

# Climate Change & Water in the Pacific Northwest

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PNWS-AWWA  
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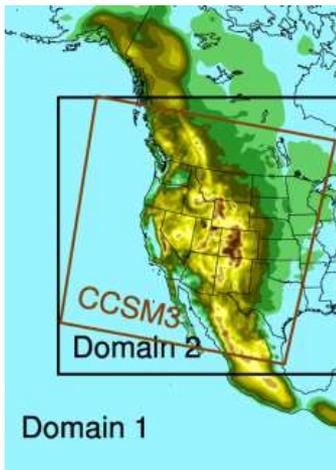


*Climate Science in the  
Public Interest*

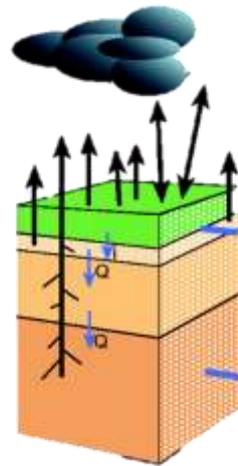


# The Climate Impacts Group

*An integrated research and stakeholder engagement team linking climate science and decision making to build climate resilience.*



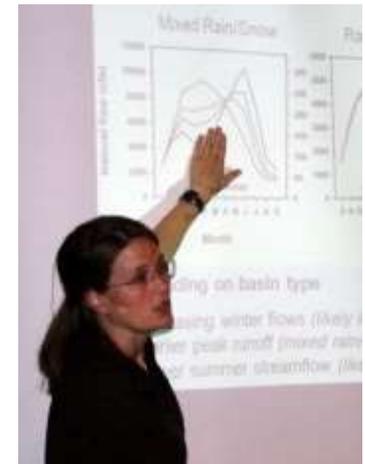
Downscaling global climate models



Macro and fine-scale hydrologic modeling



Impacts assessments



Adaptation planning and outreach

**Working since 1995 with a focus on:**

- U.S. Pacific Northwest, Western U.S., Pacific Rim
- Water, forests, fish, coasts, energy, human health, urban areas
- Stakeholders: Private, public & non-governmental actors involved in climate-sensitive policymaking, planning and decision making



Expected 21st century changes in temperature and precipitation will *transform* the hydrologic behavior of many mountain watersheds in the West.



## Decreased summer hydropower production

Summer production falls -10% by the 2020s, -15% by the 2040s, -20% by the 2080s, while summer cooling demands increase up to 400% (vs. 1917-2006)



## Decreased irrigation supply reliability

Risk of “water short year” (70% level of prorating) in the Yakima increases from 14% (1970-2005) to 32% (2020s), 36% (2040s) and 77% (2080s)



## Continued reliability of municipal water supplies

Puget Sound water suppliers project sufficient supply through at least 2050



## Increased flood risk

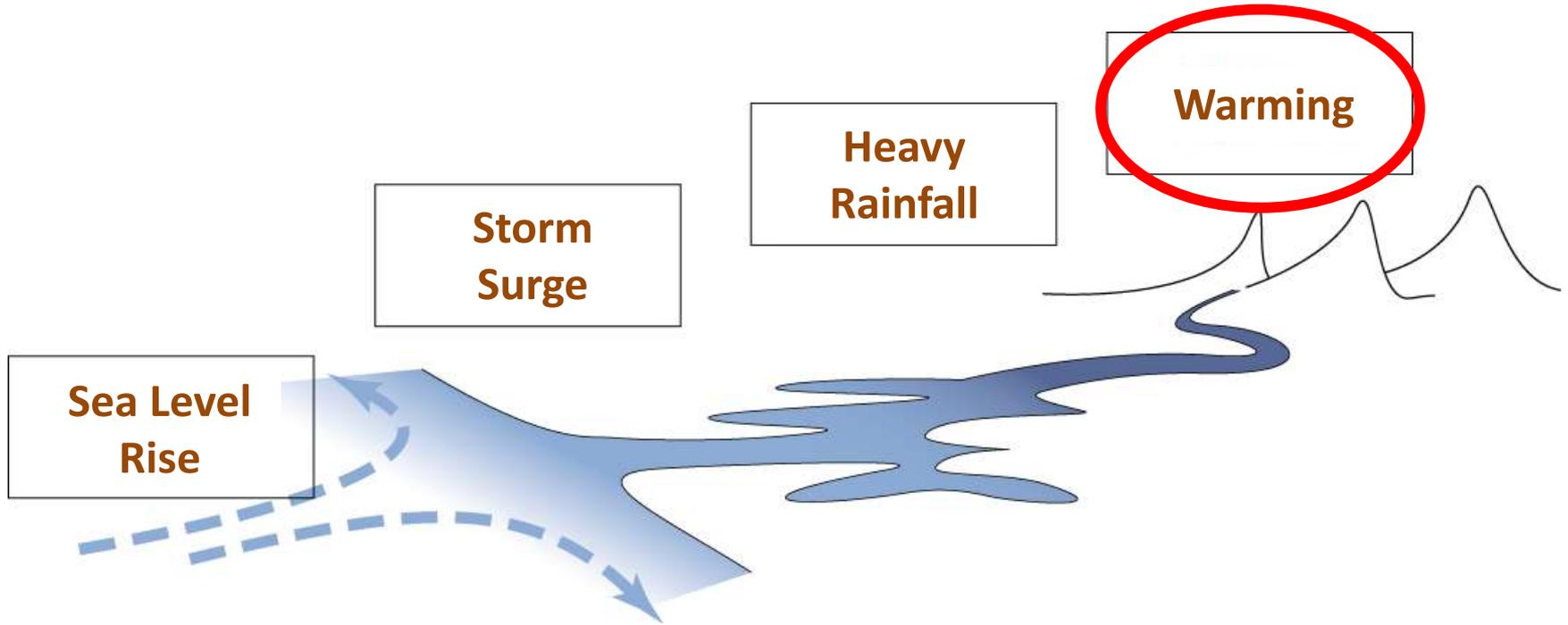
In the Skagit, up to a 74% increase in area flooded for the 100-yr event. In the Snohomish, up to a 69% increase in area flooded for the 10-year event; very little change for the 100-yr event.



## Increased stress on salmon

Lower summer streamflows + warmer stream temperatures + increased fall/winter flooding + ocean acidification

# Changing Hydrology

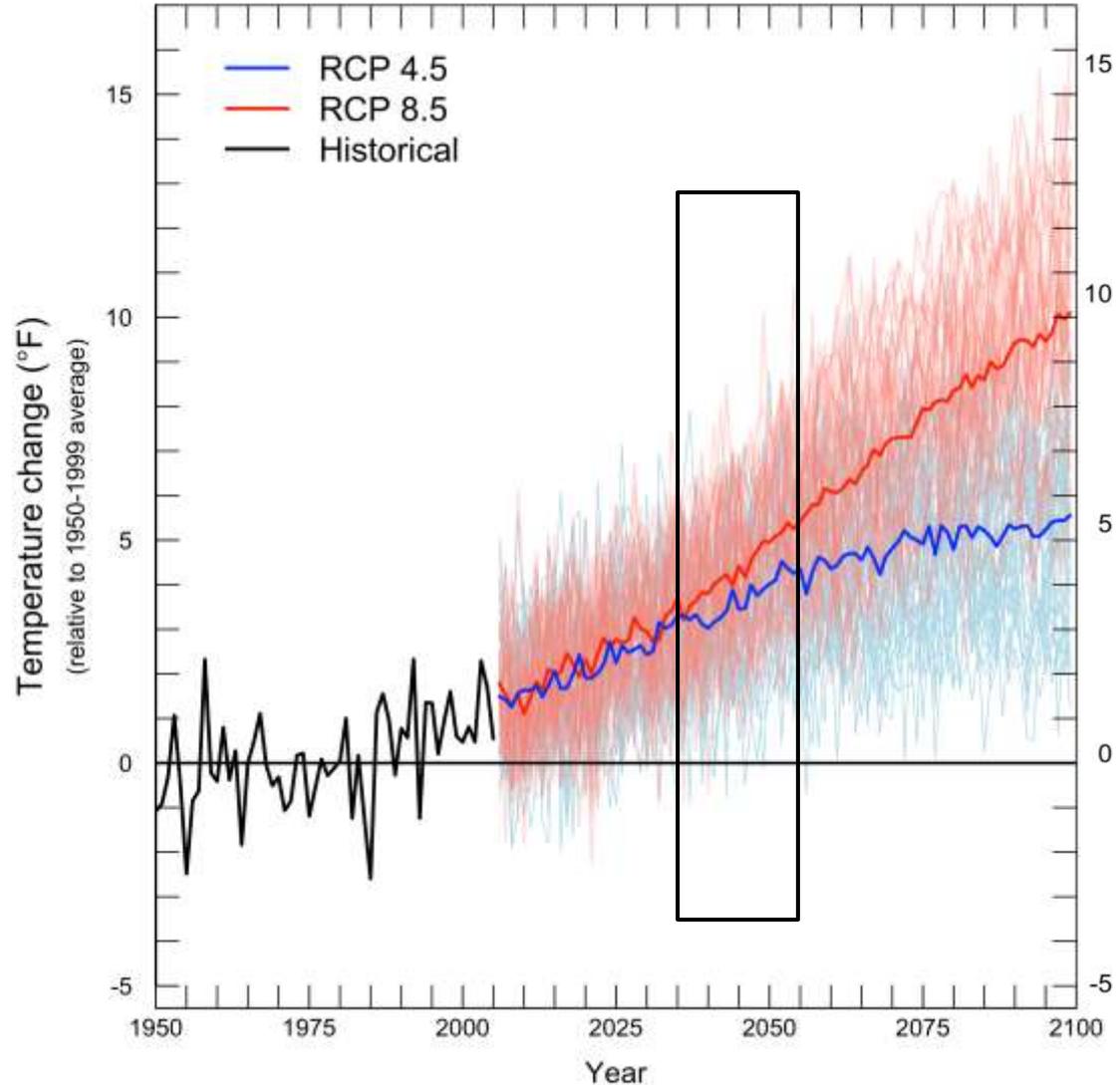


**Physical Drivers**



# All scenarios project warming

Projected Change in Average Annual PNW Temperature (relative to 1950-1999 average)



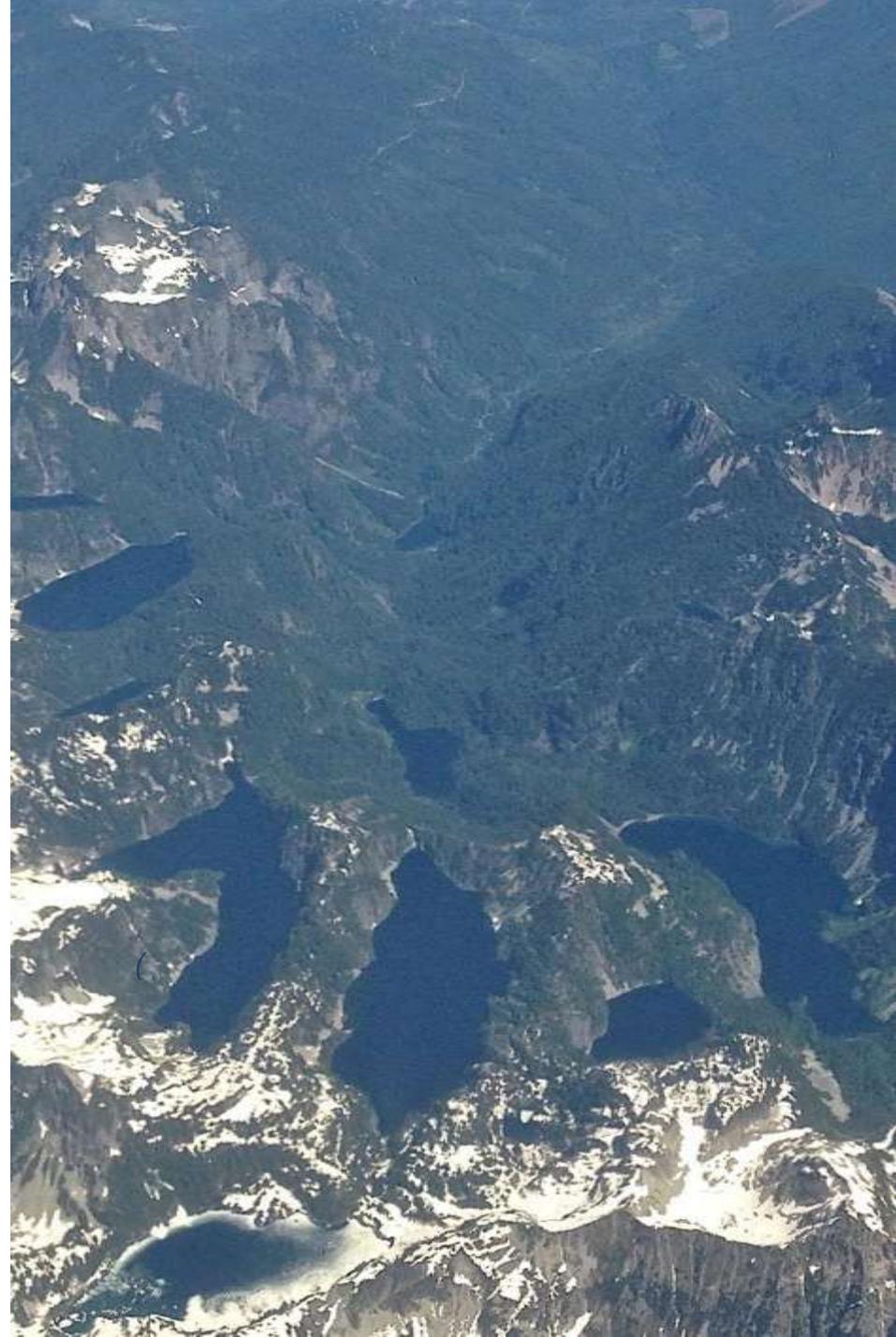
<b>2050s</b> (relative to 1950-1999)	
Low emissions (RCP 4.5)	+4.3°F (2.0-6.7°F)
High emissions (RCP 8.5)	+5.8°F (3.1-8.5°F)

Figure source: Climate Impacts Group, based on projections used in IPCC 2013; 2050 projections from Mote et al. 2013

Our primary mechanism  
for storing water – snow  
– is sensitive to  
warming.

The Cascade and Olympic  
Mountains have the highest  
fraction of “warm snow”  
(snow falling between 27-32°F)  
in the continental U.S.

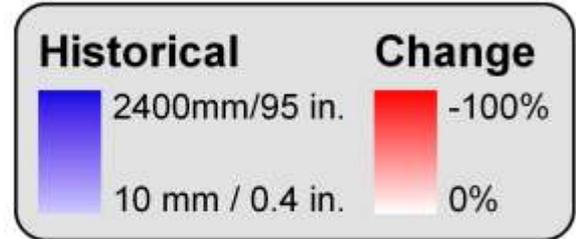
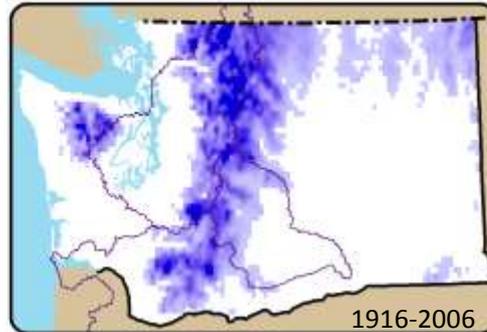
*(Mote et al. 2008)*





# All Scenarios Indicate Less Snow

## Historical



Apr. 1 Snow Water Equivalent

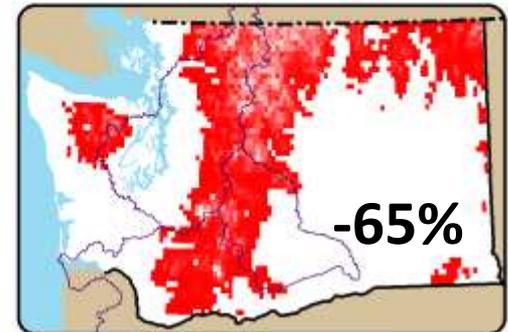
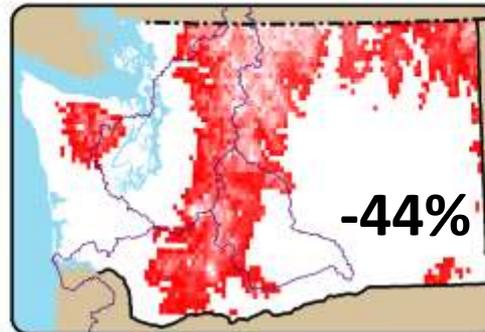
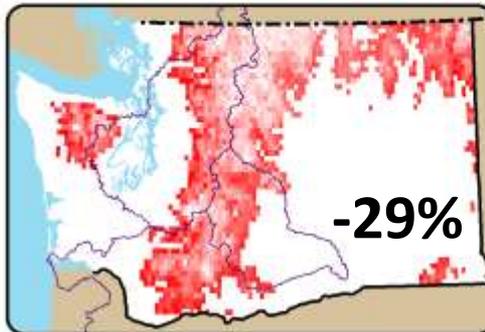
## 2020S

## 2040S

## 2080S

Medium

A1B



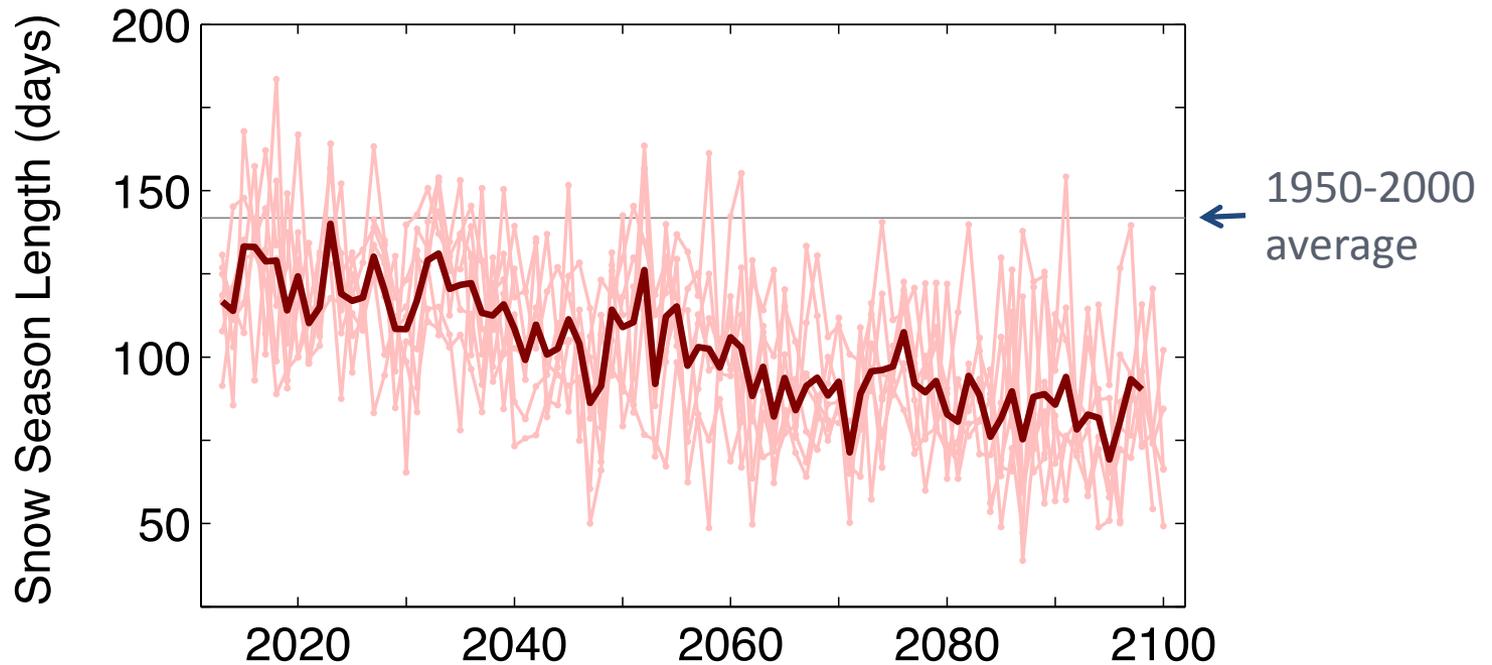
*Elsner et al. 2010*

Why? Spring snowpack is projected to decline as more winter precipitation falls as rain rather than snow, especially in warmer mid-elevation basins. Also, snowpack will melt earlier with warmer spring temperatures



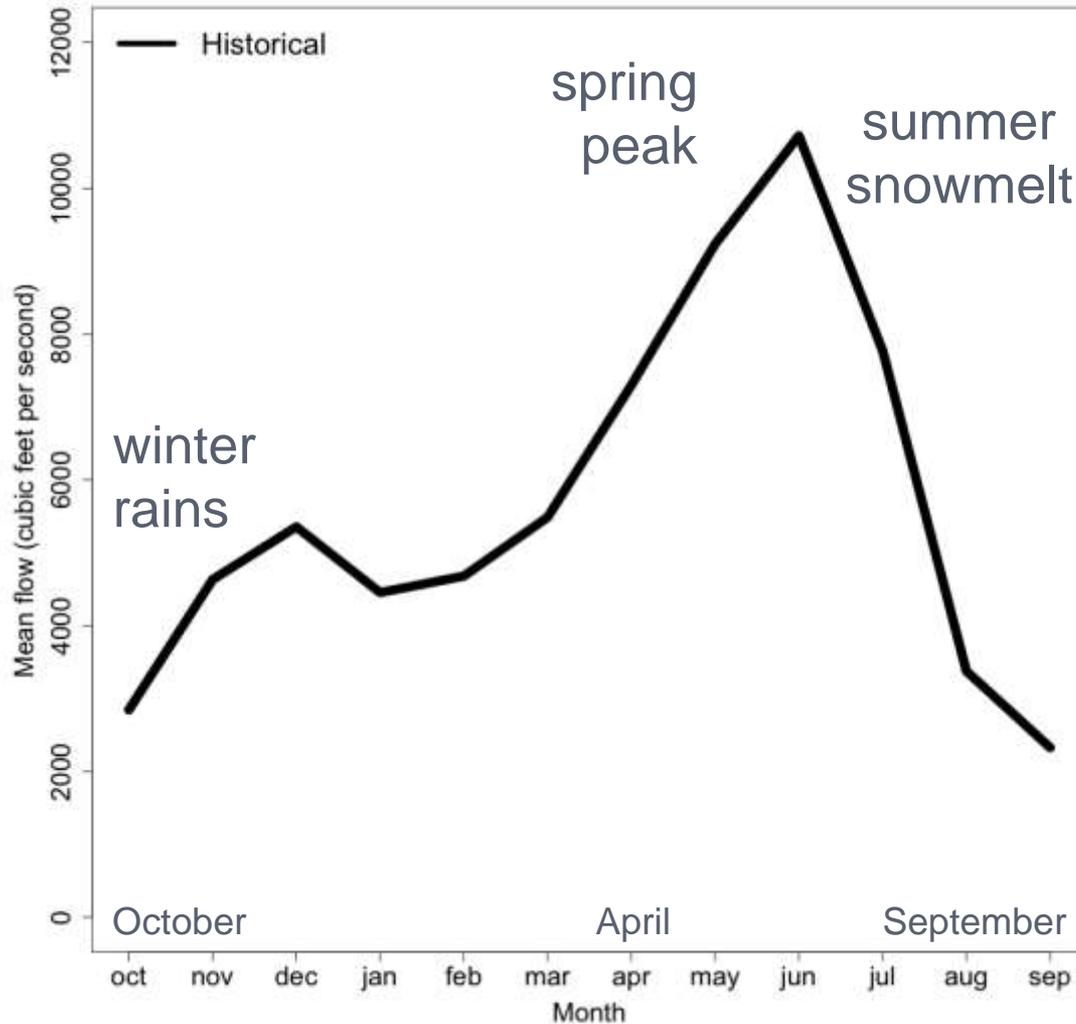
# Shorter Snow Season: Later Start, Earlier Melt

Length of Snow Season at  
4000-5000 ft. in the Cascades  
(Approx. elevation of Baker, Stevens, Crystal)



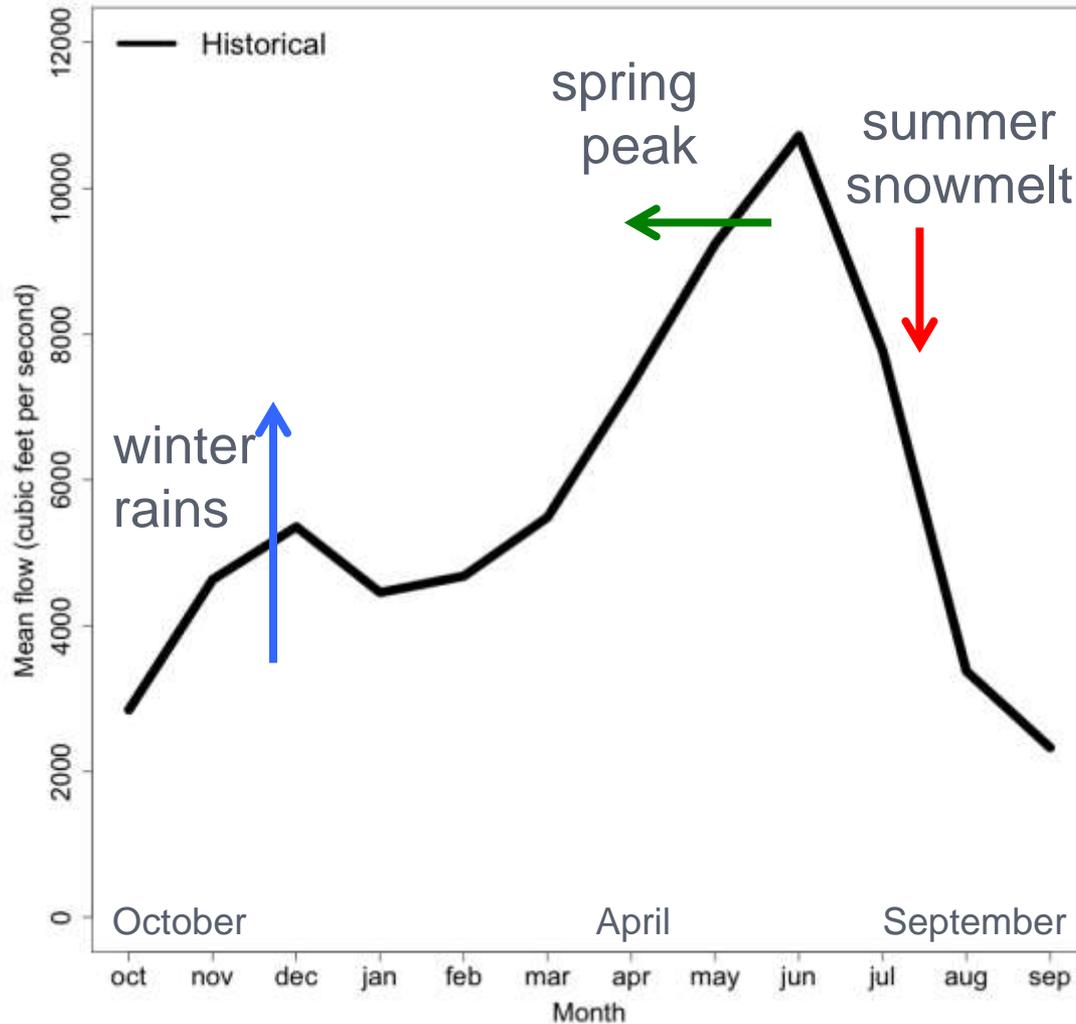


# Shifting Streamflows – Yakima Basin



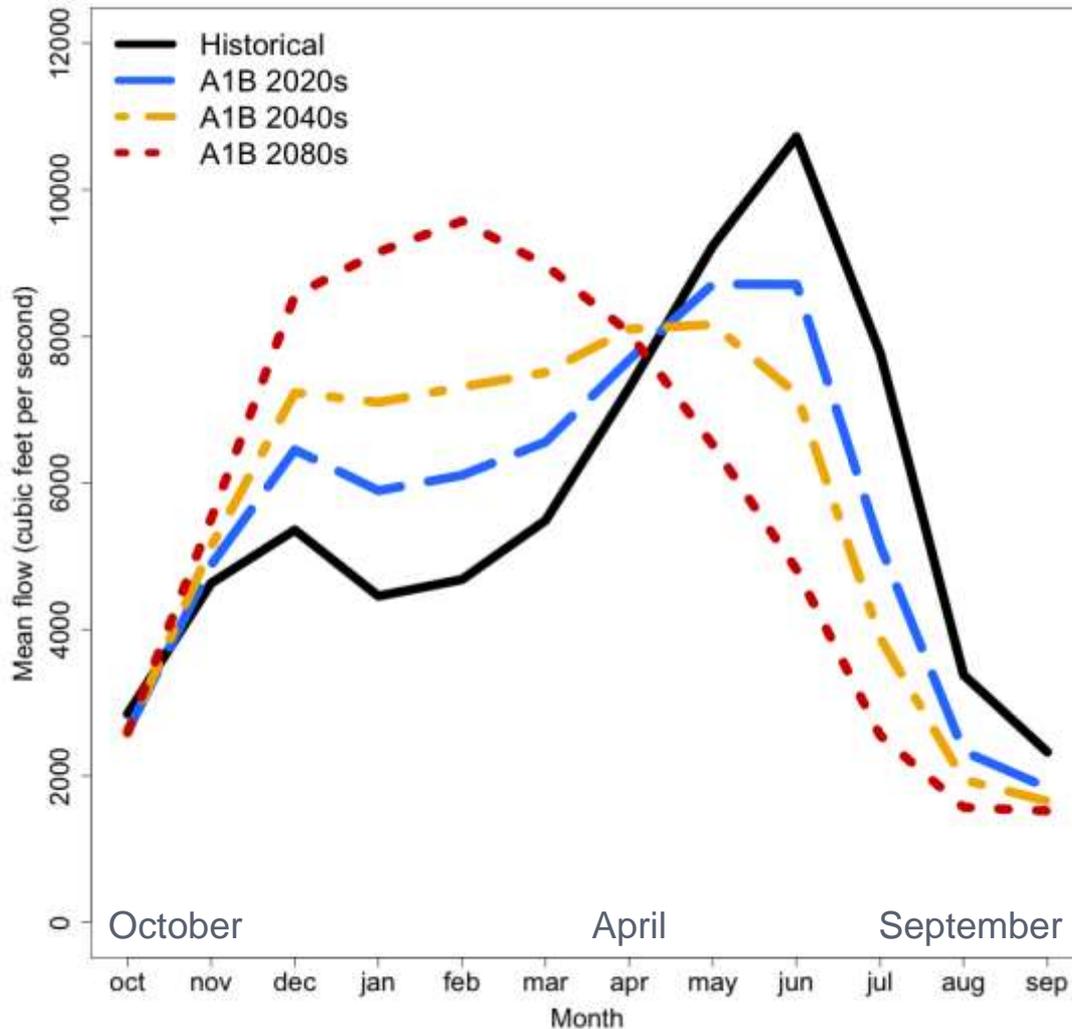


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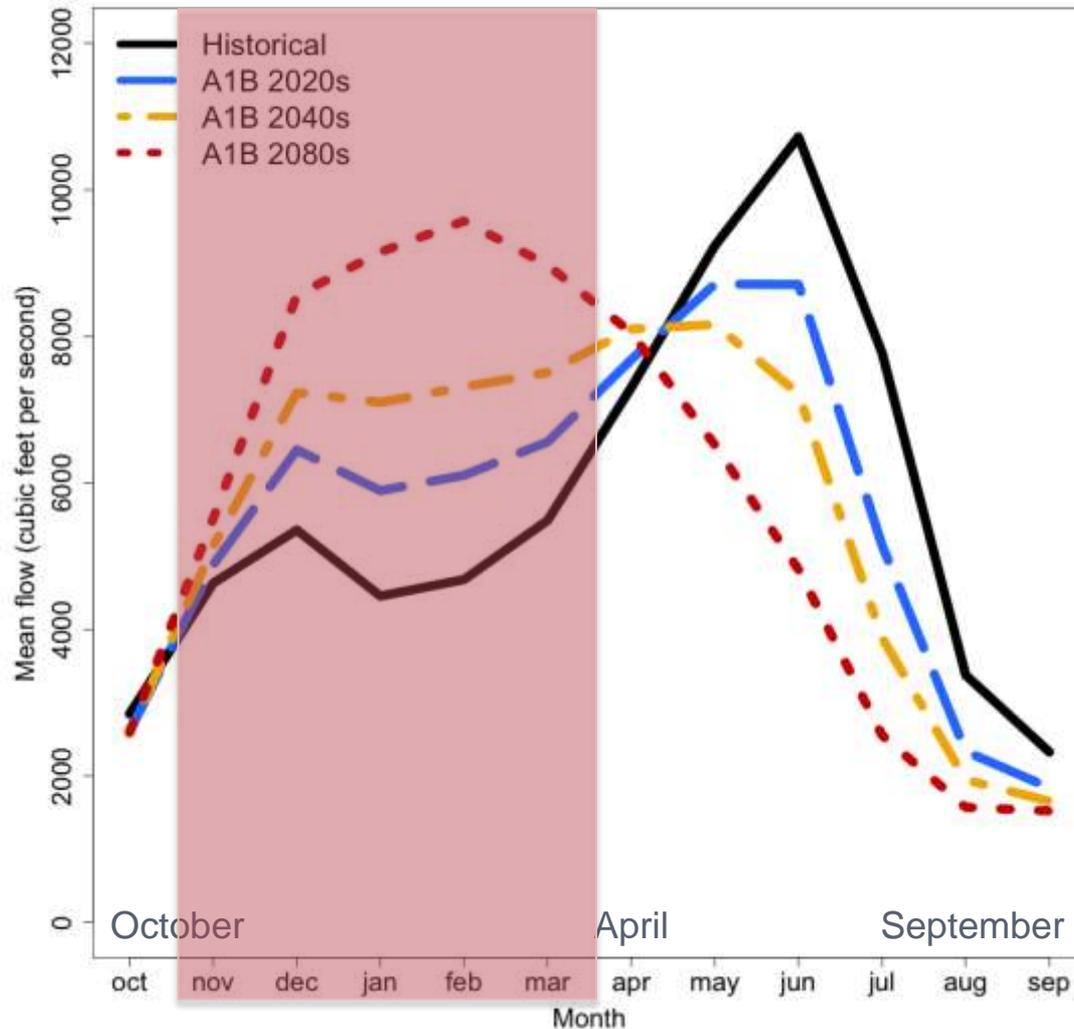


# Shifting Streamflows – Yakima Basin





# Shifting Streamflows – Yakima Basin

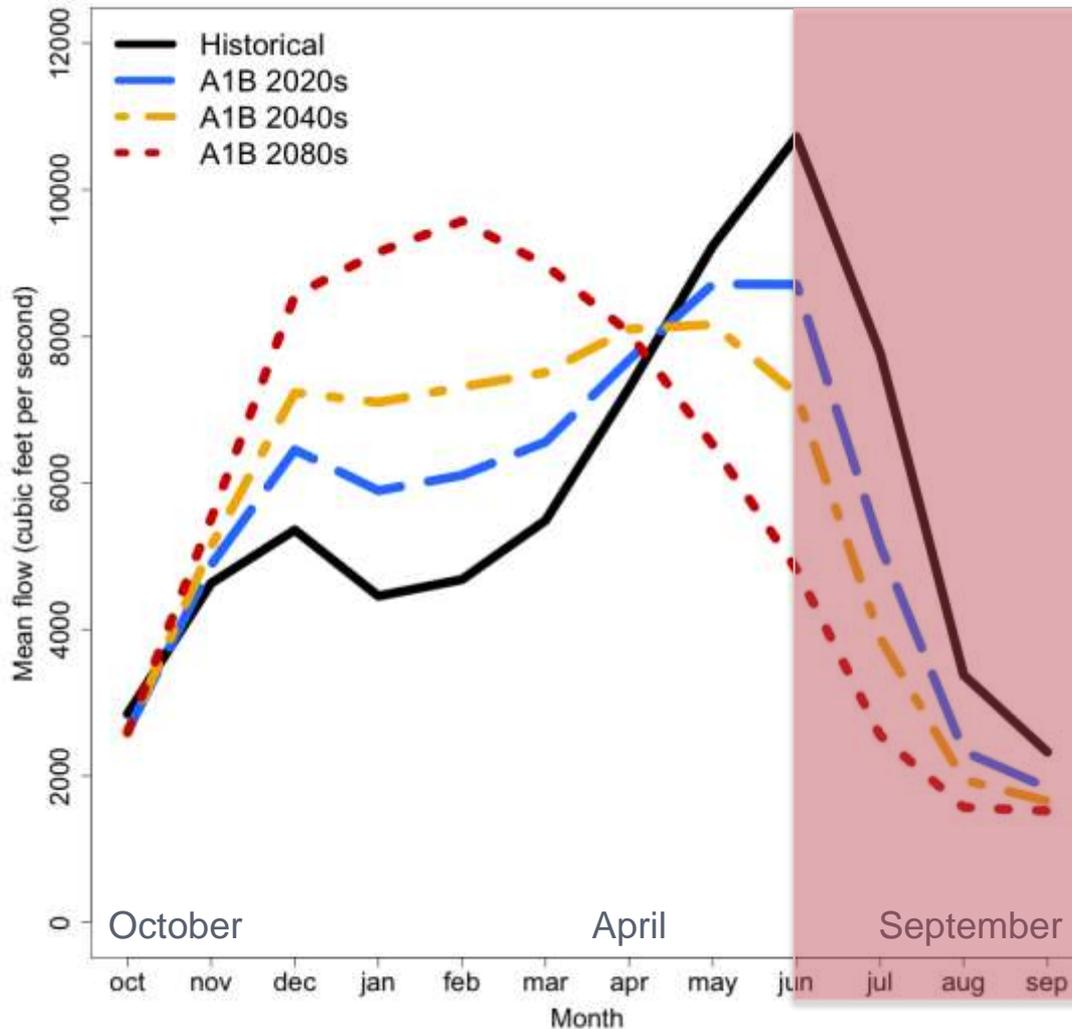


Increased:

- Flood risk,
- Landslide risk,
- Sediment flows



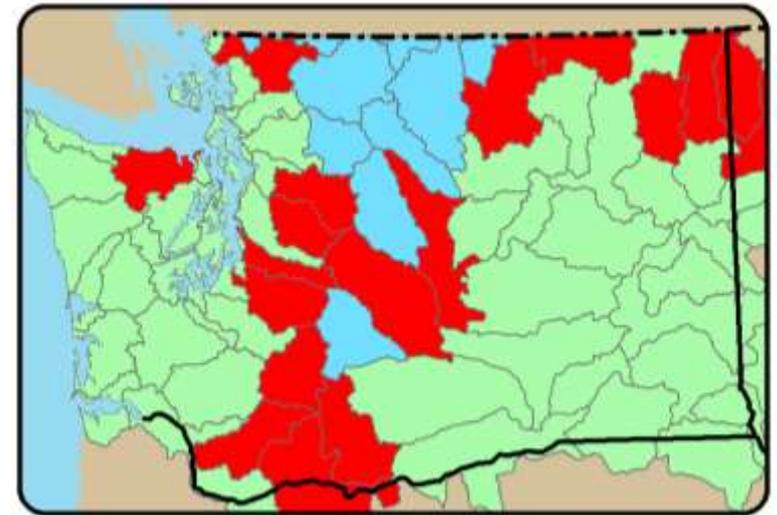
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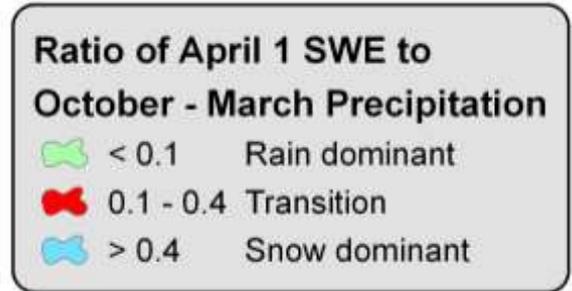
- Water needed for:
- irrigation,
  - instream flows,
  - fall hydro-production



# Shifting Streamflow Timing

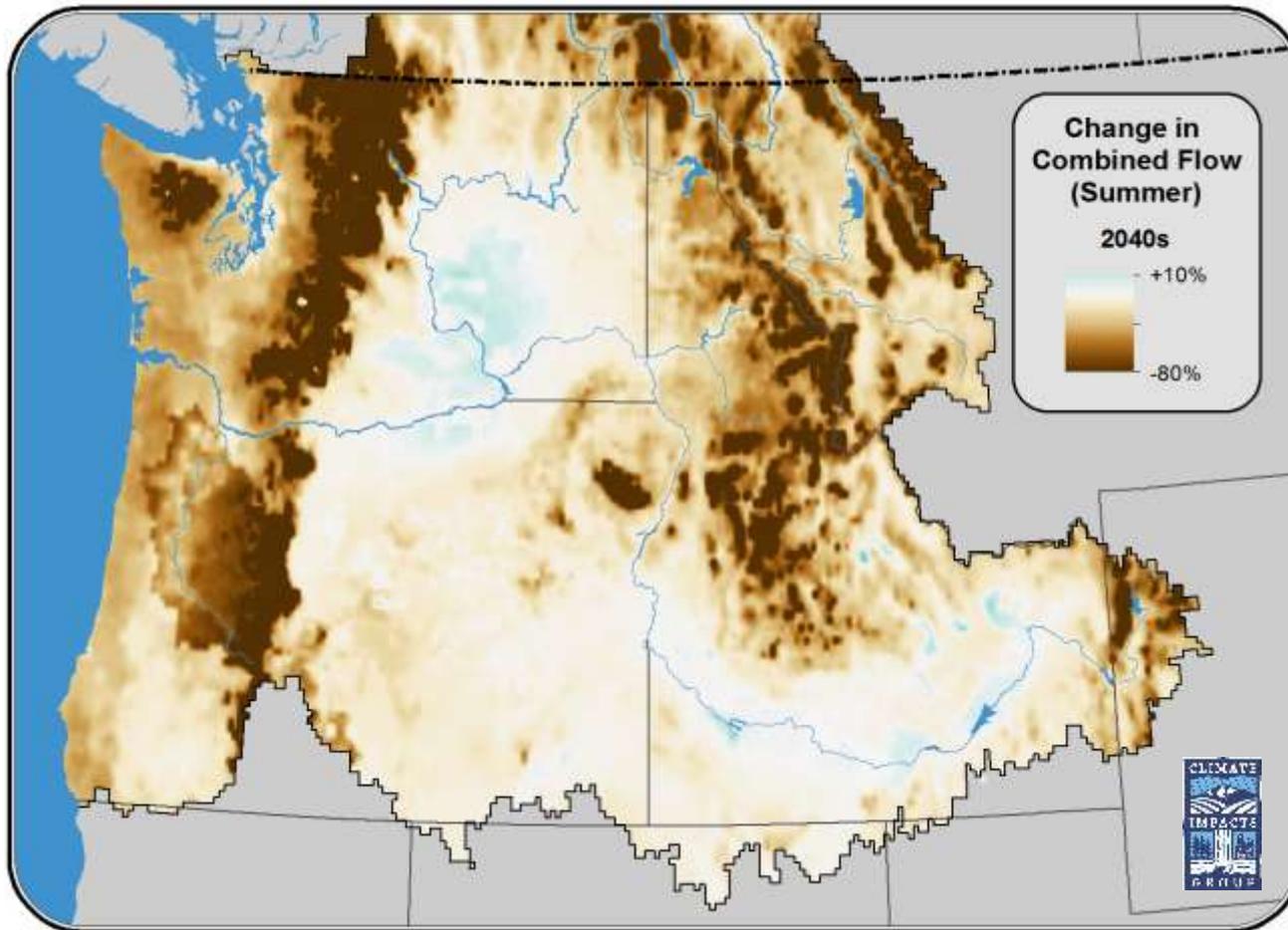


Higher winter and lower summer streamflows  
in Washington rivers with snowmelt contribution





# Reduced Summer Flows (compared to 1915-2006)

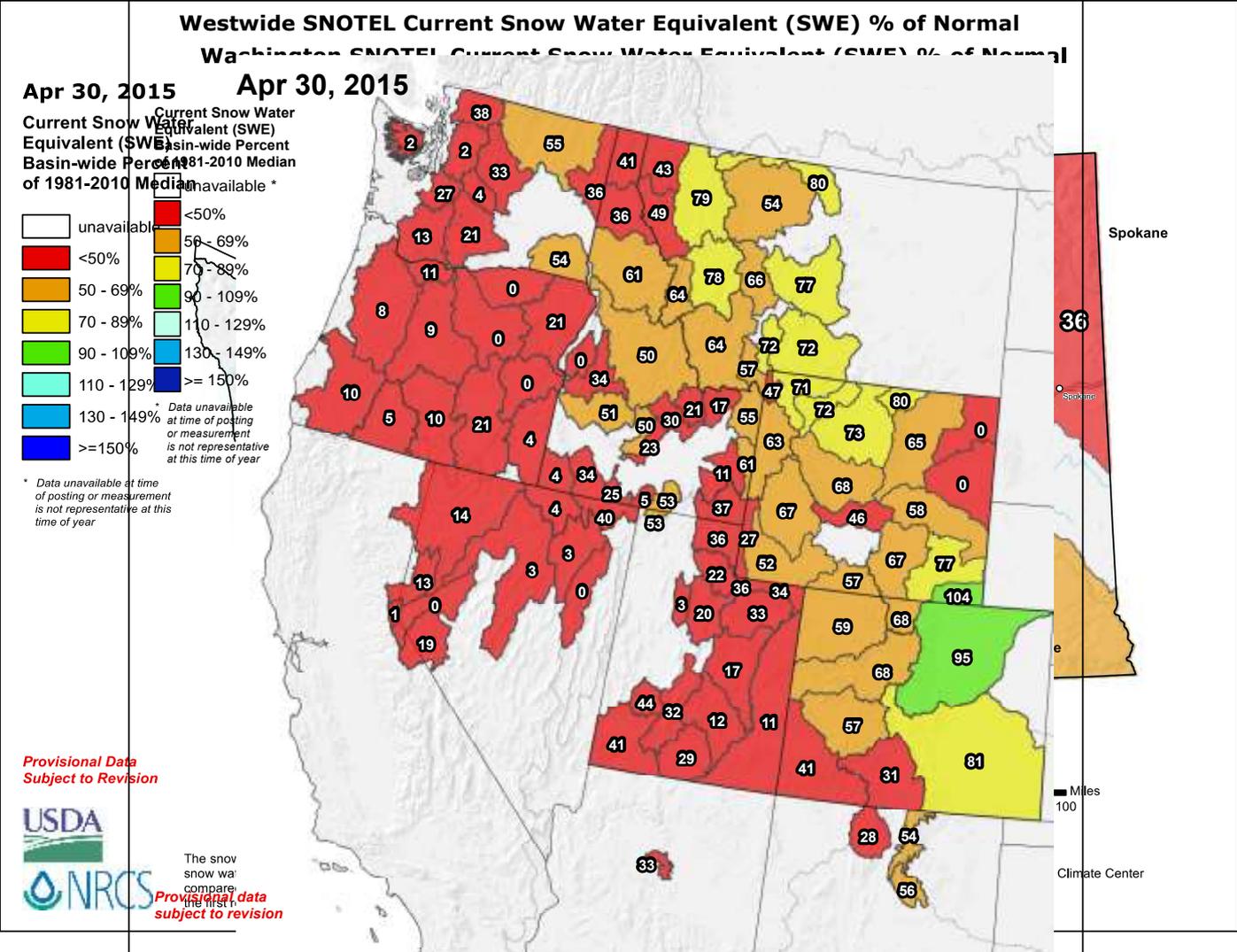


Chance of drought in Columbia basin doubles by 2040s

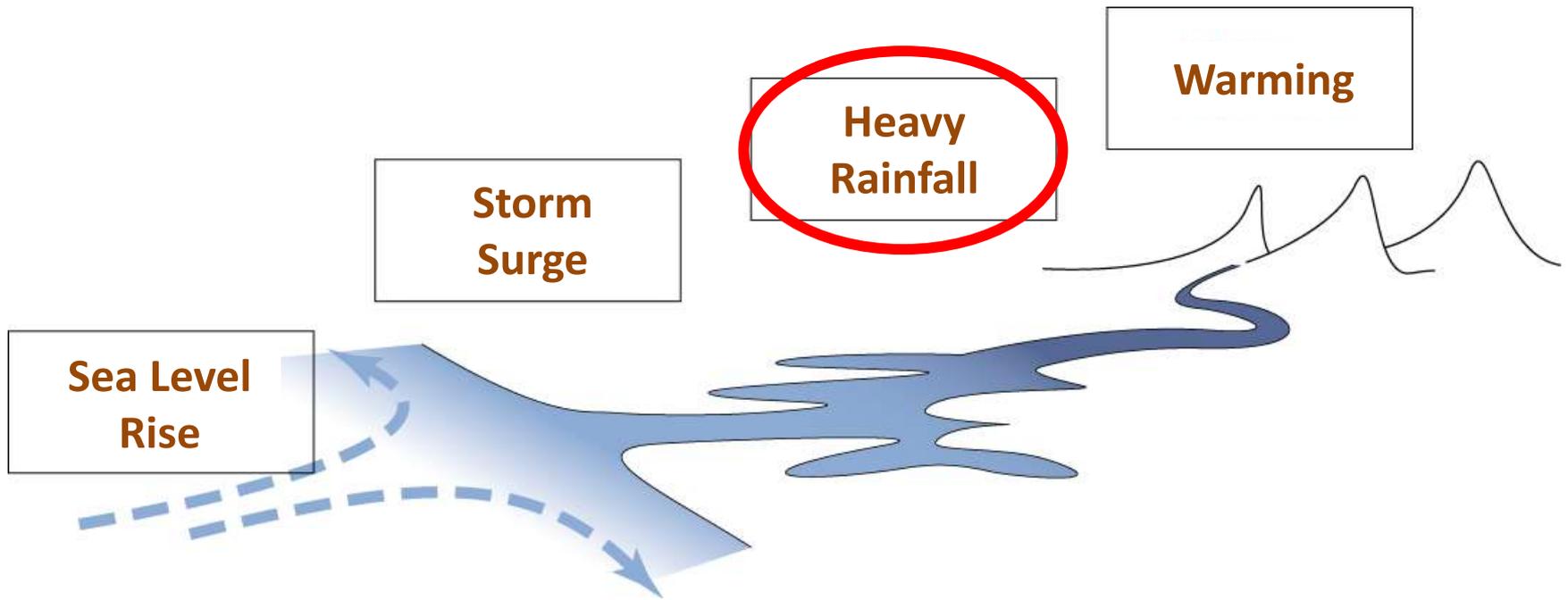
Increased summer electricity & water demand

Increased trade-offs/conflicts between water users

# 2015: An analog for the future



# Changing Hydrology



**Physical Drivers**

# Two factors affect precip change:

## ***1. Thermodynamic:***

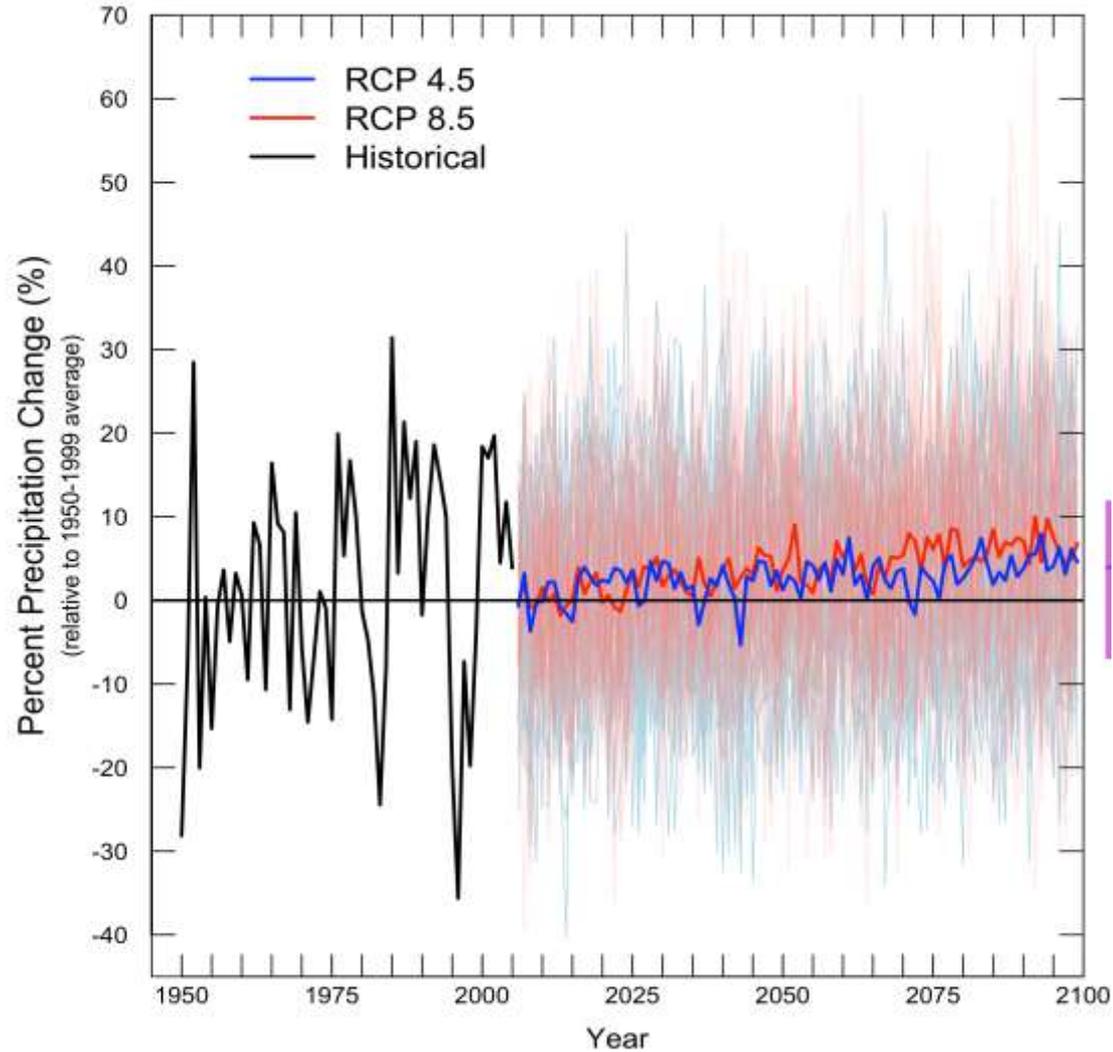
warm air holds more water

## ***1. Dynamic:***

Will the jet stream shift poleward?

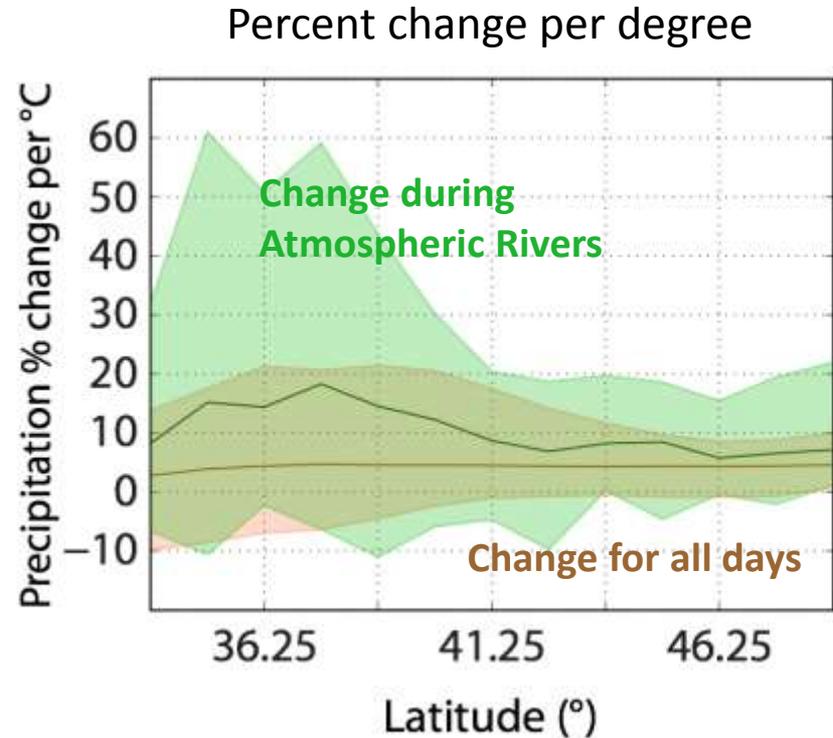
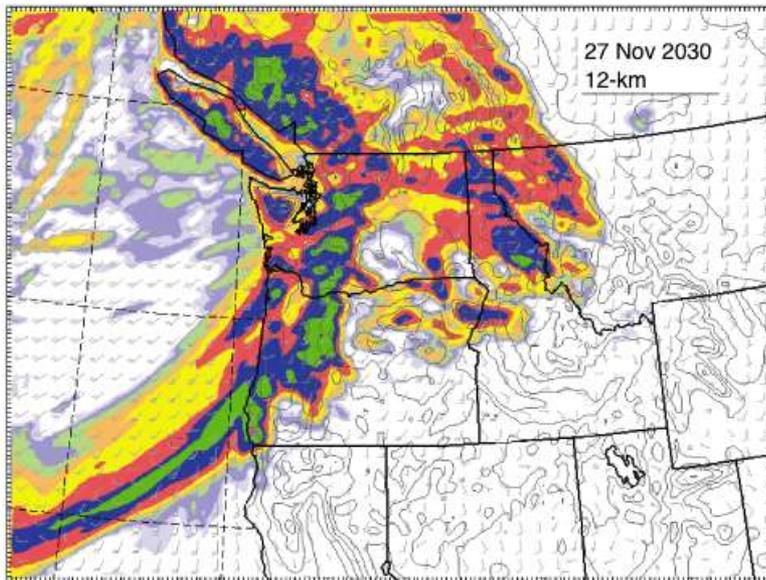
# Total Annual Rainfall: *weak trends*

Projected Change in Average Annual PNW Precipitation  
(relative to 1950-1999 average)



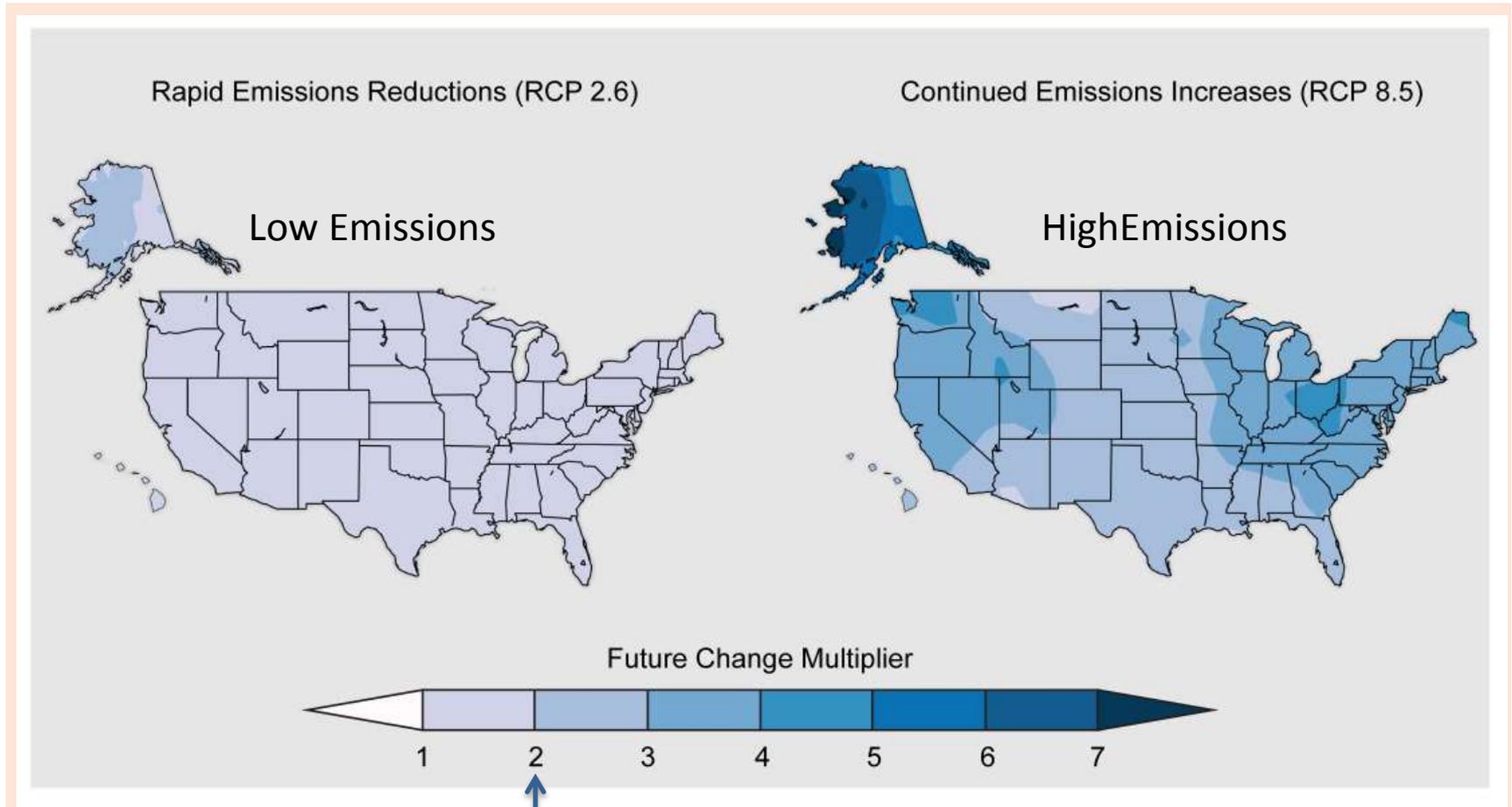
# Atmospheric rivers: strong response to warming

(aka "Pineapple Express")



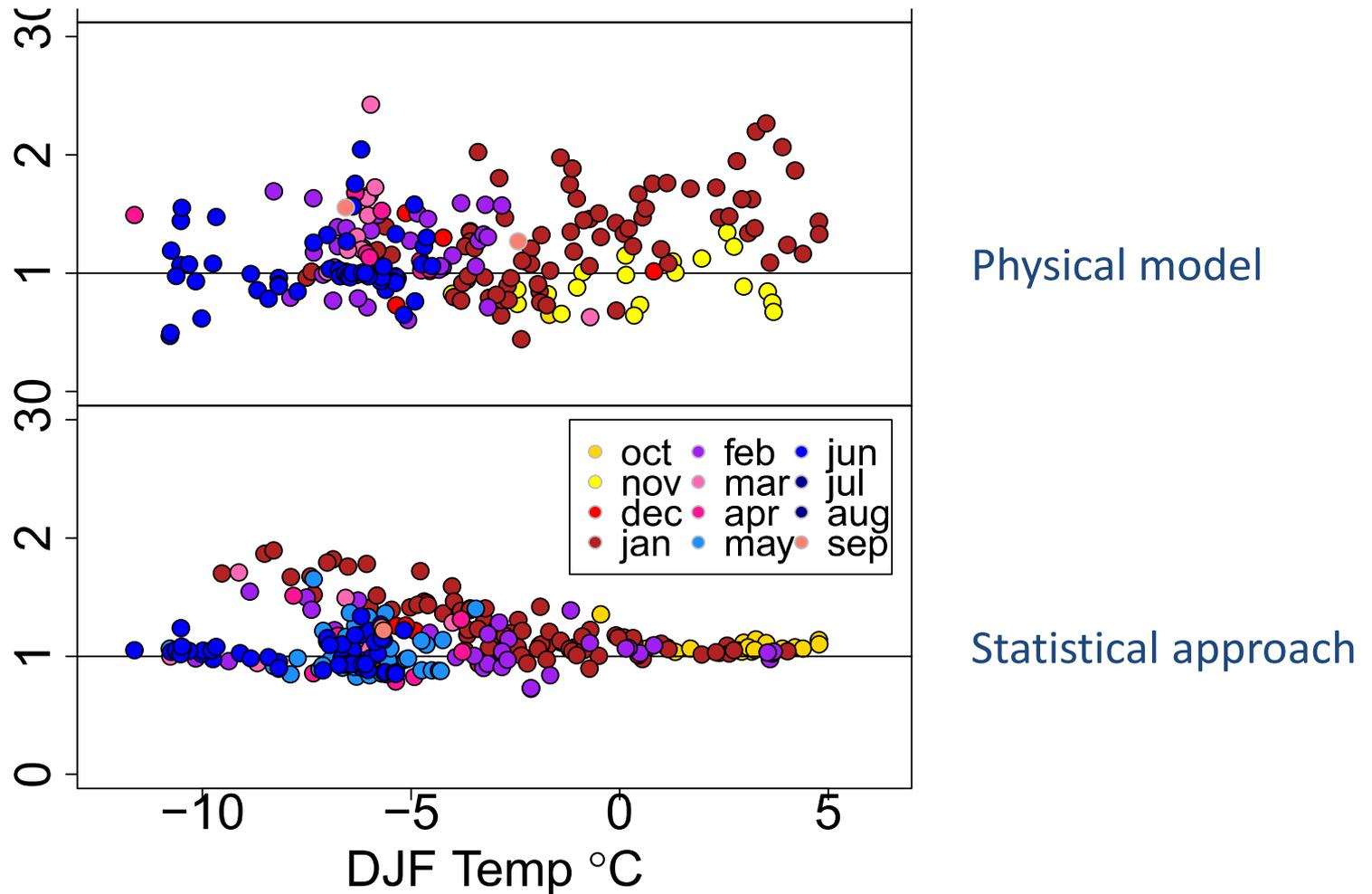
- Changes in normal precipitation: 1.5-3.5% per degree
- **Changes in extreme:** 5-12% per degree

# More Heavy Precip everywhere



*Low end = a near doubling by 2100*

# Different approaches, different results



# Flooding: Skagit River

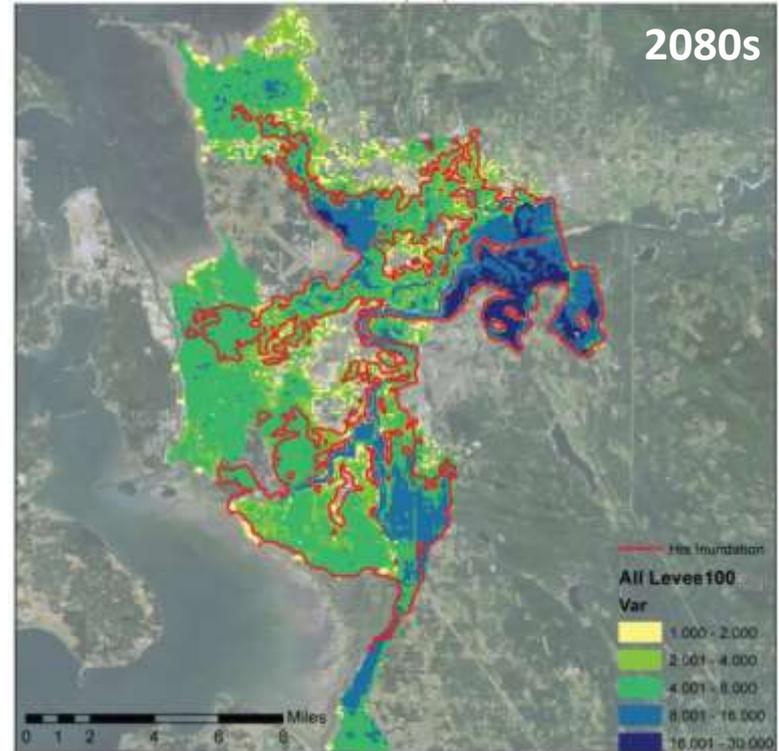


Figure Source: Joe Hamman, UW

# Flooding: Snohomish River

*10-yr Flood, 2040s*

## Inundation Depth

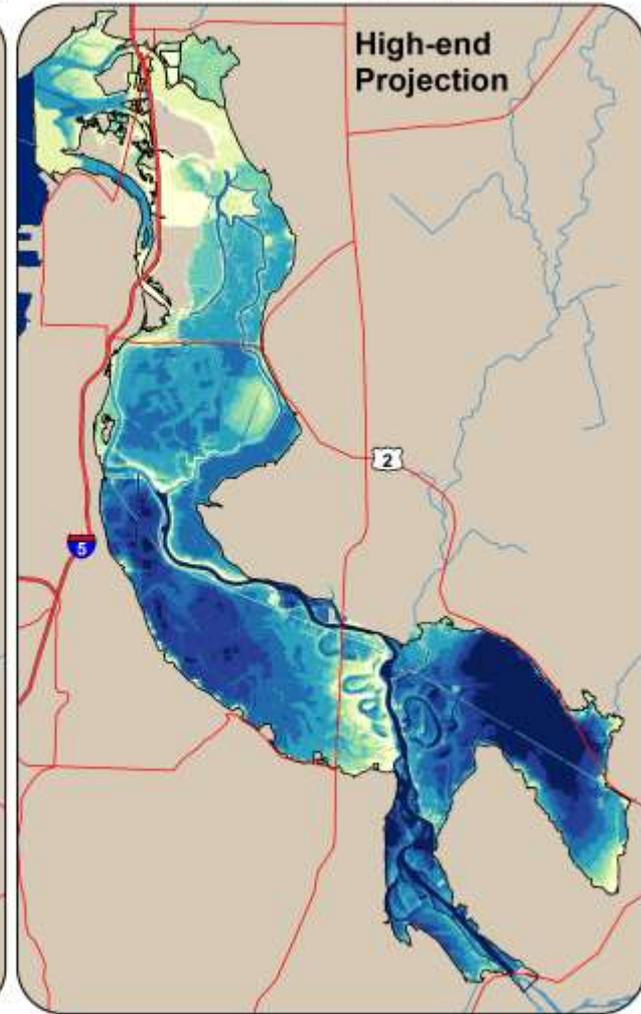
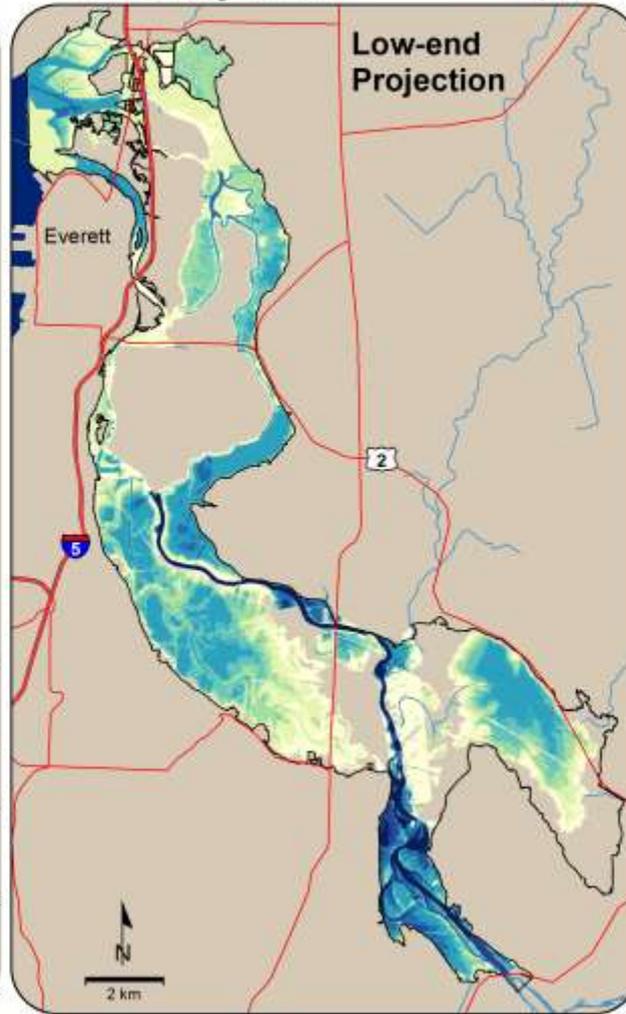
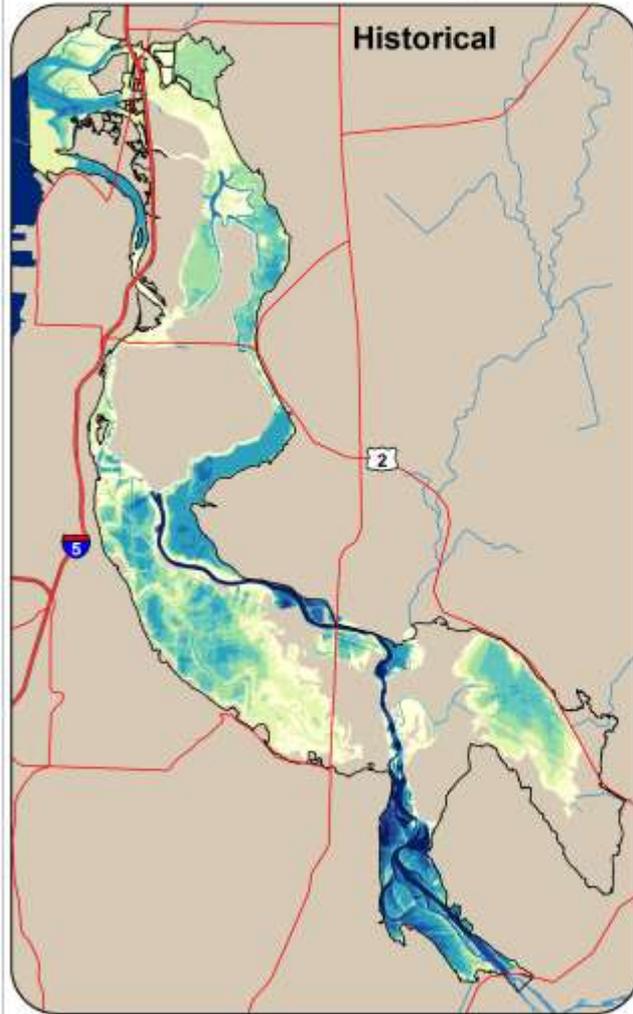
### 10-year Flood 2040 Projections



Historical

Low-end  
Projection

High-end  
Projection



# Flooding: Snohomish River

*100-yr Flood, 2040s*

## Inundation Depth

### 100-year Flood 2040 Projections



Historical

Low-end  
Projection

High-end  
Projection

*By the 2040s:*

- The **10-year** flood will become a **5-year** flood
- The **100-year** flood will become a **30-year** flood





# Building Climate Resilience Through Adaptation: Ask the Climate Questions

Can we **achieve our goals** in a changing climate?

How do we **protect our investments** as the climate changes?

What is necessary to **reduce risks** associated with a changing climate?

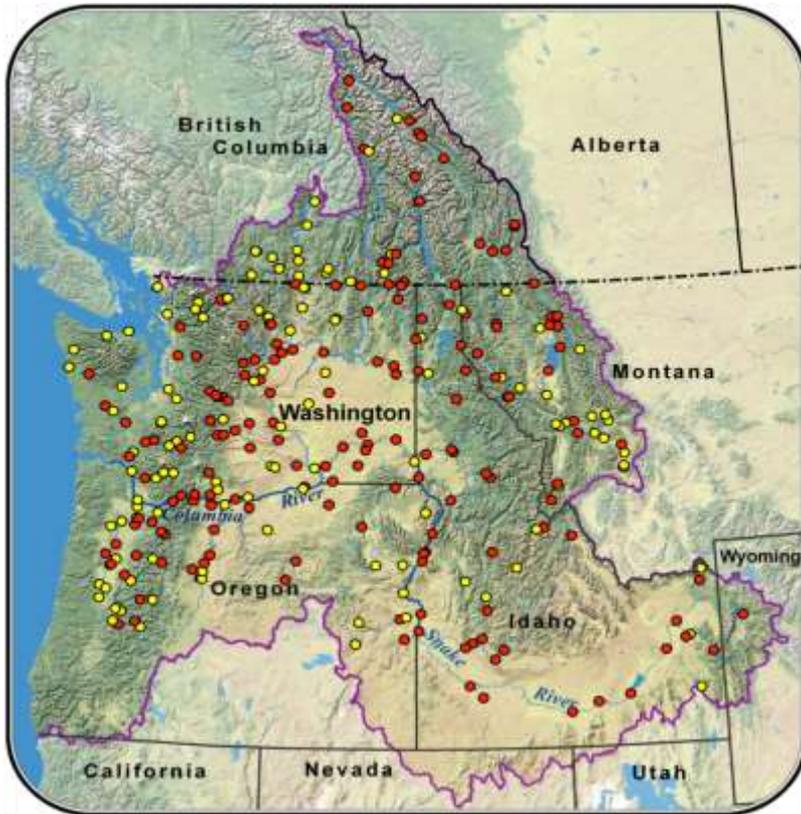
How do we **avoid creating new risks**?

What **opportunities** should we prepare for?

Answering these questions requires some information about the future...



# PNW Climate Change Scenarios



A comprehensive online suite of 21<sup>st</sup> century hydro/climate scenarios, including data for:

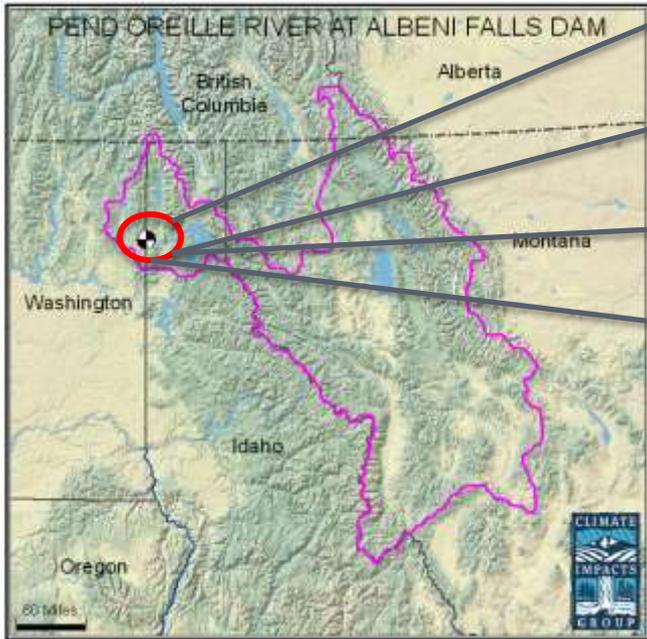
- Temperature
- Precipitation
- Snowpack
- Streamflow
- Floods & extreme low flows
- Evapotranspiration (water demand)
- Soil moisture

<http://warm.atmos.washington.edu/2860/>

*Supported by WA state (HB2860), BPA, NWPCC, ODWR, BC Ministry of Environ*



# Site-specific climate change projections

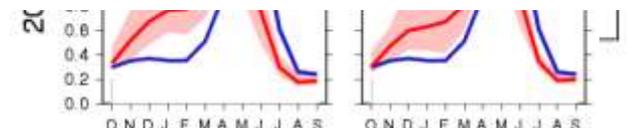
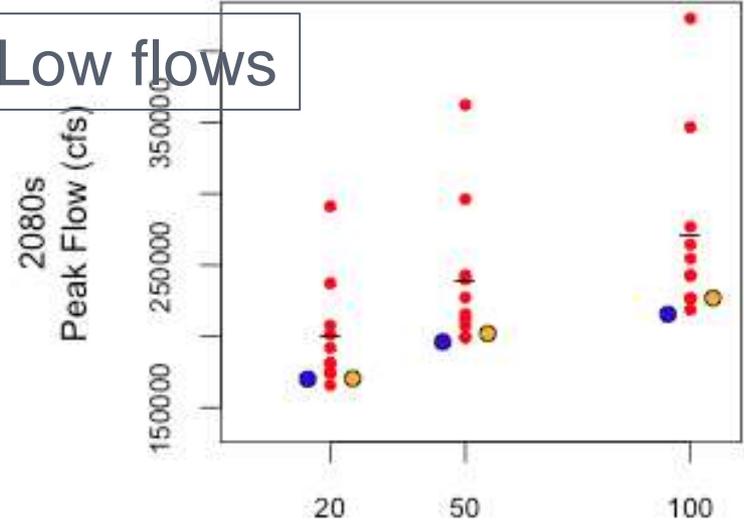
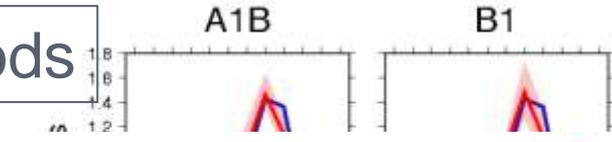
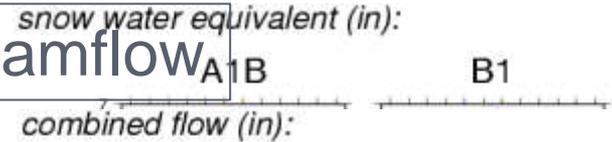


Snowpack

Streamflow

Floods

Low flows





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UNIVERSITY *of* WASHINGTON