Climate Change Impacts on Hydrology of the Western Cascades

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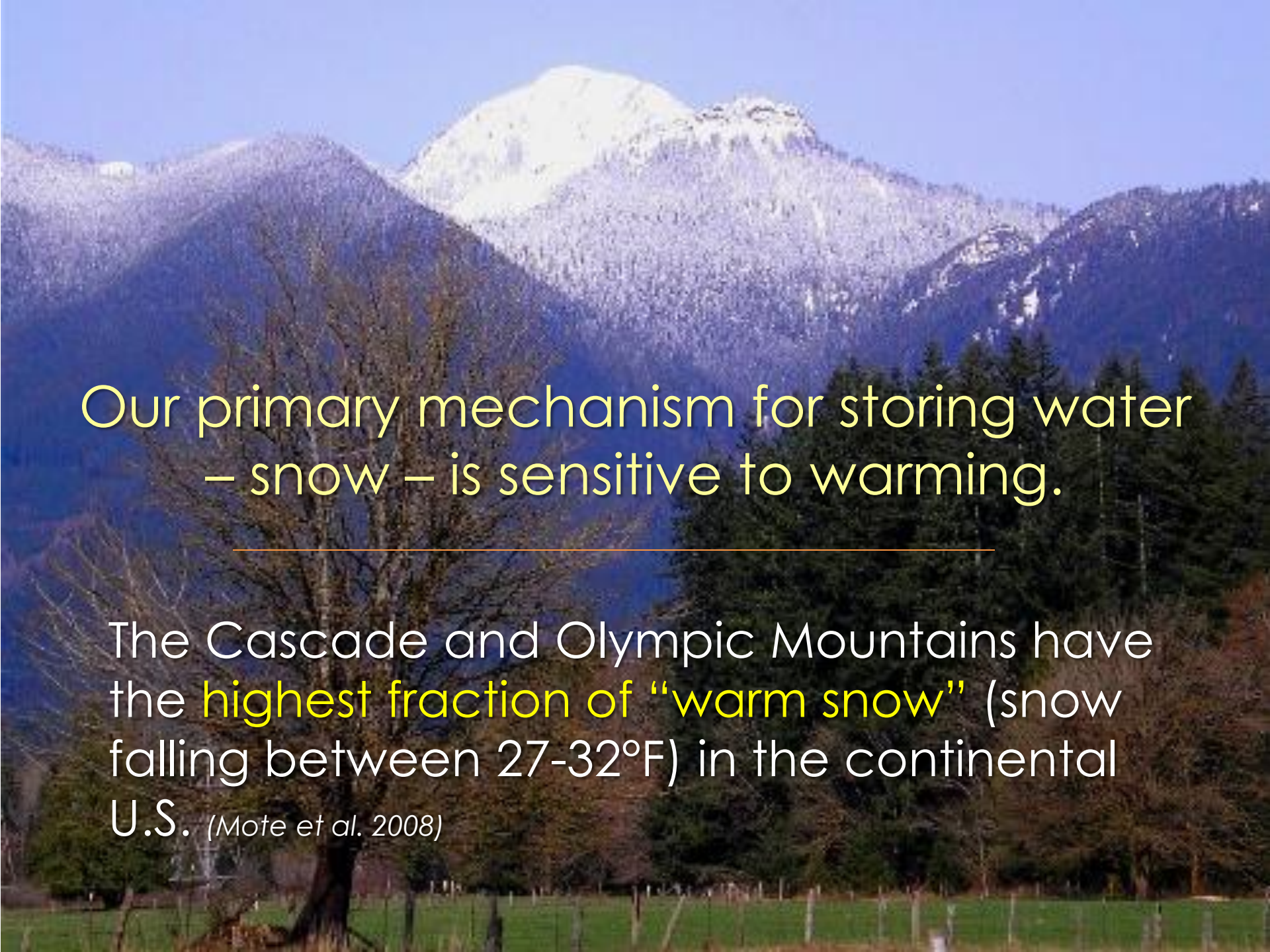
UW Climate Impacts Group

Mt Baker - Snoqualmie National Forest
Climate Change Workshop
April 28, 2011

CLIMATE IMPACTS GROUP

We care about climate and hydrologic change because:

- we have growing, and often competing, water demands
- changes in water balance are closely linked with other impact pathways (forest & aquatic ecosystems, recreation, infrastructure)



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)*

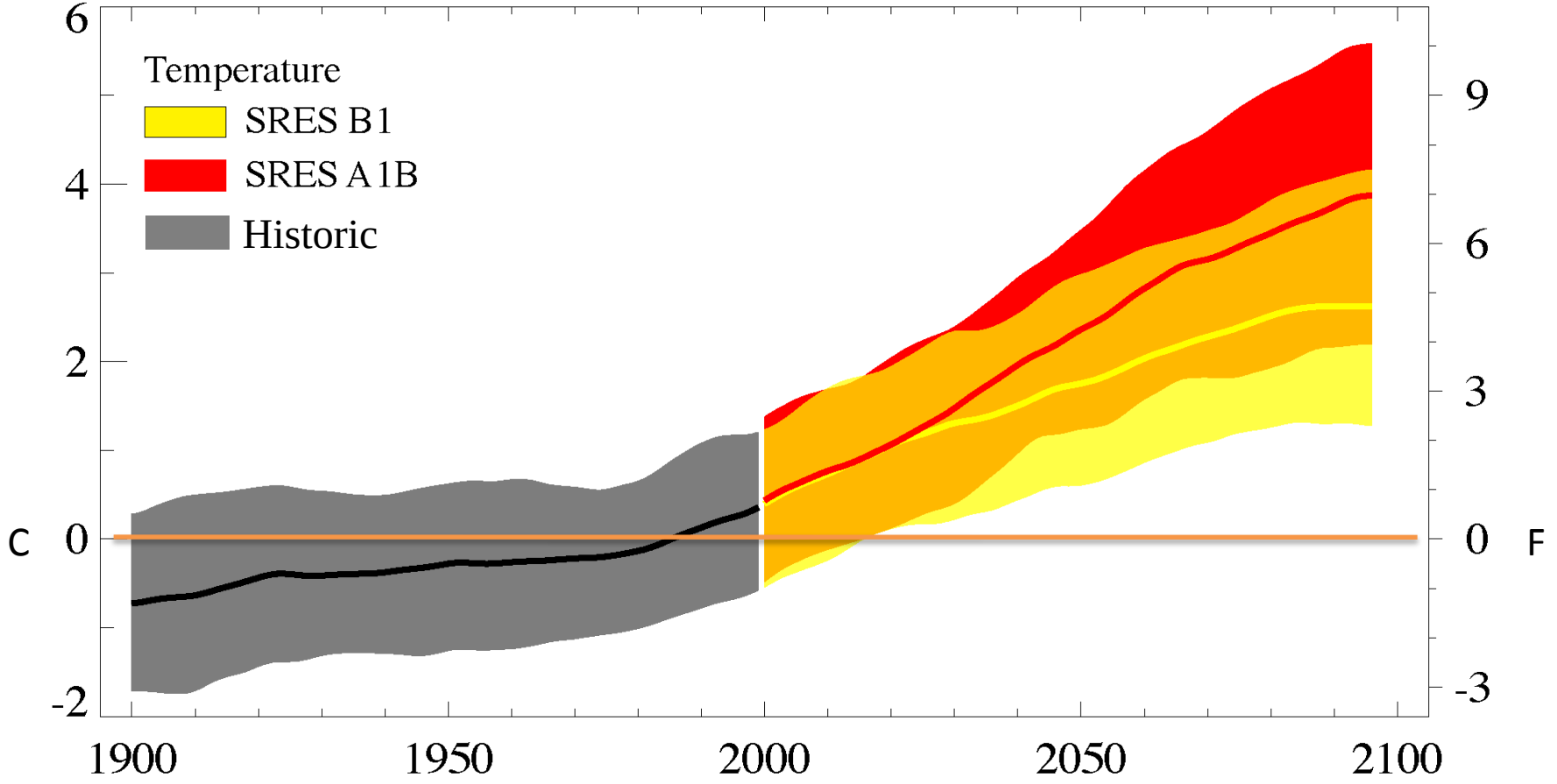
Looking Forward

Projected changes in
21st century climate
and hydrology

Projected Increases in Annual PNW Temperature

** Relative to 1970-1999 average*

2020s	+2.0°F *(1.1-3.4°F)*
2040s	+3.2°F *(1.6-5.2°F)*
2080s	+5.3°F *(2.8-9.7°F)*

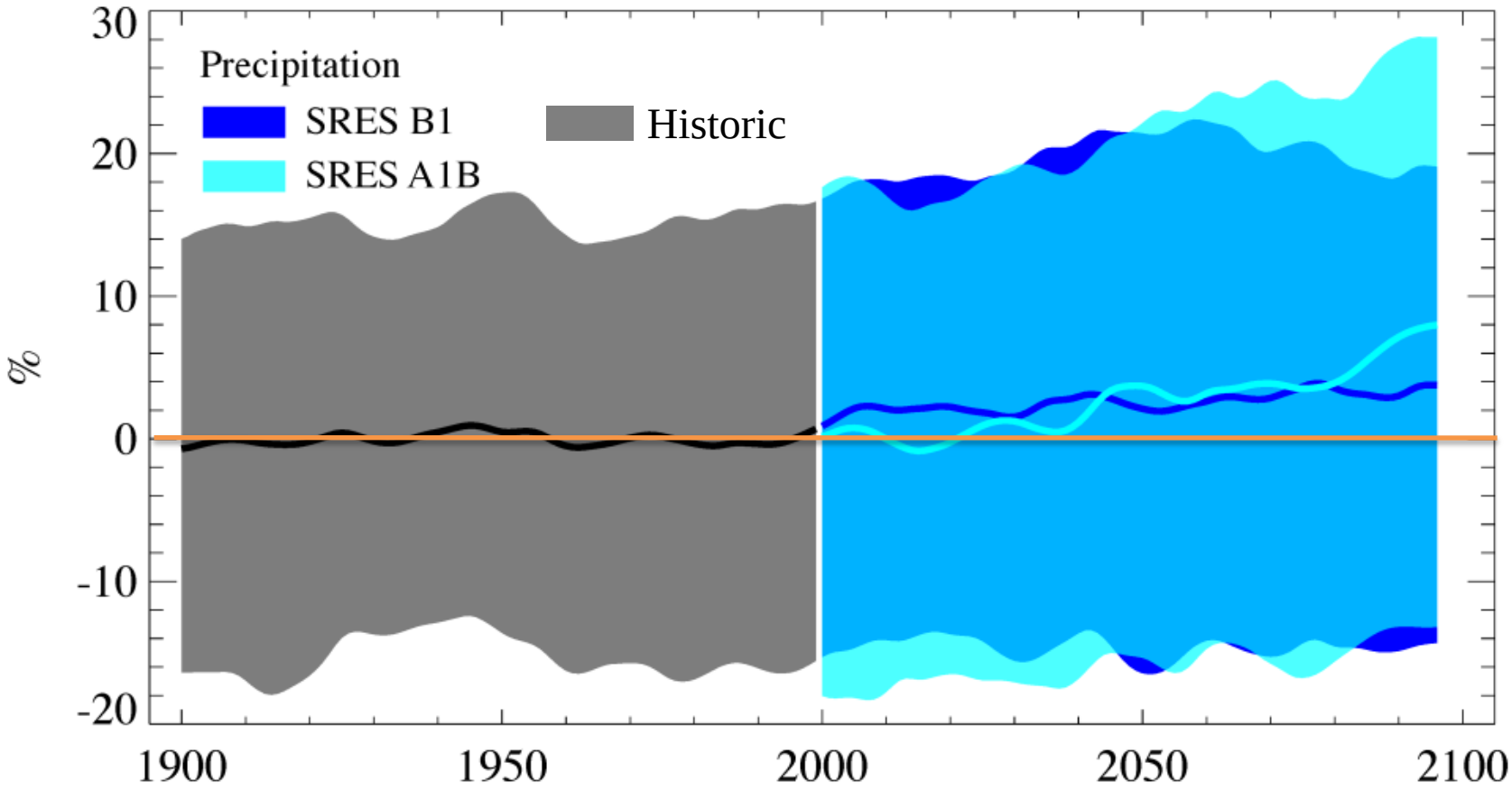


Mote and Salathé, 2009

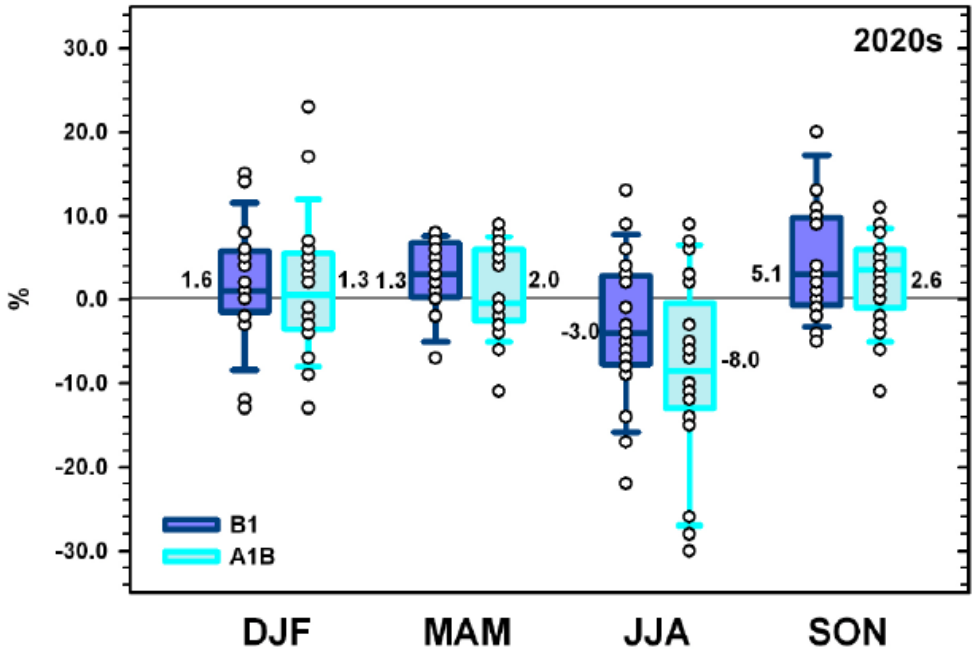
Projected Increases in Annual PNW Precipitation

** Relative to 1970-1999 average*

2020s	+1% *(-9 to 12%)*
2040s	+2% *(-11 to +12%)*
2080s	+4% *(-10 to +20%)*

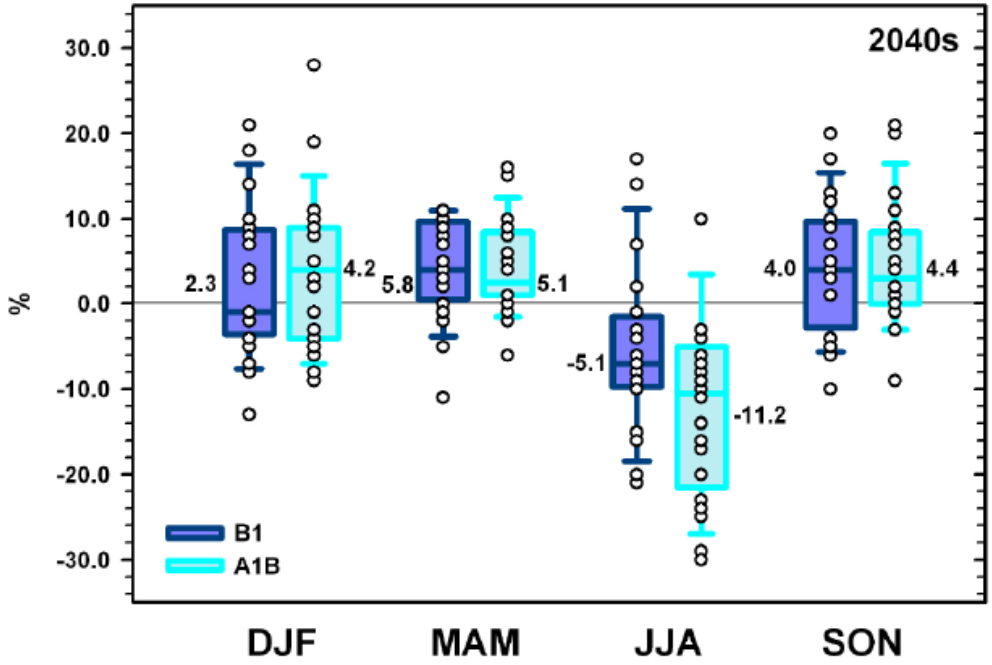


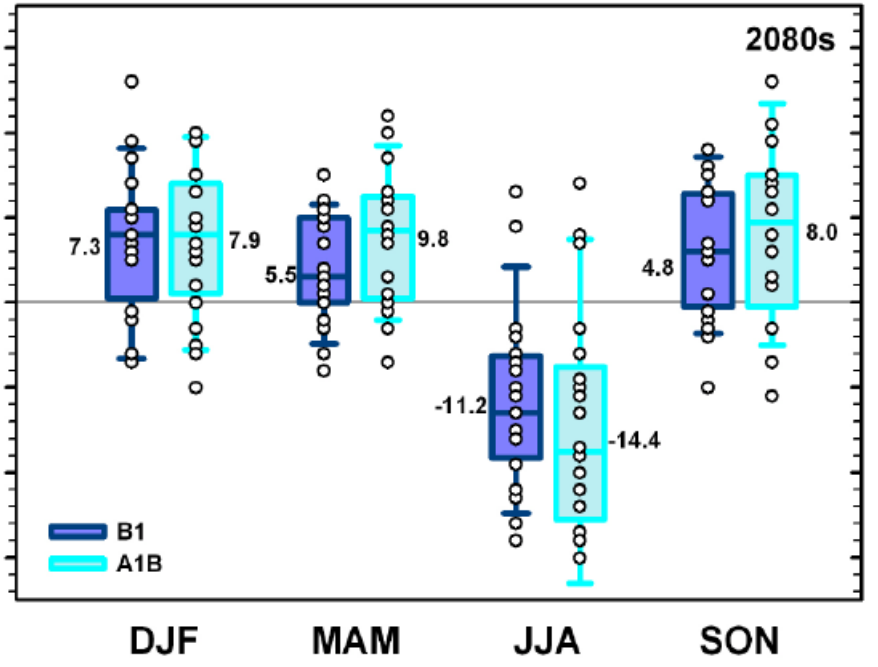
Mote and Salathé, 2009



While there is significant variability across models, we anticipate wetter winters and drier summers

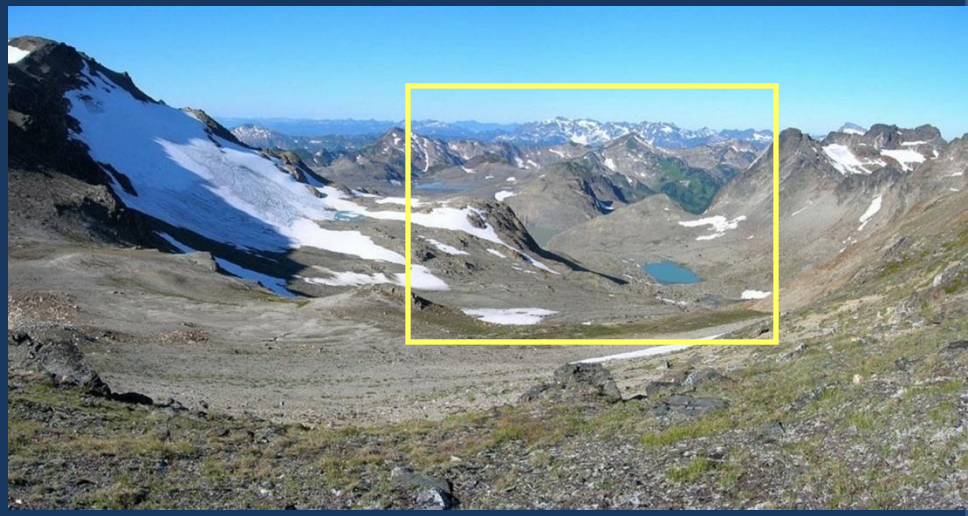
Mote and Salathé, 2009





Recession of Whitechuck Glacier (Sauk Headwaters)

1973



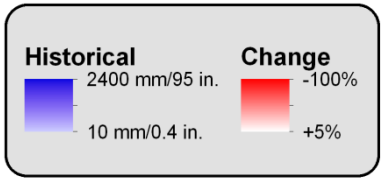
2006

North Cascades Glacier Climate Project (NCGCP)
Photos courtesy of Dr. Mauri Pelto, Nichols College

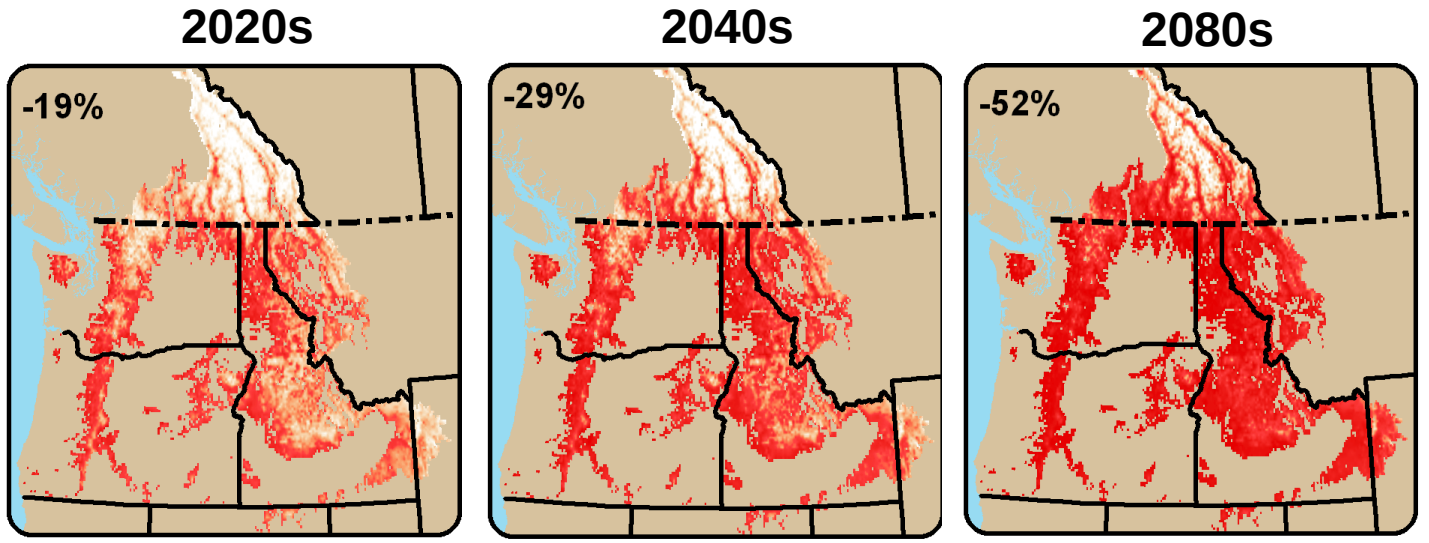

Loss of glacial mass may ***increase*** summer flow in the short term and ***decrease*** summer flow in the long term.

Key Impact: Loss of April 1 Snow Cover

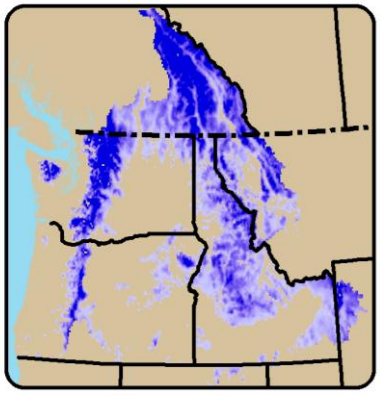
Map: Rob Norheim

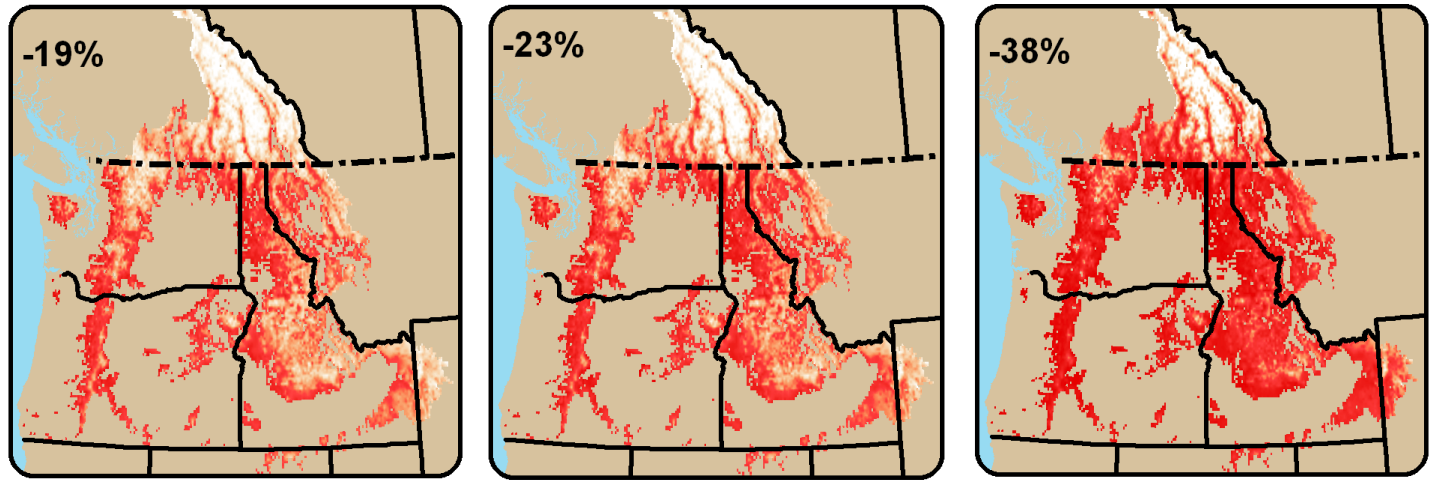


Projections compared to 1970-1999 average



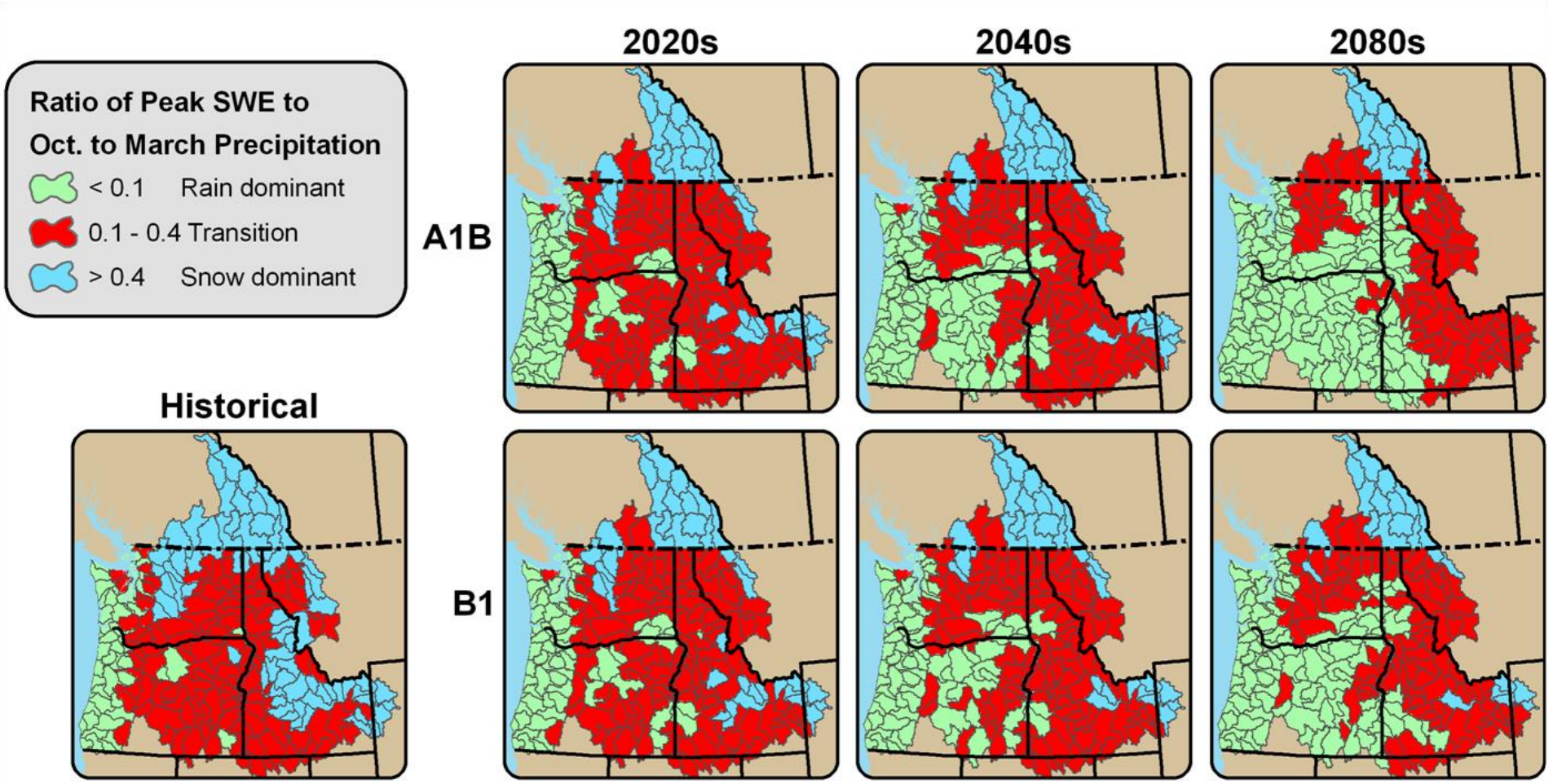
Historical





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

Key Impact: Shift in Hydrologic Basin Types

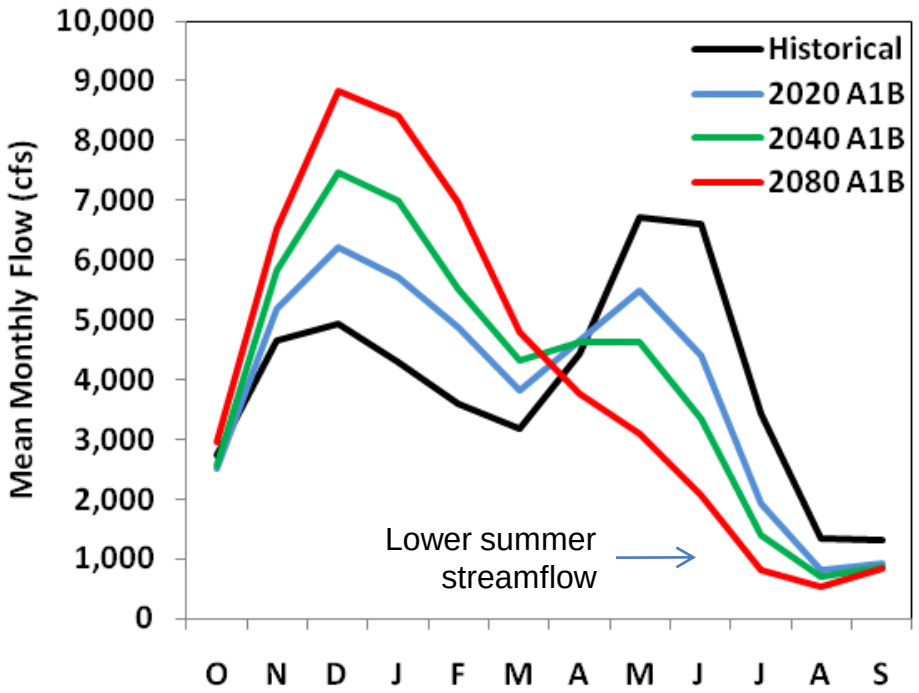


Historically snow dominated watersheds in the eastern Cascades will slowly shift toward becoming transient watersheds (blue to red).

Map: Rob Norheim

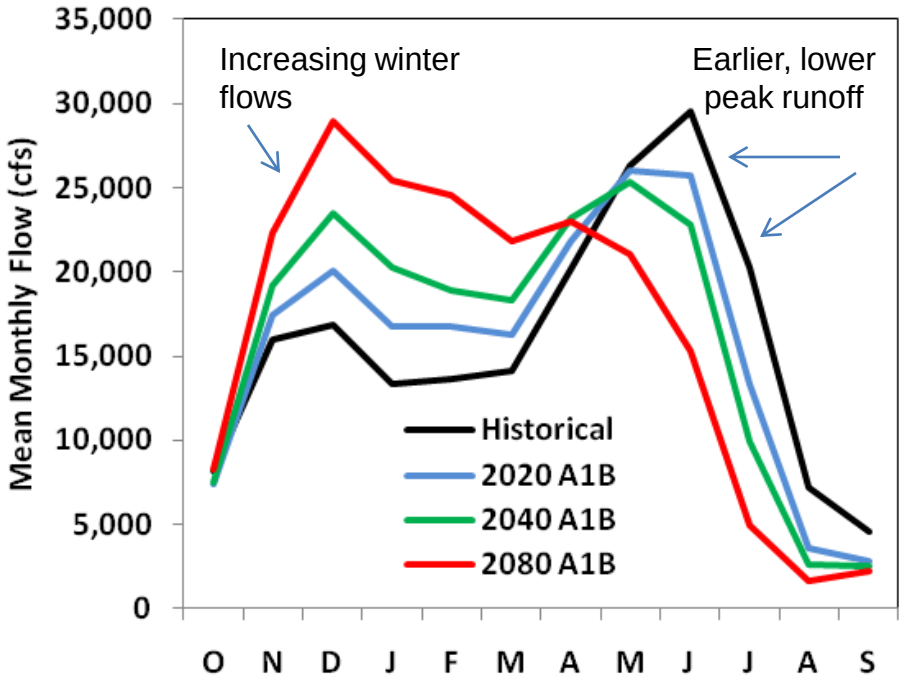
Impacts to Seasonal Streamflow Timing

Skykomish River near Gold Bar



Mix Rain/Snow "Transient" Basin

Skagit River at Mt Vernon



Snow Dominant Basin

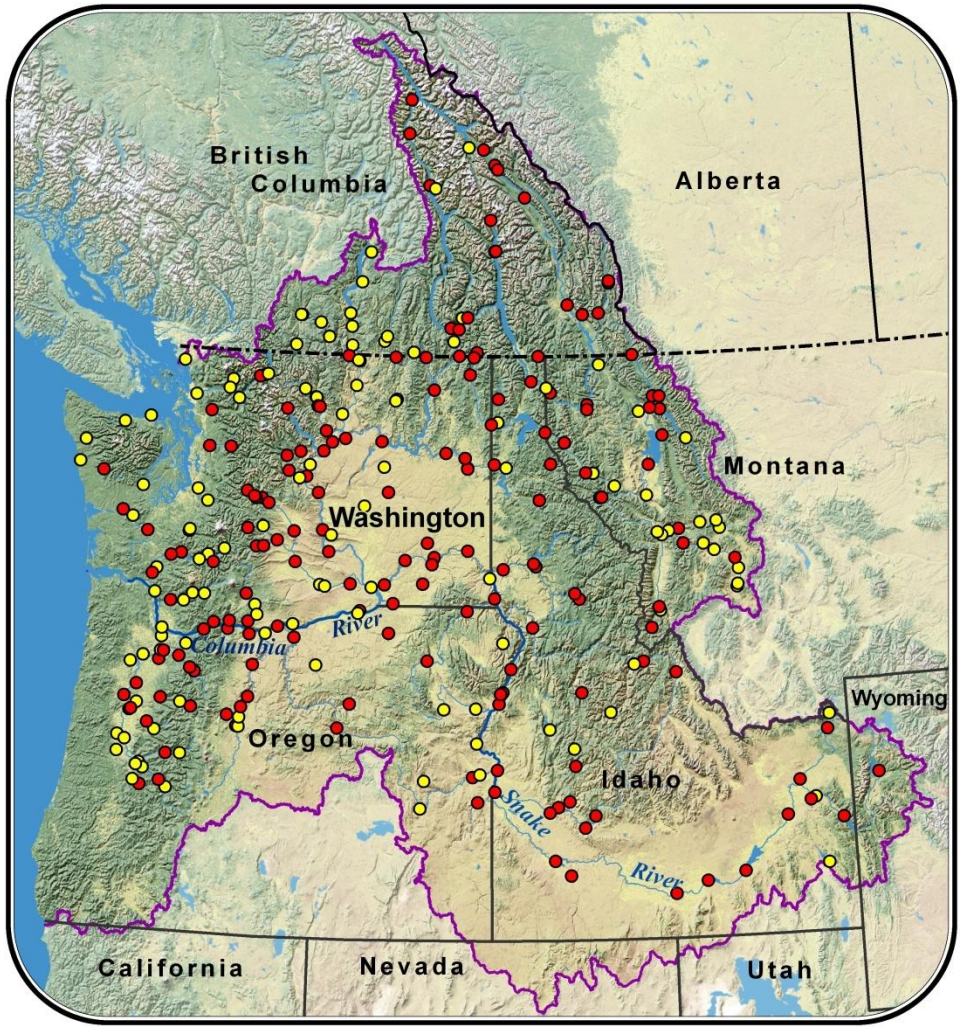
Elsner et al. 2009

Naturalized flows (i.e., no dams)

The Columbia Basin Climate Change Scenarios Project

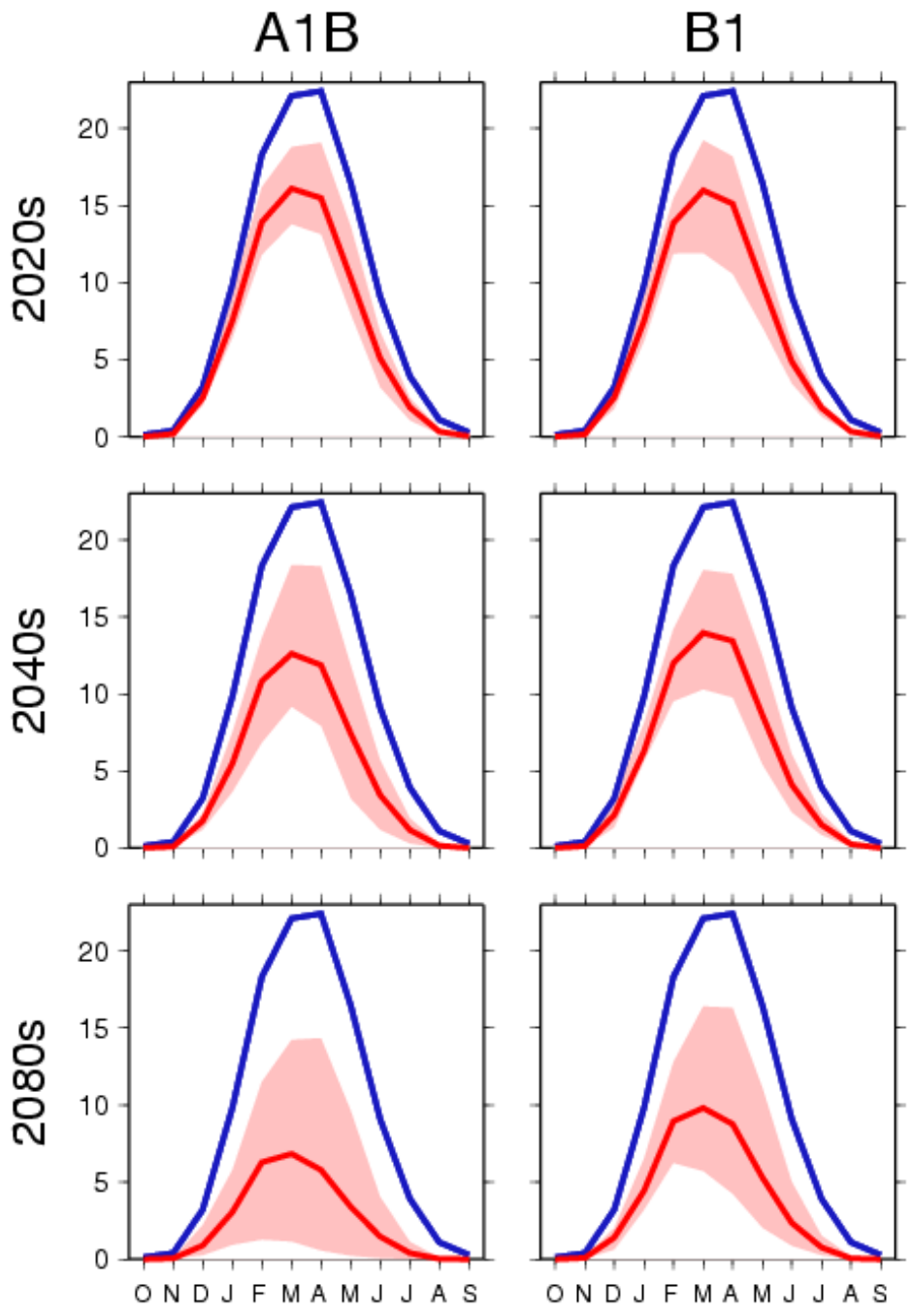
A comprehensive suite of free 21st century hydro/climate scenarios for almost 300 sites in the PNW, including data for:

- streamflow
- evapotranspiration
- flood & low flow statistics
- precip, temp
- soil moisture
- snowpack

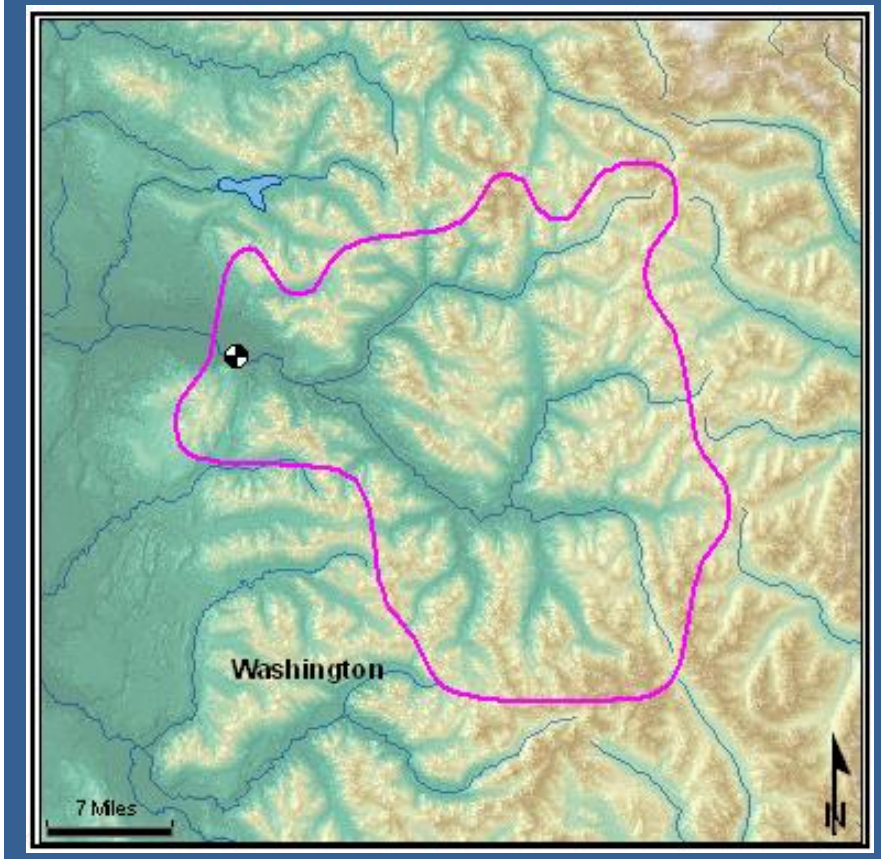


http://www.hydro.washington.edu/2860/

snow water equivalent (in):



Skykomish River near Gold Bar



Historical

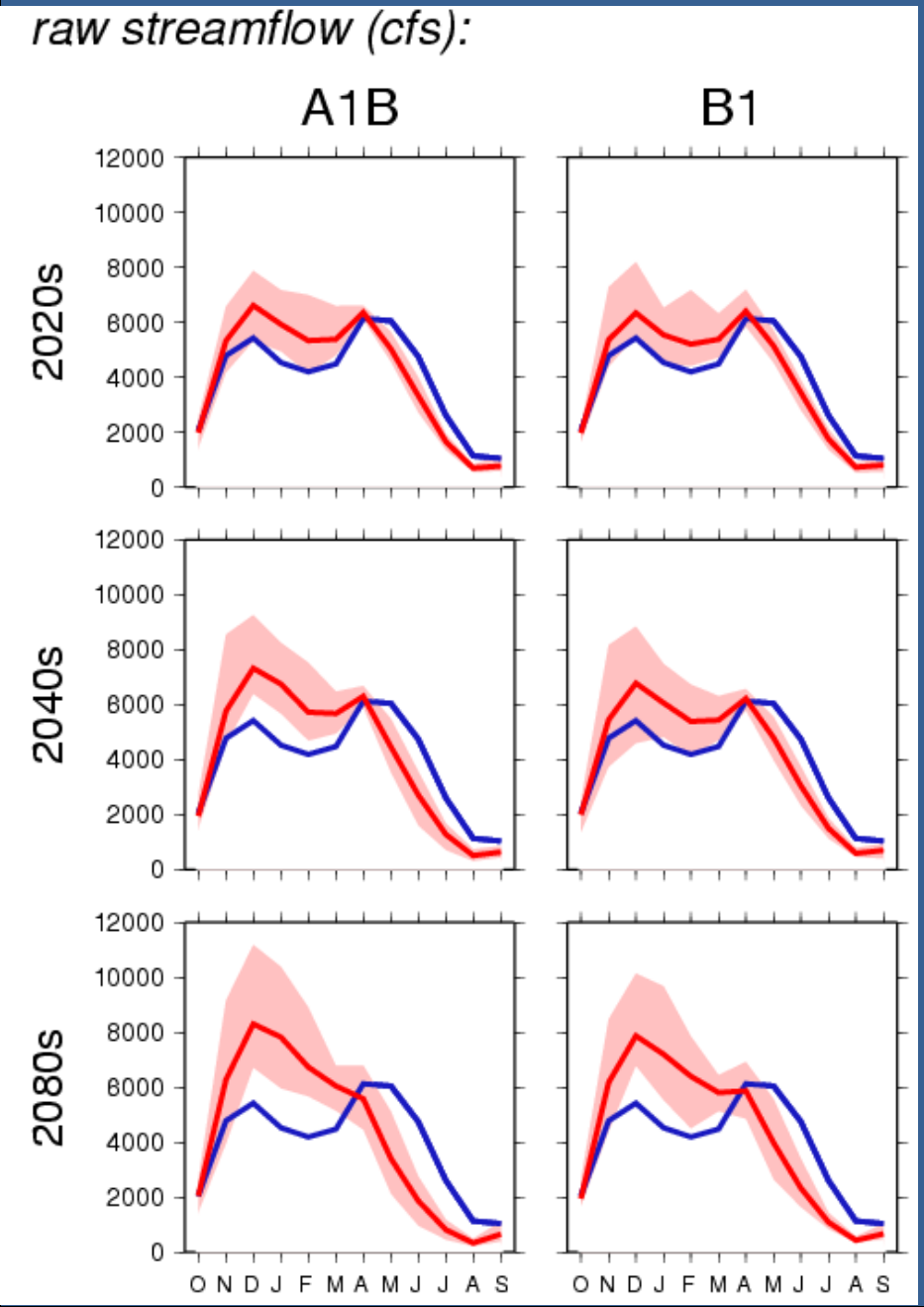
Future Projections - mean

Future Projections - range

Data source: CIG, http://www.hydro.washington.edu/2860/

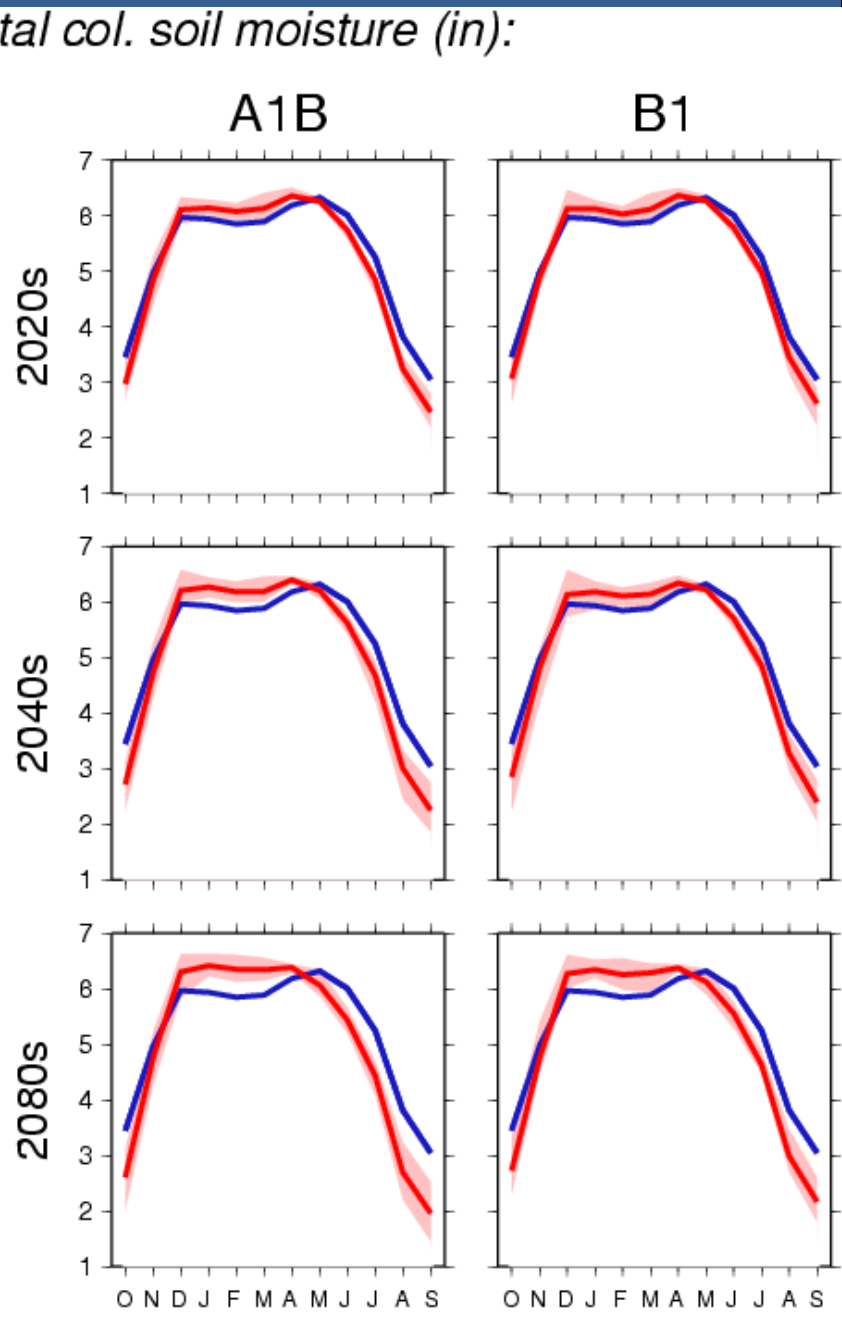
Flow

raw streamflow (cfs):



Soil Moisture

total col. soil moisture (in):



Changes in Hydrologic Extremes

Dec 2007 Flood Damage
Sauk River near
Darrington

Cedar River at
Chester Morse Lake
during extreme low flows

2040s Changes in Flood Risk
Skykomish River near Gold Bar

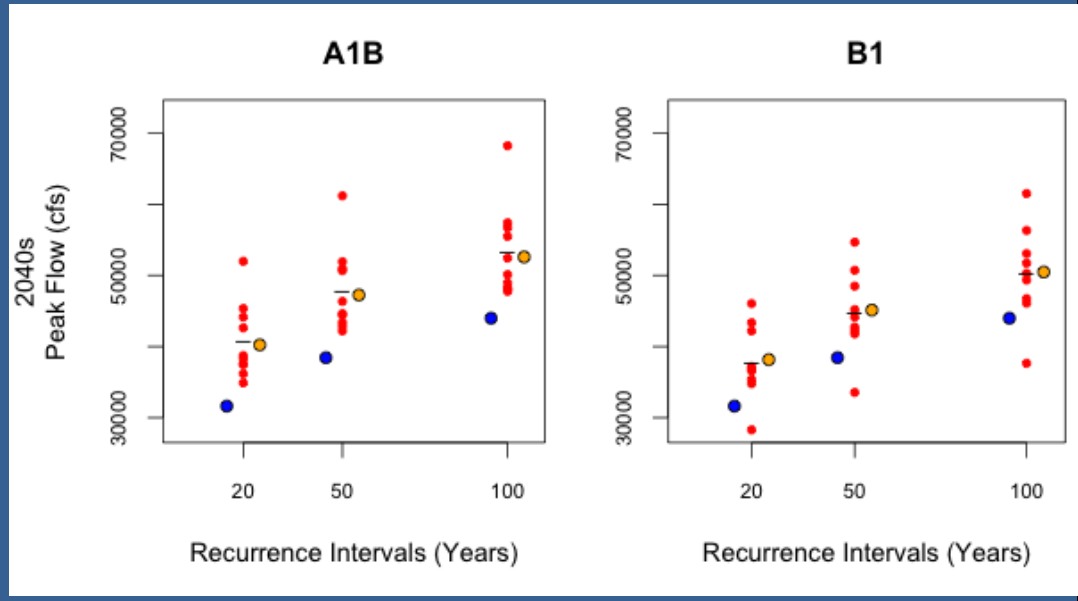
A1B (medium scenario):

- Central tendency of hybrid delta scenarios is:
  - **21% increase**
- Range of increase is 9% to 55%

B1 (low scenario):

- Central tendency of hybrid delta scenarios is:
  - **14% increase**
- Range is decrease of 14% to increase of 40%

Projected 20, 50, 100-year floods using different downscaling techniques



Data source: CIG, http://www.hydro.washington.edu/2860/

2040s Changes in Low Flows
Skykomish River near Gold Bar

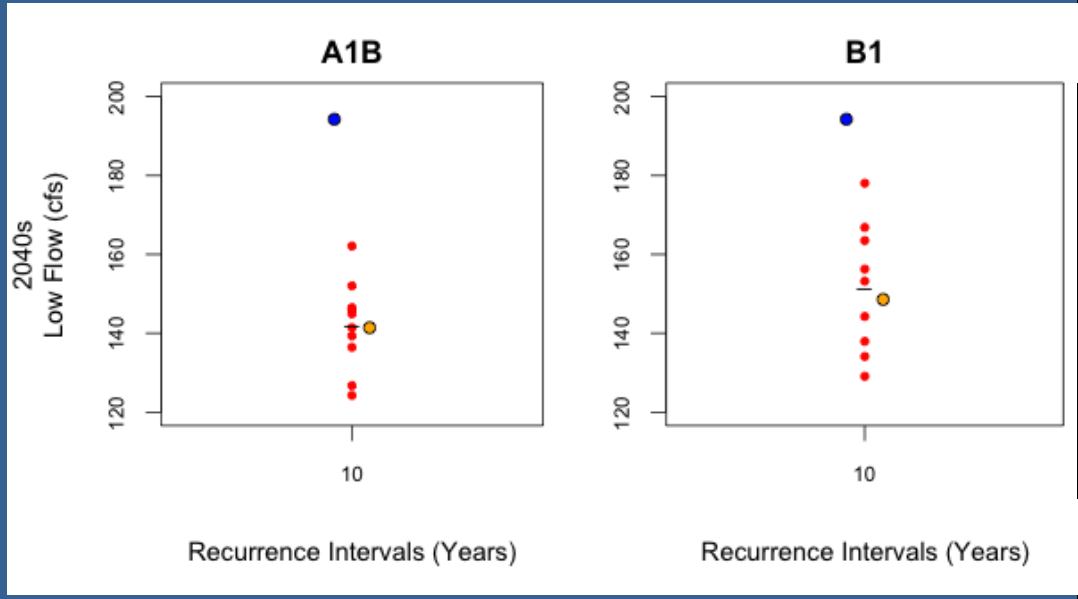
A1B (medium scenario):

- Central tendency (hybrid delta scenarios) is:
  - **27% decrease**
- Range of decrease is 17% to 36%

B1 (low scenario):

- Central tendency (hybrid delta scenarios) is:
  - **22% decrease**
- Range of decrease is 8% to 34%

Projected 7Q10 low flow using different downscaling techniques



7Q10: 7-day consecutive low flow with a 10-year recurrence interval

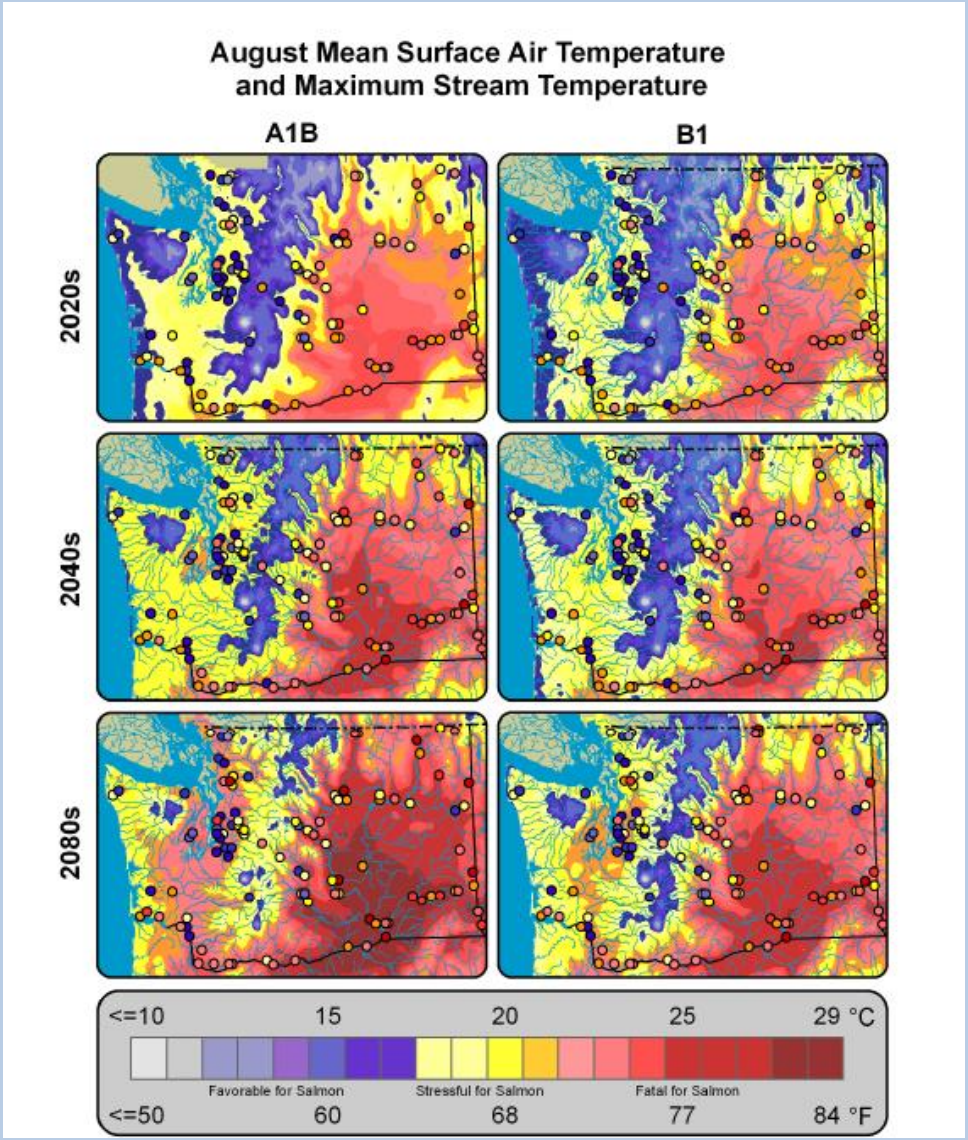
- Historical
- Hybrid Delta Projections
- Traditional Delta Projections

Data source: CIG, http://www.hydro.washington.edu/2860/

Looking Forward

Related Impacts

Aquatic Ecosystem Impacts



Mantua, N., I. Tohver, A.F. Hamlet, 2010: Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State, *Climatic Change*, online first, doi: 10.1007/s10584-010-9845-2

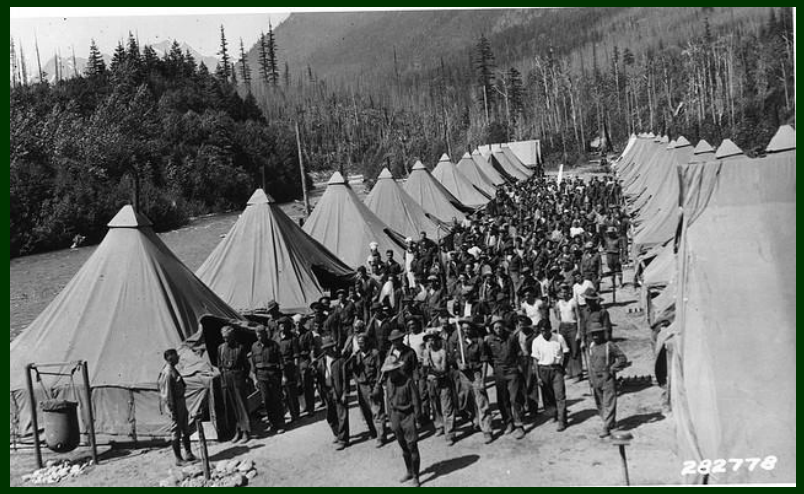
Stormwater Management

Index-Galena Rd
November 2006

Example Application:
Improving Estimates
of the 100-year Flood
Olympic National Forest

Forest Access

Mountain Loop Highway 8.6mi east of Verlot Ranger Station
Jan 2011

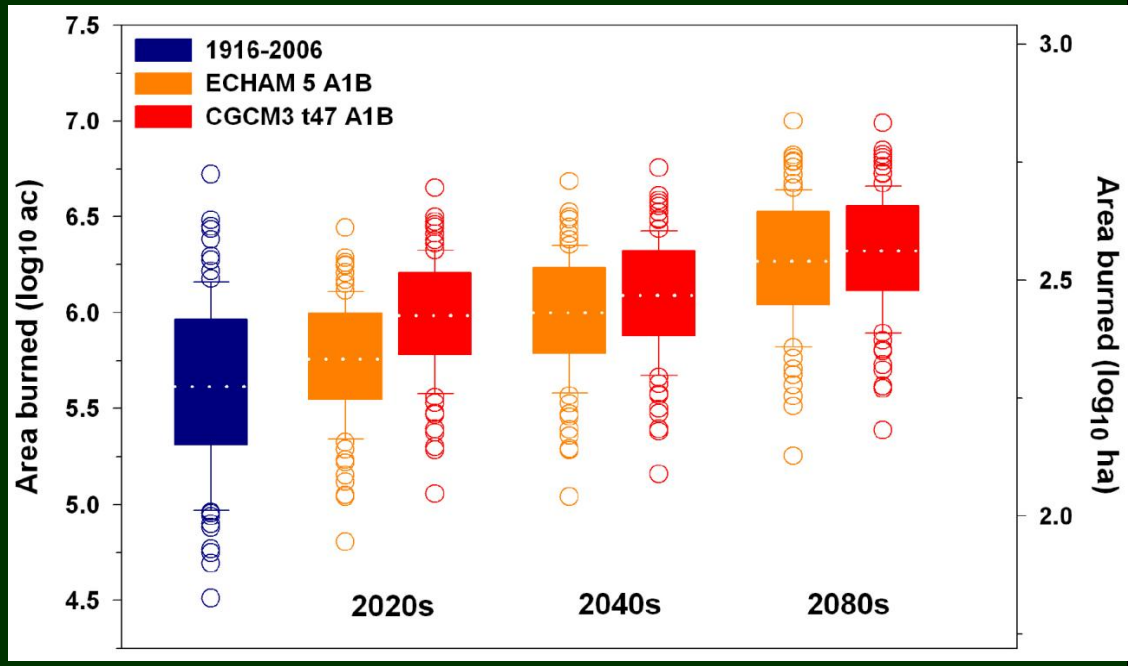


Forest fire training at Skagit Civilian Cons. Corps camp, Mt. Baker National Forest, Washington - 1933

Forest Disturbance

Crystal Mine Fire Aug 2009
Snoqualmie Ranger District

Projected Area Burned in WA



Littell, J.S., E.E. Oneil, D. McKenzie, J.A. Hicke, J.A. Lutz, R.A. Norheim, and M.M. Elsner. 2010. Forest ecosystems, disturbance, and climatic change in Washington State, USA. Climatic Change 102(1-2): 129-158, doi: 10.1007/s10584-010-9858-x

Sediment Impacts

RAINIER'S ROCKS ARE FILLING RIVERBEDS

Dr. Tim Abbe | 01.04.10 | Restoration | 2 Comments

Paul Kennard, NPS [by Steve Ringman, Seattle Times]

The fallout from Mount Rainier's shrinking glaciers is beginning to roll downhill, and nowhere is the impact more striking than on the volcano's west side.

By Sandi Doughton
Seattle Times science reporter

Related:
flows (PDF)
Archive | State's shrinking glaciers: Going ... going ... gone? (2006)

The fallout from Mount Rainier's shrinking glaciers is beginning to roll downhill, and nowhere is the impact more striking than on the volcano's west side.

"This is it in spades," said Park Service geologist Paul Kennard, scrambling up a 10-foot-tall mass of dirt and boulders bulldozed back just enough to clear the road.

As receding glaciers expose crumbly slopes, vast amounts of gravel and sediment are being sluiced into the rivers that flow from the Northwest's tallest peak. Much of the material sweeps down in rain-driven slurries called debris flows, like those that repeatedly have slammed Mount Rainier National Park's Westside Road.

http://www.abbegeomorphology.com/?p=69

Increased Landslide Risks

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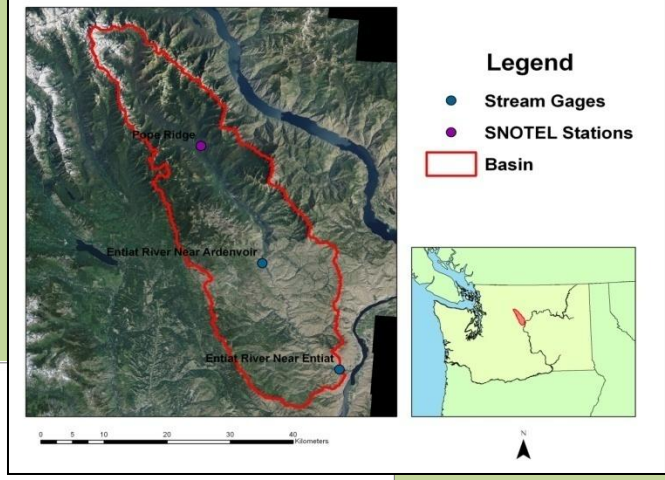
http://cses.washington.edu/cig/

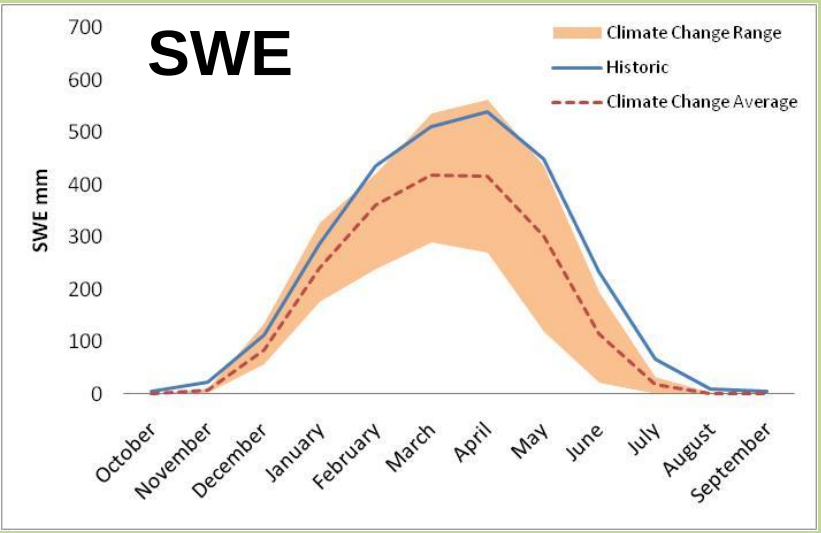
Entiat River Basin

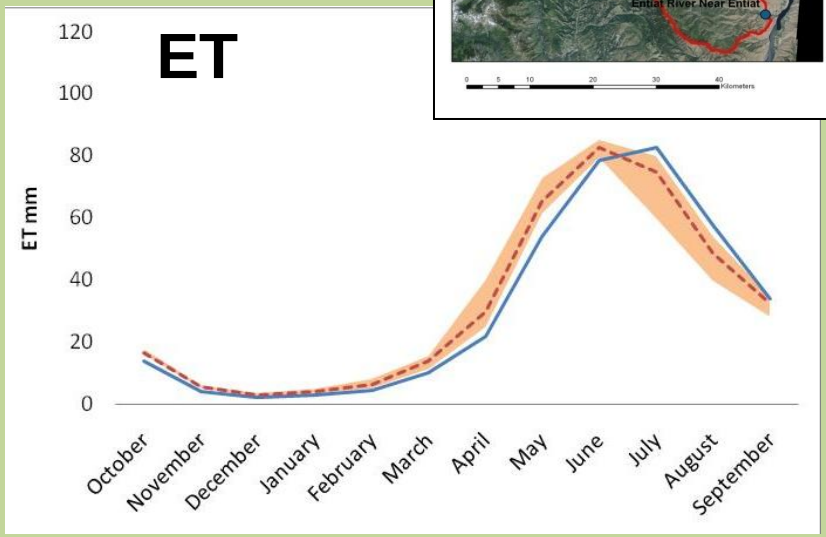
Fine Scale Projections (100m)

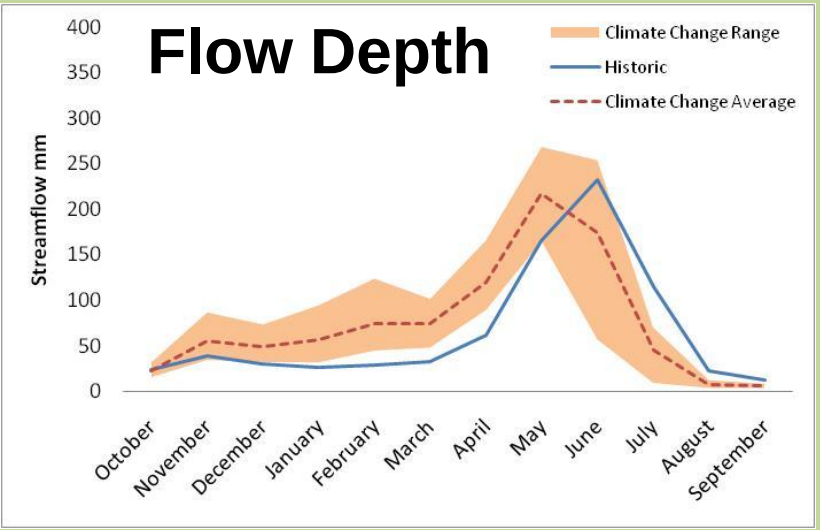
2030-2059 A1B

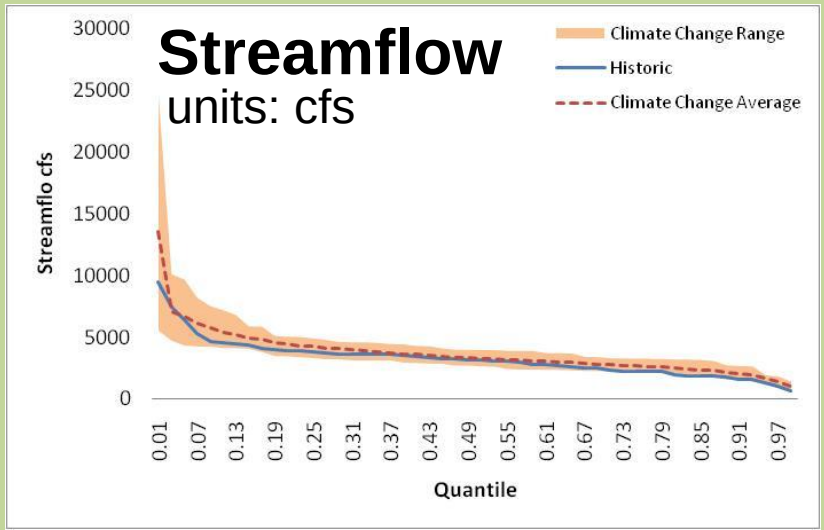
In collaboration with the USFS PNW Research Station











Units:mm unless otherwise noted

Exploring the Effects of Climate Change on Vegetation Disturbance and Recovery Processes

- Improve soil depth map
- Overlay maps of soil moisture stress (from hydrology model) and aerial photos
- Determine whether regeneration patterns coincide with patterns of soil moisture stress
- If a relationship is established, how might climate change impact vegetation recovery


Limited veg recovery on south-facing slope


Strong veg recovery on south-facing slope


Some regions without forest regeneration