February 2015

Climate Change and its Impacts on Water Resources and Extreme Events in Washington State

Regional Historical Trends

Climate Change Projections

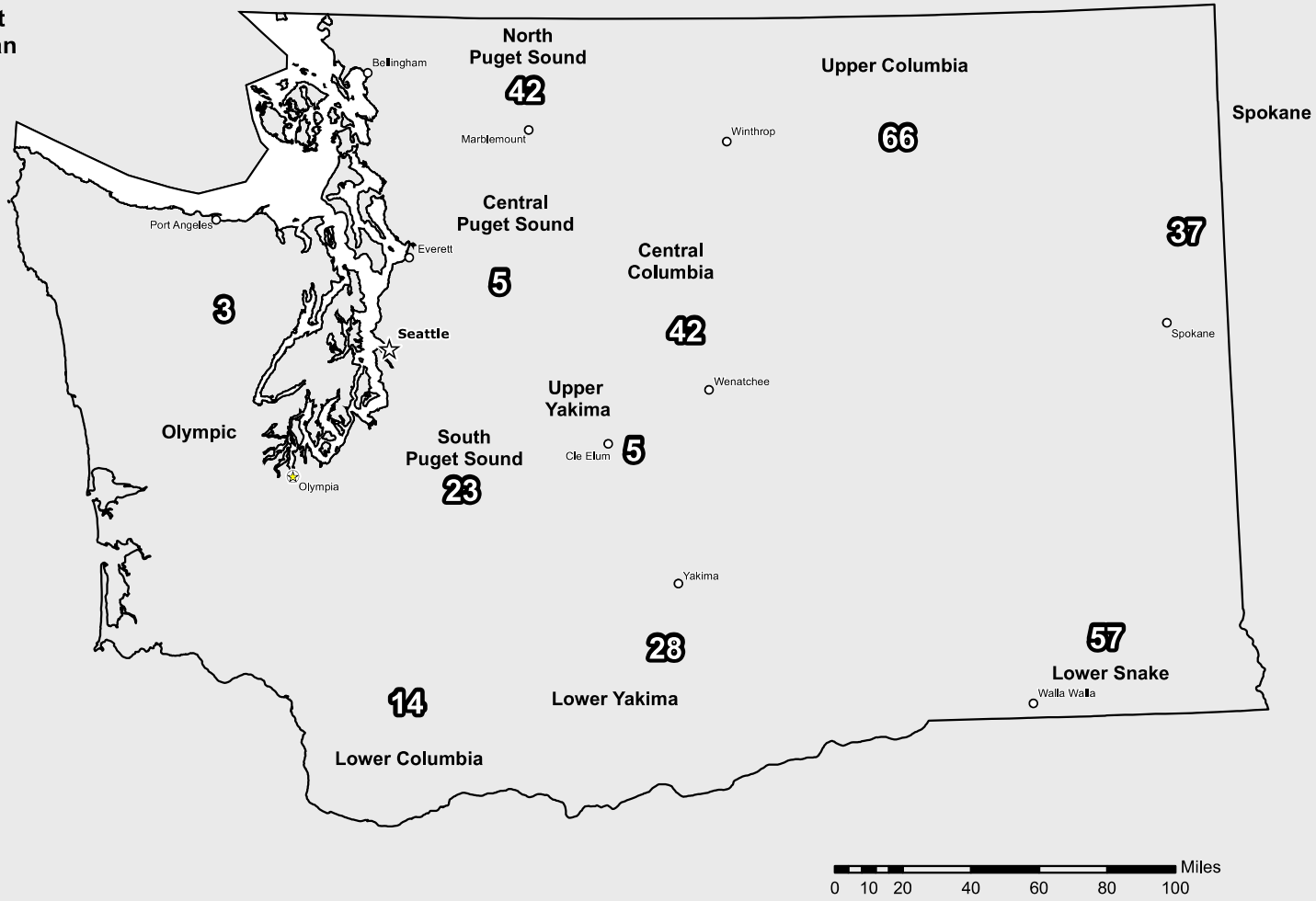
Washington SNOTEL Current Snow Water Equivalent (SWE) % of Normal

Apr 01, 2015

Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median

- unavailable *
- <50%
- 50 - 69%
- 70 - 89%
- 90 - 109%
- 110 - 129%
- 130 - 149%
- >=150%

* *Data unavailable at time of posting or measurement is not representative at this time of year*

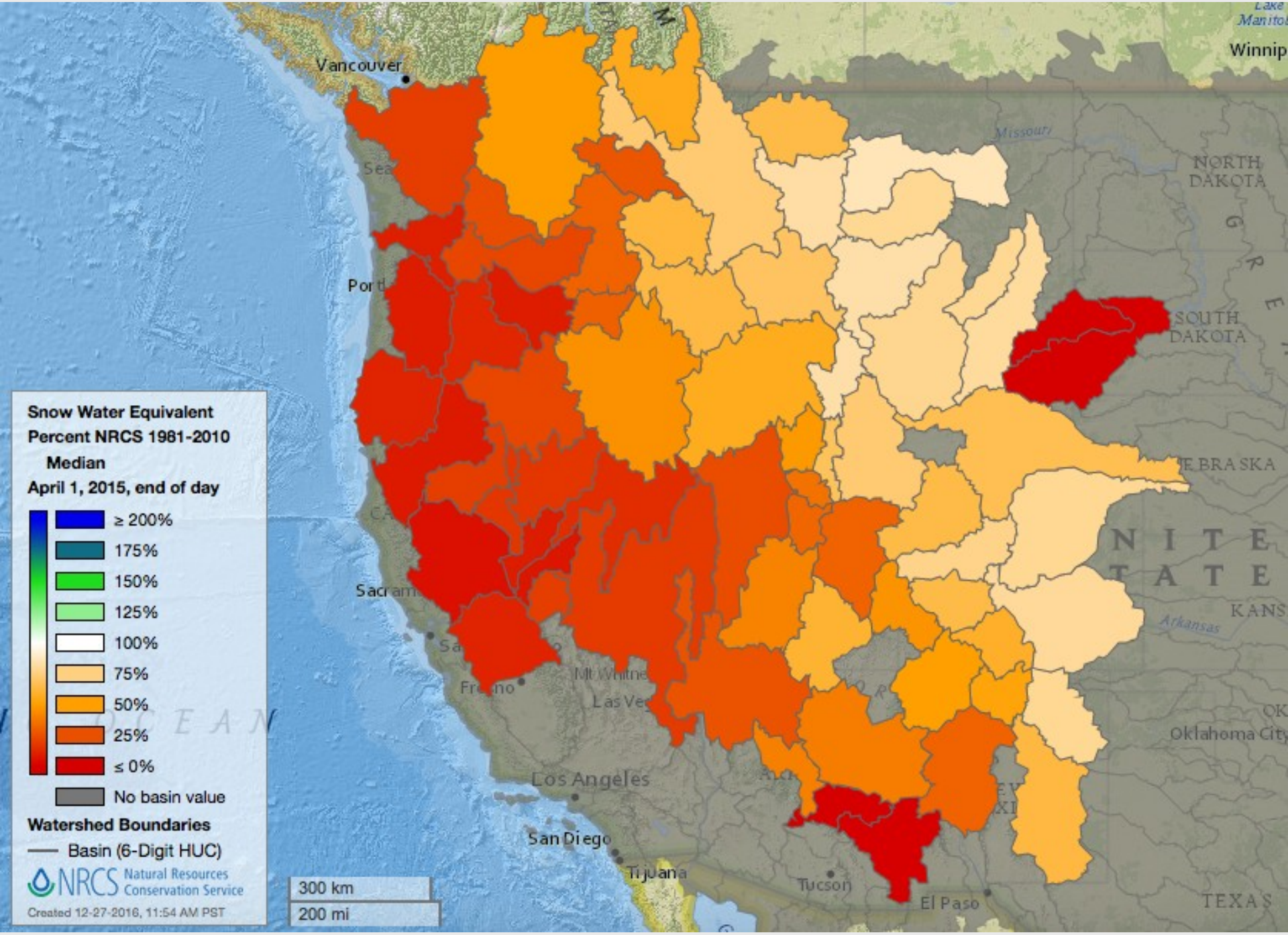


Provisional Data Subject to Revision

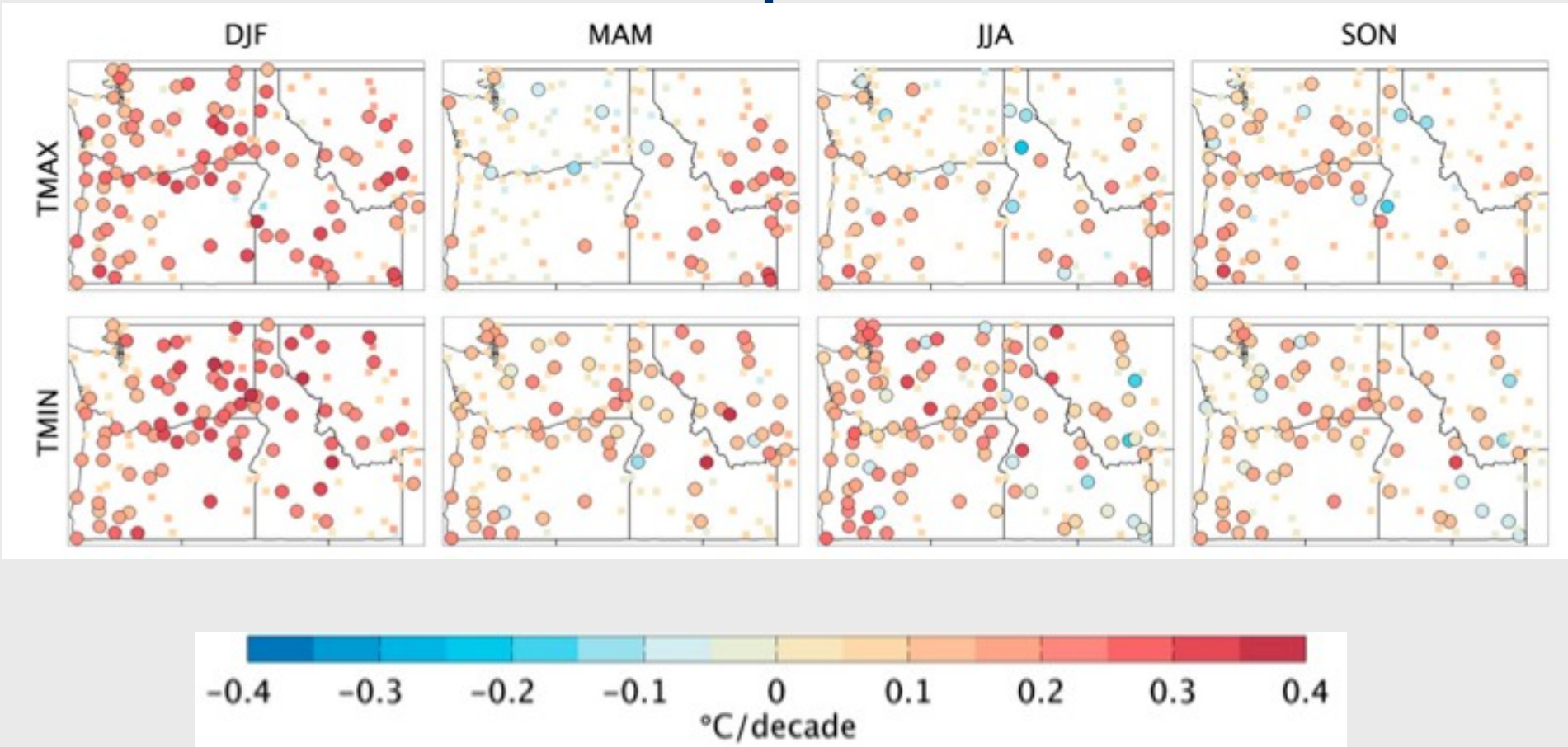
USDA NRCS

The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).

Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

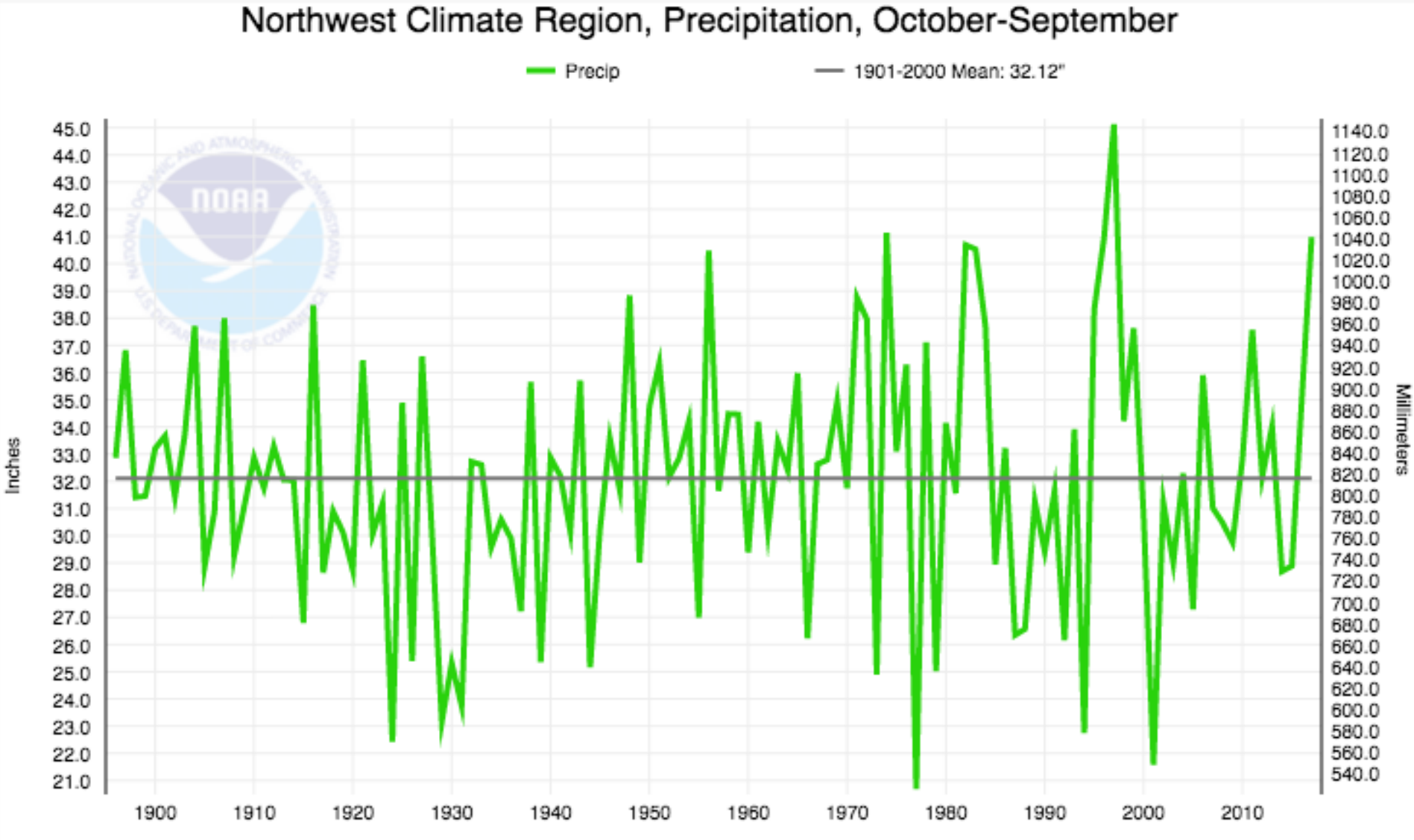

Snow Water Equivalent
Percent NRCS 1981-2010
Median
April 1, 2015, end of day
≥ 200%
175%
150%
125%
100%
75%
50%
25%
≤ 0%
No basin value
Watershed Boundaries
Basin (6-Digit HUC)
NRCS Natural Resources Conservation Service
Created 12-27-2016, 11:54 AM PST
300 km
200 mi
Vancouver
Missouri
NORTH DAKOTA
SOUTH DAKOTA
Arkansas
Oklahoma City
Los Angeles
San Diego
Tijuana
Tucson
El Paso
TEXAS

1920-2012 Temperature Trends

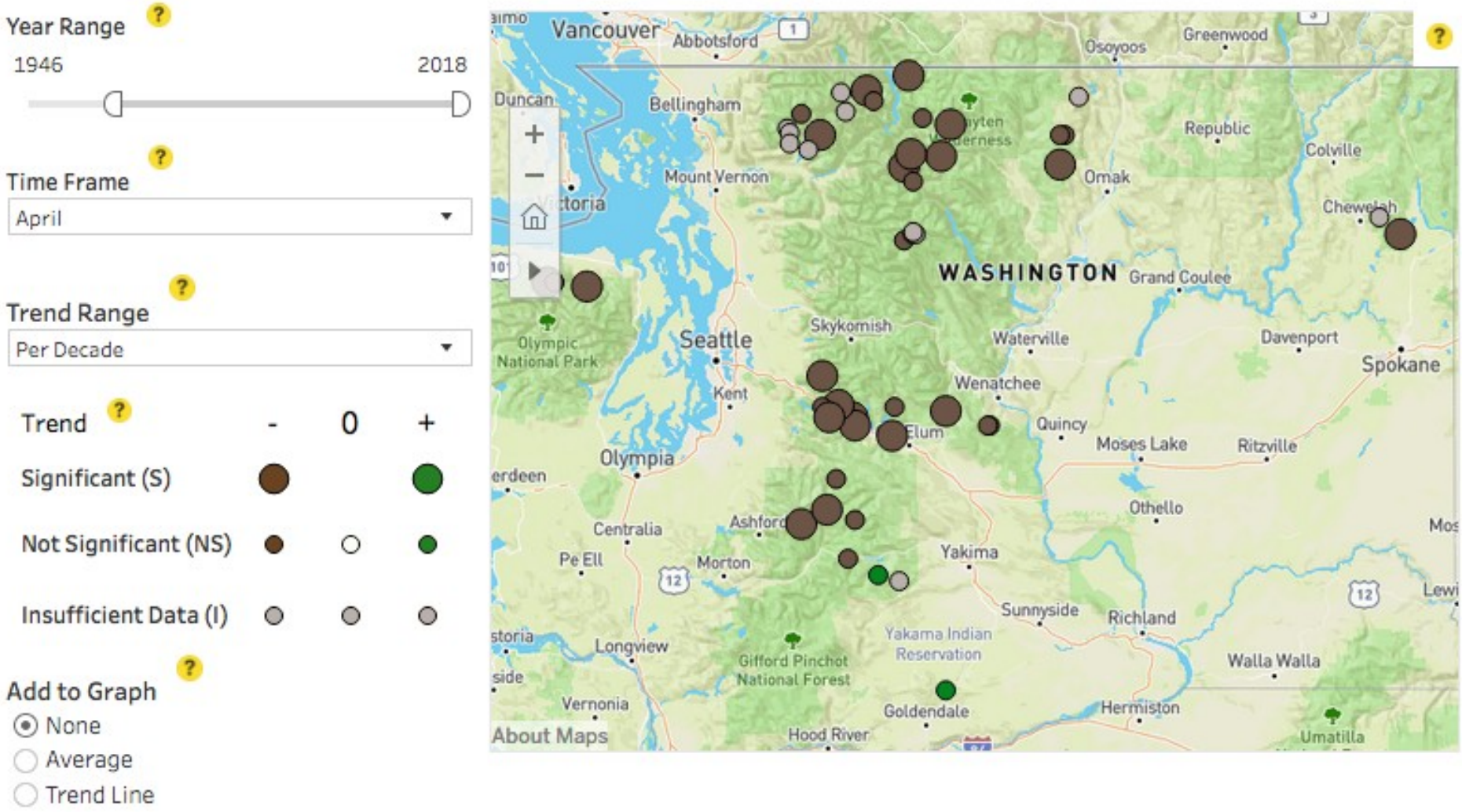


Squares aren't significant linear trends; circles are significant at 95%

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

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



Temperature | Precipitation | Snow Water Equivalent

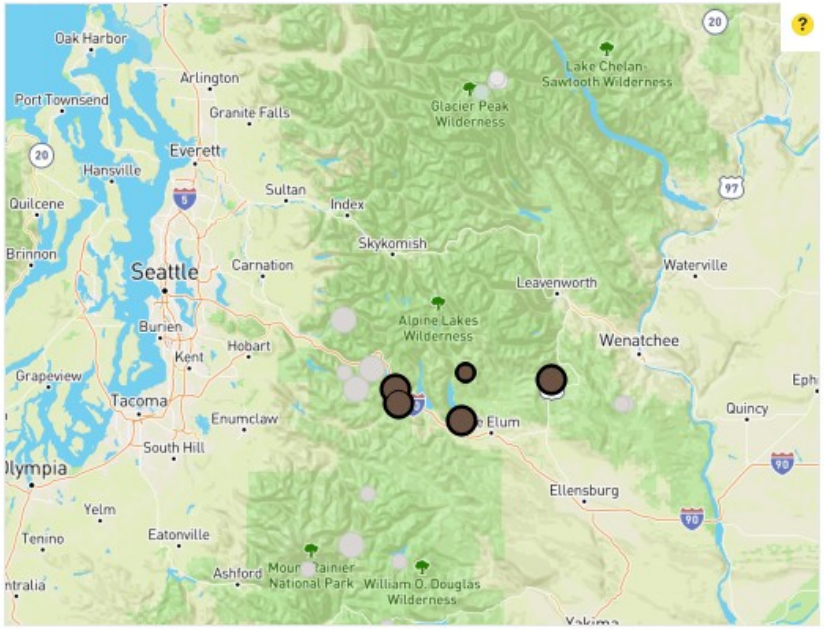
Year Range
1926 to 2018

Time Frame
April

Trend Range
Per Decade

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

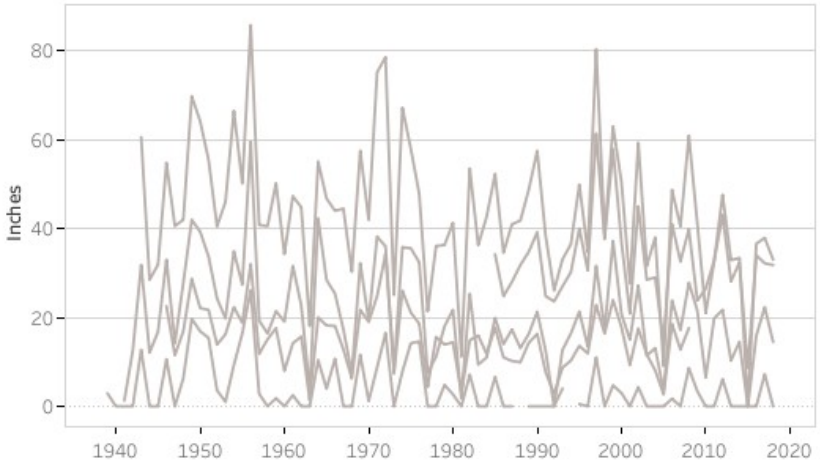
Add to Graph
- (●) None
- ( ) Average
- ( ) Trend Line



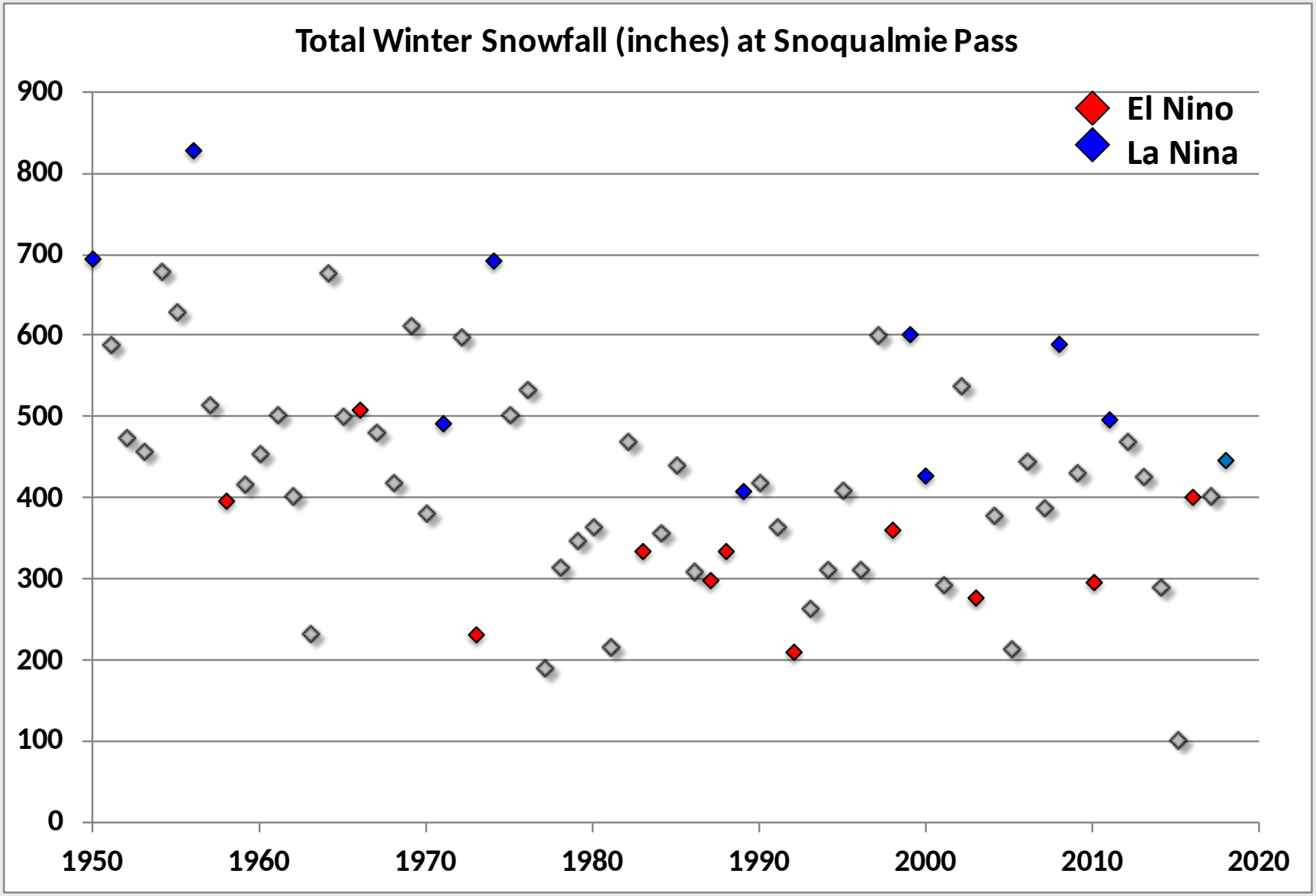
Trend Data (% Change Per Decade)

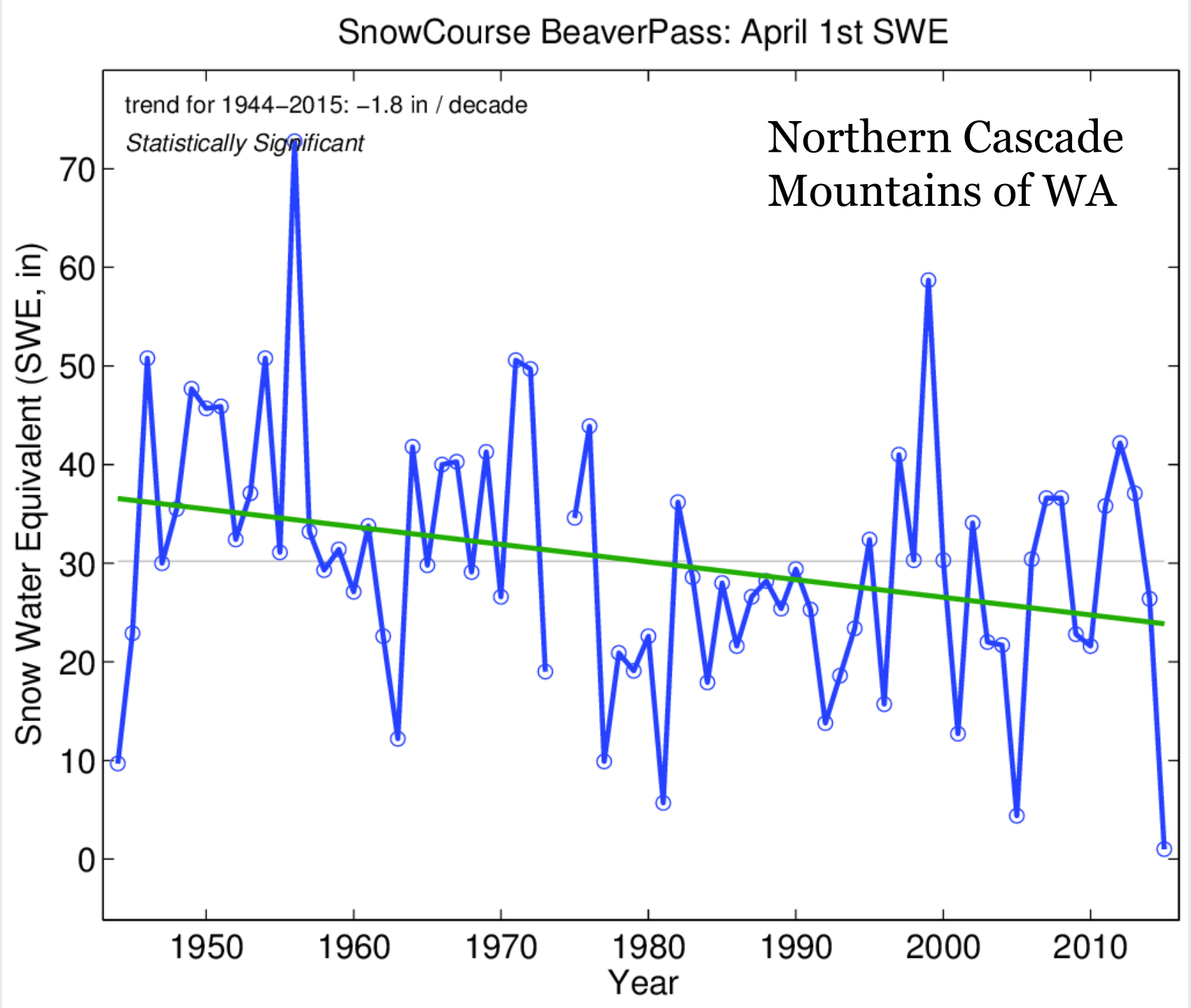
Blewett Pass ..	WA	S	-	6
Dommerie Fla..	WA	S	-	10.6
Sasse Ridge P..	WA	NS	-	2.8
Stampede Pa..	WA	S	-	4.2
Tunnel Avenue	WA	S	-	5.8

April Snow Water Equivalent (1939-2018)

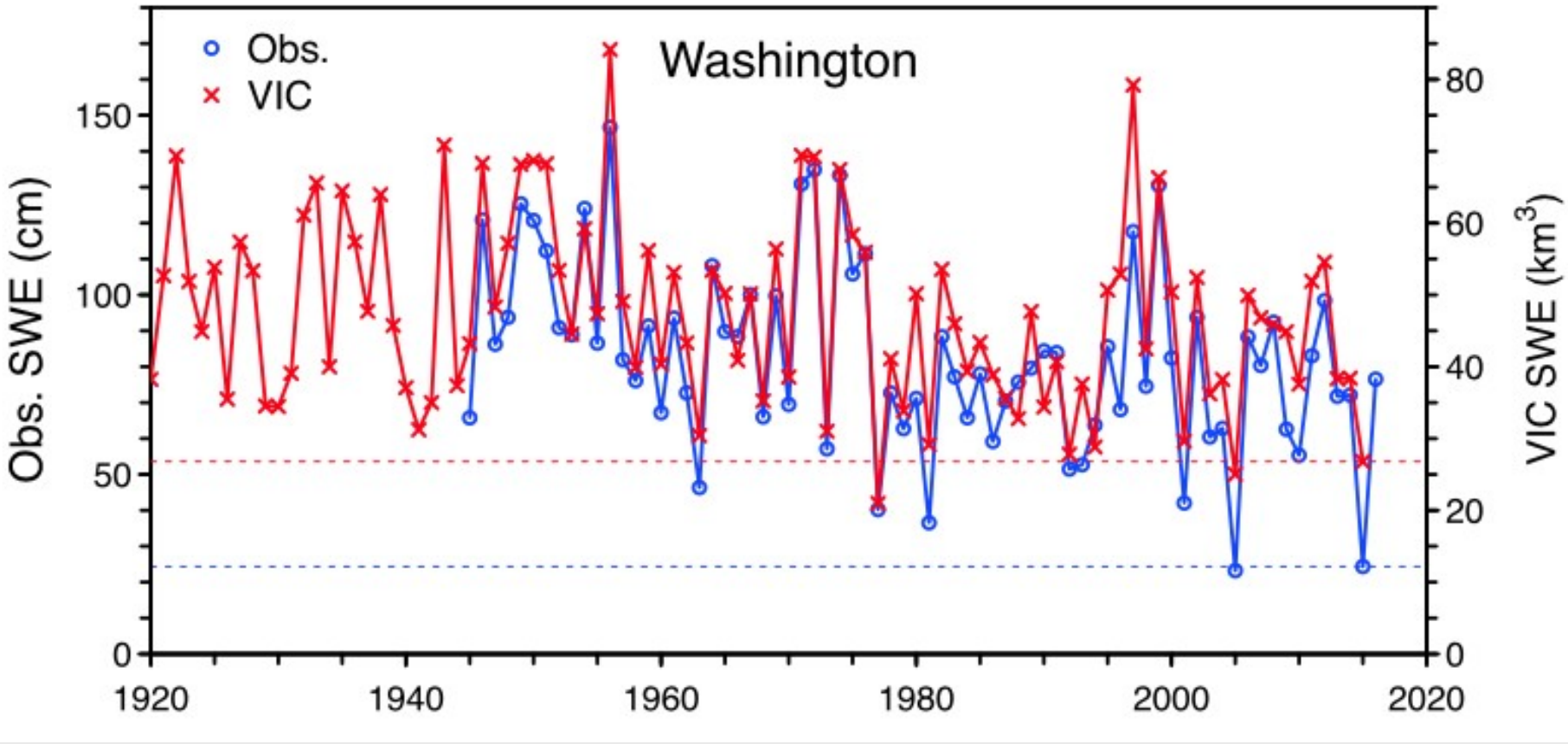


SWE Data Source: National Resources Conservation Service (NRCS) historical snow course data


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


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

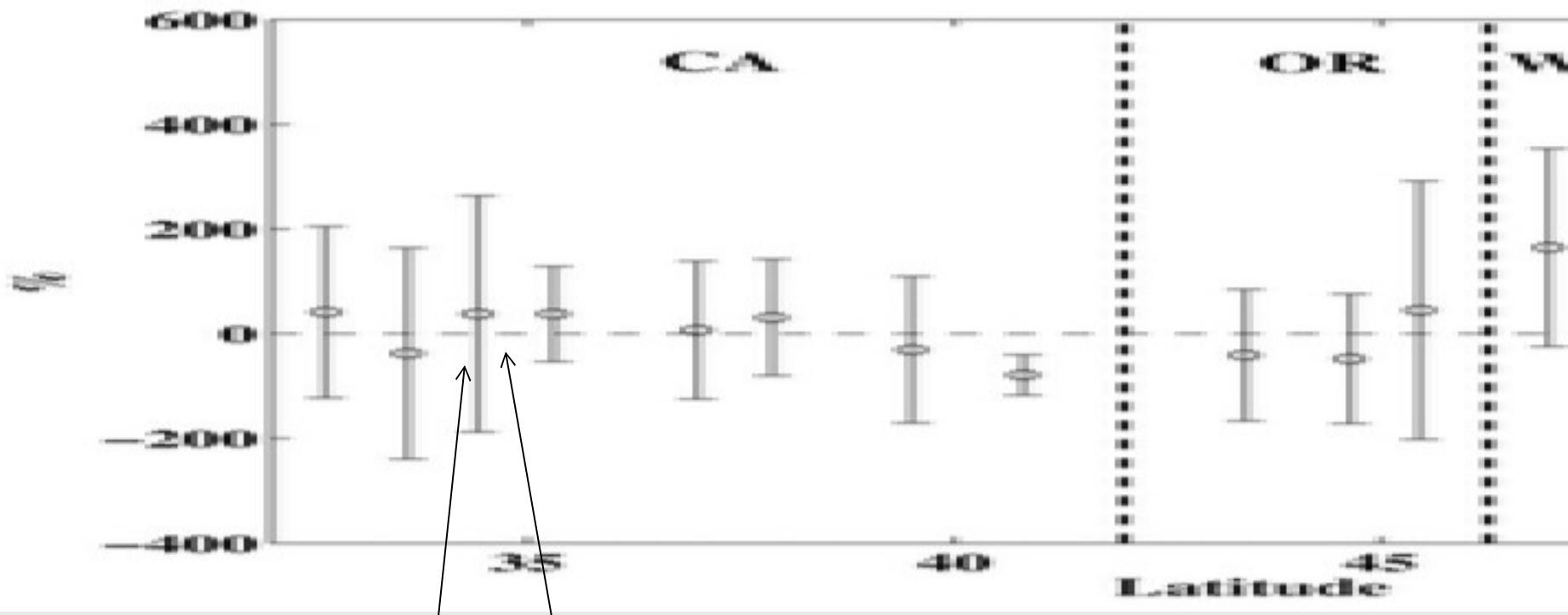
Snow Water Equivalent (SWE) for 1 April



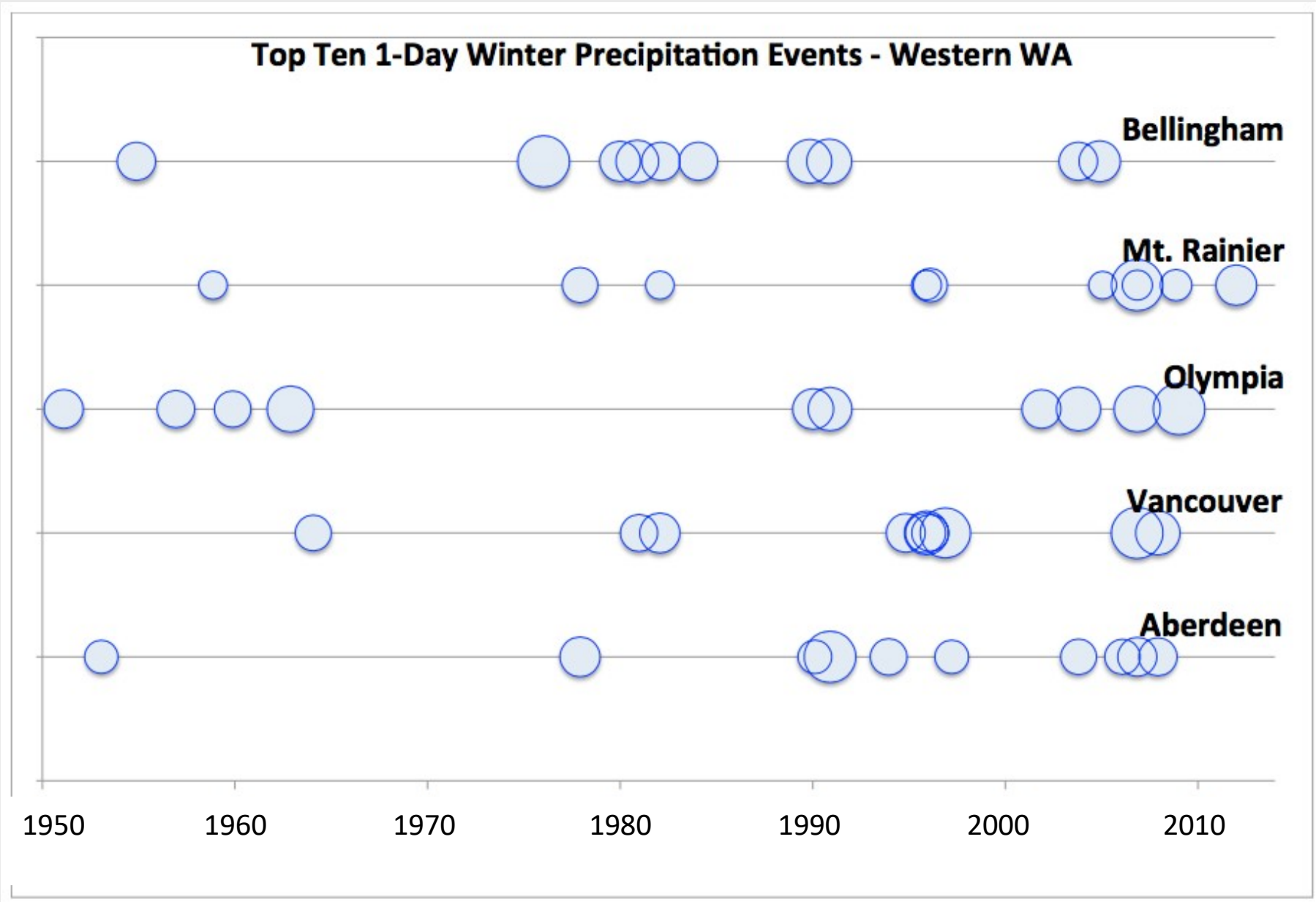
Mote et al. (2016)

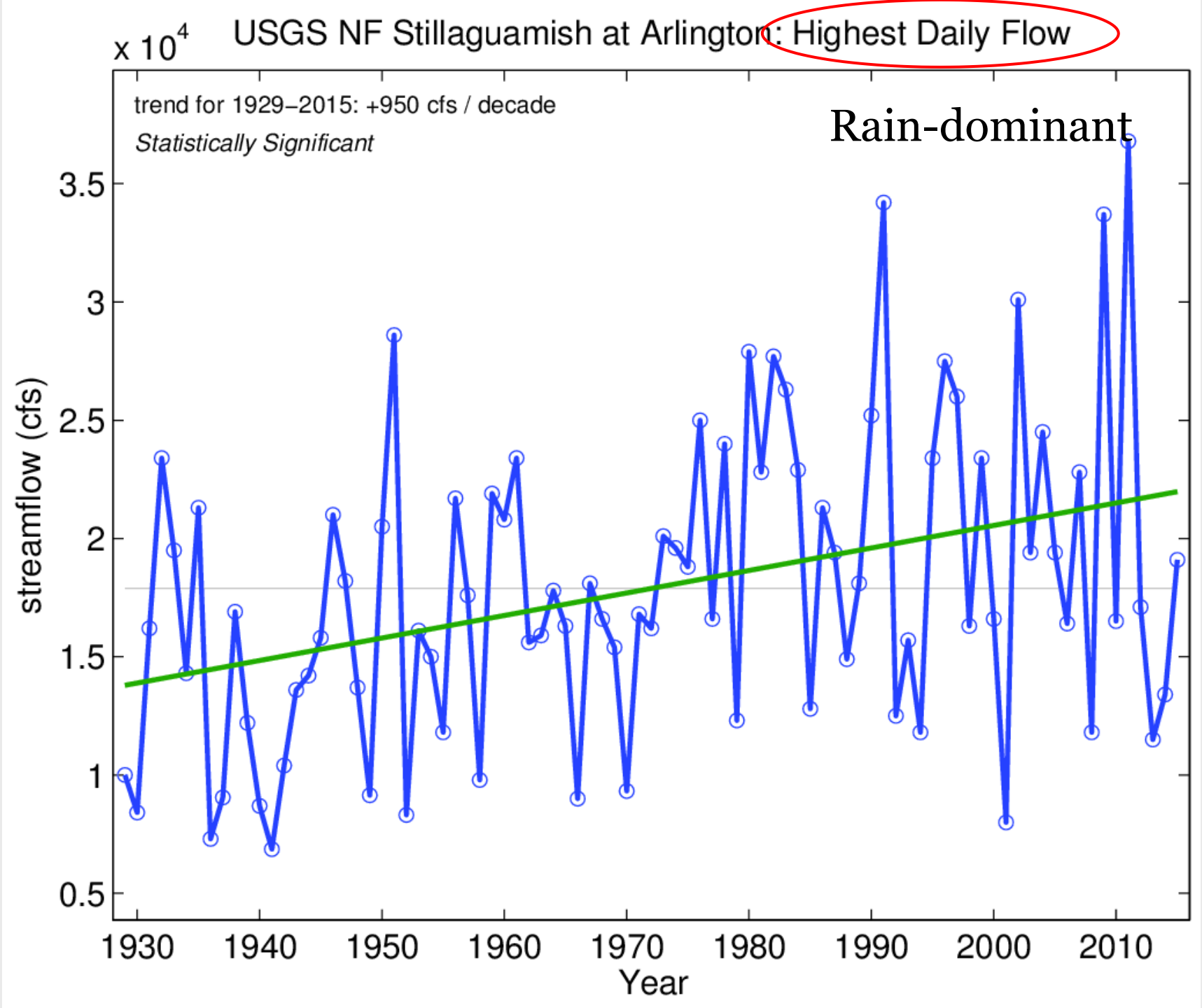
60-Year Trends for the Top Precipitation Events along the West Coast of North America

Top 60 Top 20



Mass et al. (2011)

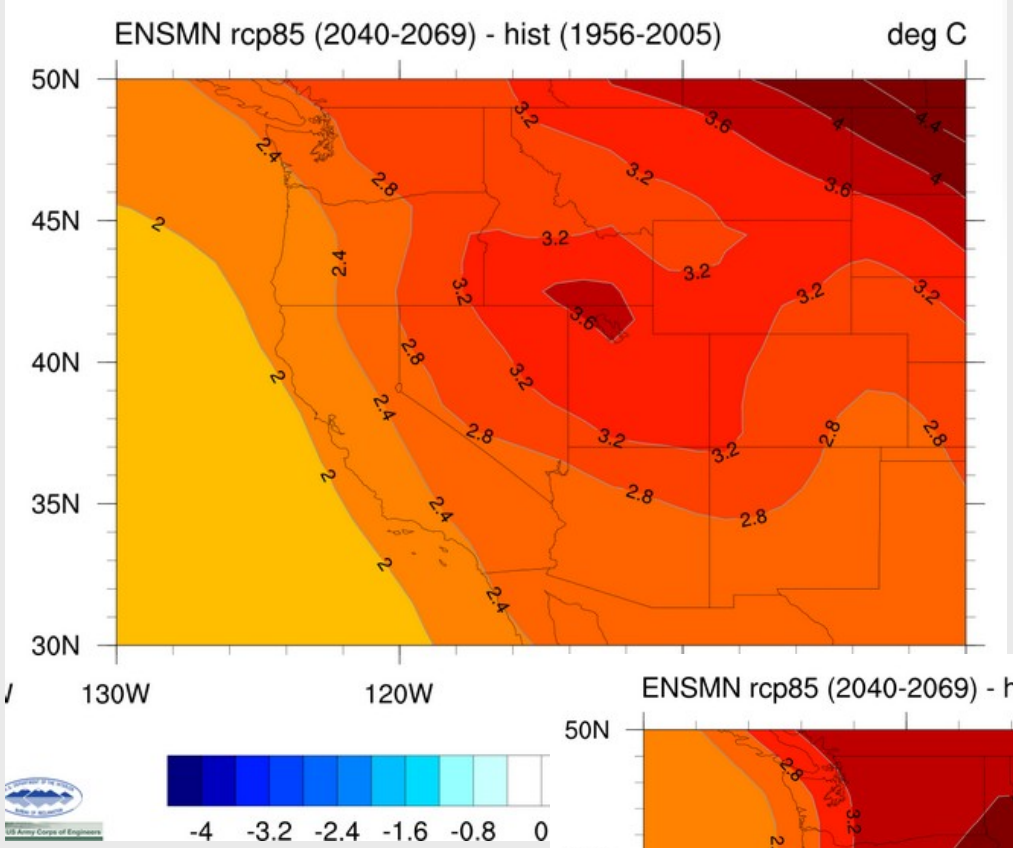

Top Ten 1-Day Winter Precipitation Events - Western WA
Bellingham
Mt. Rainier
Olympia
Vancouver
Aberdeen
1950
1960
1970
1980
1990
2000
2010


USGS NF Stillaguamish at Arlington: Highest Daily Flow
x 10^4
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

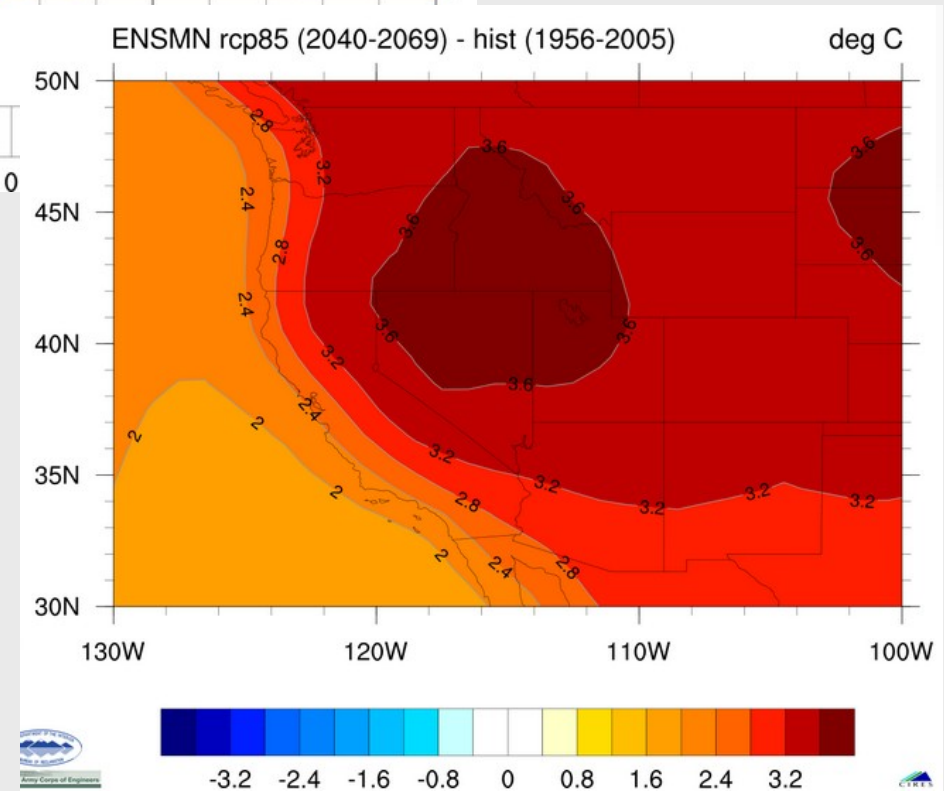

January 2053...
I DON'T CARE WHAT THEY SAY, THIS GLOBAL WARMING SCARE IS JUST A BUNCH OF LOONY LEFT-WING ENVIRONMENTAL ANTI-GROWTH HYPE!
SO, IS THIS YOUR FIRST WINTER HERE IN SEATTLE?
HORSEY


Positive proof of global warming.
18th Century
1900
1950
1970
1980
1990
2018

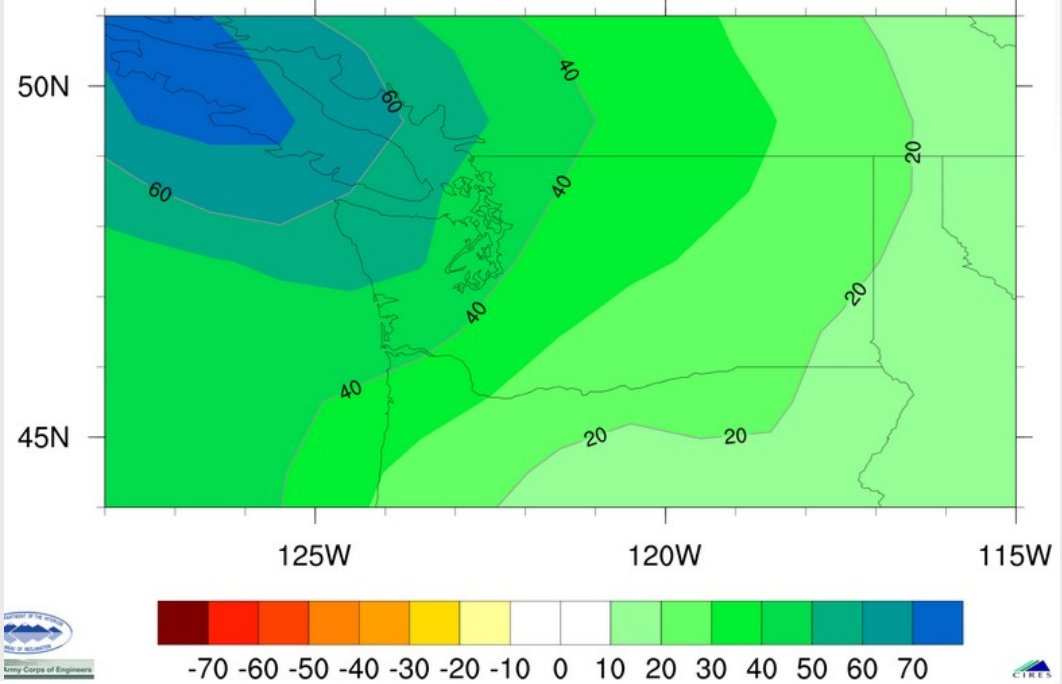
Modeled Change in Temperature by the Middle of the 21st Century



Dec-Jan-Feb

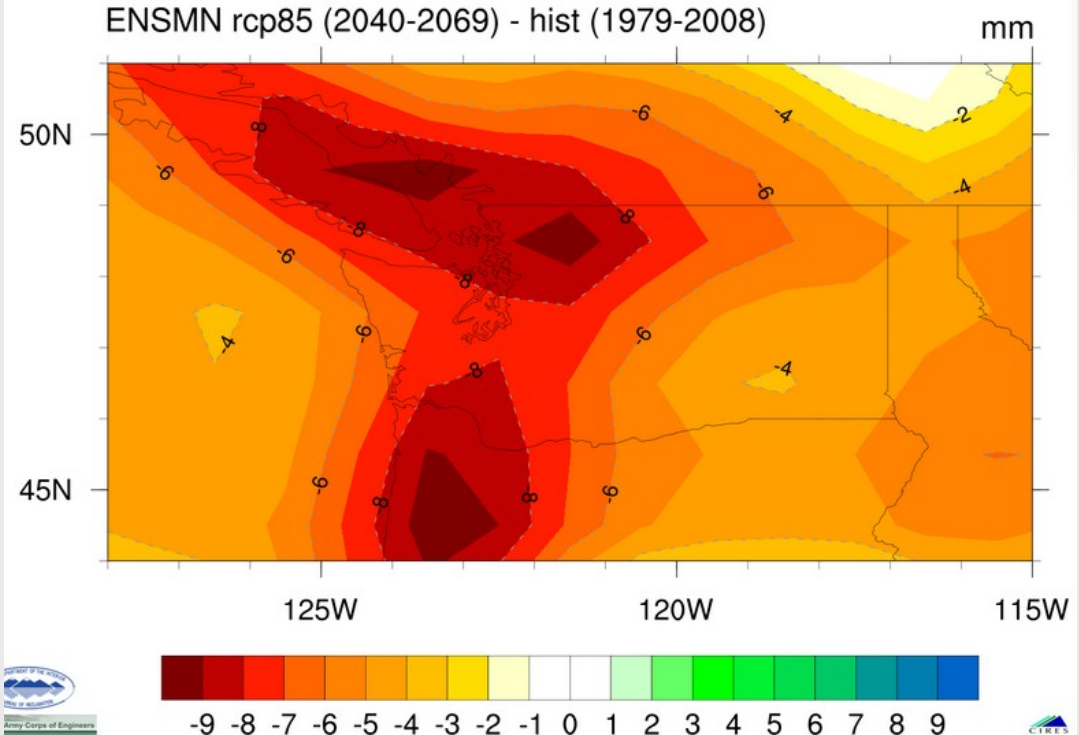


Jun-Jul-Aug

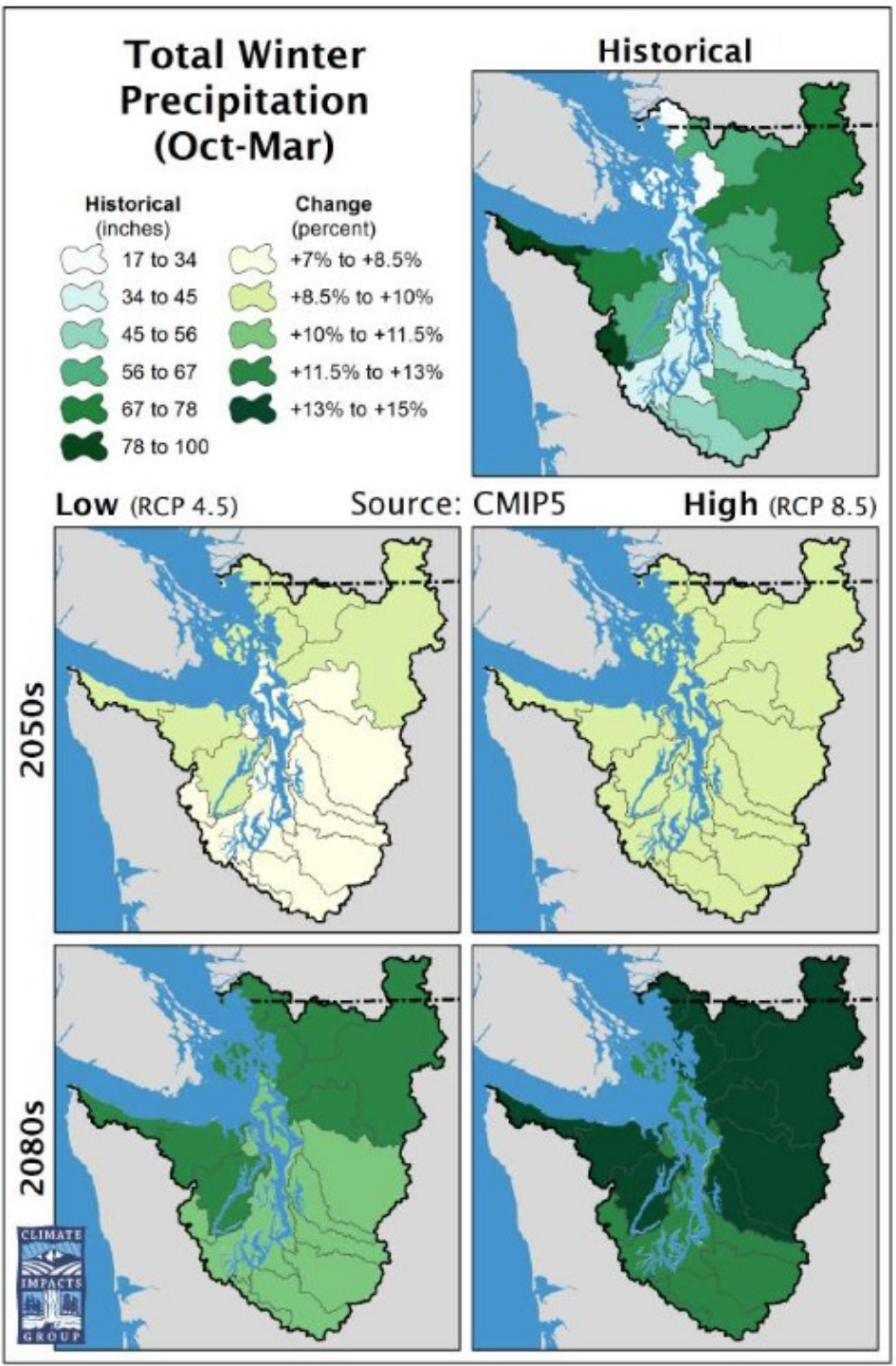


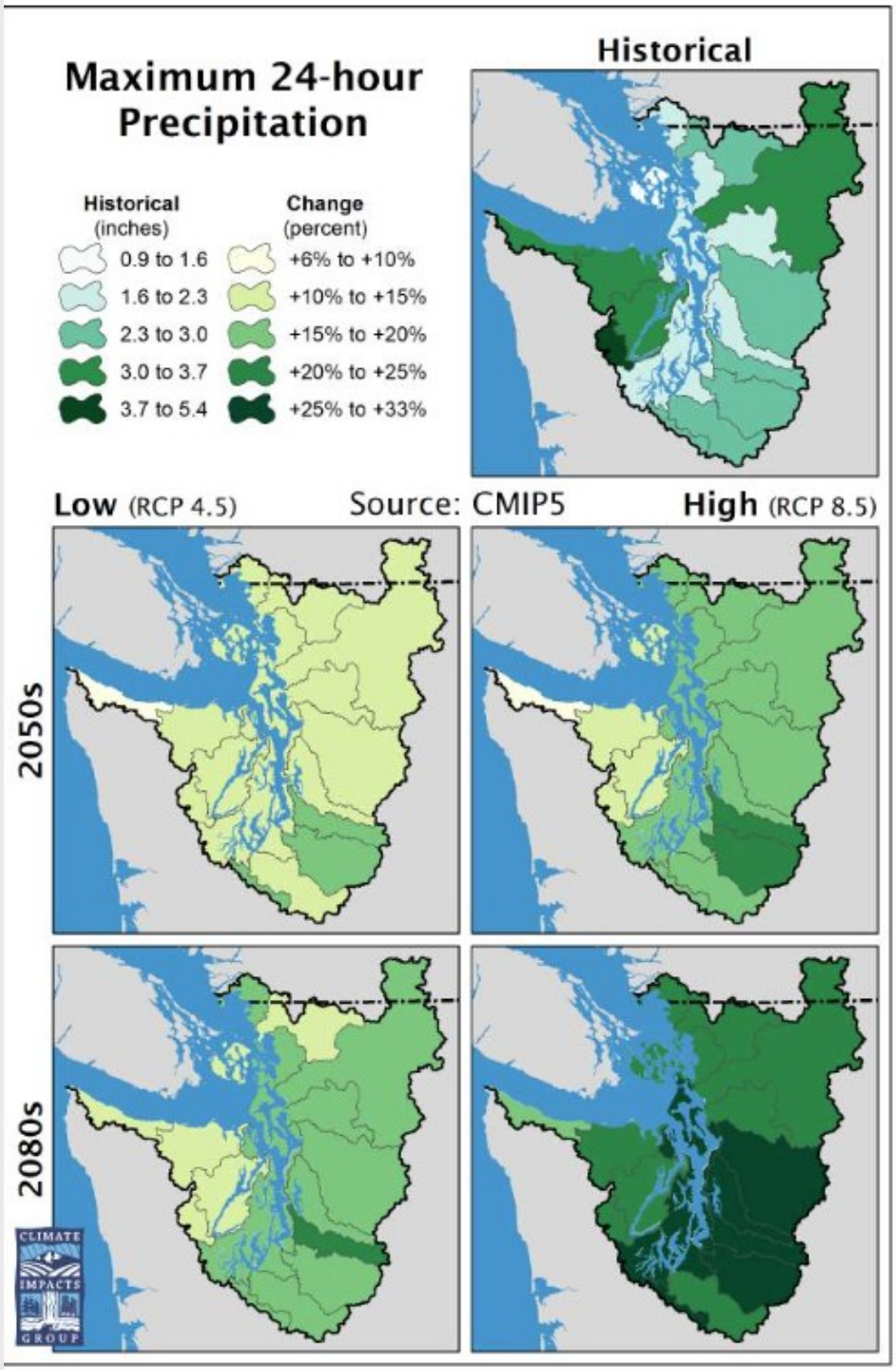
Modeled Change in Precipitation

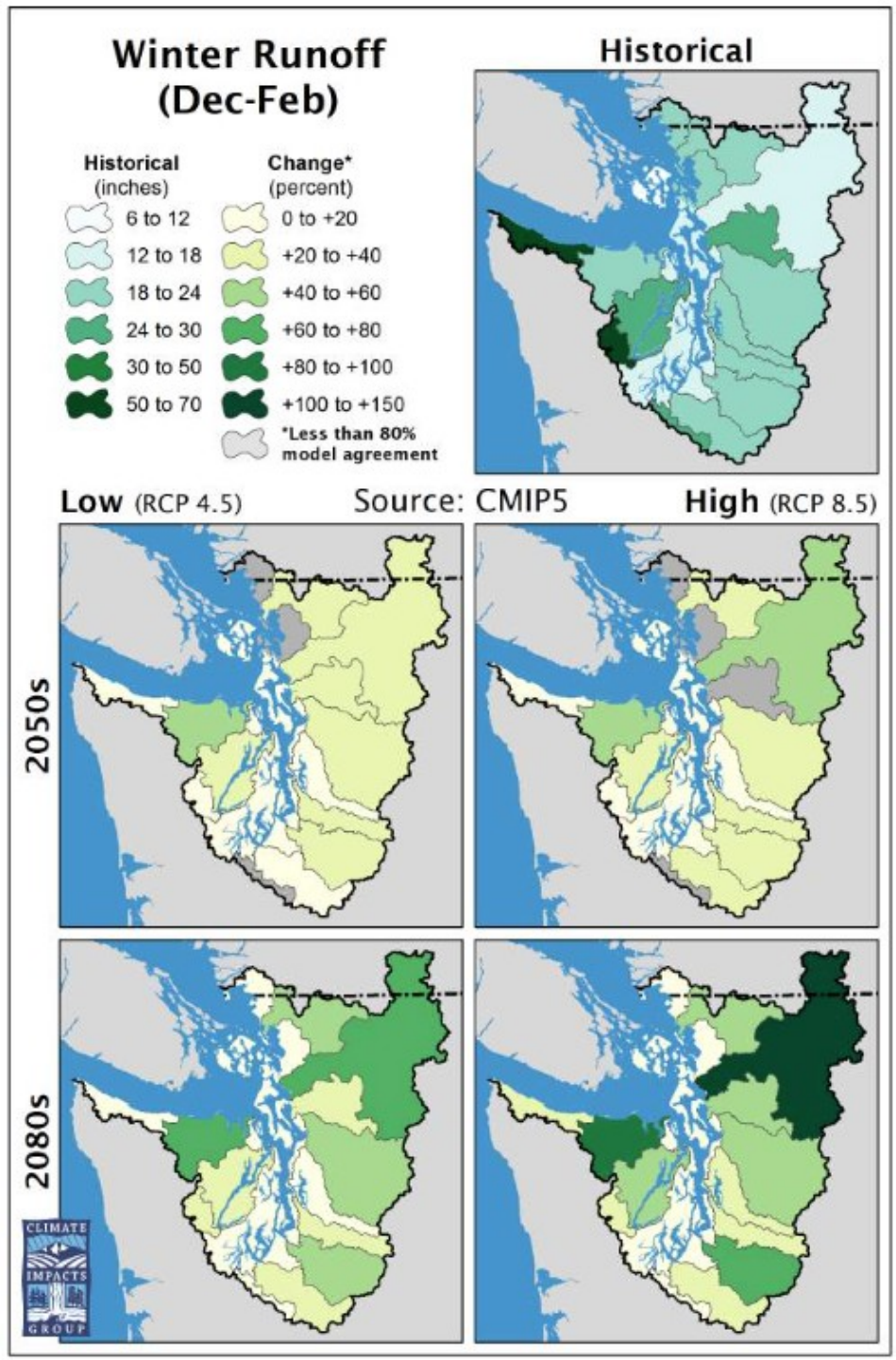
Nov-Dec-Jan

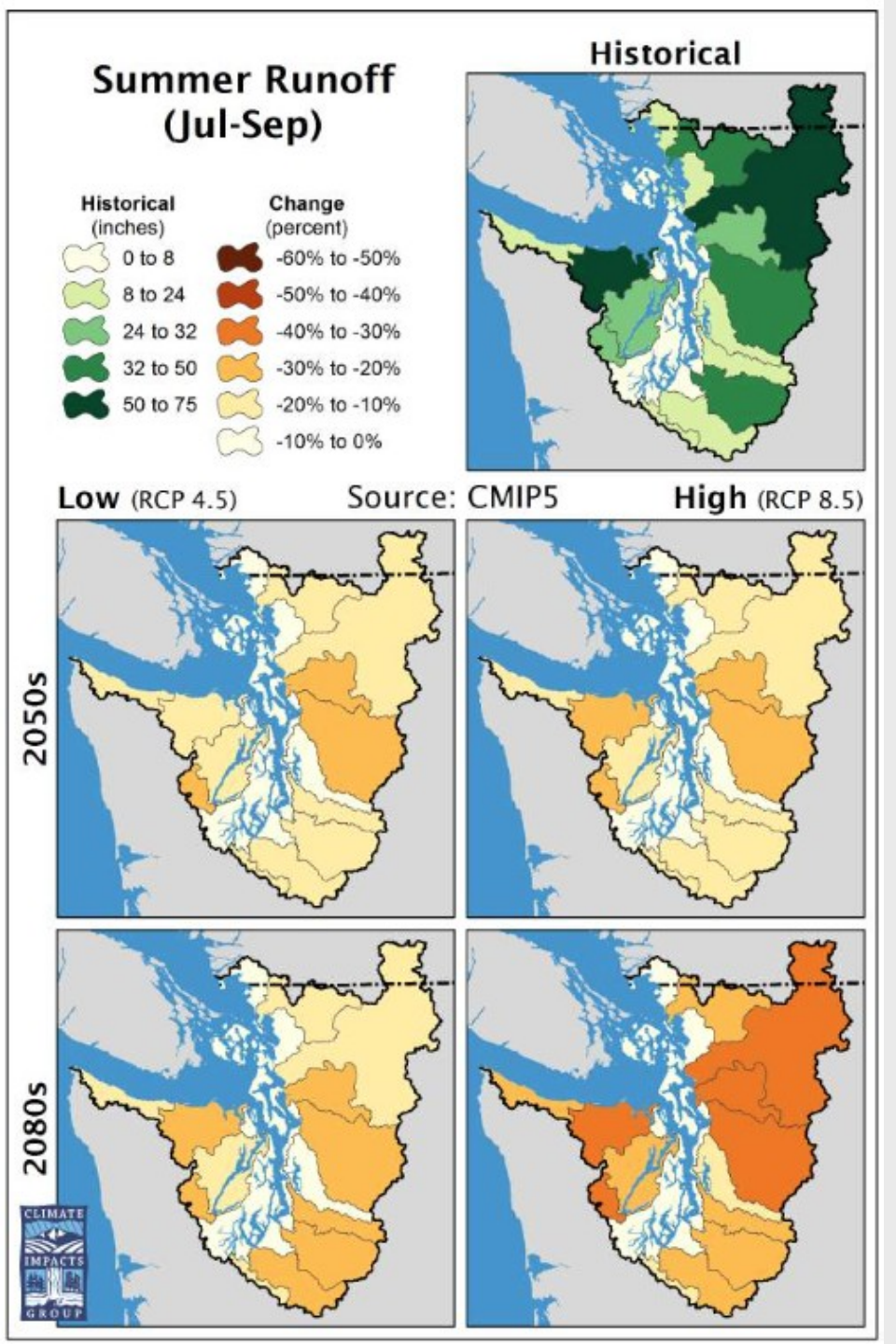


Jun-Jul-Aug


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

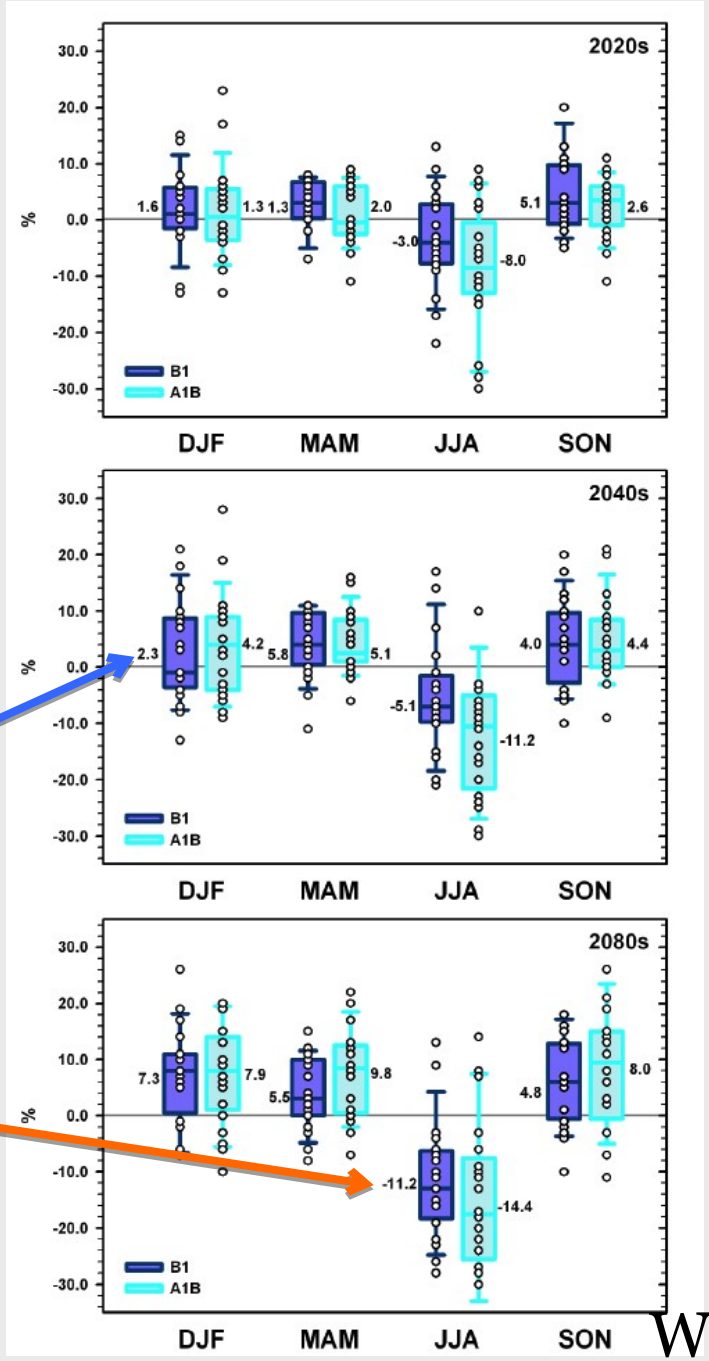

Winter Runoff
(Dec-Feb)
Historical
Historical (inches)
6 to 12
12 to 18
18 to 24
24 to 30
30 to 50
50 to 70
Change* (percent)
0 to +20
+20 to +40
+40 to +60
+60 to +80
+80 to +100
+100 to +150
*Less than 80% model agreement
Low (RCP 4.5)
Source: CMIP5
High (RCP 8.5)
2050s
2080s
CLIMATE IMPACTS GROUP


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

P
C

Season

- Changes relative to 1970-1999 mean



2020s

2040s

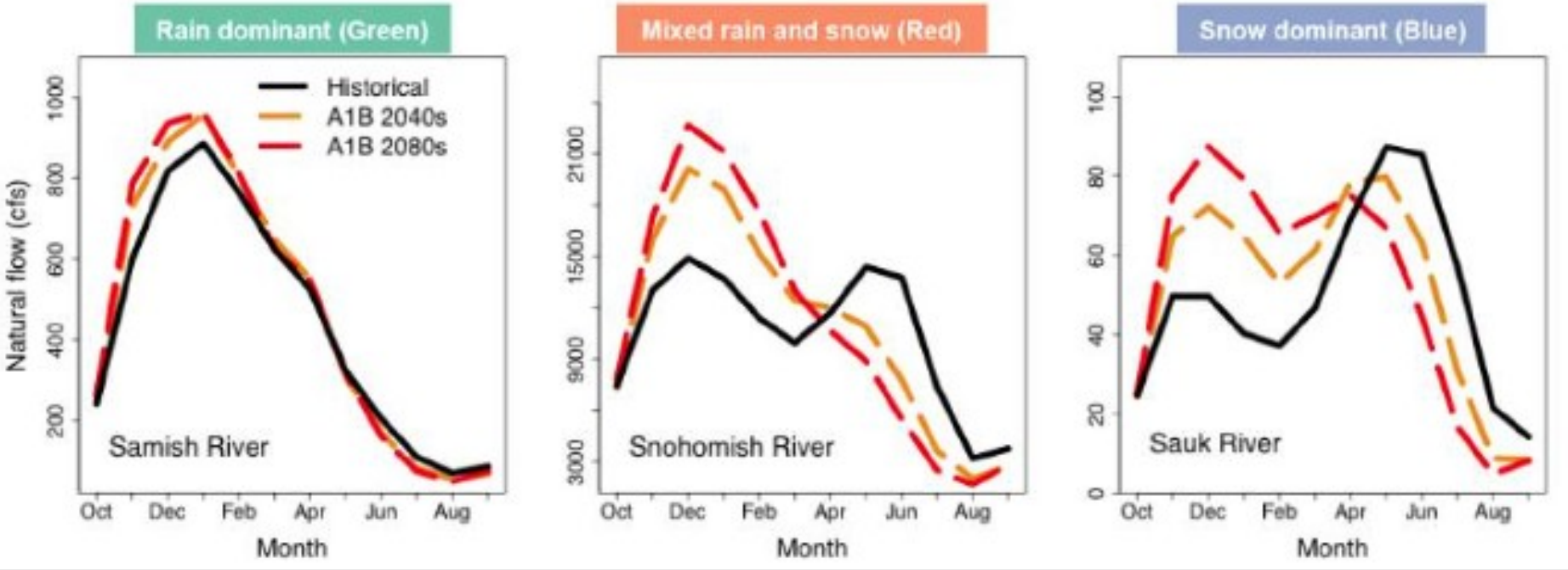
2080s

Wetter winters

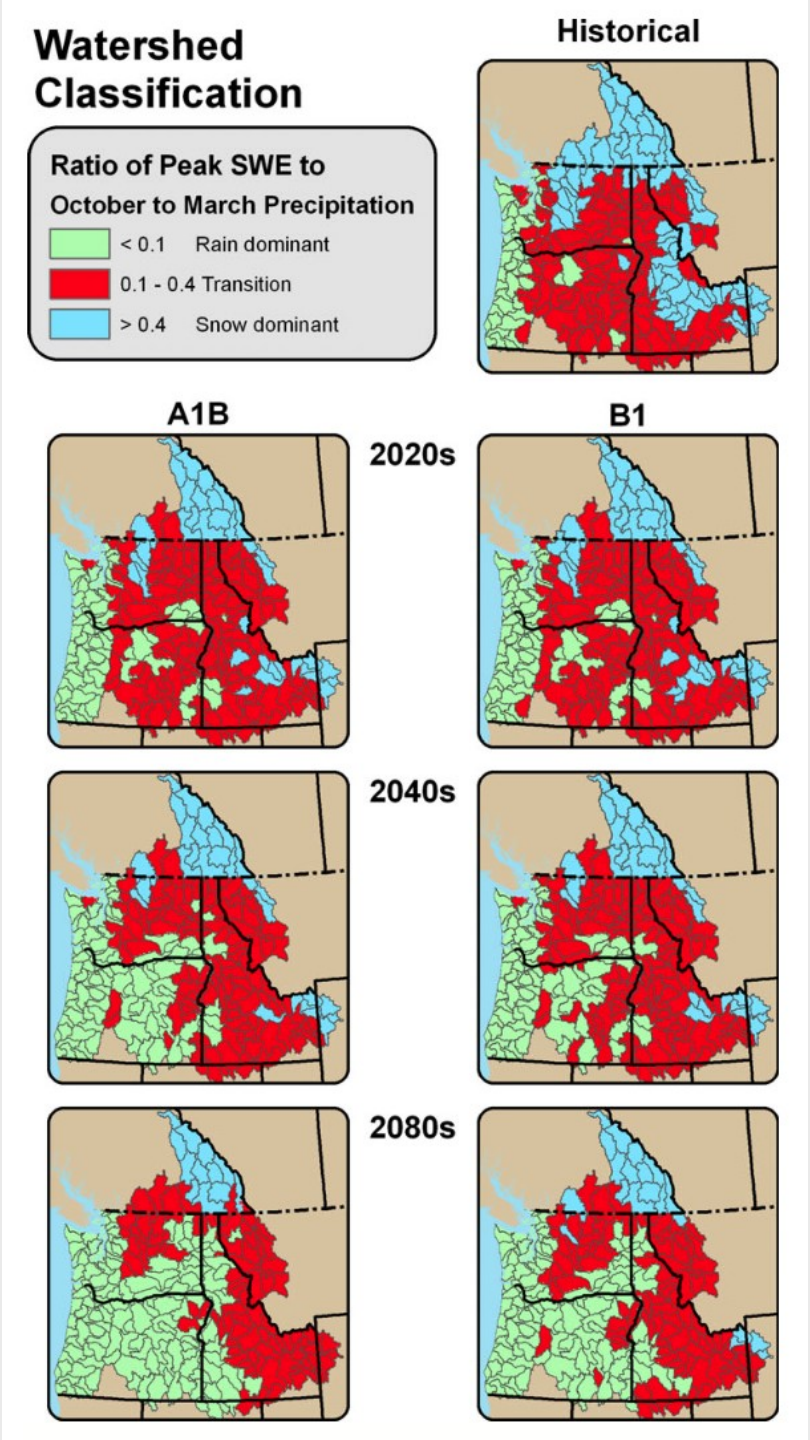
Drier summers

(slide courtesy of Ingrid Tohver - UW CIG)

Expected Transitions in Watershed Types

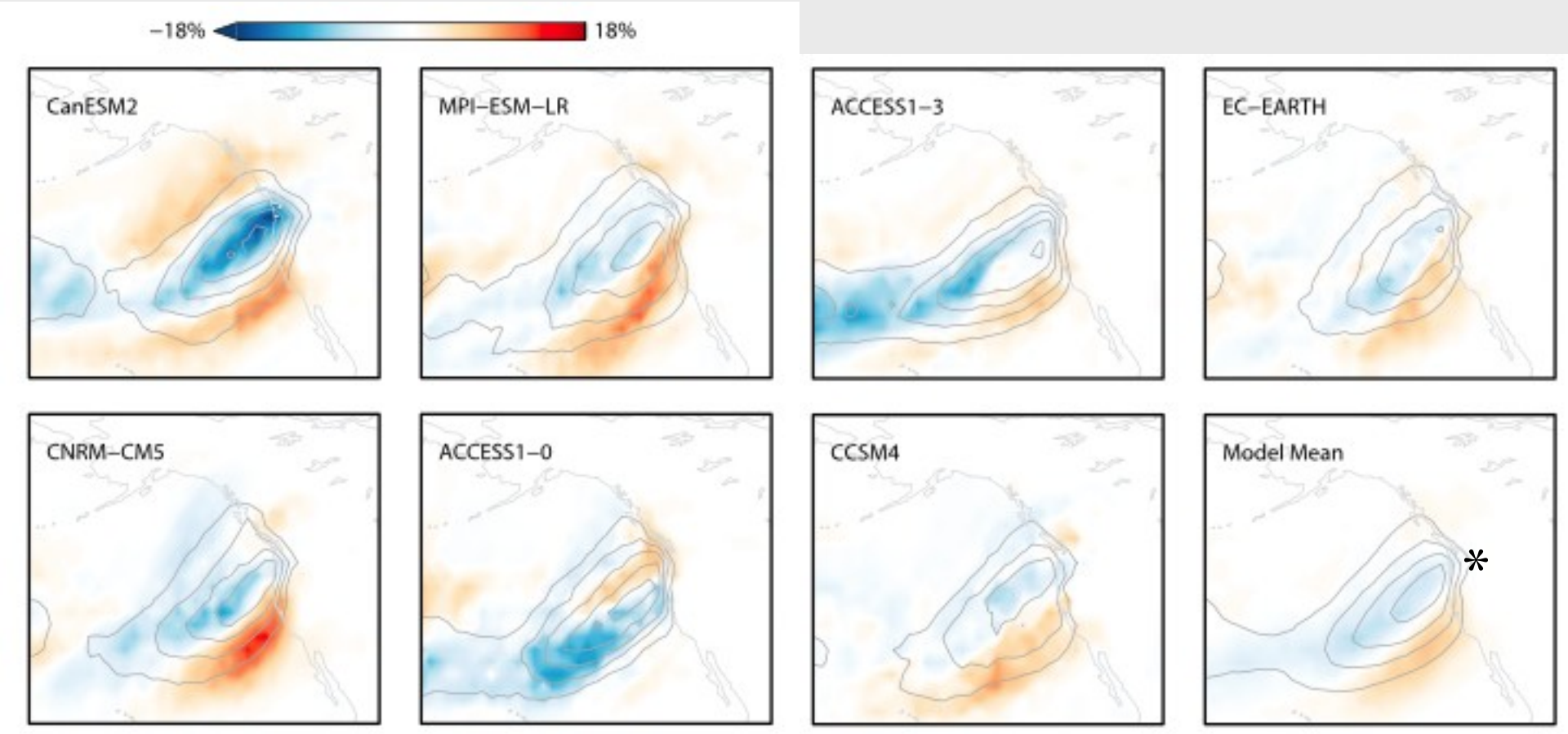


Hamlet et al. 2013



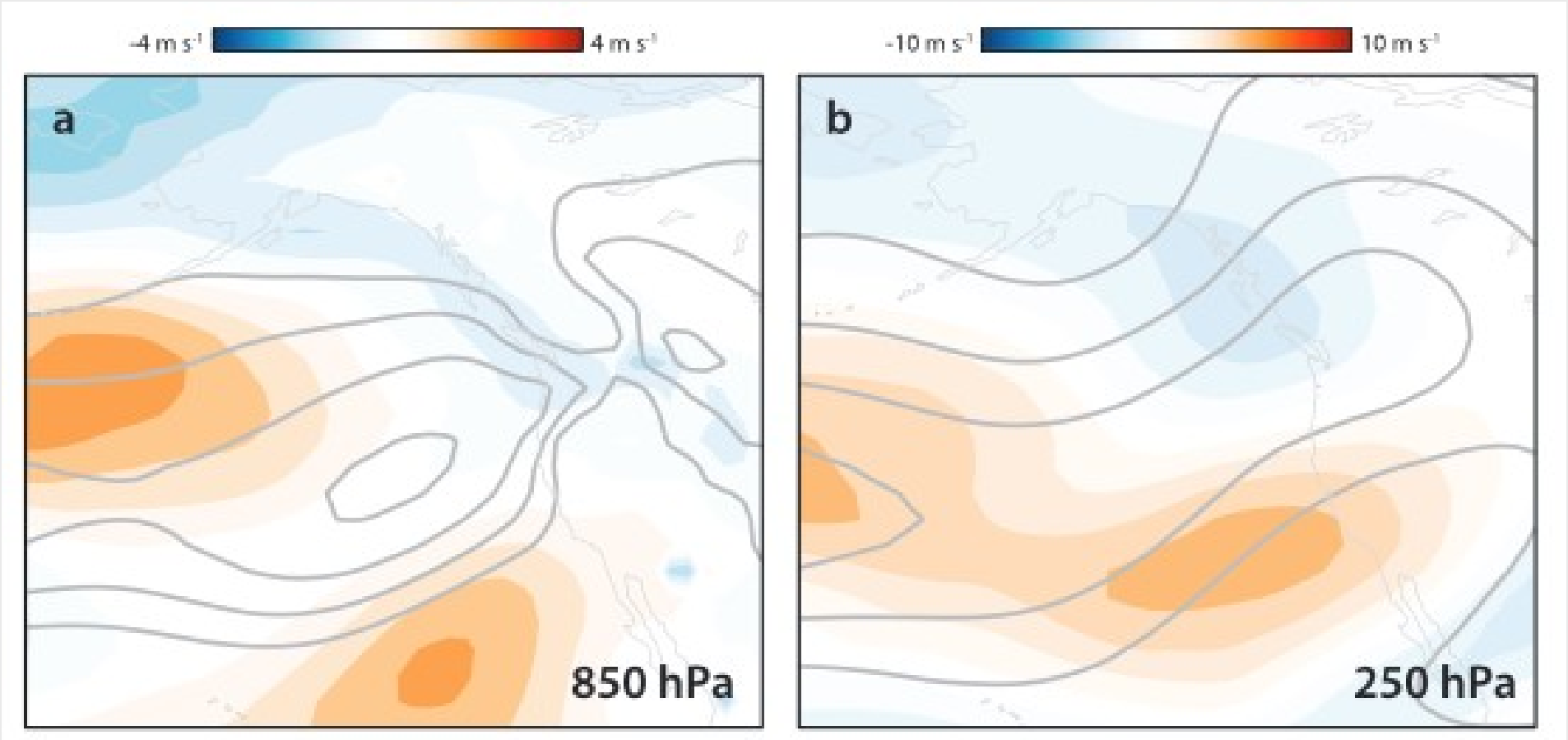
Tohver et al. 2014

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



Payne and Magnusdottir (2015)

RCP8.5 Simulations: Slight weakening of low-level onshore flow into the Pac NW; Equatorward broadening of zonal flow maxima in lower and upper-troposphere

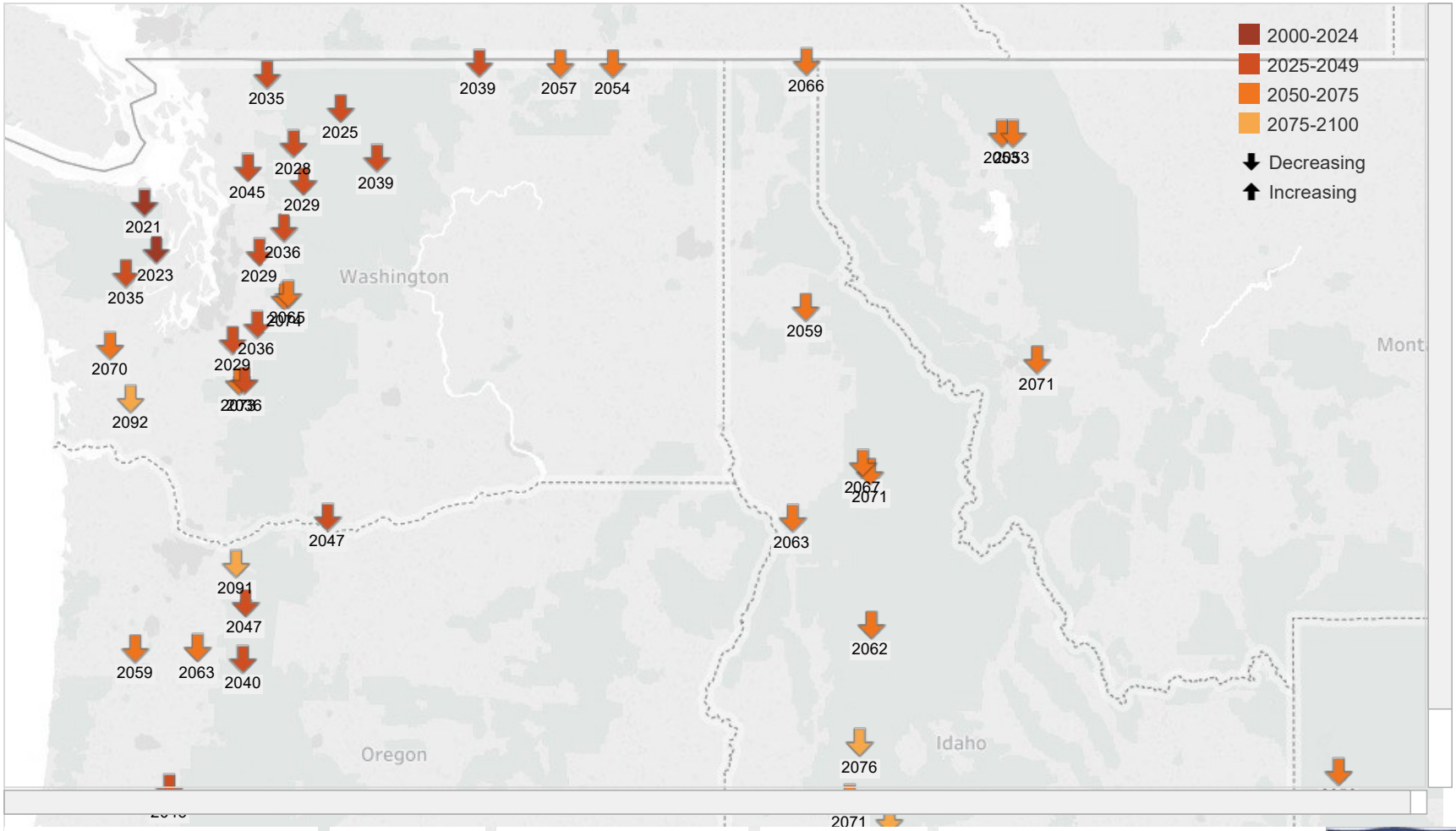


Payne and Magnusdottir (2015)

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

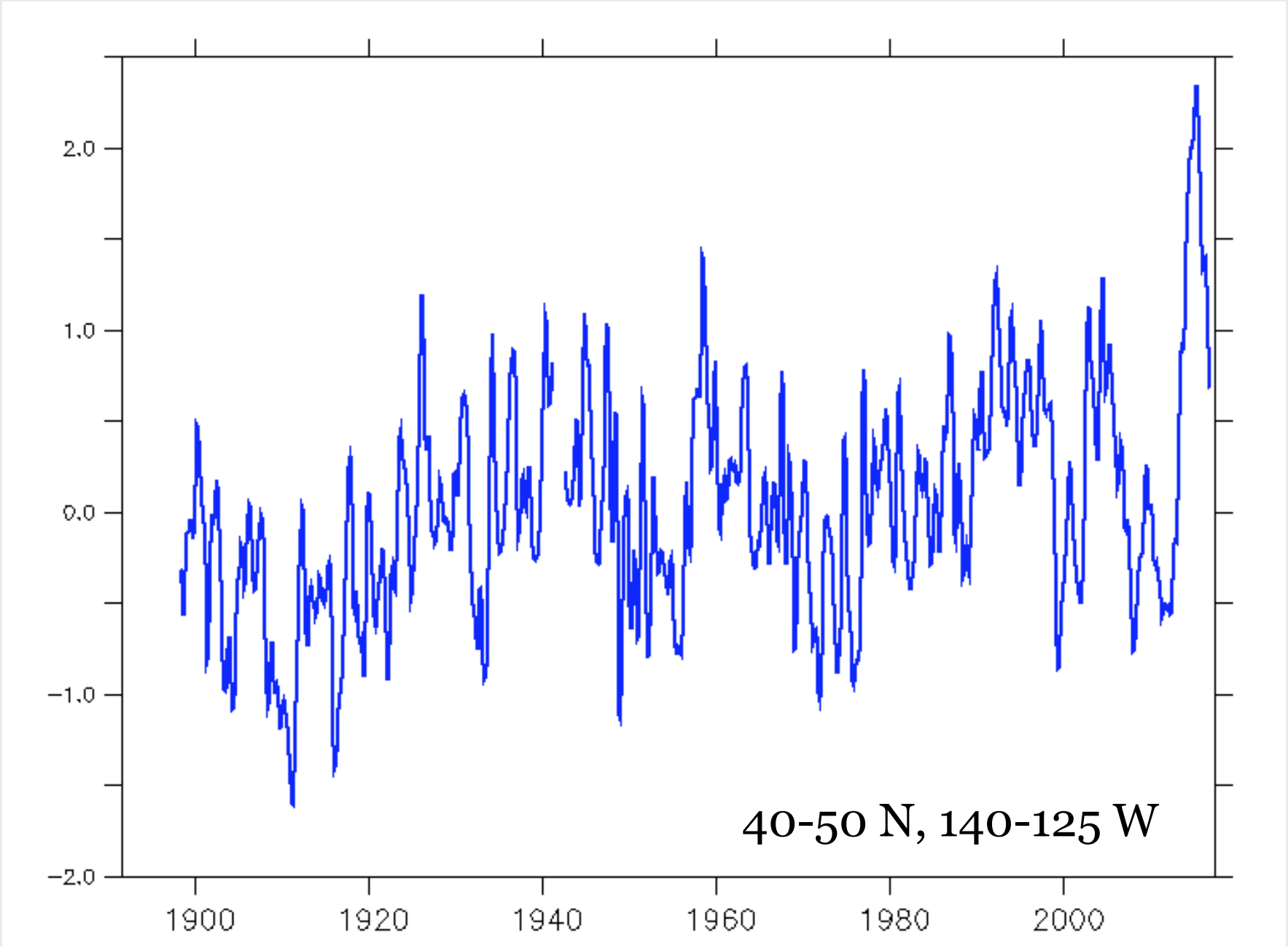
Ecosystem Concerns

- 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.
- 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?

Sea Surface Temperature (SST) Anomalies Offshore the Pacific NW



INDESCRIBABLE... INDESTRUCTIBLE! NOTHING CAN STOP IT!

THE BLOB

STEVEN McQUEEN

ANETA CORSEAUT · EARL ROWE

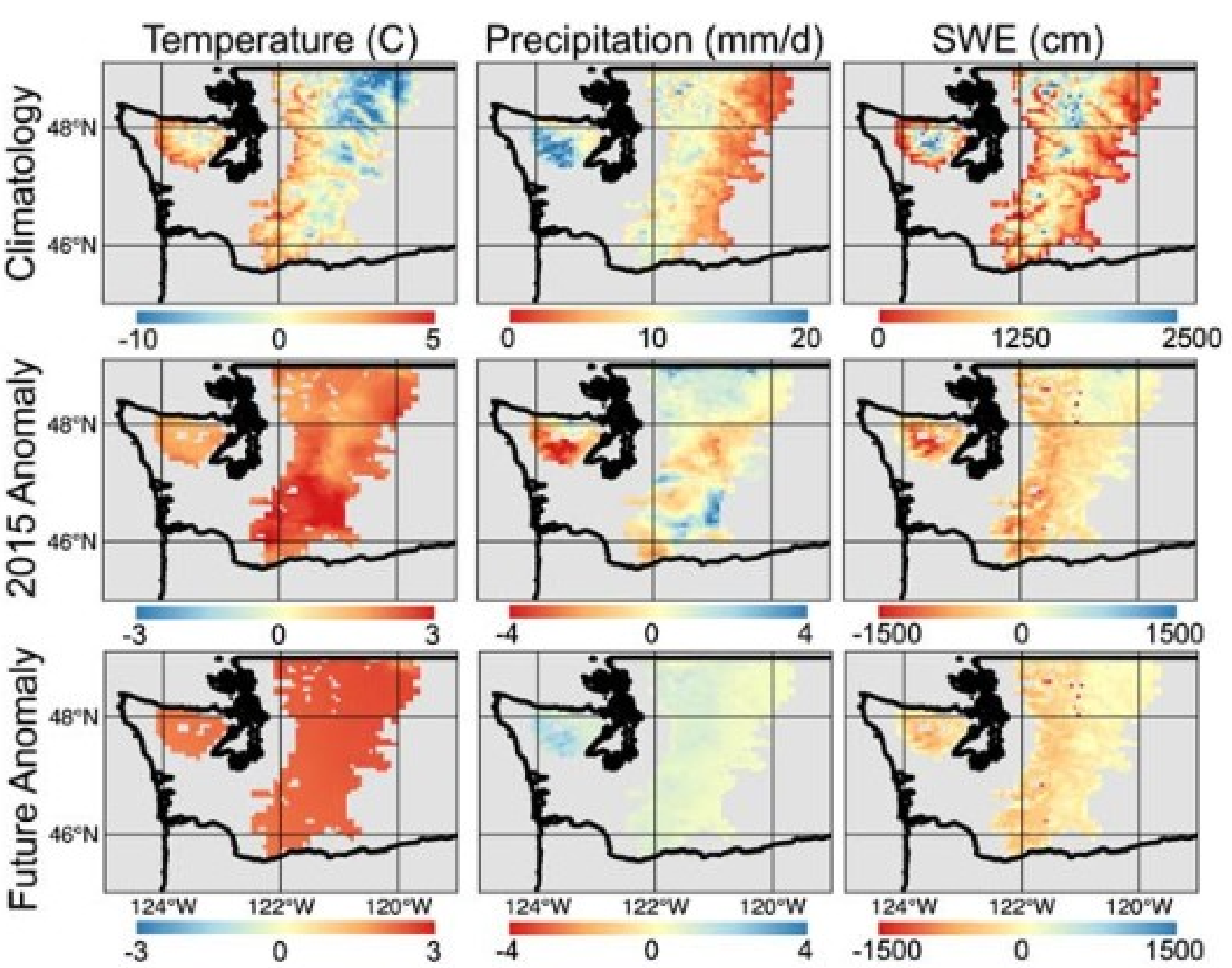
PRODUCED BY JACK H. HARRIS · DIRECTED BY IRVIN S. YEAWORTH, JR. · SCREENPLAY BY THEODORE SIMONSON AND KATE PHILLIPS

FROM AN IDEA BY KENNETH J. HEUCKE

A TONWIN PRODUCTION · COLOR BY DE LUXE

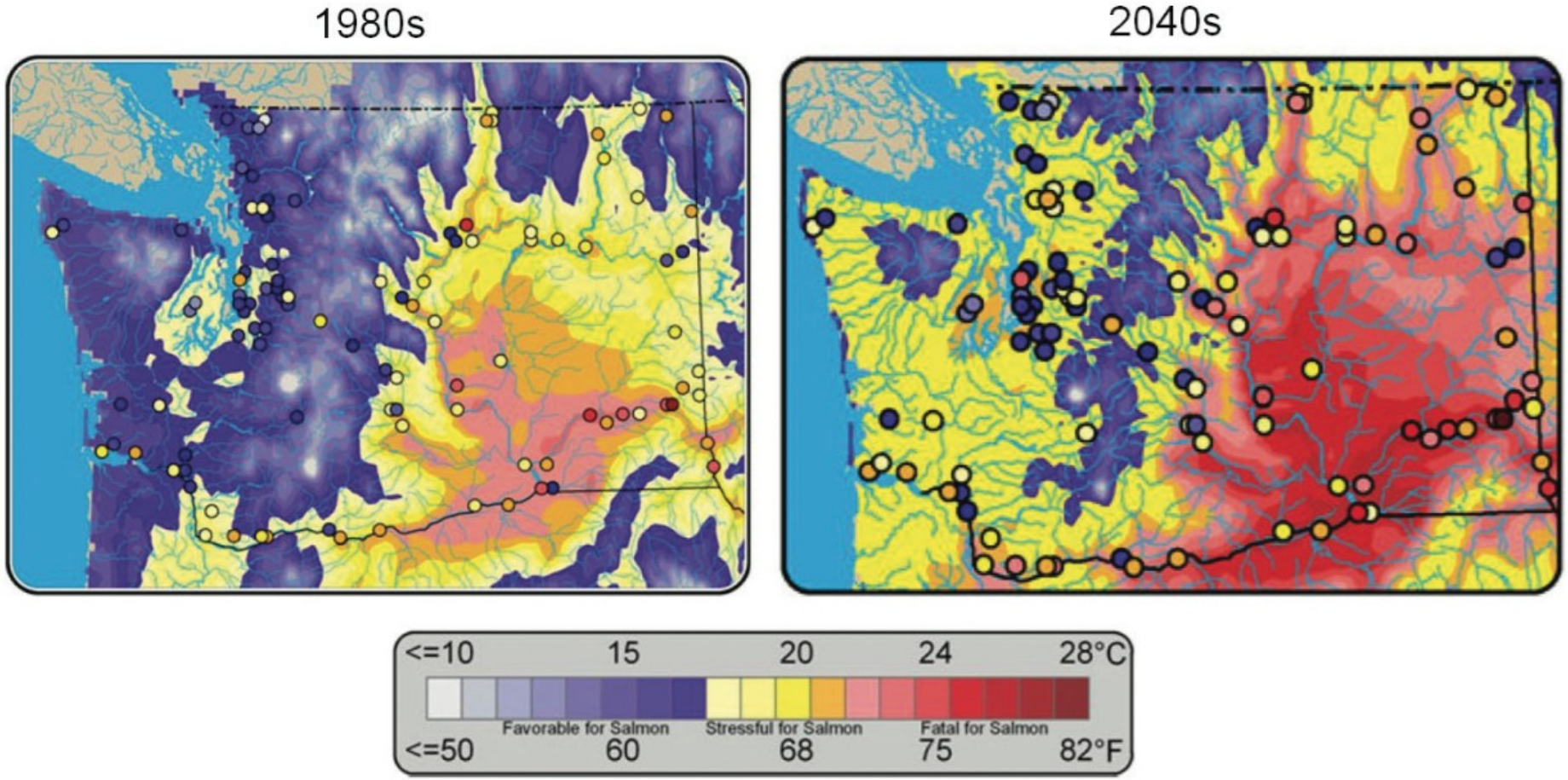
1950-2015

2040-2069

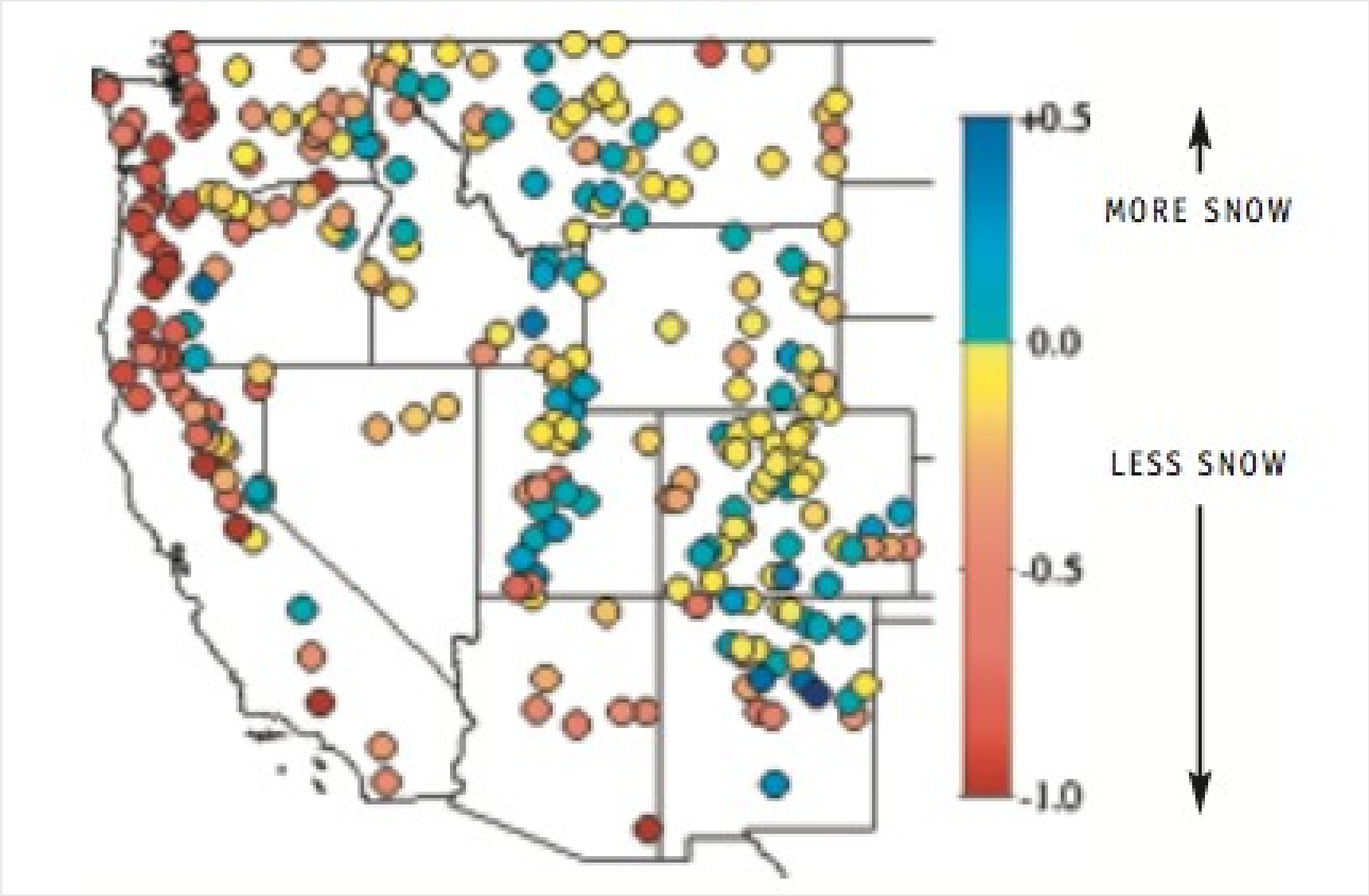


Marlier et al. (2017)

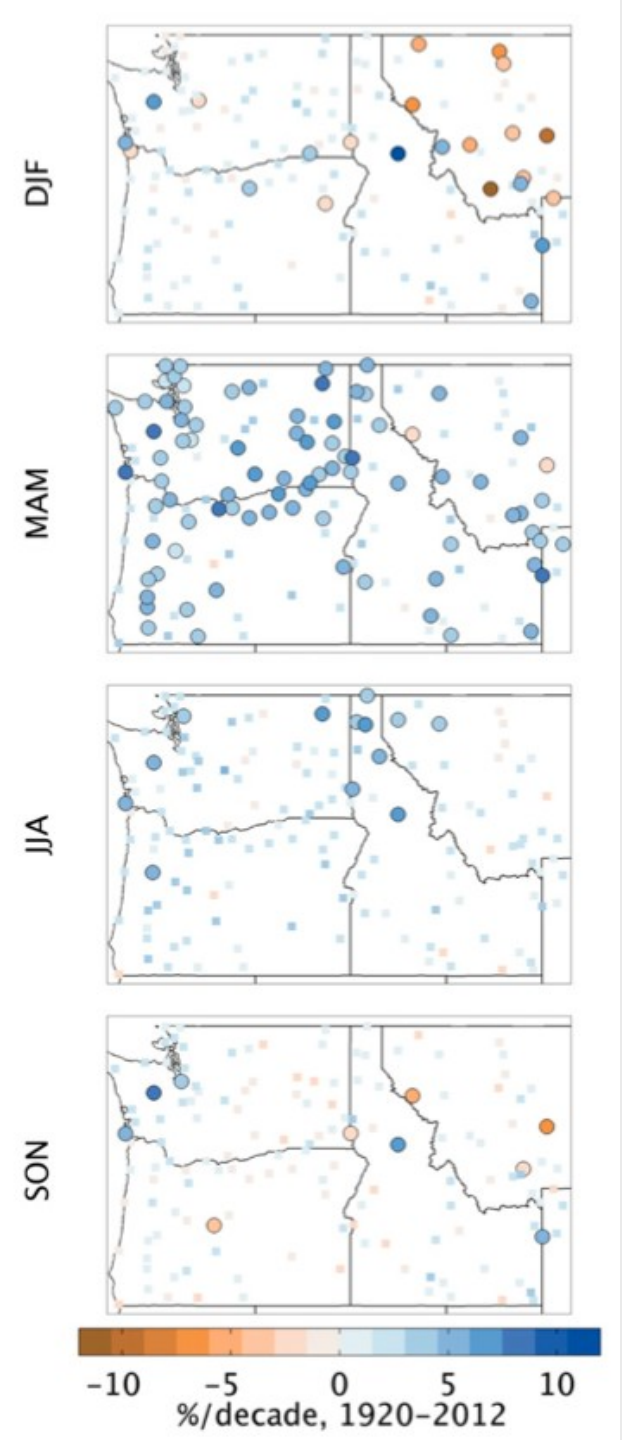
August Mean Air Temperatures (fill) and Maximum Summer Stream Temperatures (dots)



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



S



Precipitation Trends (1920-2012)

significant linear trends; circles are significant at 95%

Abatzoglou et al. 2014 (J. Climate)

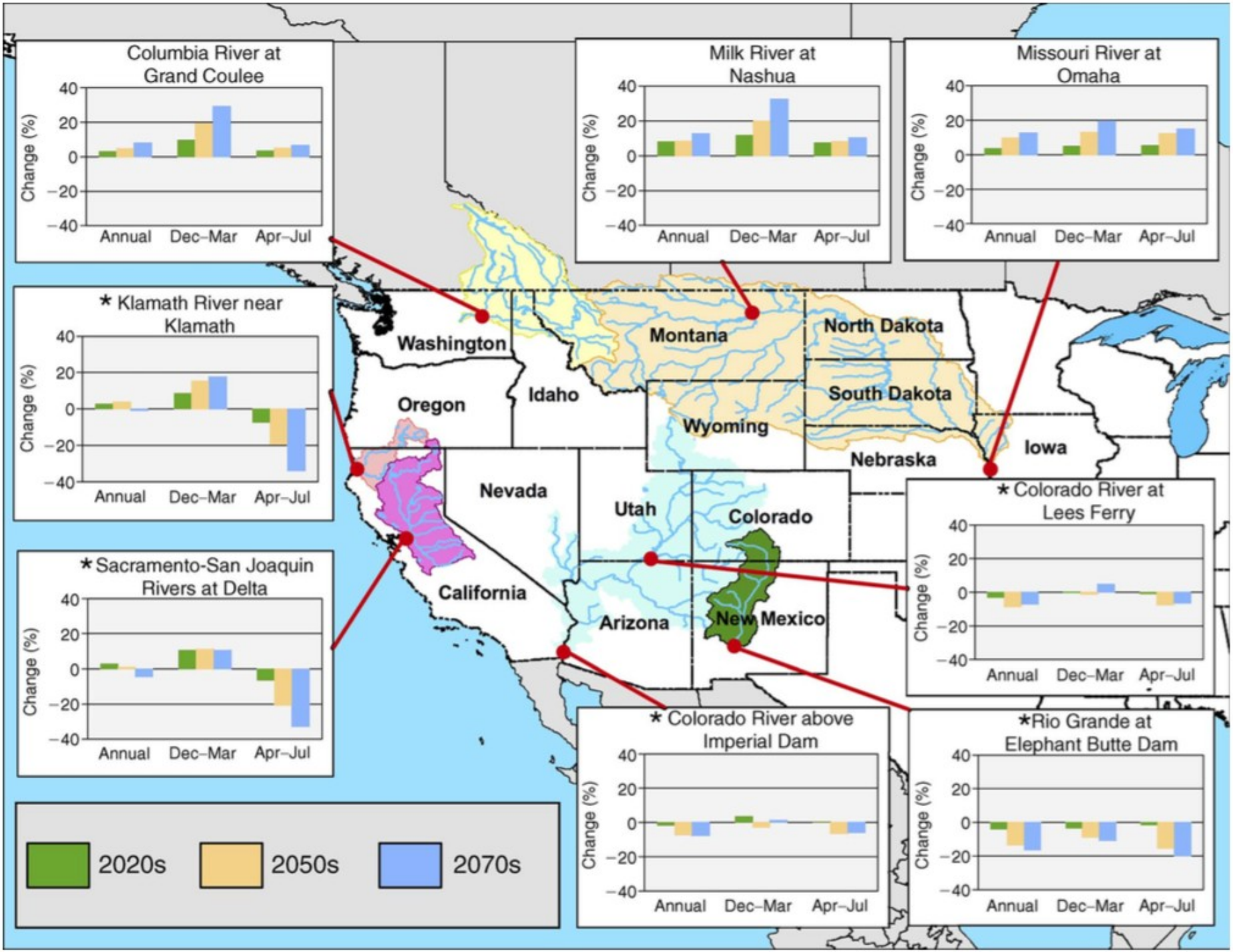
References

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/

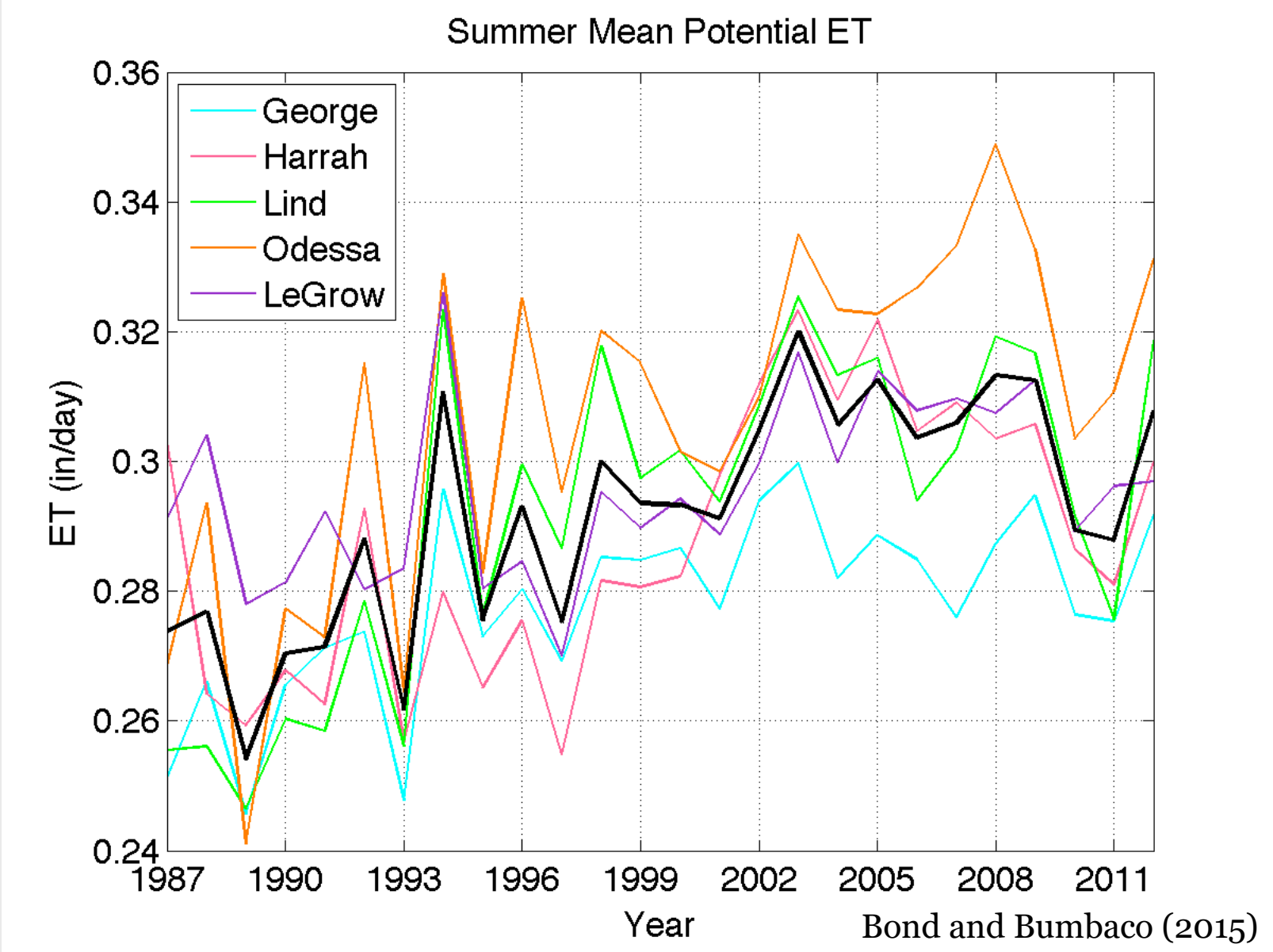
US Environmental Protection Agency (2016): Climate Impacts in the Northwest. Available at https://www.epa.gov/climate-impacts/climate-impacts-northwest#Reference2

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.

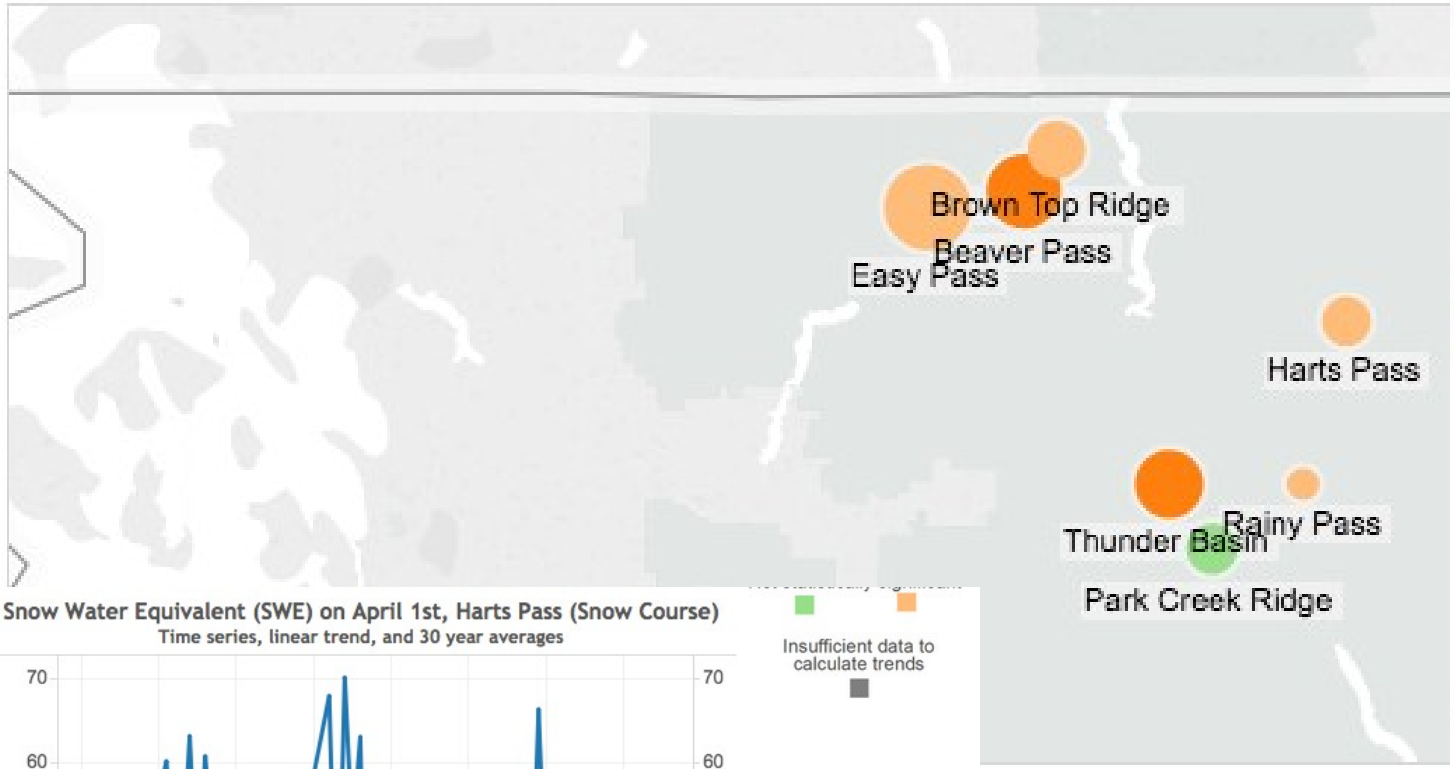

Columbia River at Grand Coulee
Milk River at Nashua
Missouri River at Omaha
* Klamath River near Klamath
* Sacramento-San Joaquin Rivers at Delta
* Colorado River at Lees Ferry
* Colorado River above Imperial Dam
*Rio Grande at Elephant Butte Dam
Change (%)
40
20
0
−20
−40
Annual
Dec–Mar
Apr–Jul
Washington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

Potential Evapotranspiration (pET)



Bond and Bumbaco (2015)

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

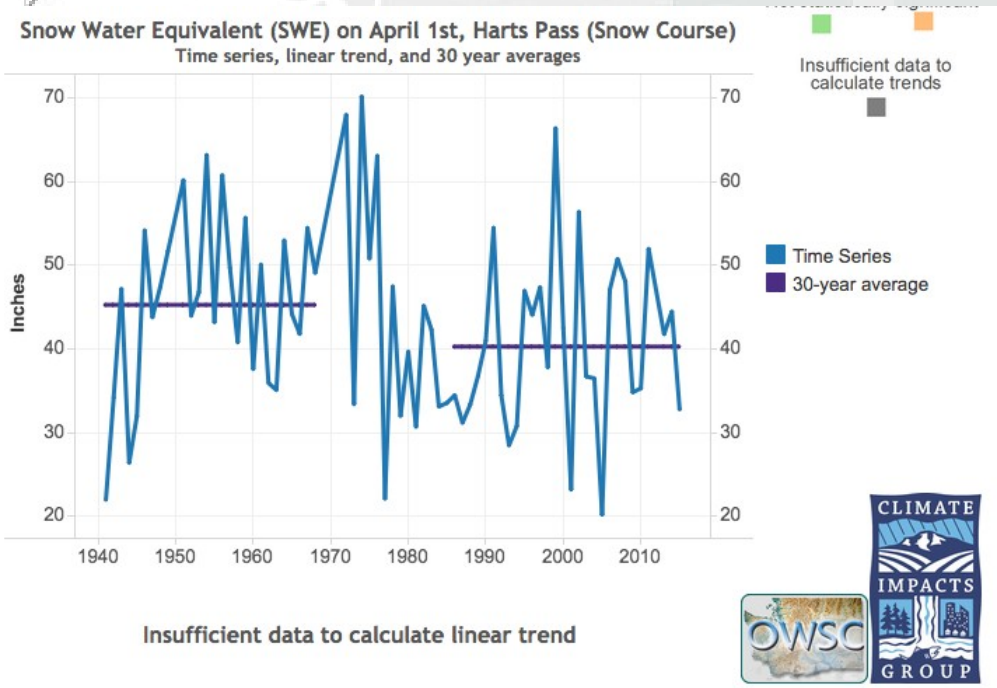
Significance

Positive trend | Negative trend

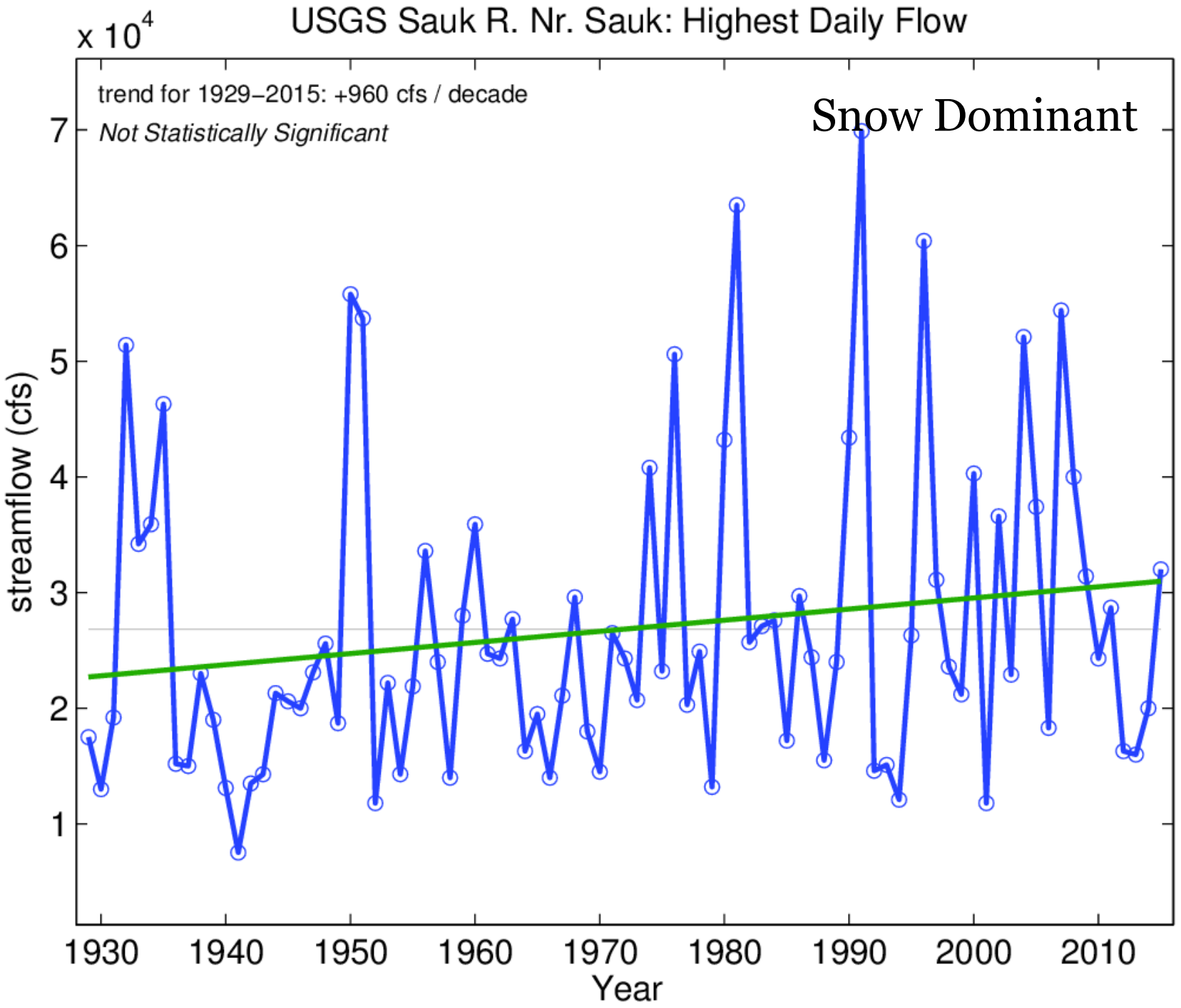
Statistically significant

Not statistically significant

Insufficient data to calculate trends



G. Mauger
K. Bumbaco


USGS Sauk R. Nr. Sauk: Highest Daily Flow
x 10^4
trend for 1929–2015: +960 cfs / decade
Not Statistically Significant
Snow Dominant
streamflow (cfs)
Year
1
2
3
4
5
6
7
1930
1940
1950
1960
1970
1980
1990
2000
2010