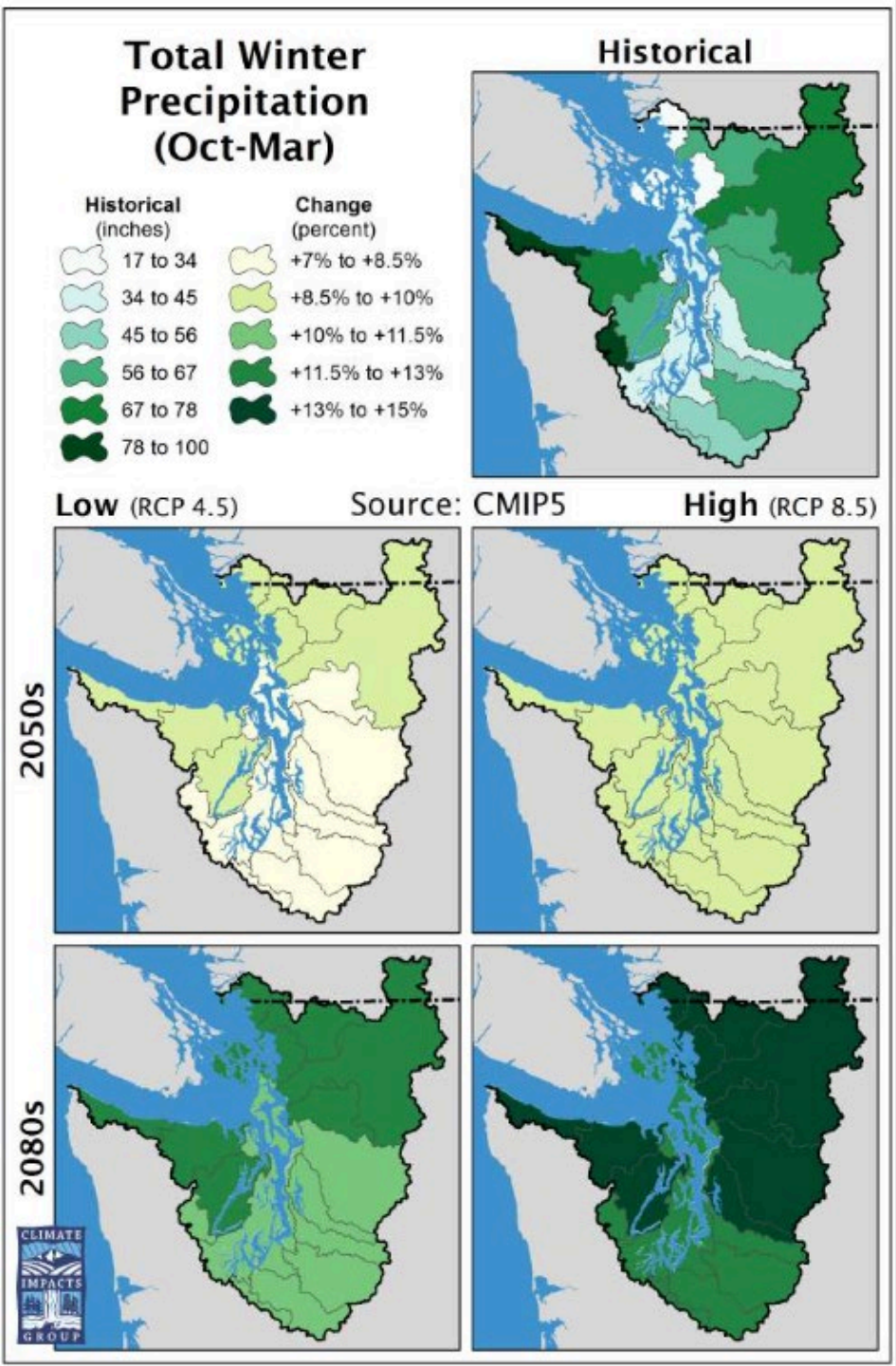


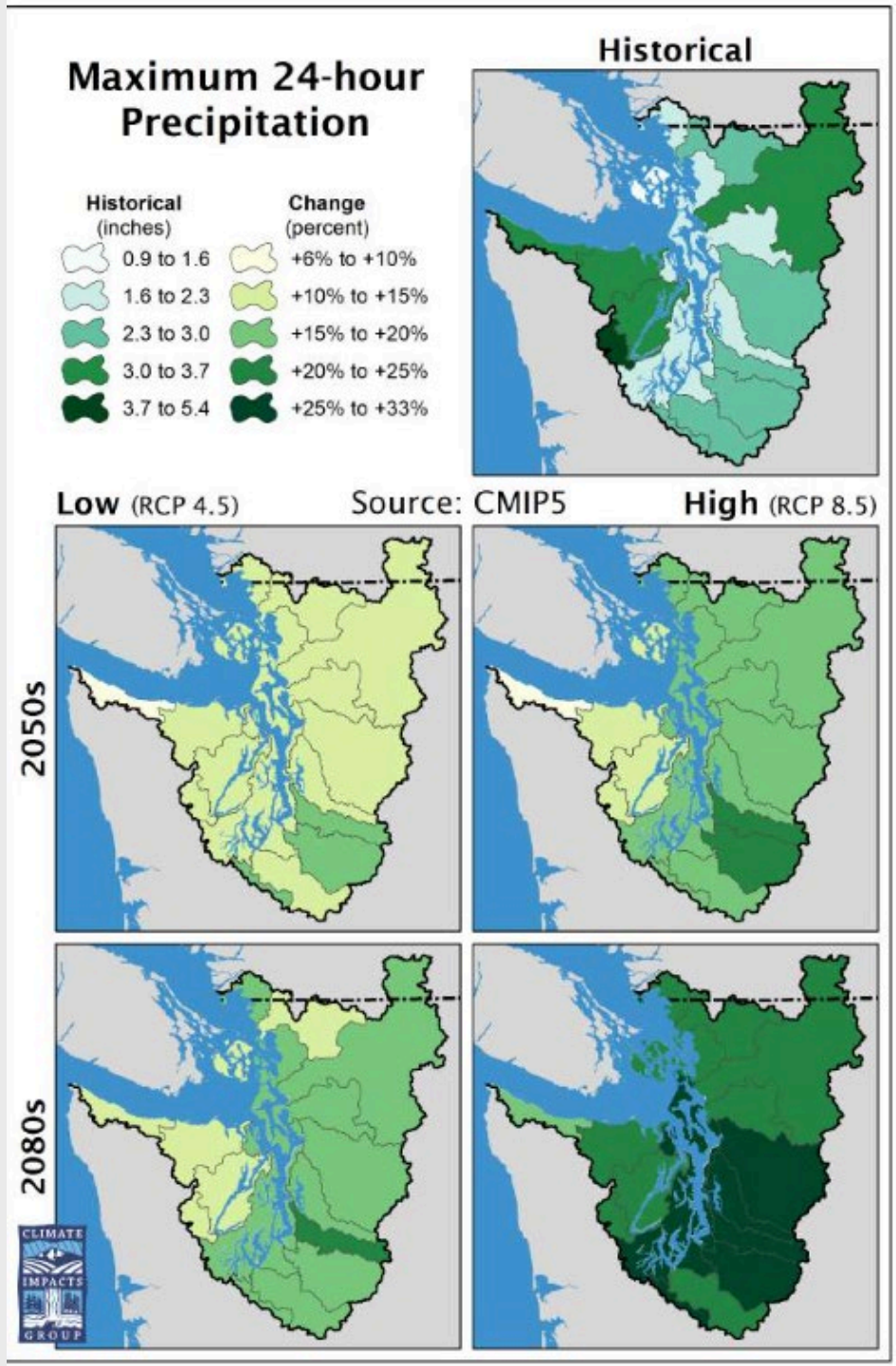
Modeled Change in Precipitation

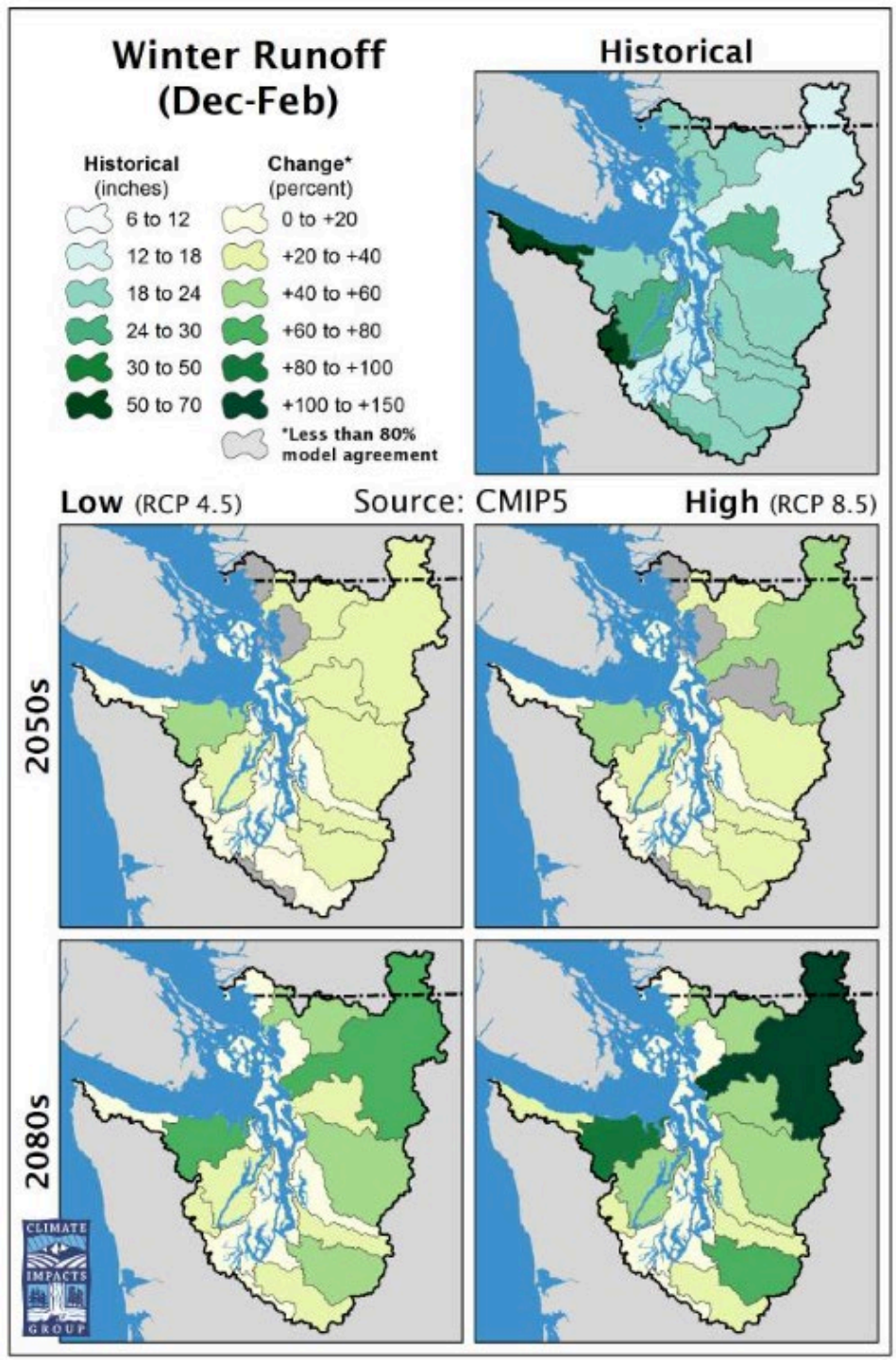
Nov-Dec-Jan

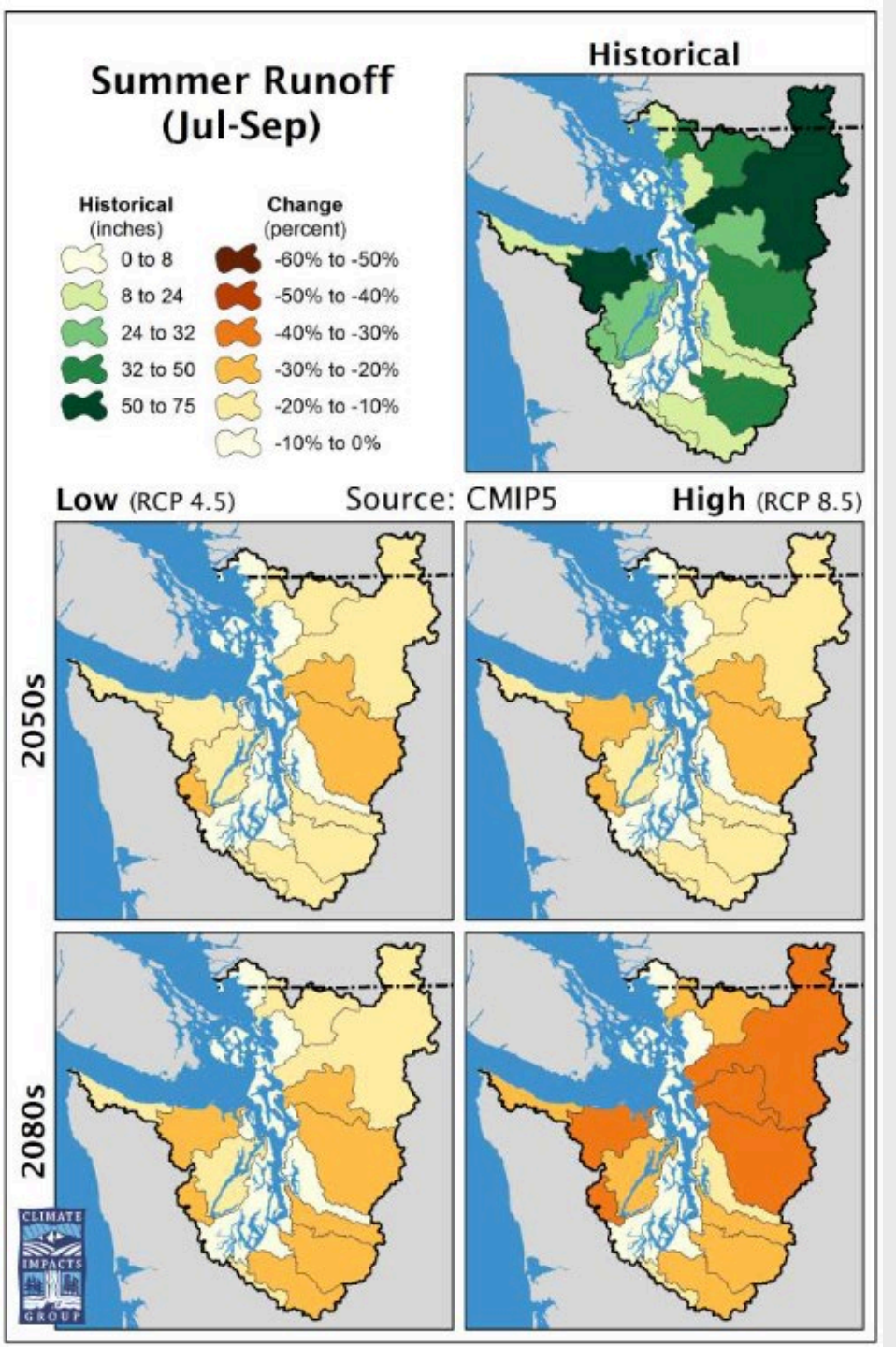


Jun-Jul-Aug

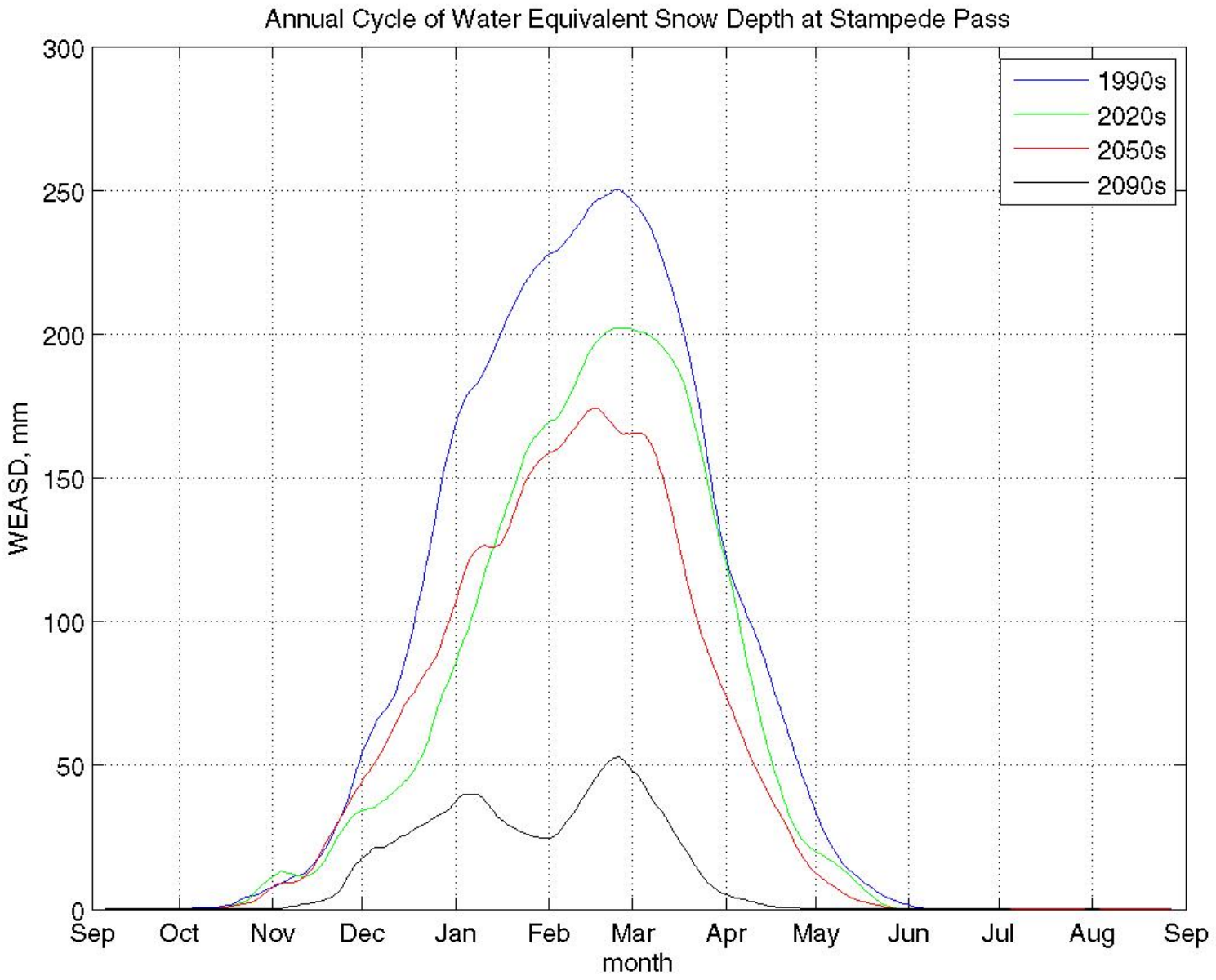

Total Winter Precipitation (Oct-Mar)
Historical
Historical (inches)
17 to 34
34 to 45
45 to 56
56 to 67
67 to 78
78 to 100
Change (percent)
+7% to +8.5%
+8.5% to +10%
+10% to +11.5%
+11.5% to +13%
+13% to +15%
Low (RCP 4.5)
Source: CMIP5
High (RCP 8.5)
2050s
2080s
CLIMATE IMPACTS GROUP


Maximum 24-hour Precipitation
Historical
Historical (inches)
0.9 to 1.6
1.6 to 2.3
2.3 to 3.0
3.0 to 3.7
3.7 to 5.4
Change (percent)
+6% to +10%
+10% to +15%
+15% to +20%
+20% to +25%
+25% to +33%
Low (RCP 4.5)
Source: CMIP5
High (RCP 8.5)
2050s
2080s
CLIMATE IMPACTS GROUP

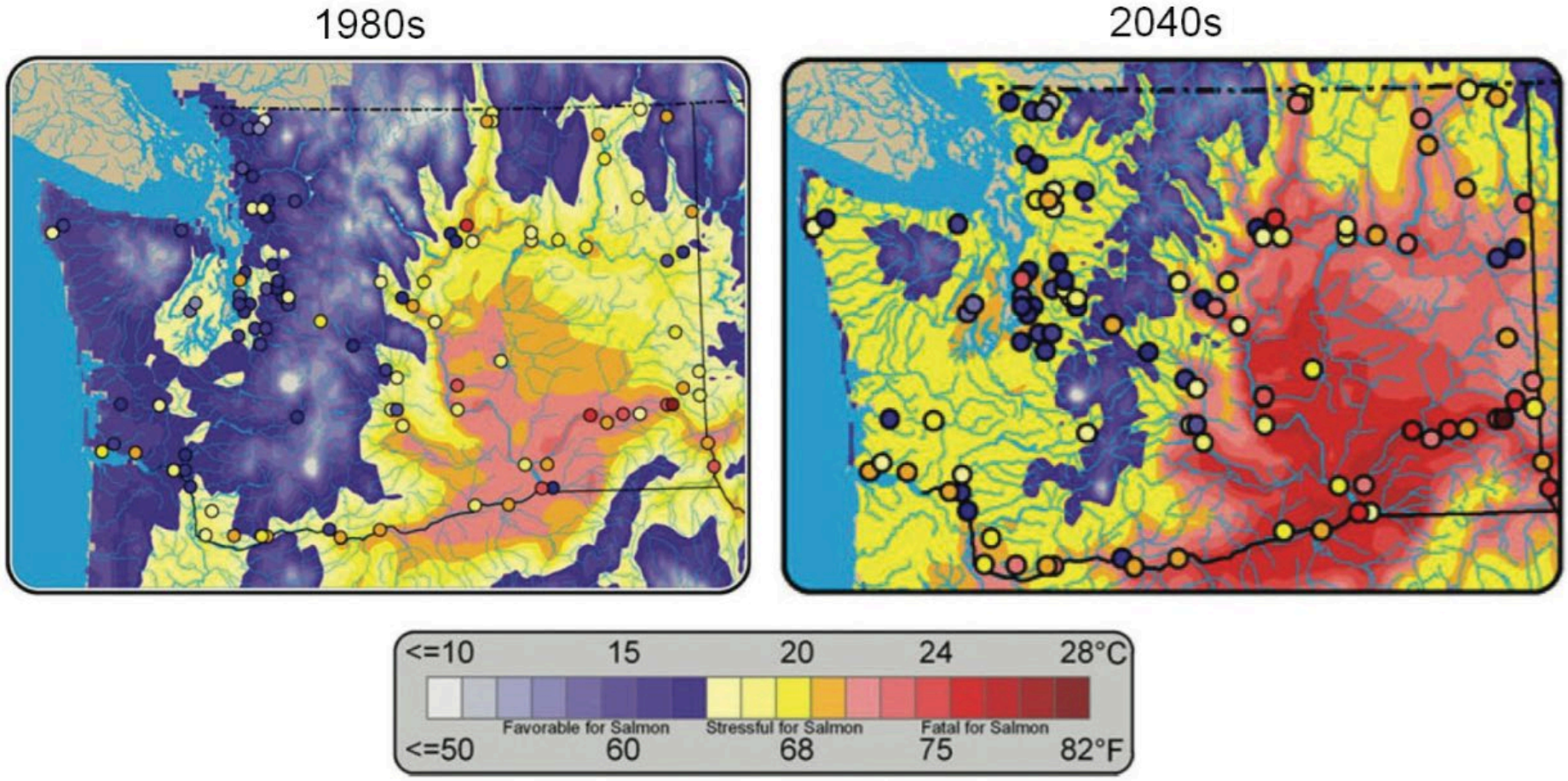

Winter Runoff
(Dec-Feb)
Historical
Historical
(inches)
6 to 12
12 to 18
18 to 24
24 to 30
30 to 50
50 to 70
Change*
(percent)
0 to +20
+20 to +40
+40 to +60
+60 to +80
+80 to +100
+100 to +150
*Less than 80%
model agreement
Low (RCP 4.5)
Source: CMIP5
High (RCP 8.5)
2050s
2080s
CLIMATE
IMPACTS
GROUP


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

Large Drop in Snowpack in the Mountains

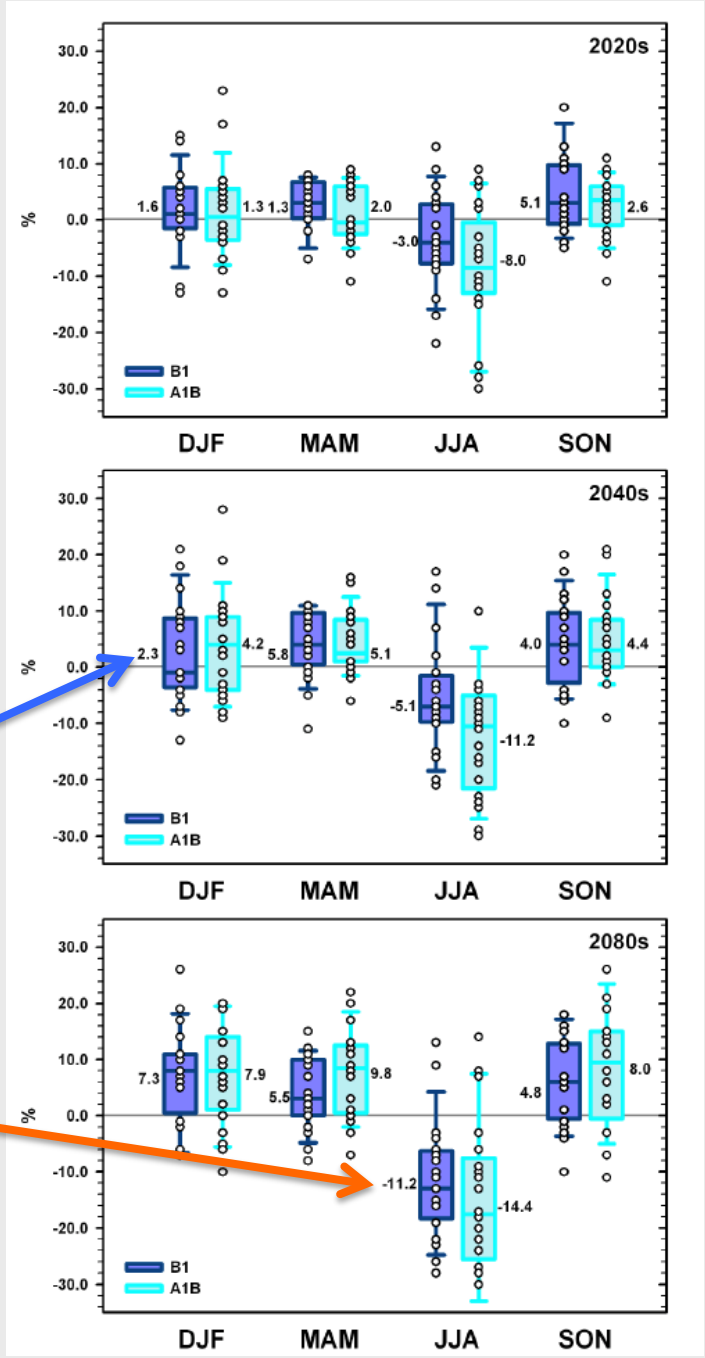


August Mean Air Temperatures (fill) and Maximum Summer Stream Temperatures (dots)



Precipitation Changes by Season

- Changes relative to 1970-1999 mean



2020s

2040s

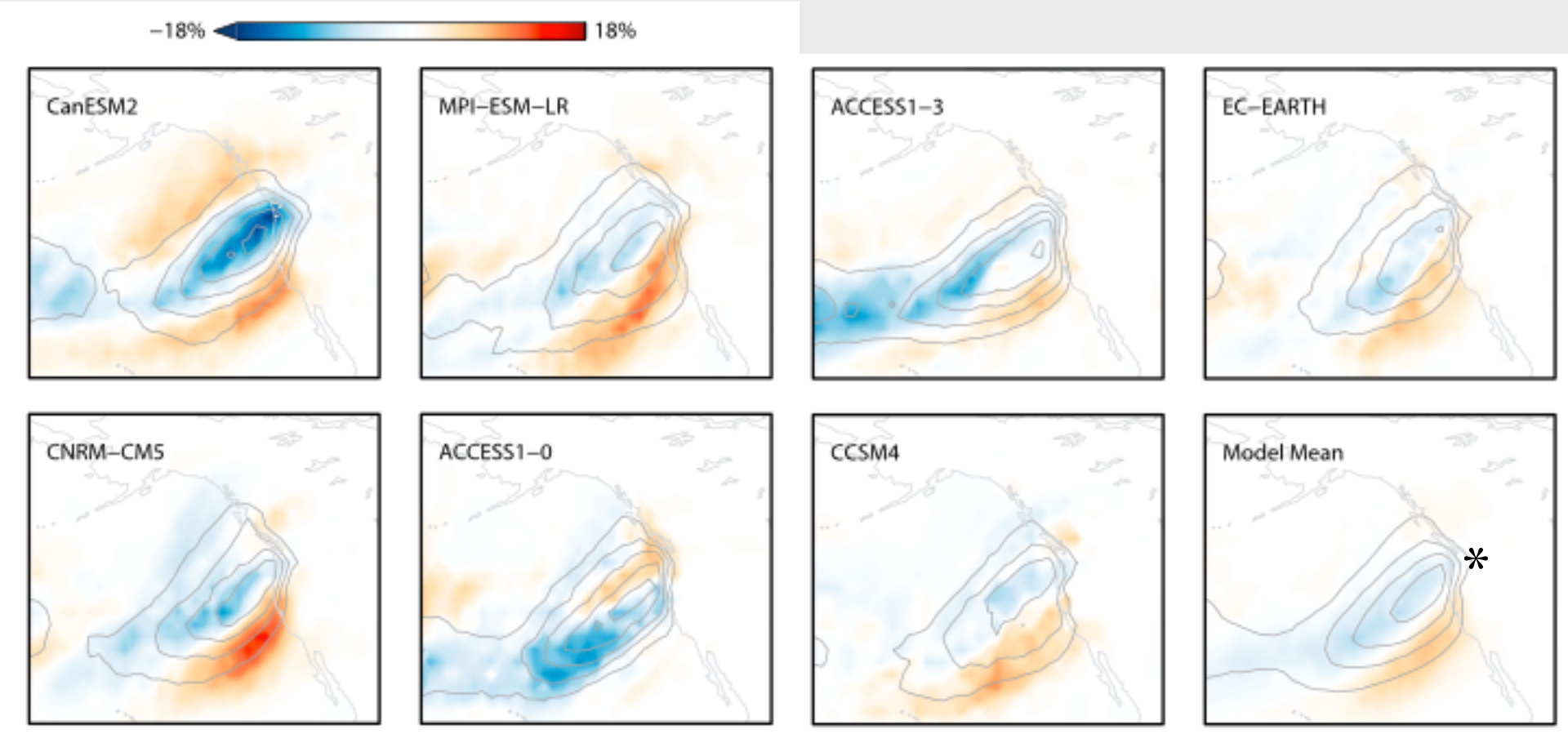
2080s

Wetter winters

Drier summers

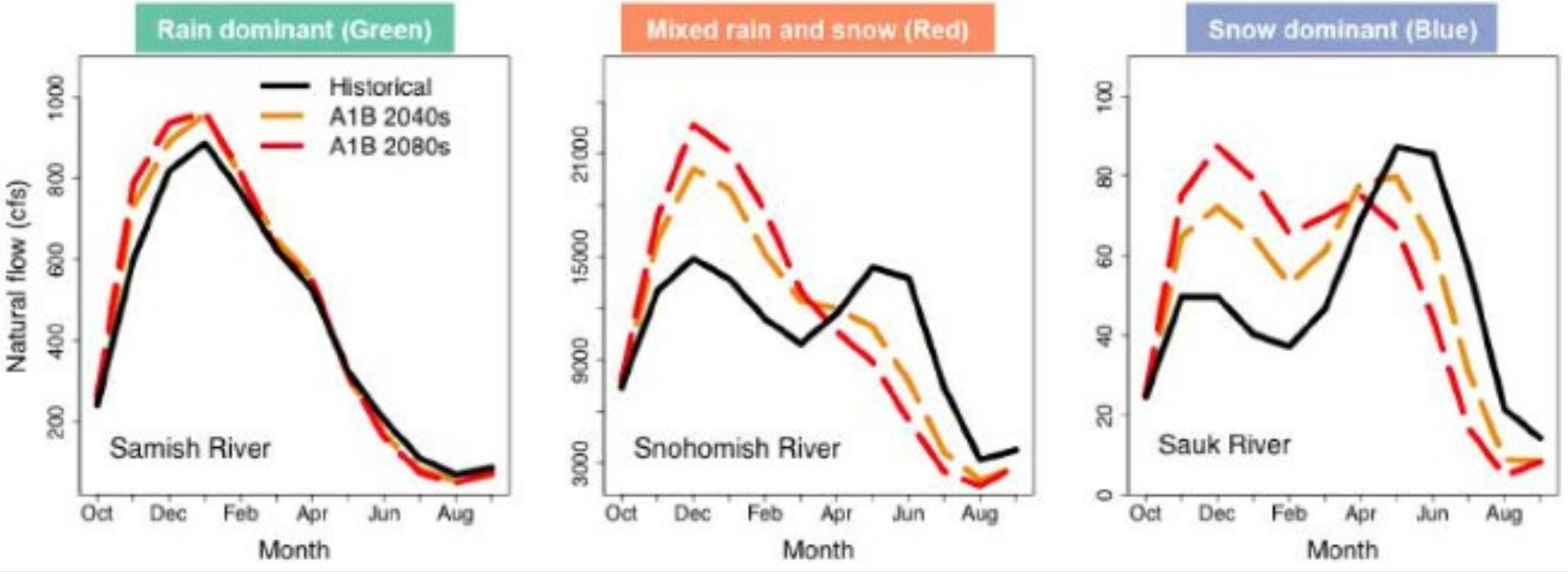
(slide courtesy of Ingrid Tohver - UW CIG)

Modeled Changes in Atmospheric River Frequency
RCP 8.5: (2080-2099) – (1980-1999)

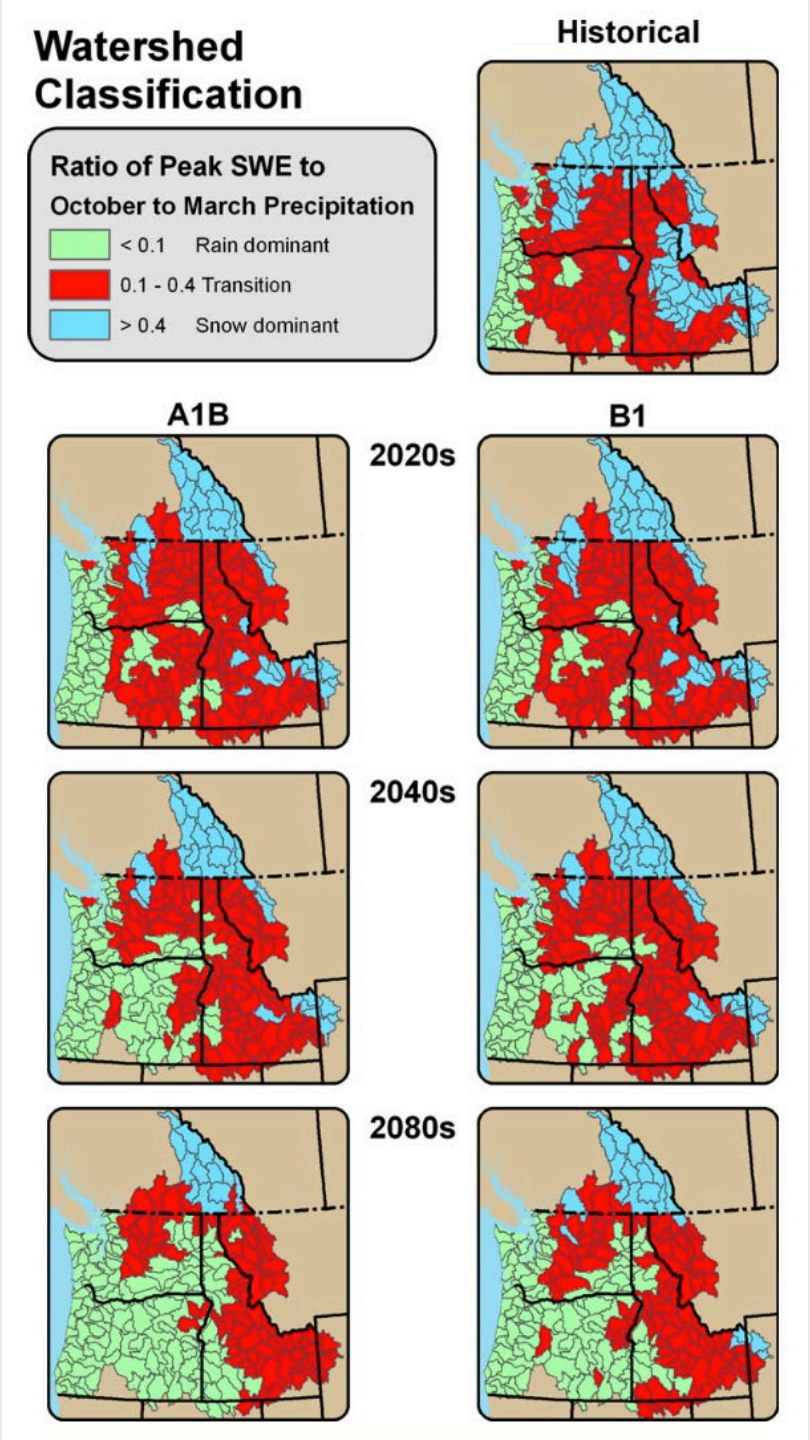


Payne and Magnusdottir (2015)

Expected Transitions in Watershed Types

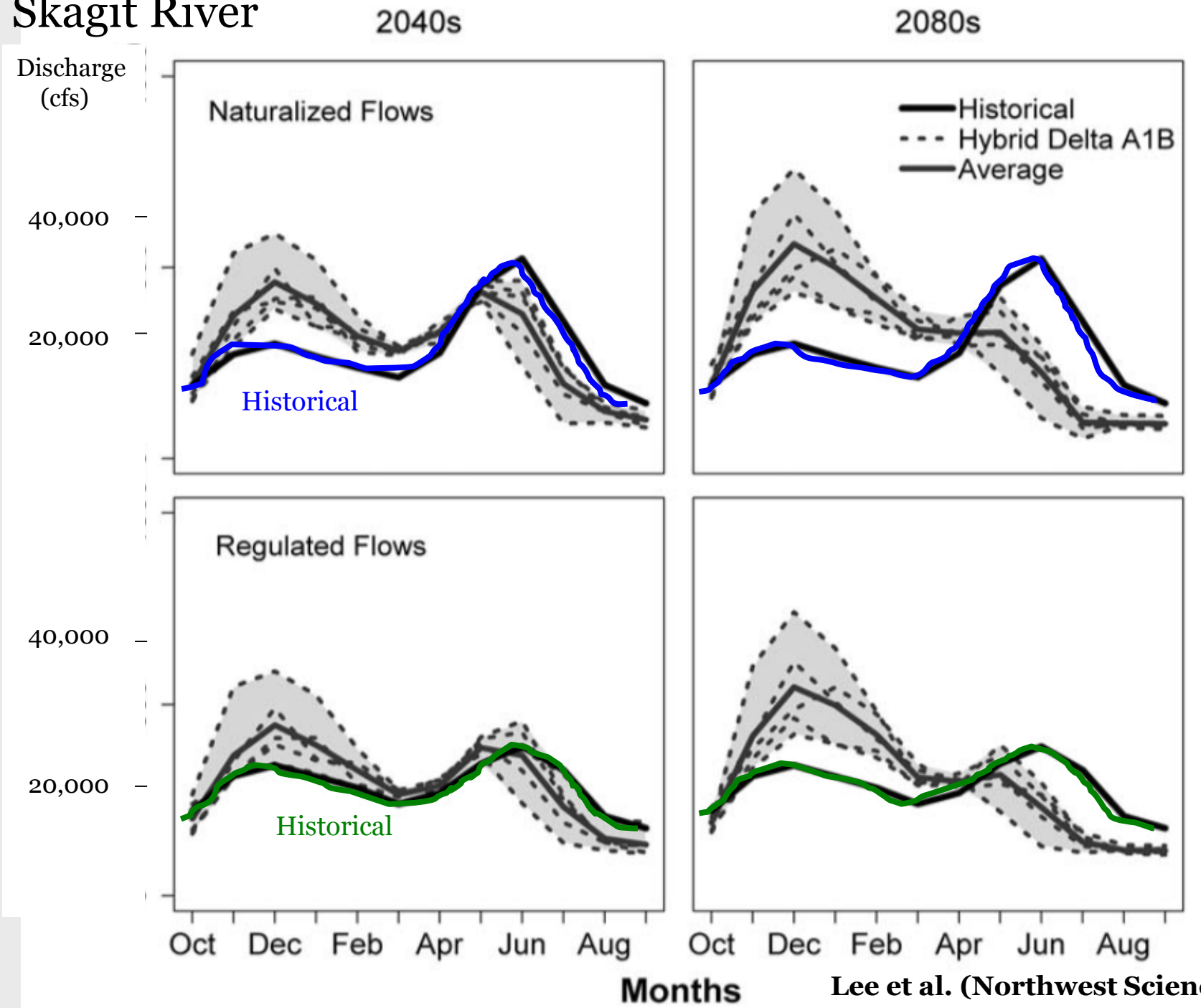


Hamlet et al. 2013



Tohver et al. 2014

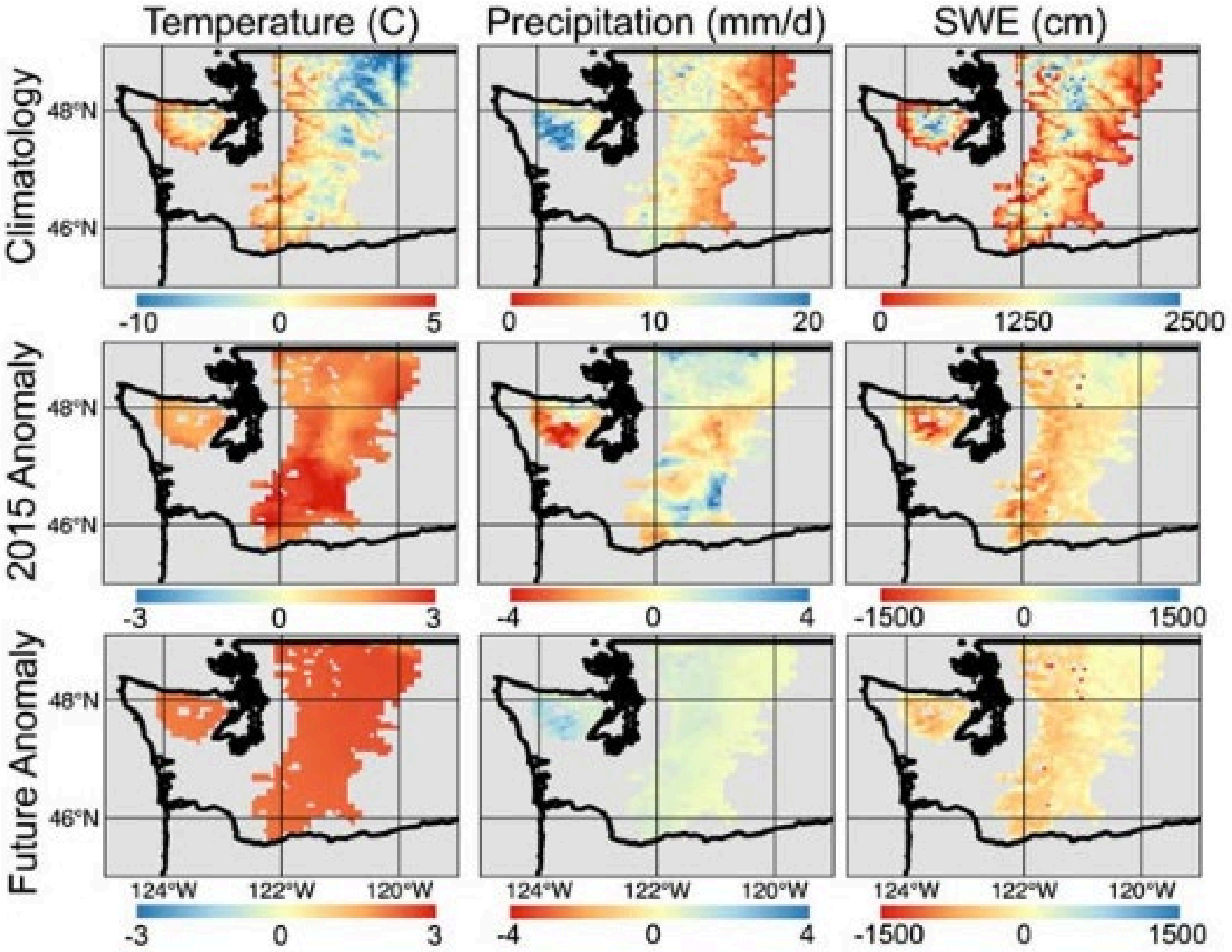
Skagit River



Lee et al. (Northwest Science, 2016)

1950-2015

2040-2069



Marlier et al. (2017)


I WANT A RECOUNT.
"SCIENCE"
X+Y÷ZΠ
√8X -79W
? ? ?
TIME TO BURN MORE FOSSIL FUELS...
AND YOUR BOOKS.
AL GORE
OSCAR
FED UP CITIZENS
NEWS
COLD WAVE STRIKES
I'M WARMING TO THAT IDEA.
Kelly
©2014 ONION SYNDICATE

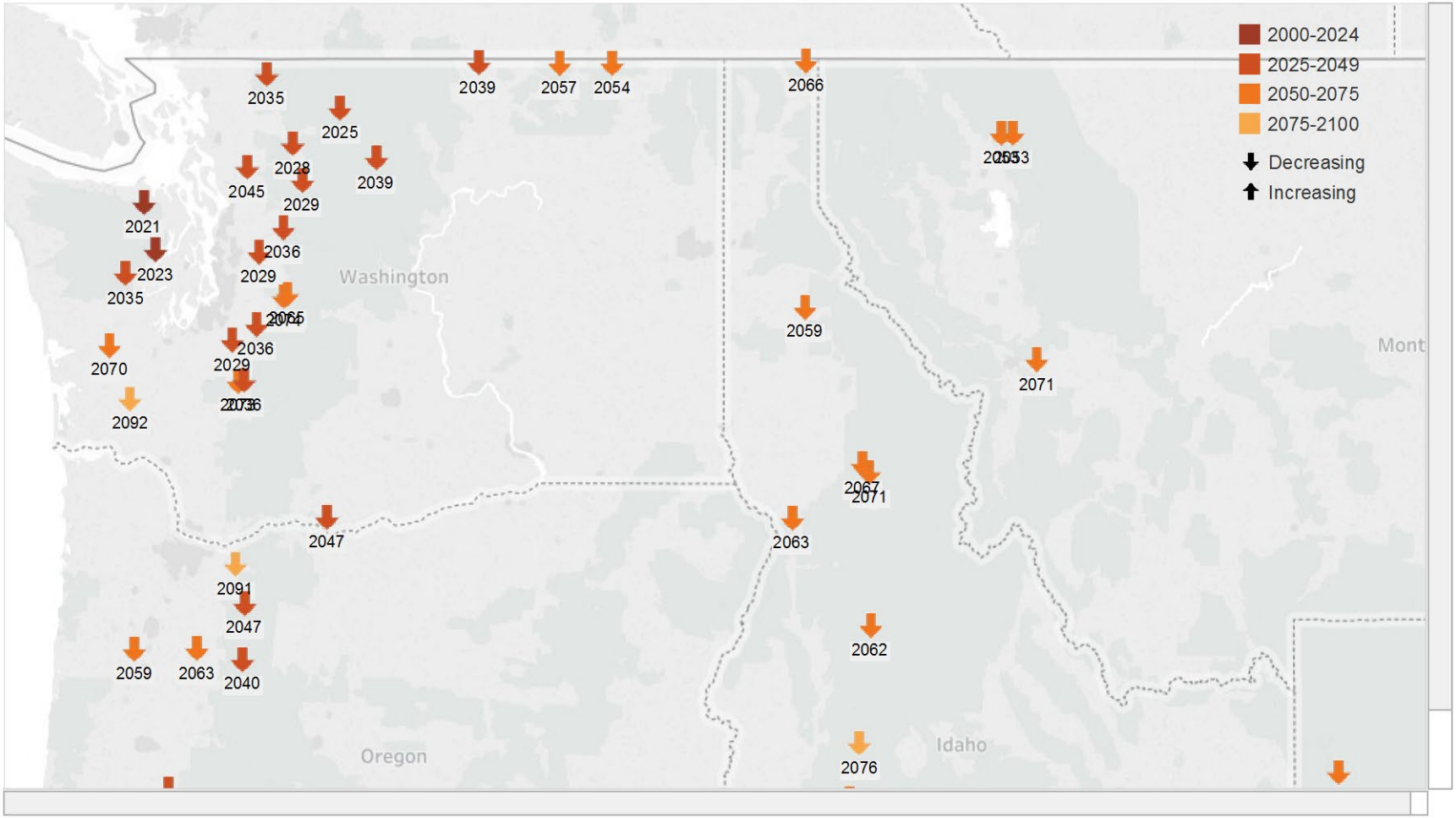
Expectations for the Pac NW

- Variations on time scales of seasons to multiple years will dominate long-term trends for the next 2-3 decades
- Greater increases in minimum rather than maximum temperatures; higher humidity
- Wetter winters and drier summers (probably)

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%

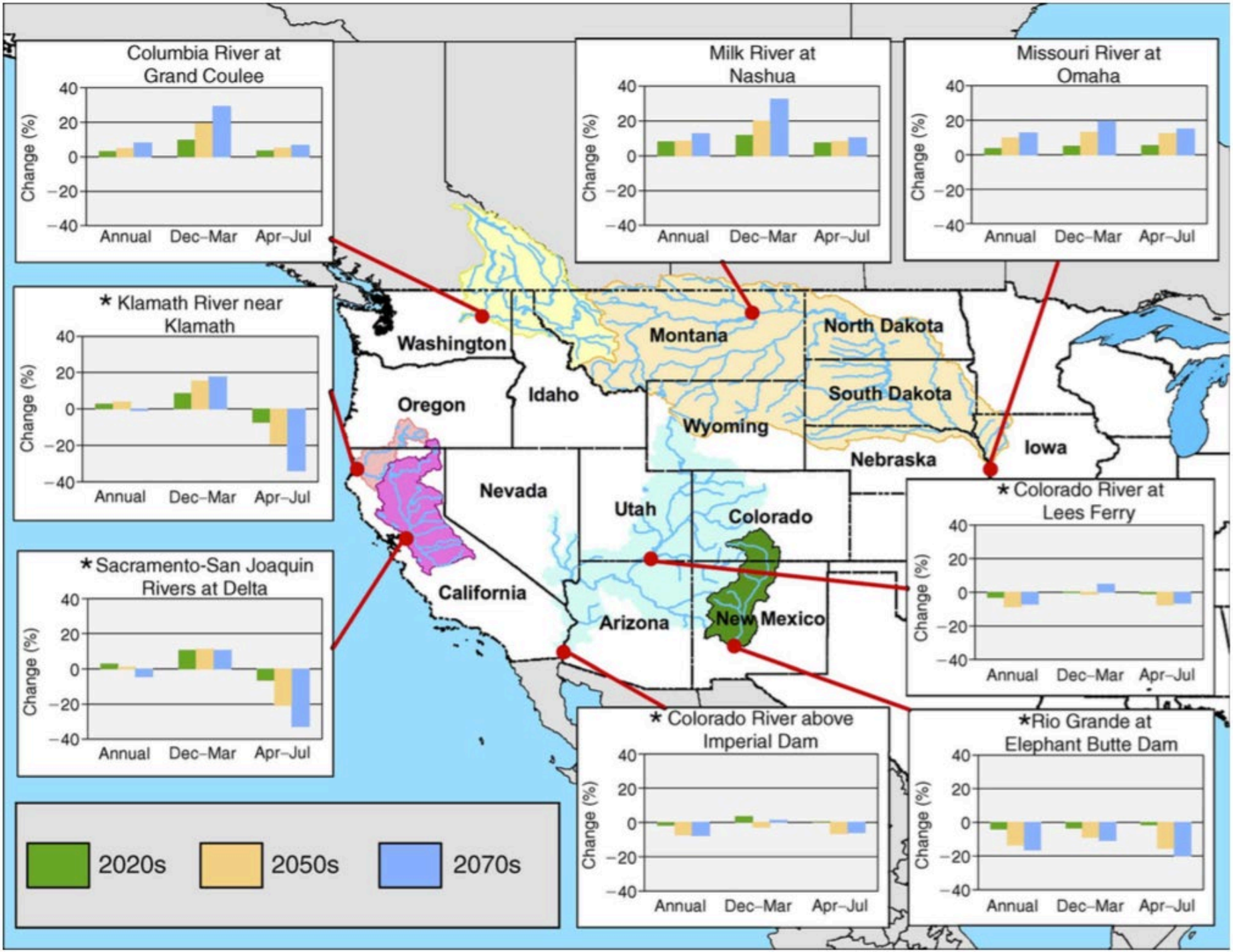
Month
July
☐ Show history

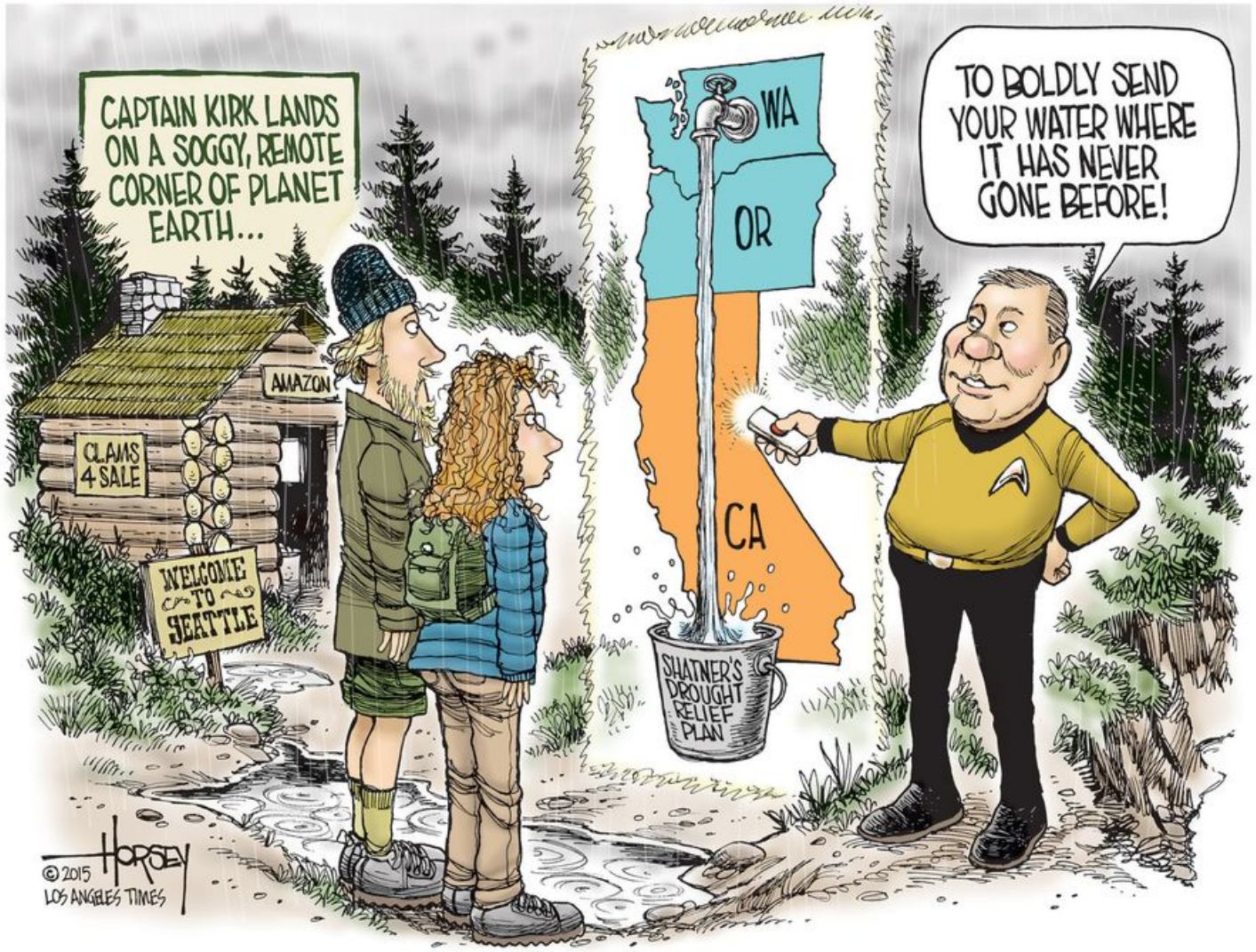
When will the climate change signal in July streamflow exceed the interannual variability?

CLIMATE IMPACTS GROUP

Water Management Challenges

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


Columbia River at Grand Coulee
Milk River at Nashua
Missouri River at Omaha
* Klamath River near Klamath
* Sacramento-San Joaquin Rivers at Delta
* Colorado River at Lees Ferry
* Colorado River above Imperial Dam
*Rio Grande at Elephant Butte Dam
Change (%)
40
20
0
−20
−40
Annual
Dec–Mar
Apr–Jul
Washington
Oregon
California
Idaho
Nevada
Montana
Wyoming
Utah
Arizona
Colorado
New Mexico
North Dakota
South Dakota
Nebraska
Iowa
2020s
2050s
2070s


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

Ecosystem Concerns

- Water and Air Temperature Impacts
- Aquatic Migration
- Invasive Species
- Sea Level Rise/Saltwater Intrusion
- Riverine Habitat

Final Remarks

- Record temperature anomalies occurred during 2014-16 in the western US.
- Natural variability in the climate system (e.g., El Nino) will continue to dominate overall trends for some time

- Future decades will feature not just warmer temperatures but probably also wetter winters and slightly drier summers
- Relative to historical norms, Pacific NW stream flows are generally expected to be greater in winter and lower in summer. Extreme events (ARs) liable to include greater moisture contents.

- Will overall water supply or water quality be a bigger issue?

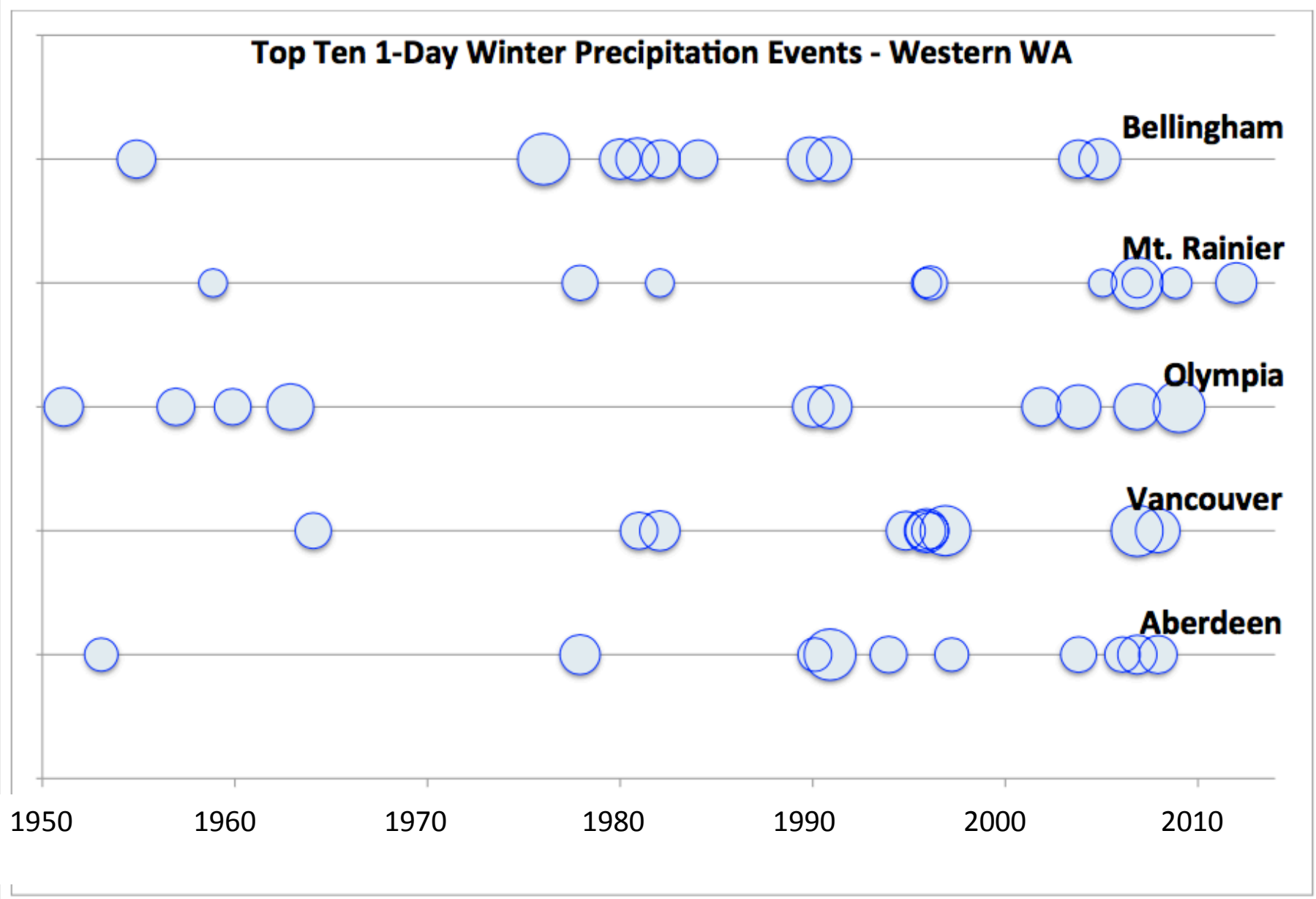
References

US Bureau of Reclamation (2016): SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water 2016. Available at http://www.usbr.gov/climate/secure/

US Environmental Protection Agency (2016): Climate Impacts in the Northwest. Available at https://www.epa.gov/climate-impacts/climate-impacts-northwest#Reference2

US Geological Survey (2009): Climate Change and Water Resources Management: A Federal Perspective. Available at https://pubs.usgs.gov/circ/1331/

Dettinger, M., B. Udall and A. Georgakakos (2015): Western water and climate change. **Ecological Applications**, 25(8), 2069-2093.


Top Ten 1-Day Winter Precipitation Events - Western WA
Bellingham
Mt. Rainier
Olympia
Vancouver
Aberdeen
1950
1960
1970
1980
1990
2000
2010

Trends in Fraction of Snow versus Rain in Winter (1949-2004)