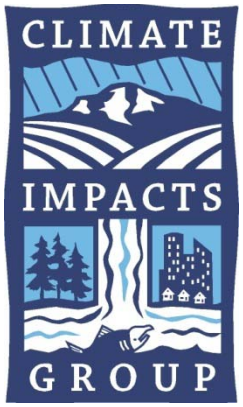
Hydrologic Implications of Climate Change for the Western U.S., Pacific Northwest, and Washington State

Alan F. Hamlet

•JISAO/CSES Climate Impacts Group
•Dept. of Civil and Environmental Engineering
University of Washington



Department of Civil and Environmental Engineering

Recession of the Muir Glacier

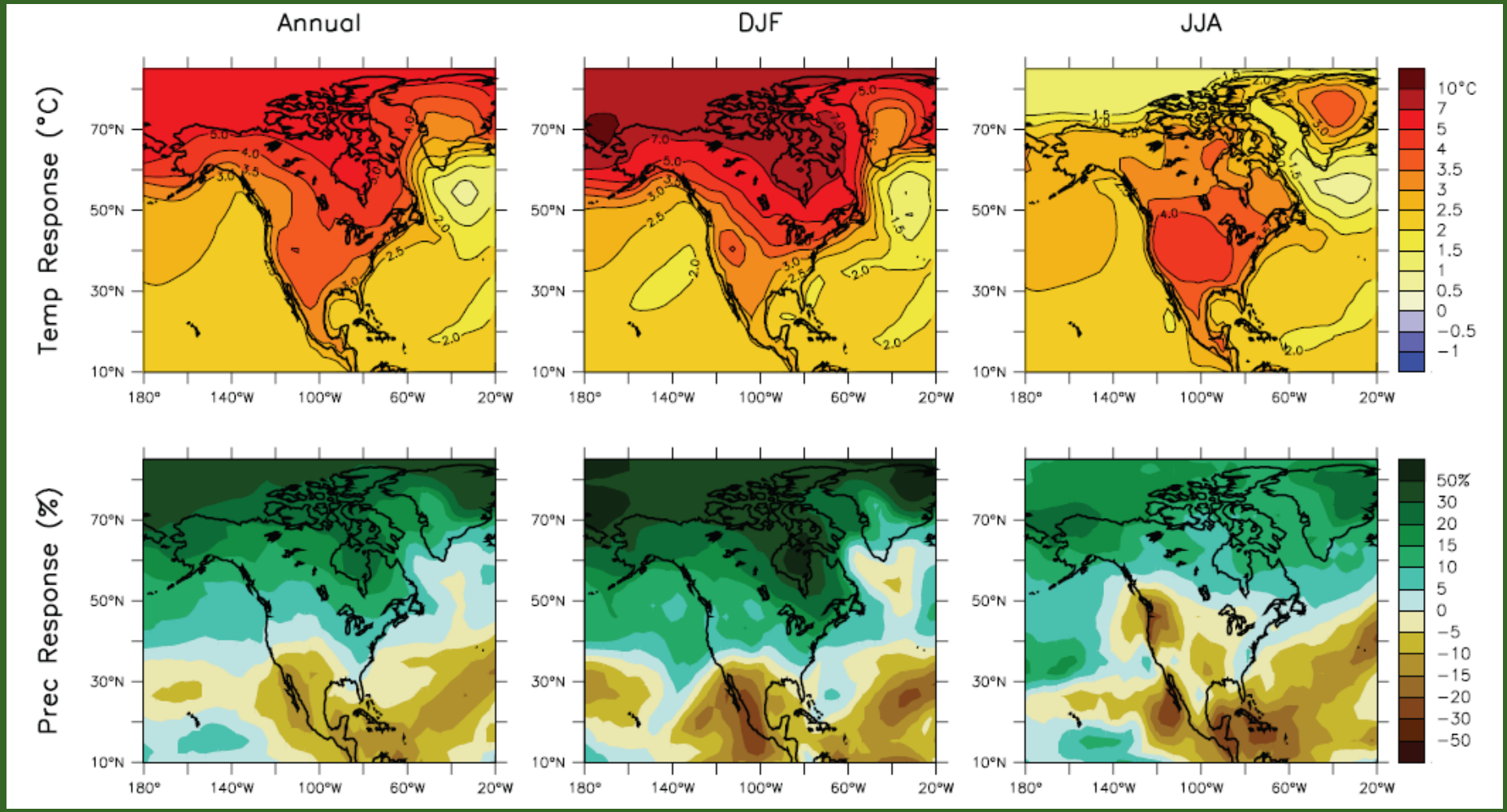
Aug, 13, 1941

Aug, 31, 2004

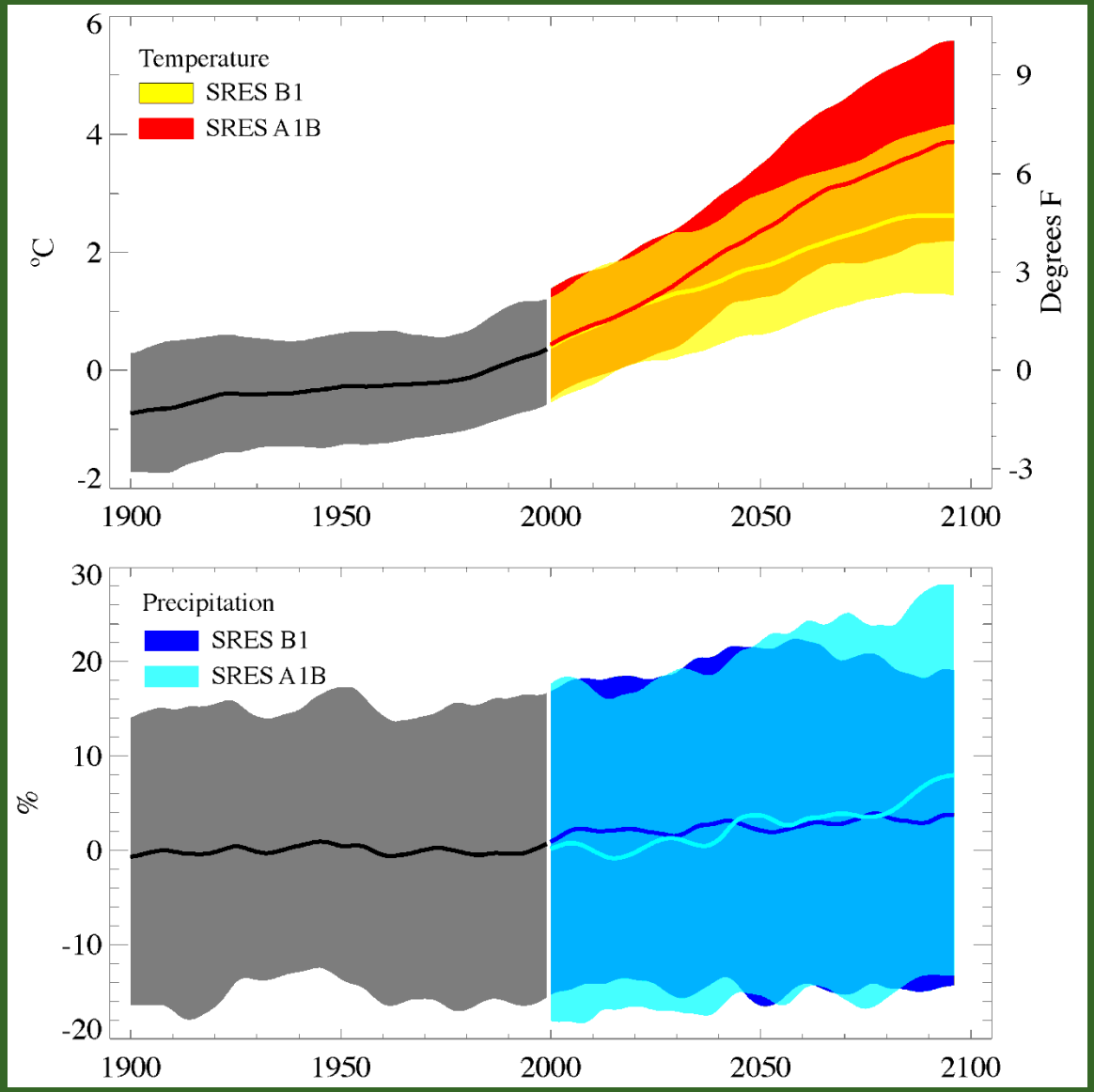
Image Credit: *National Snow and Ice Data Center, W. O. Field, B. F. Molnia*
http://nsidc.org/data/glacier_photo/special_high_res.html

Global Climate Change Scenarios for the PNW

Consensus Forecasts of Temperature and Precipitation Changes from IPCC AR4 GCMs

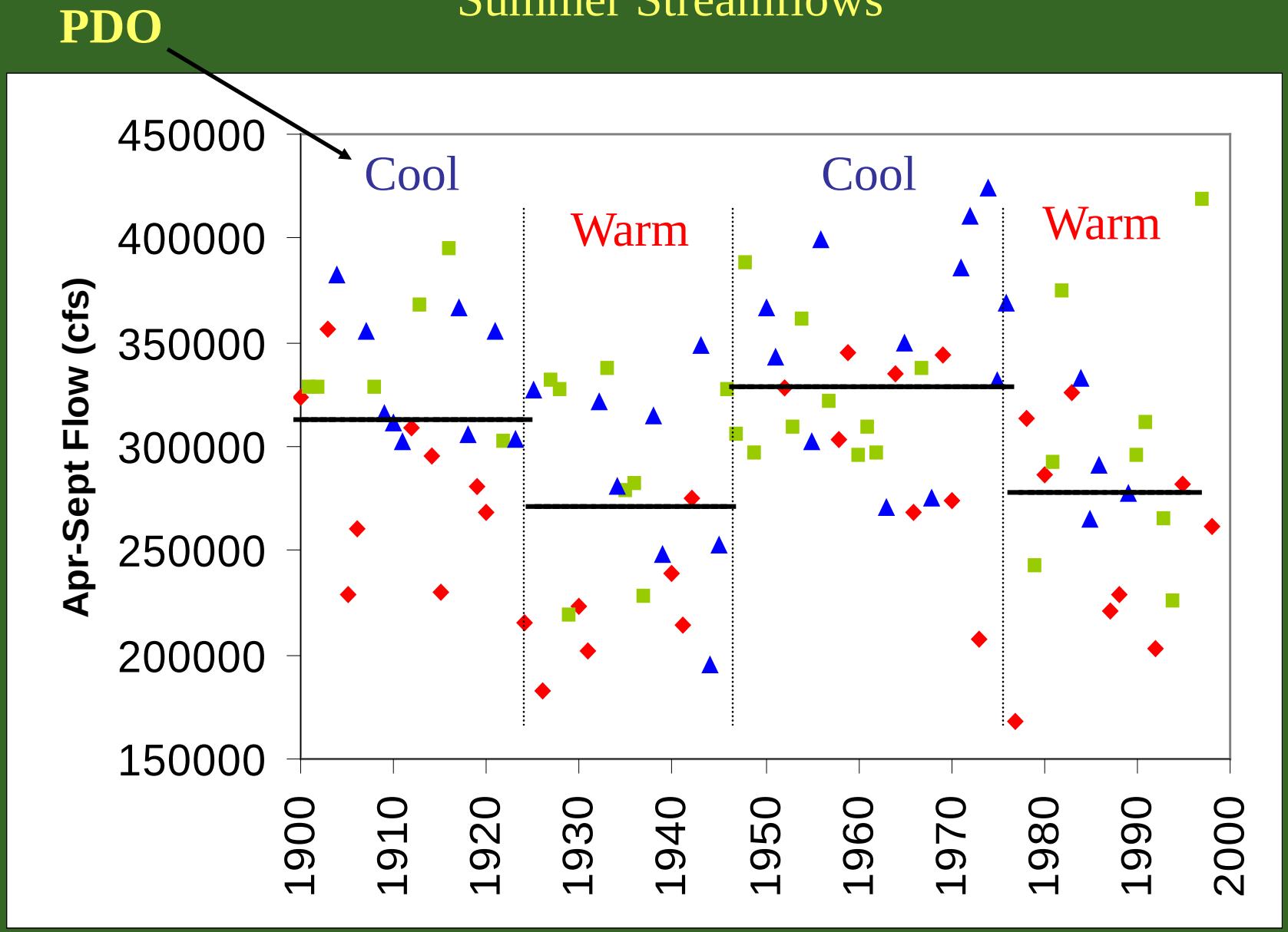


21st Century Climate Impacts for the Pacific Northwest Region



Mote, P.W. and E. P. Salathe Jr., 2009: Future climate in the Pacific Northwest (in review)

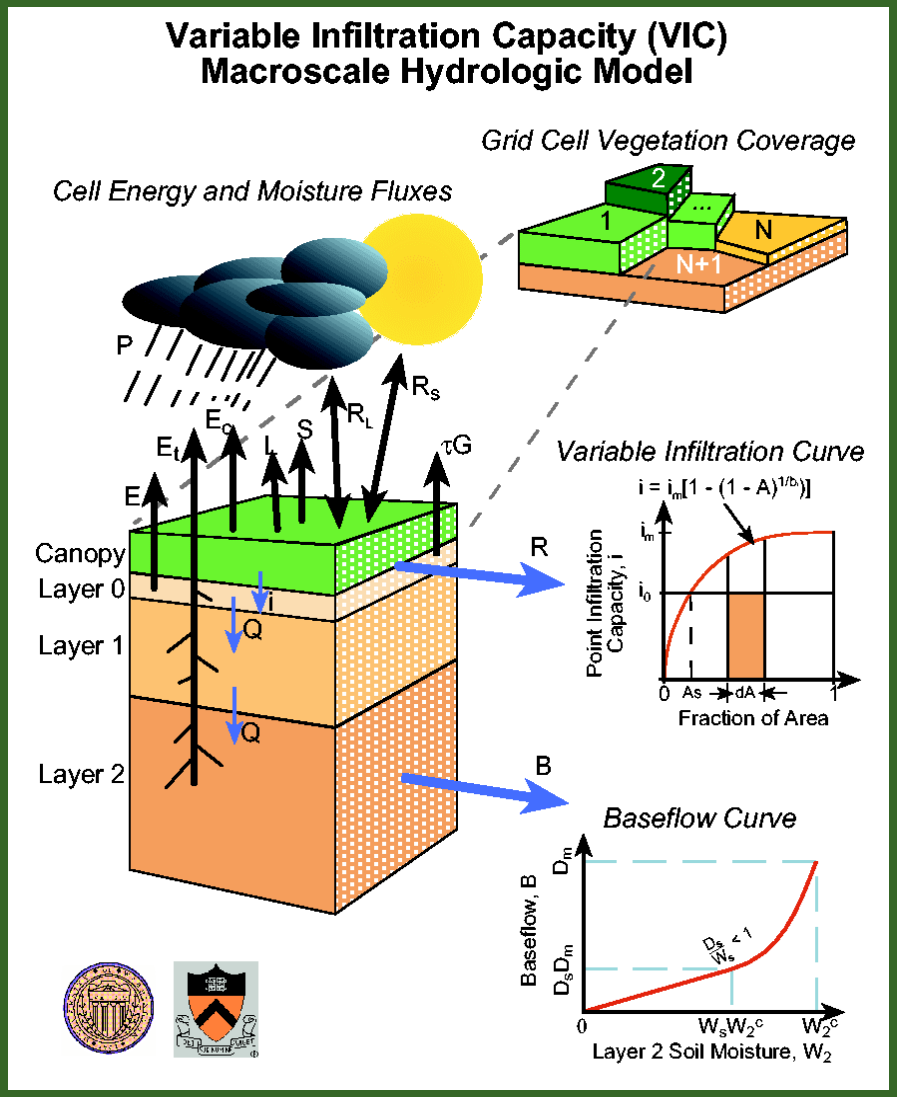
Effects of the PDO and ENSO on Columbia River Summer Streamflows

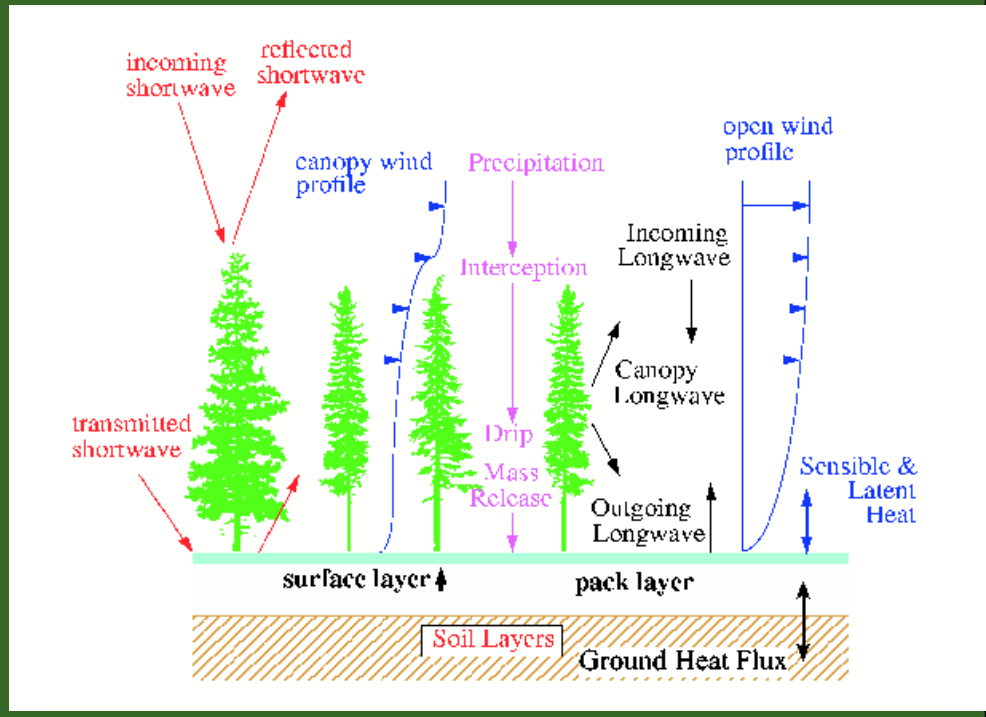


Red=warm ENSO Green=ENSO neutral Blue=cool ENSO

Snowpack

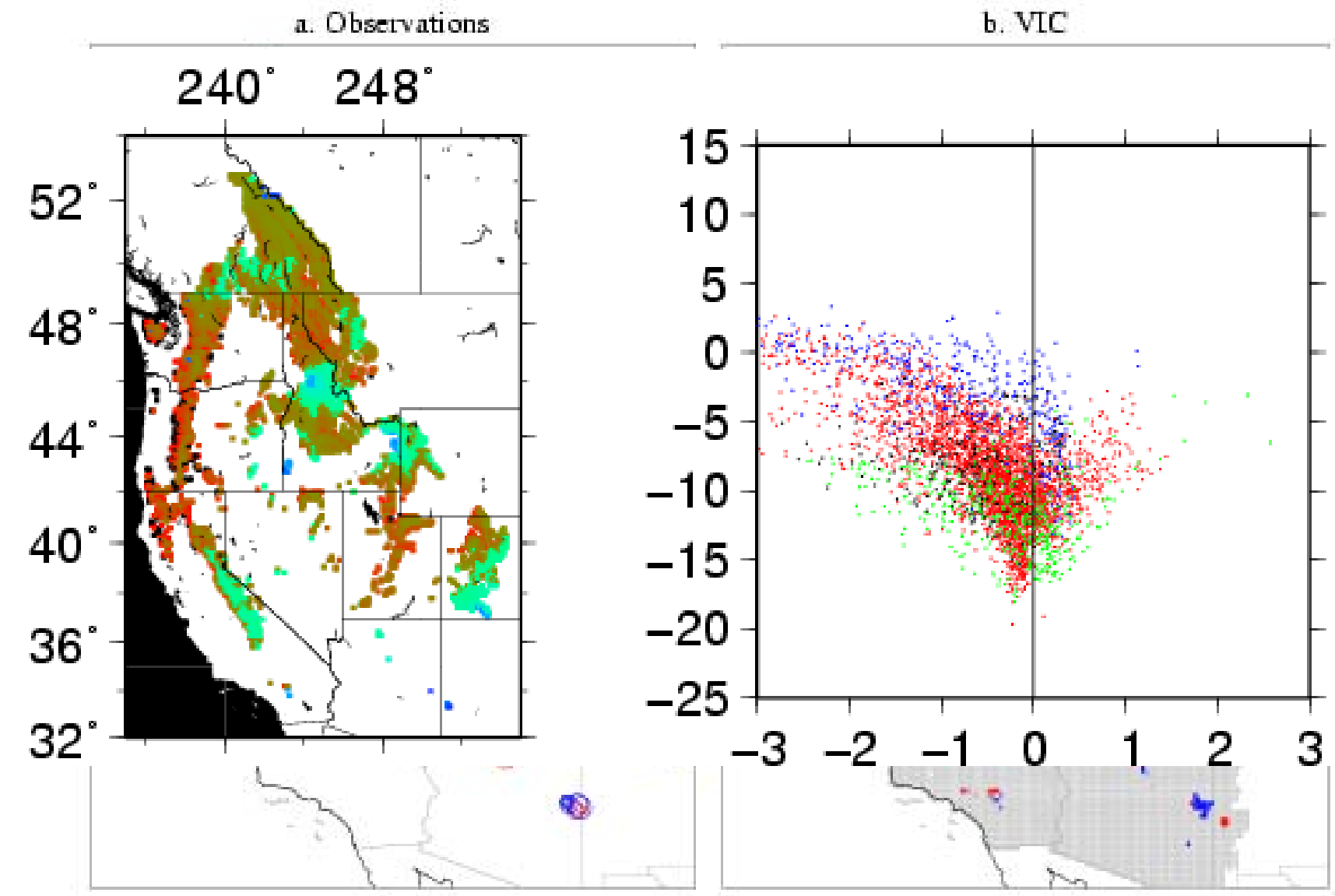
Schematic of VIC Hydrologic Model and Energy Balance Snow Model





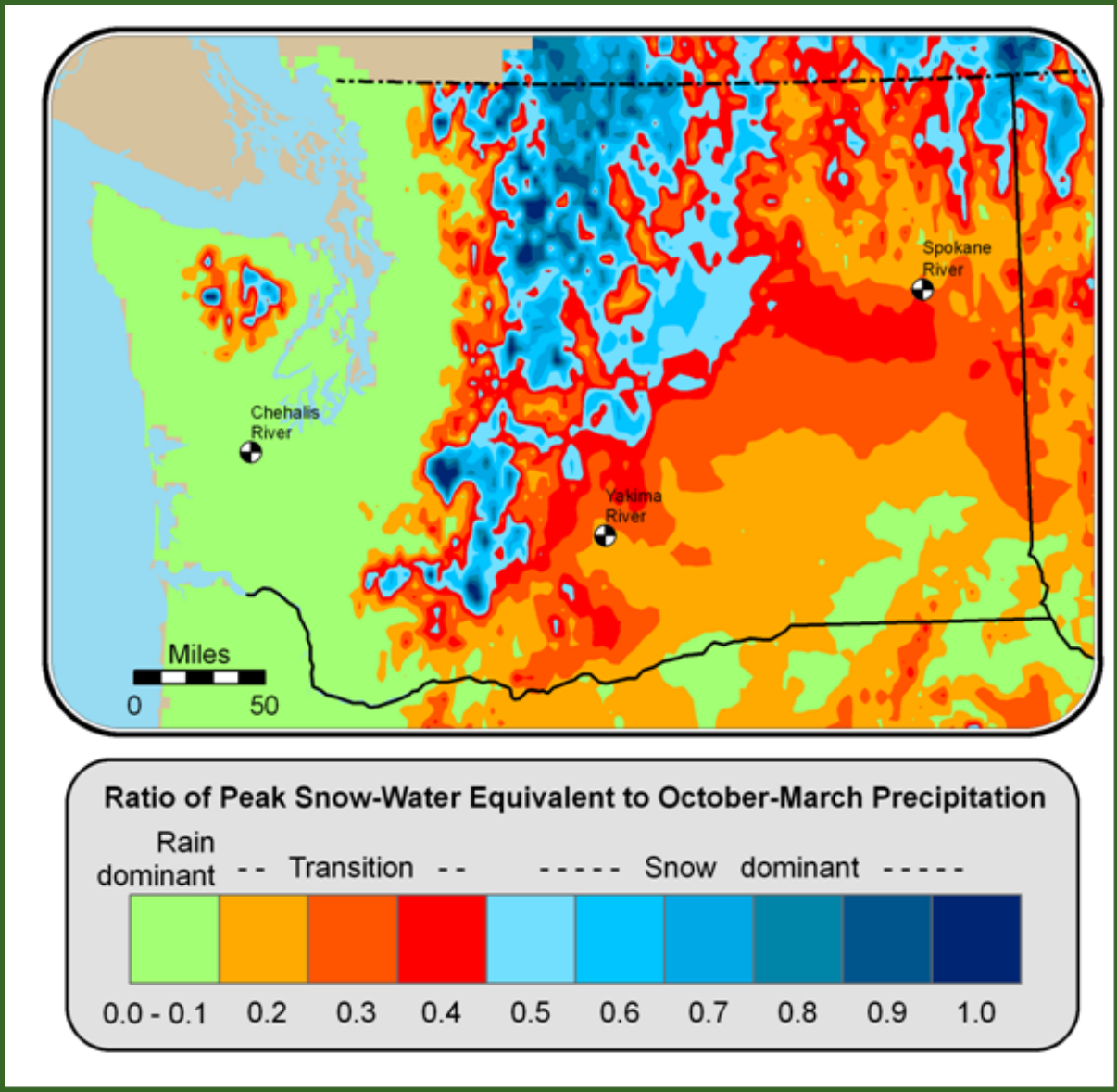
Snow Model

Trends in April 1 SWE 1950-1997



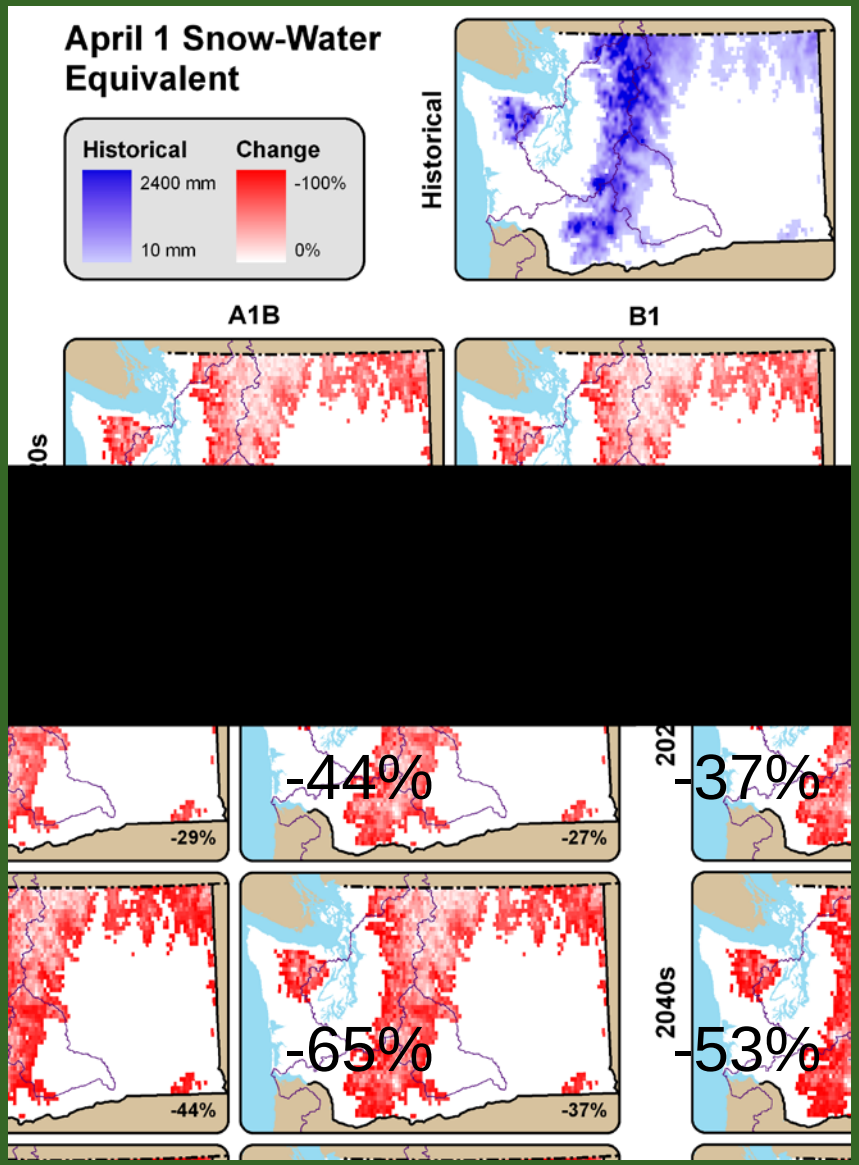
Mote P.W.,Hamlet A.F., Clark M.P., Lettenmaier D.P., 2005, Declining mountain snowpack in western North America, BAMS, 86 (1): 39-49

Plotting Areas of High Hydrologic Disturbance



Elsner et al., 2009: Implications of 21st Century climate change for the hydrology of Washington State (in review)

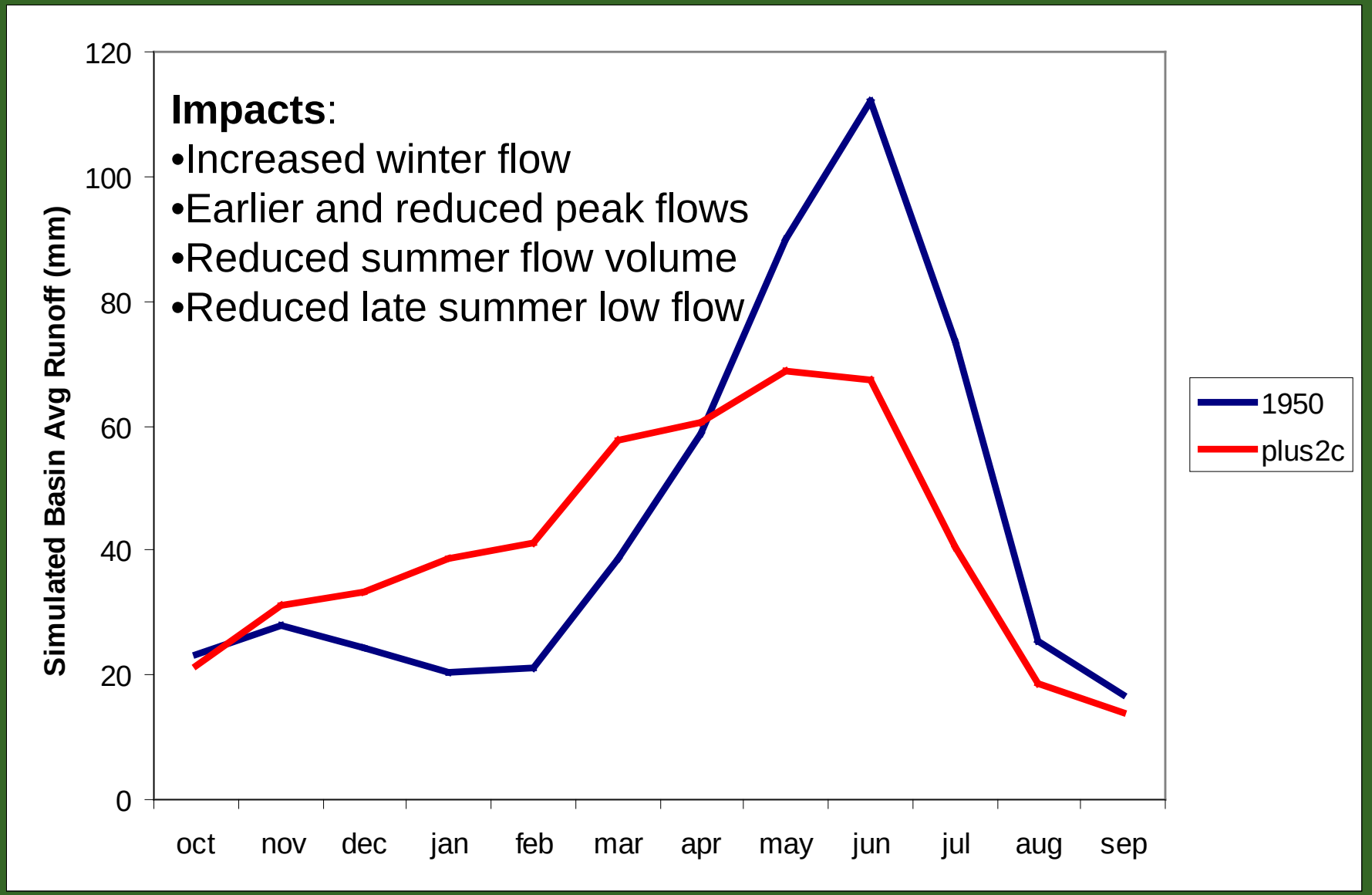
Change in Long-Term Mean April 1 SWE in WA



Elsner et al., 2009: Implications of 21st Century climate change for the hydrology of Washington State (in review)

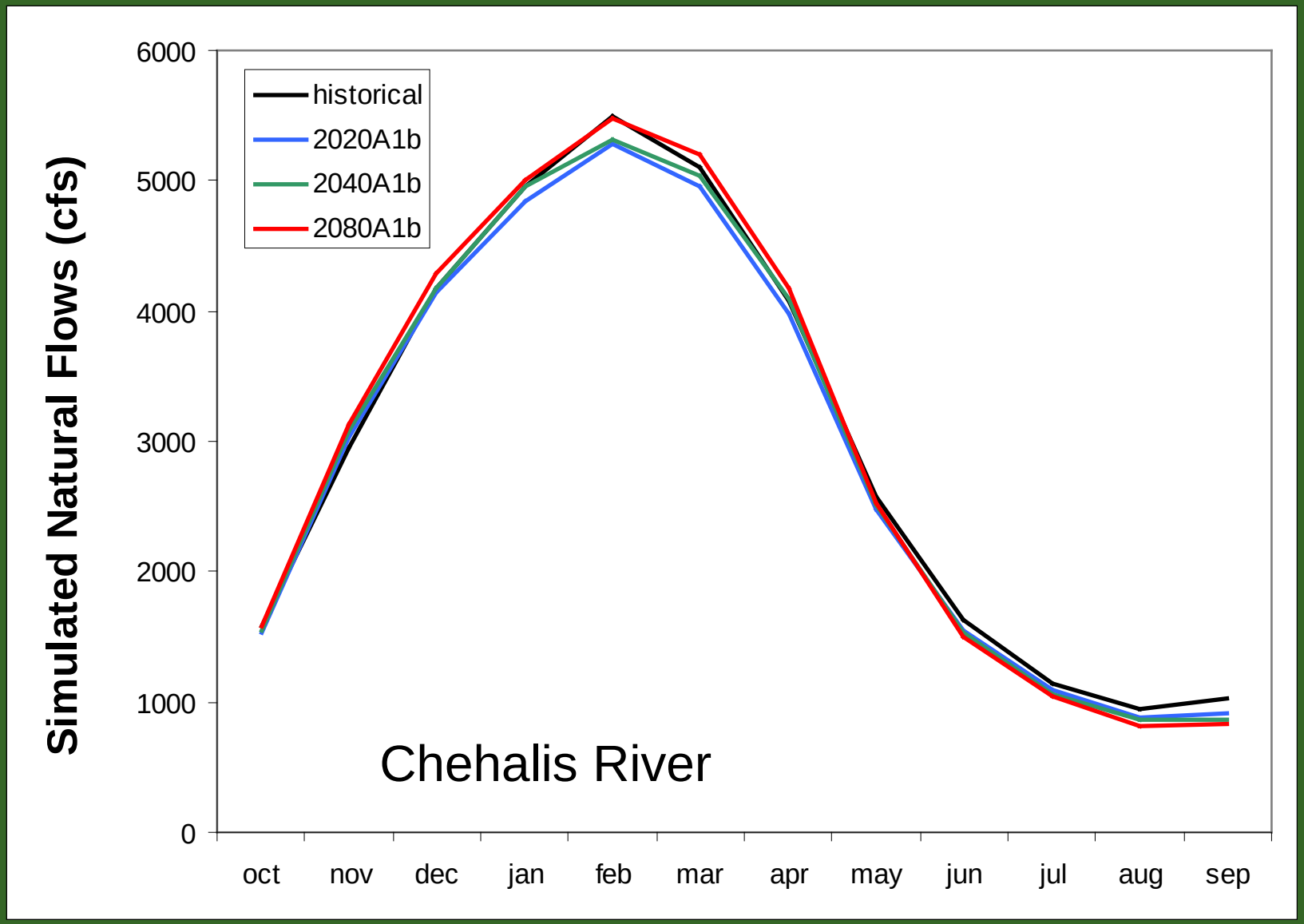
Changes in Seasonal Streamflow Timing

Simulated Changes in Natural Runoff Timing in the Naches River Basin Associated with 2 C Warming

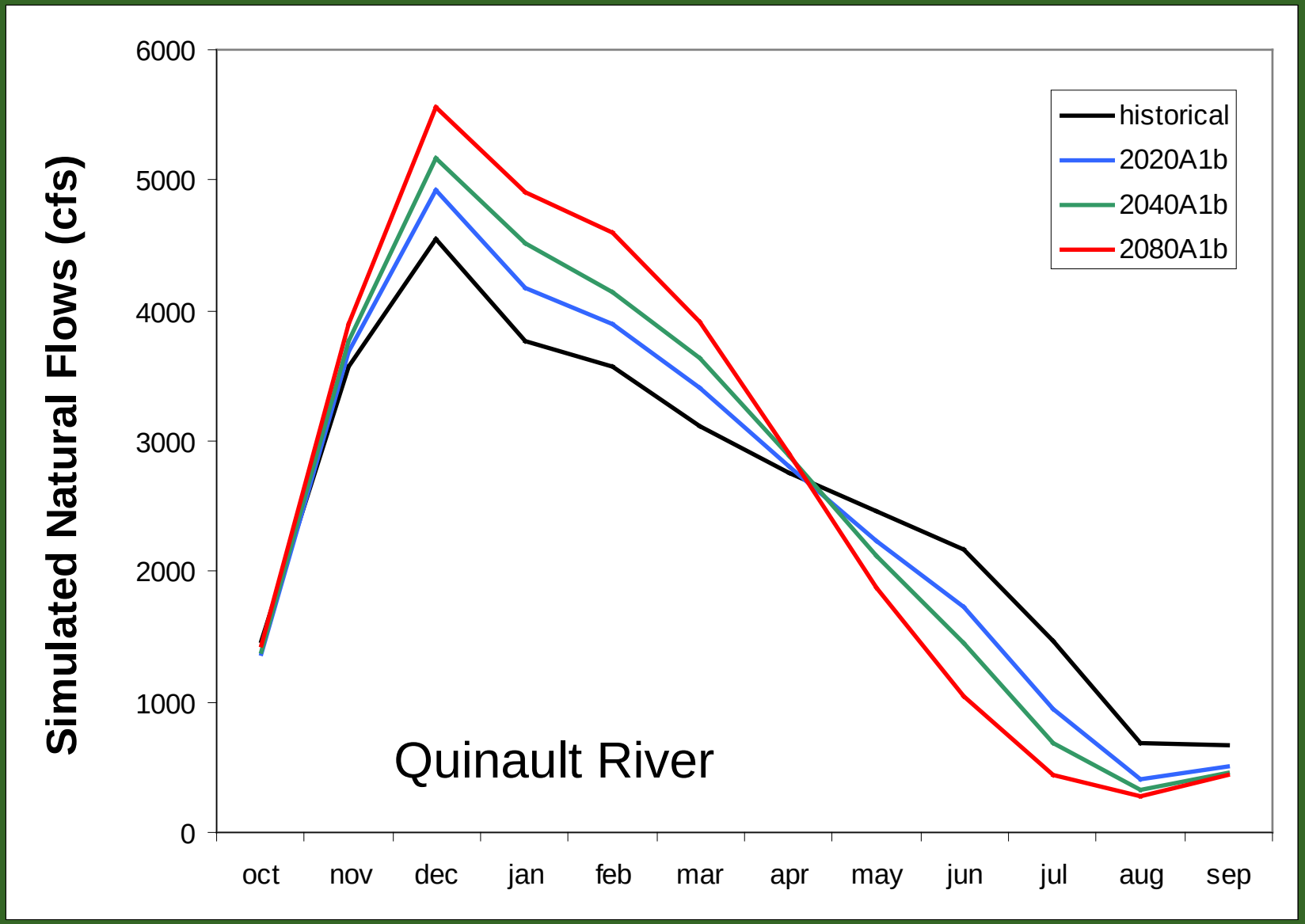


Projected Streamflow Timing Shifts in Washington

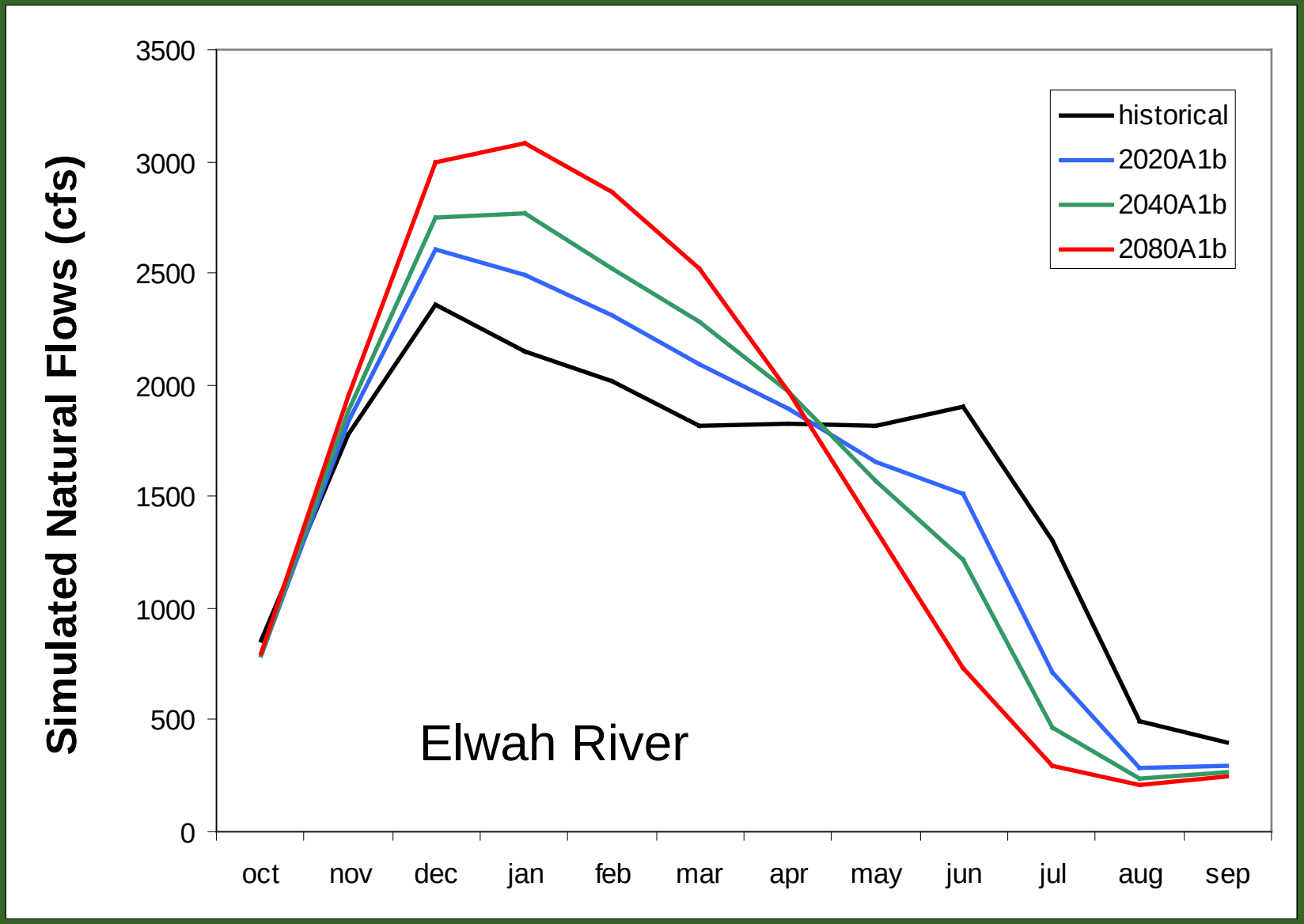
Historical and Projected 21st Century Flows for the A1b Scenario



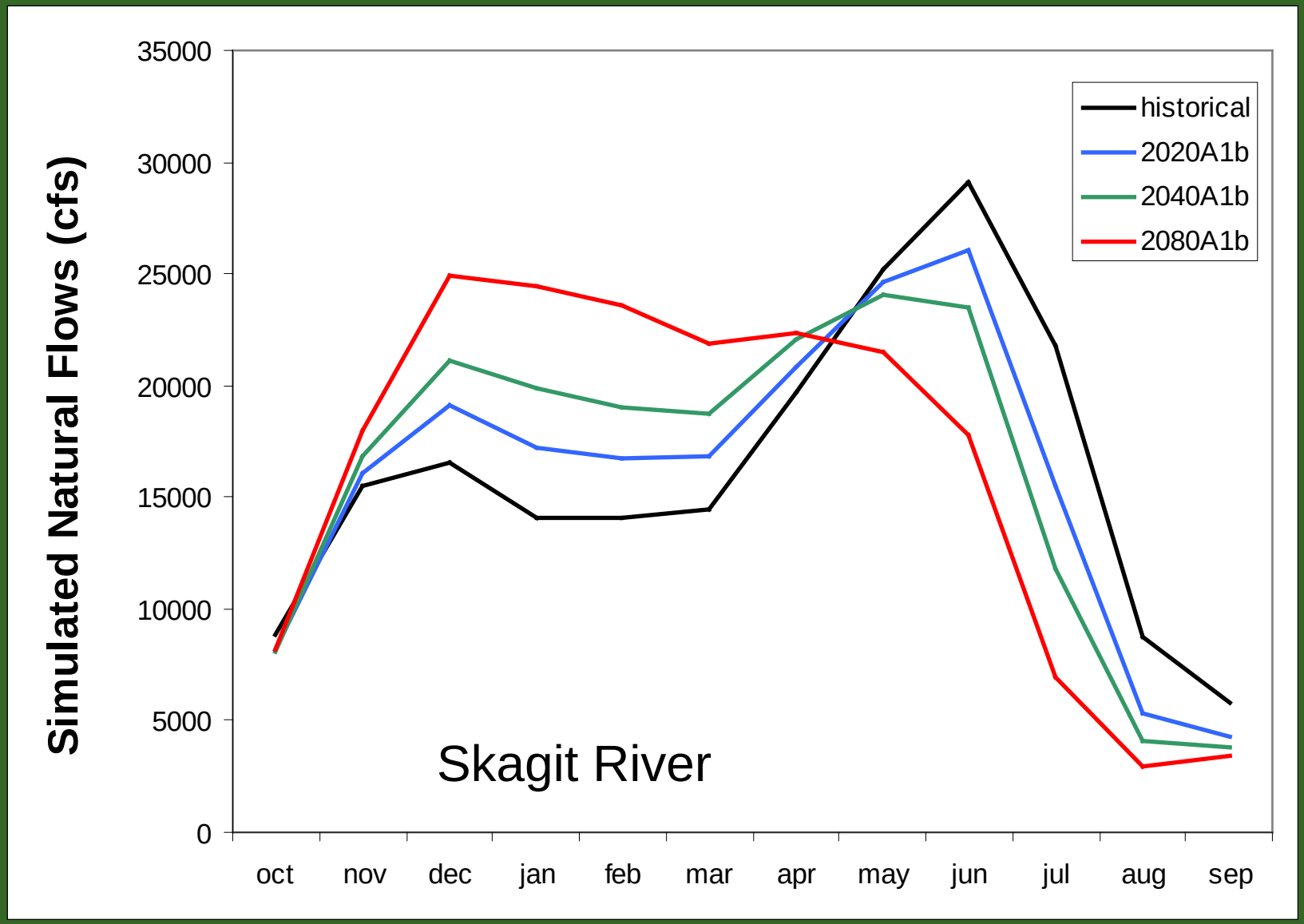
Historical and Projected 21st Century Flows for the A1b Scenario



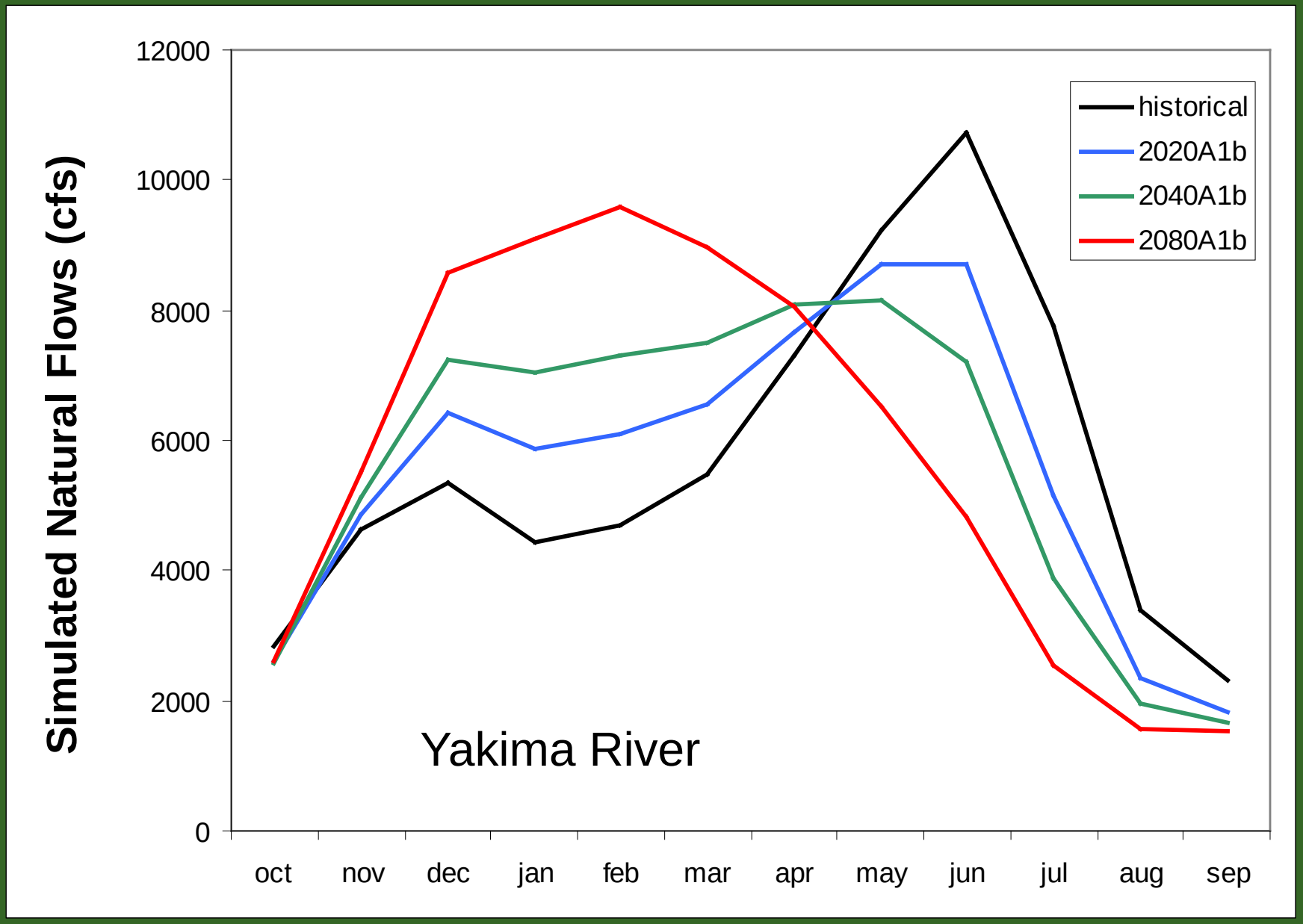
Historical and Projected 21st Century Flows for the A1b Scenario



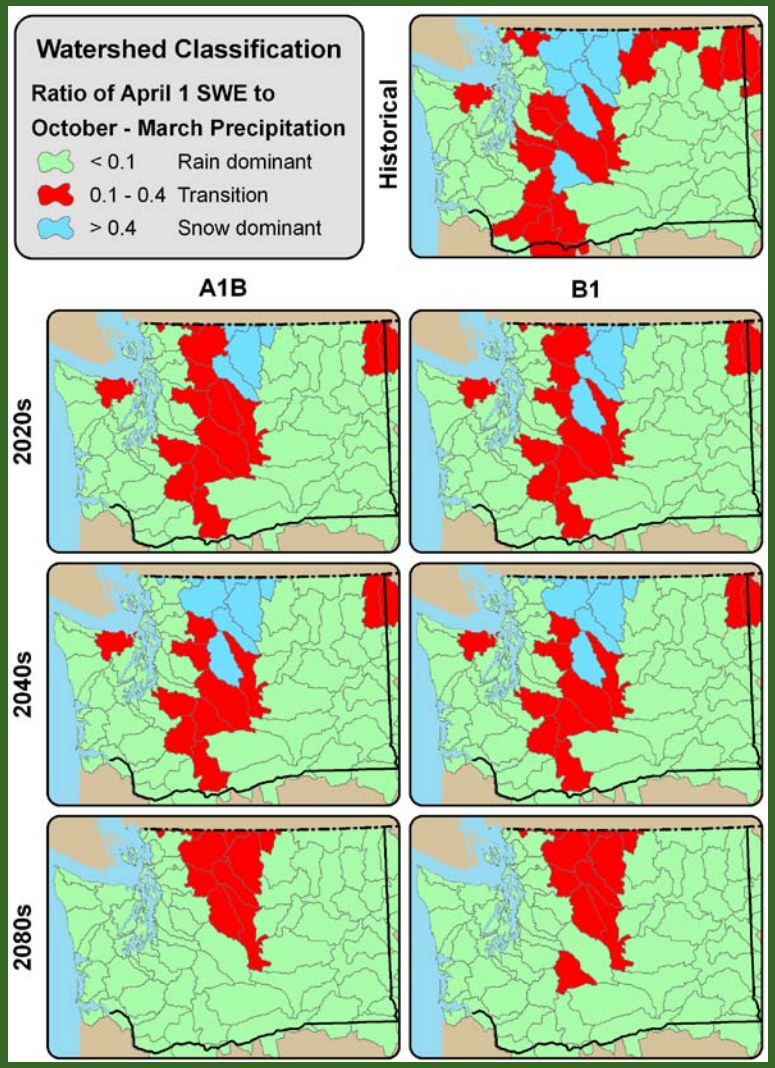
Historical and Projected 21st Century Flows for the A1b Scenario



Historical and Projected 21st Century Flows for the A1b Scenario



Climate Change Will Result in Widespread Transformation of Snowmelt and Transient Watersheds to Rain Dominant Watersheds



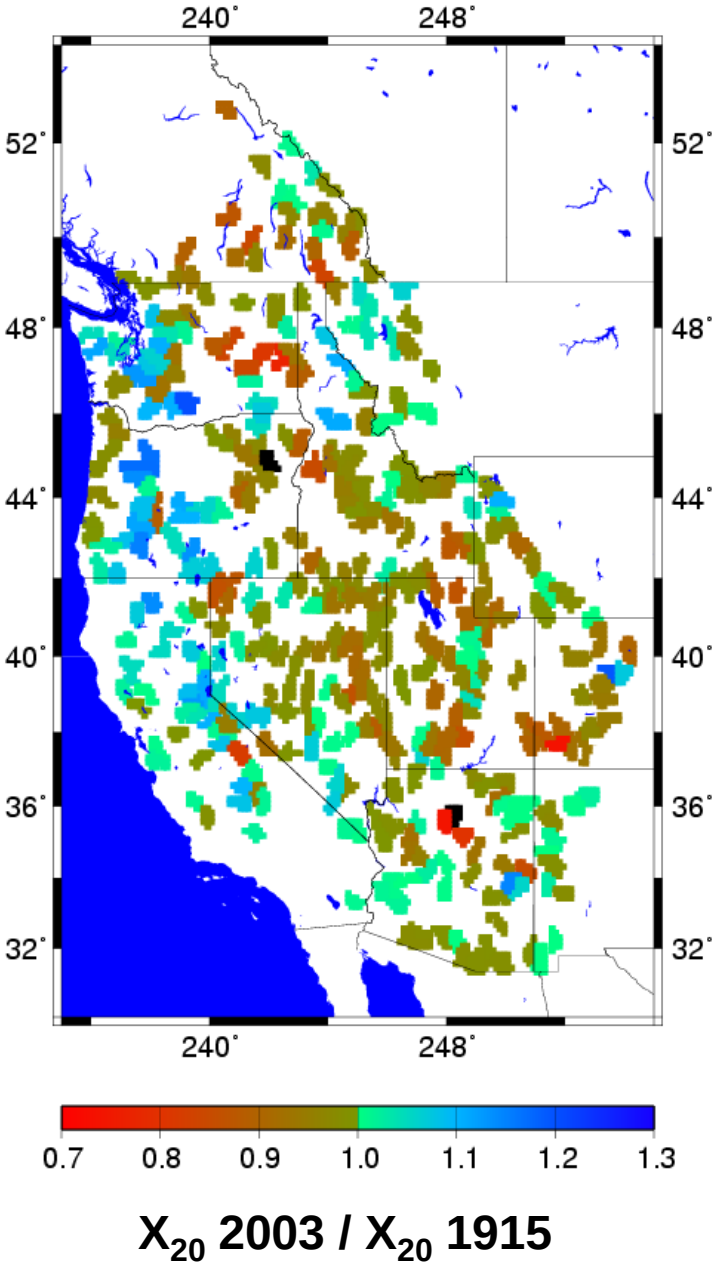
Mantua, N., I. Tohver, A.F. Hamlet, 2009: Impacts of climate change on key aspects of freshwater salmon habitat in Washington State, (in review)

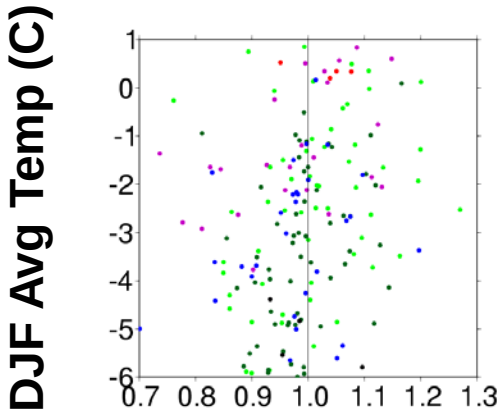
Changes in Hydrologic Extremes

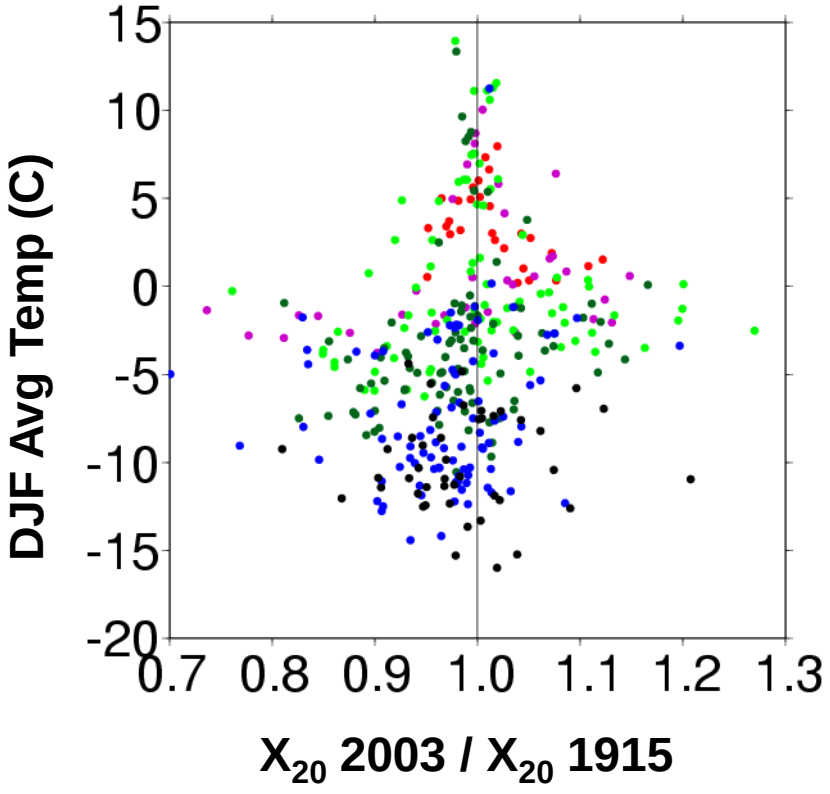
seattlepi.com

FLOODING IN WESTERN WASHINGTON (1/8/09)

Simulated Changes in the 20-year Flood Associated with 20th Century Warming







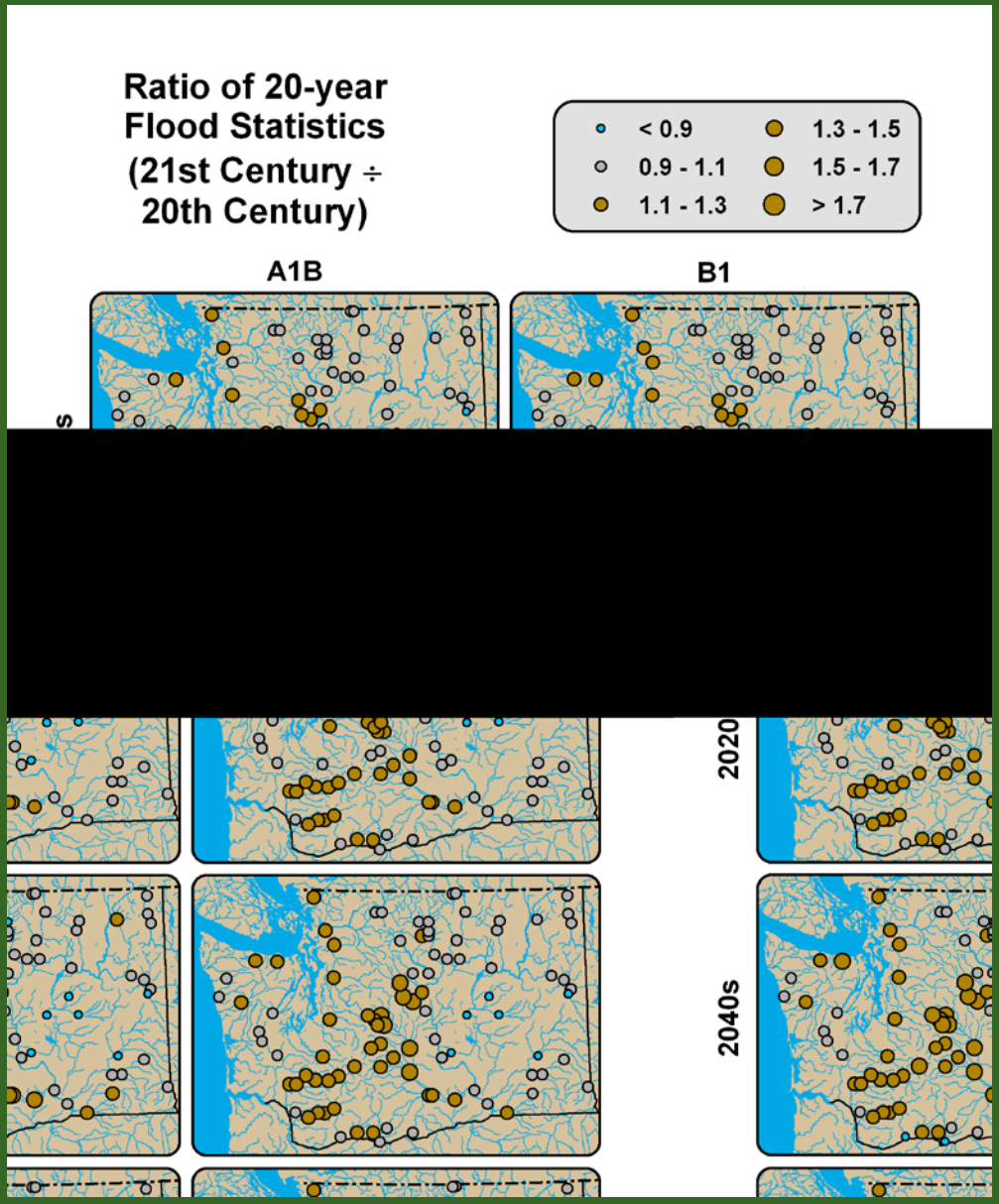
Summary of Flooding Impacts

Rain Dominant Basins:
Possible increases in flooding due to increased precipitation intensity, but no significant change from warming alone.

Mixed Rain and Snow Basins Along the Coast:
Strong increases due to warming and increased precipitation intensity (both effects increase flood risk)

Inland Snowmelt Dominant Basins:
Relatively small overall changes because effects of warming (decreased risks) and increased precipitation intensity (increased risks) are in the opposite directions.

Future Projections of Flood Risk in Washington

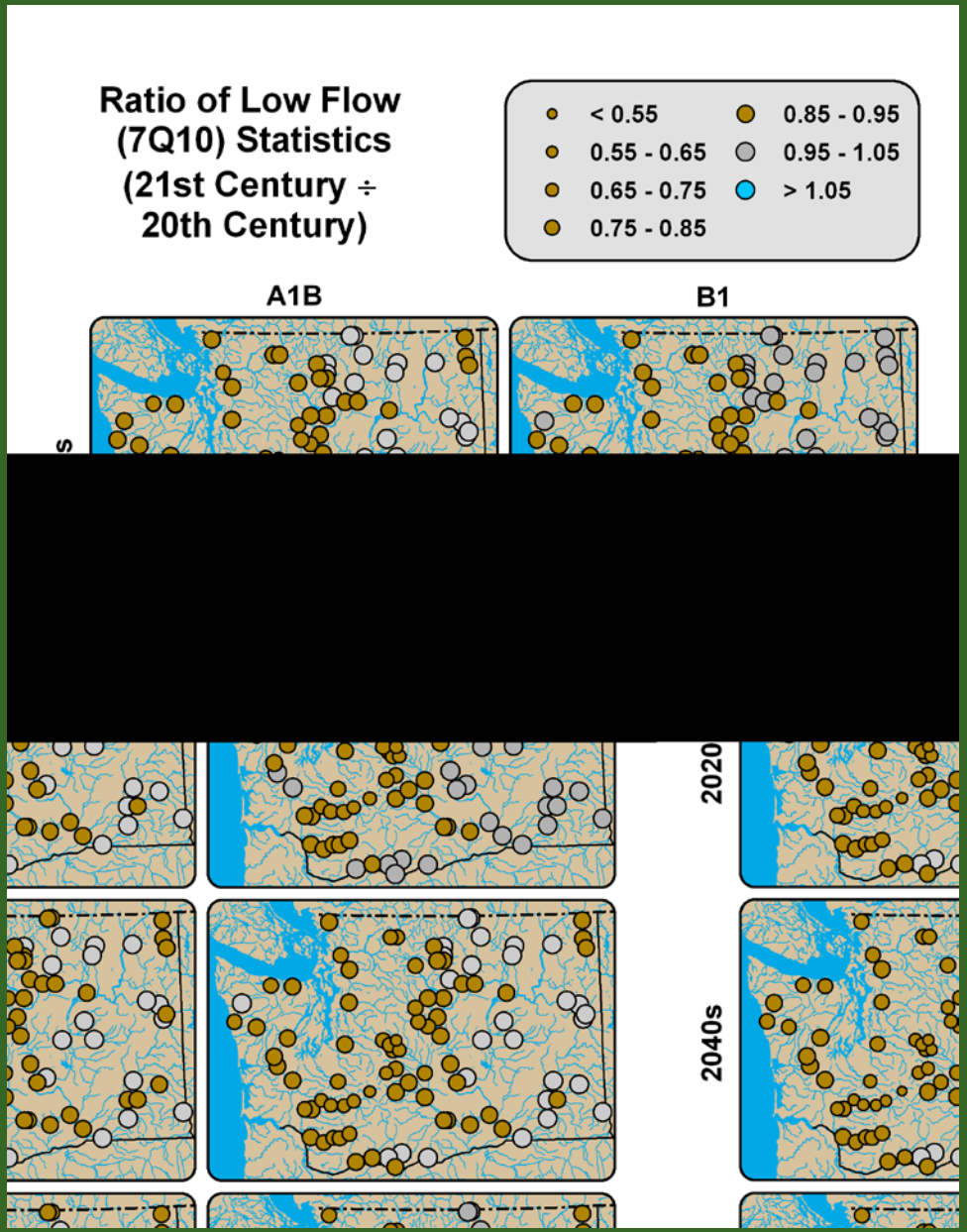


- Floods in western WA are expected to increase in magnitude due to the combined effects of warming and increasingly intense winter storms.

- In other parts of the State, changes in flooding are smaller, and in eastern WA projected *reductions* in flood risk are common due to loss of spring snow cover.

Mantua, N., I. Tohver, A.F. Hamlet, 2009: Impacts of climate change on key aspects of freshwater salmon habitat in Washington State, (in review)

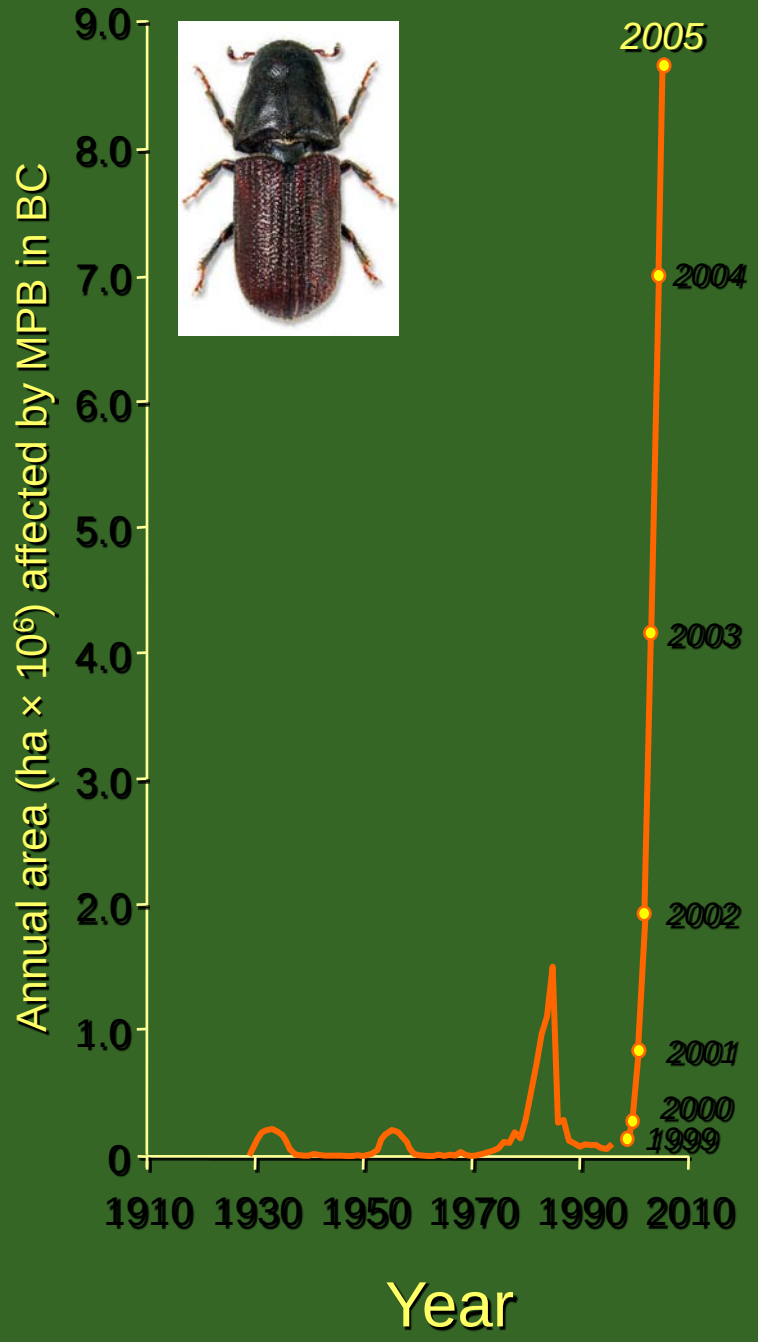
Changes in Low Flow Risks



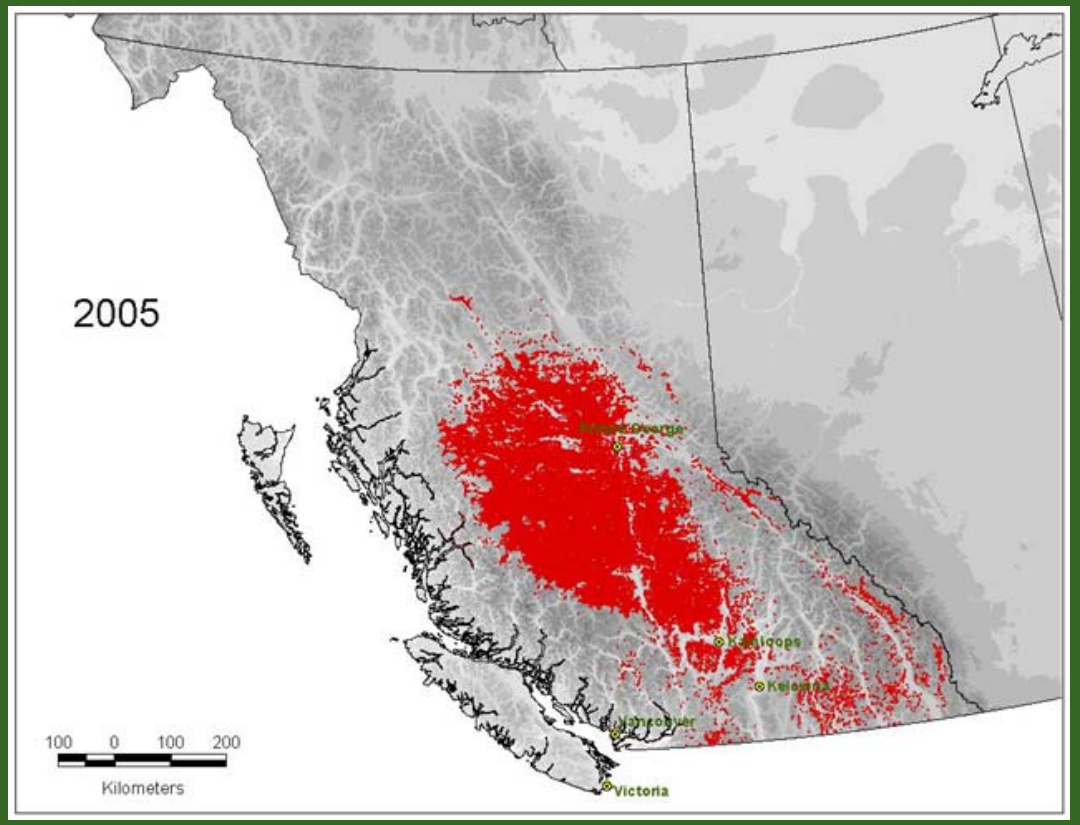
7Q10 values are projected to systematically decline in western WA due to loss of snowpack and projected dryer summers

Mantua, N., I. Tohver, A.F. Hamlet, 2009: Impacts of climate change on key aspects of freshwater salmon habitat in Washington State, (in review)

Landscape Scale Disturbance



Bark Beetle Outbreak in British Columbia



(Figure courtesy Allen Carroll)

Wide-Spread Glacial Retreat has Accompanied 20th Century Warming.

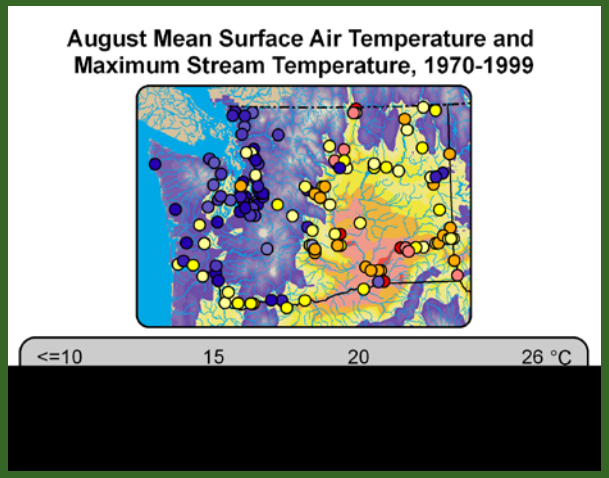
1902

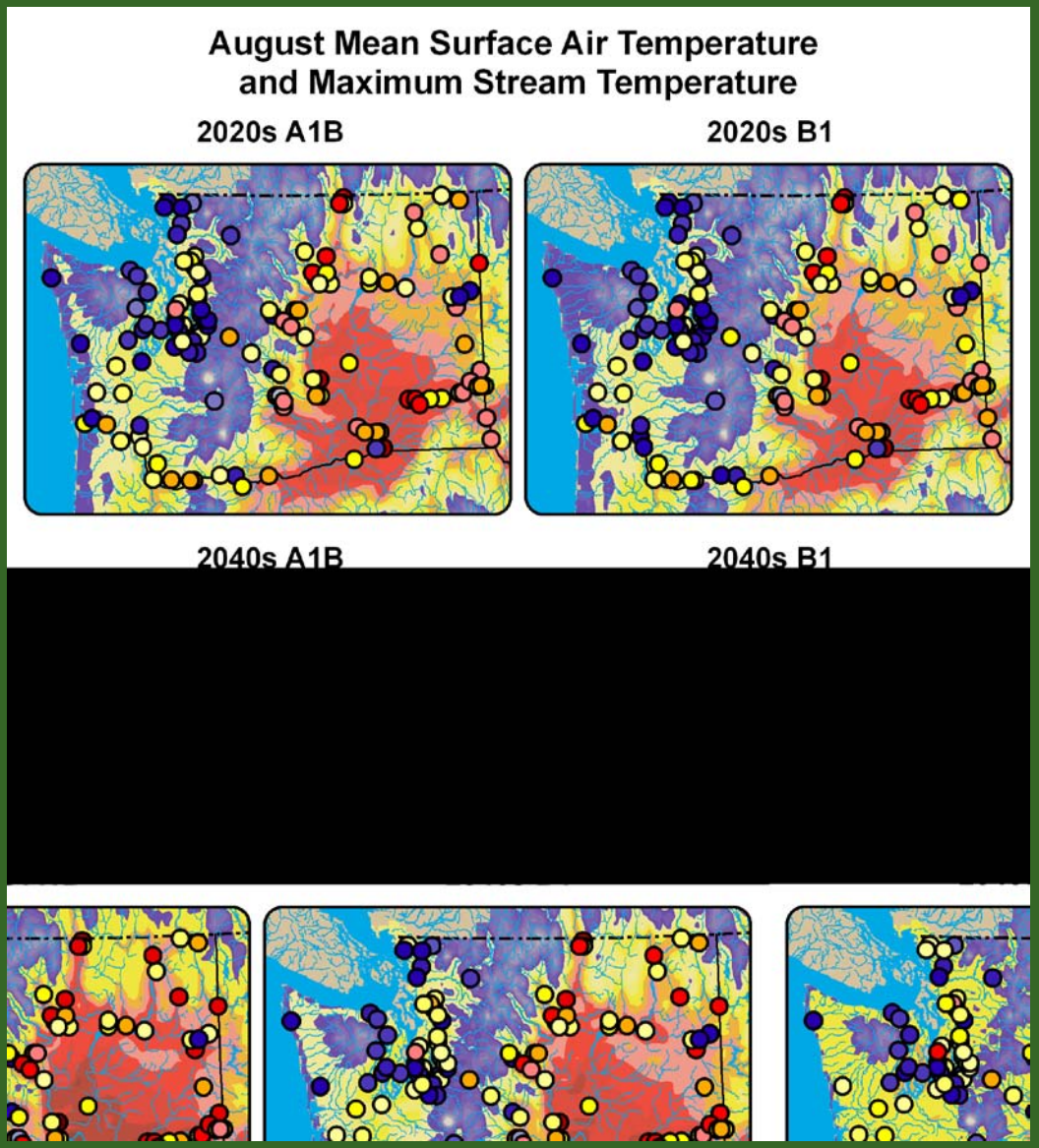
2002

The recession of the Illecillewaet Glacier at Rogers Pass between 1902 and 2002.
Photographs courtesy of the Whyte Museum of the Canadian Rockies & Dr. Henry Vaux.


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

Warming Air Temperatures will Increase Water Temperature





Mantua, N., I. Tohver, A.F. Hamlet, 2009: Impacts of climate change on key aspects of freshwater salmon habitat in Washington State, (in review)

Sediment Transport

Sediment Impact Pathways:

Increasing precipitation intensity may increase the severity of extreme events (e.g. mud slides, inundation of public access areas, etc.)

Loss of glaciers may mobilize large “reservoirs” of fine sediments stored beneath them.

Loss of snowpack may reduce the “armoring” effect of the snowpack in moderate elevation areas, leading to increased land slide risk and increased sediment loadings. (conversion of moderate elevation areas from avalanche risk to land slide risk).

Changes in forest disturbance patterns, particularly fire, may be important driver of impacts.

Adaptation

Approaches to Adaptation and Planning

- **Anticipate changes.** Accept that the future climate will be substantially different than the past.

- **Use scenario based planning** to evaluate options rather than the historic record.

- **Expect surprises** and plan for flexibility and robustness in the face of uncertain changes rather than counting on one approach.

- **Plan for the long haul**. Where possible, make adaptive responses and agreements “self tending” to avoid repetitive costs of intervention as impacts increase over time.