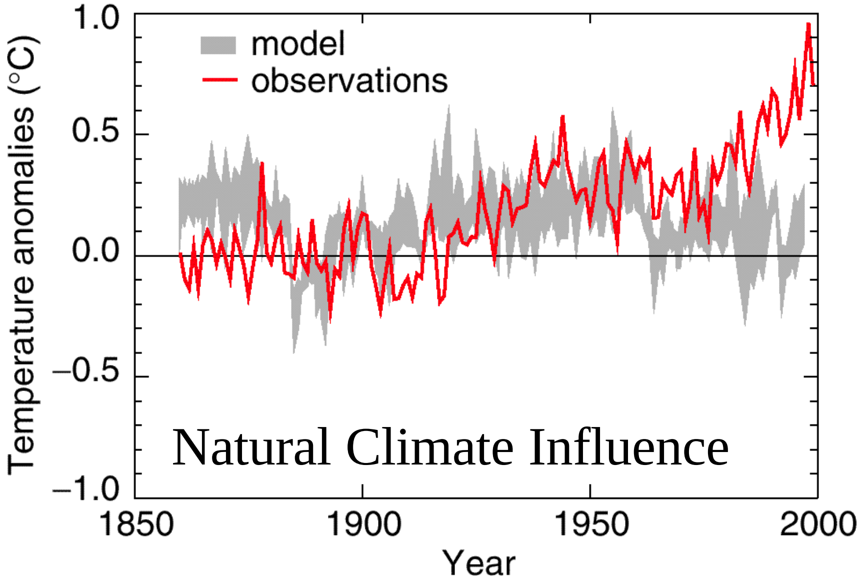
Effects of Climate Change on the Columbia River Basin's Water Resources

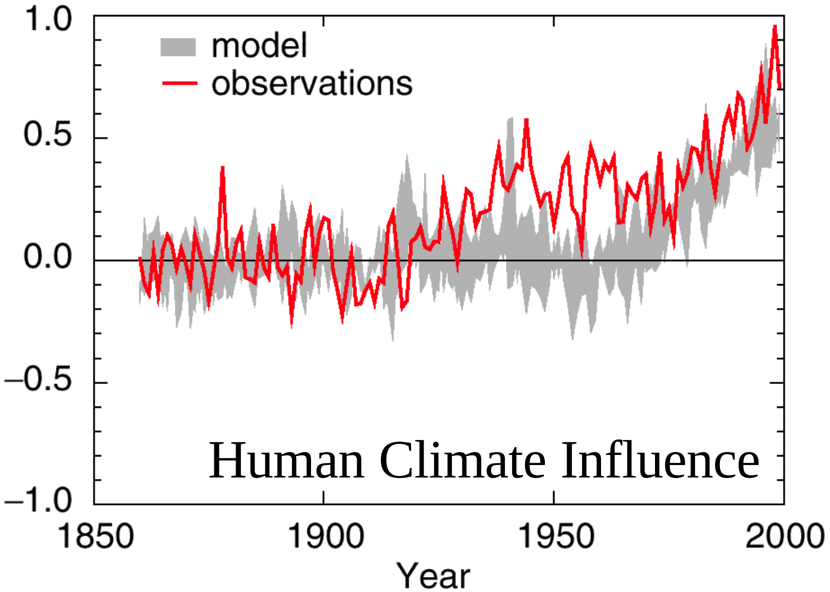
JISAO Center for Science in the Earth System
Climate Impacts Group
and Department of Civil and Environmental Engineering
University of Washington

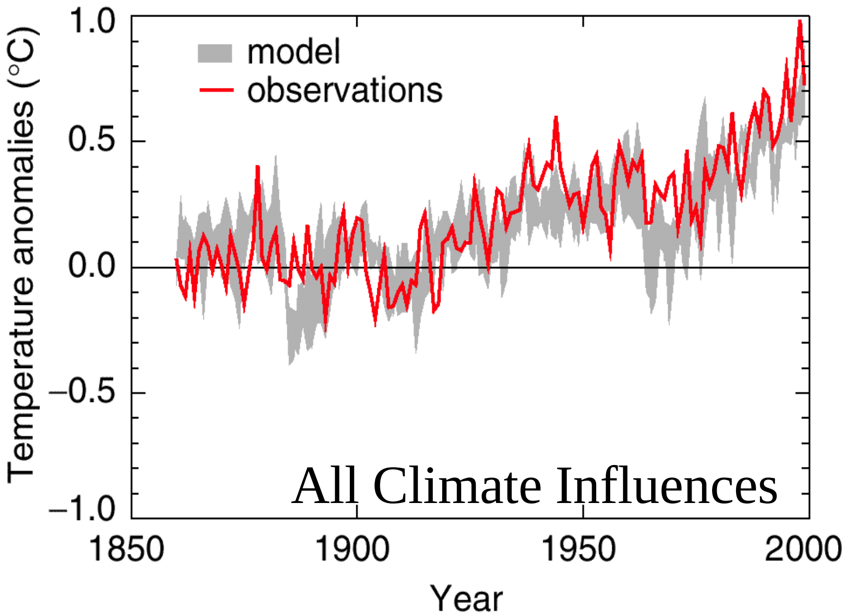
Nov, 2005

Alan F. Hamlet
Philip W. Mote
Nathan Mantua
Dennis P. Lettenmaier

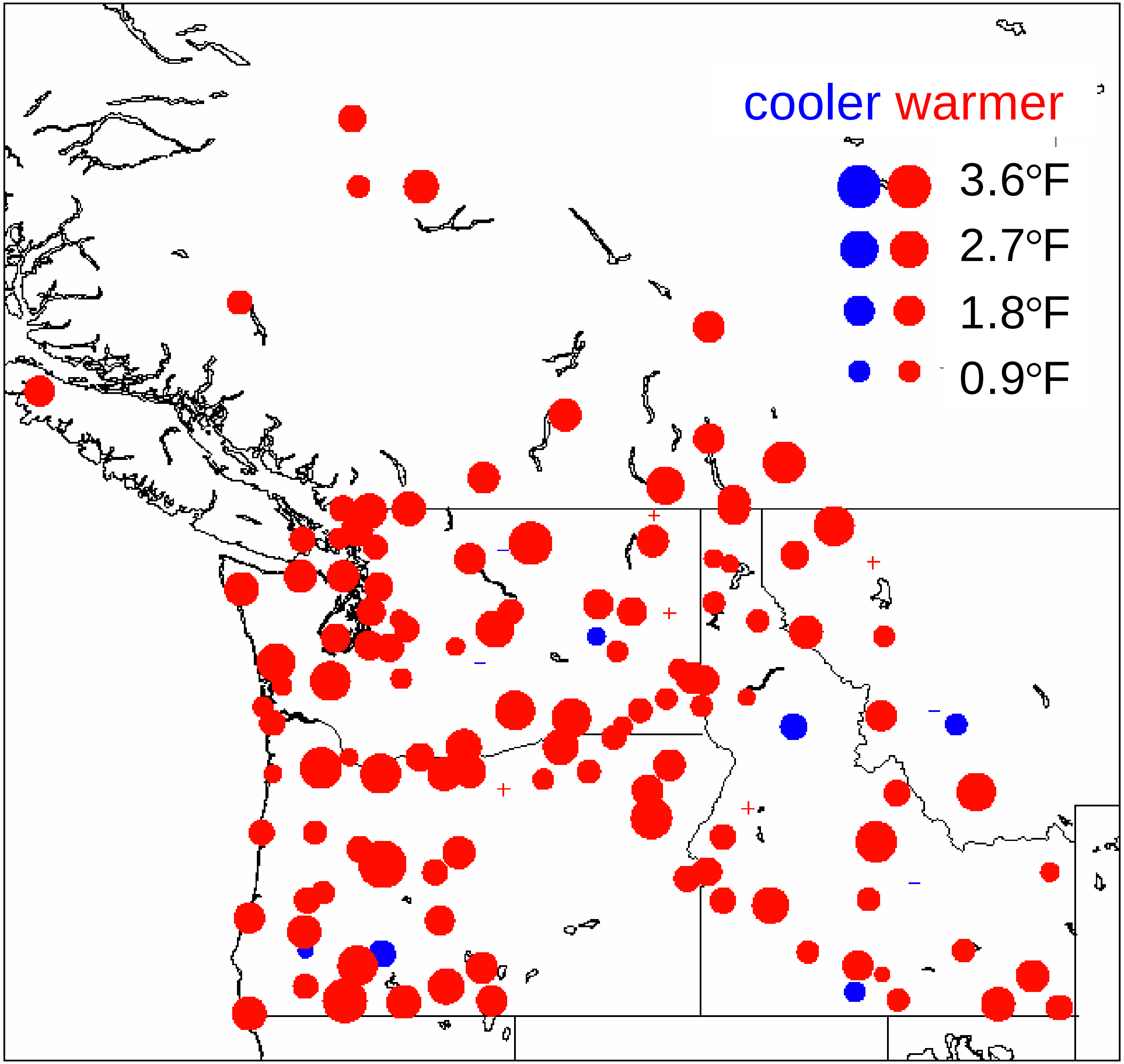
Natural AND human influences explain the observations of global warming best.



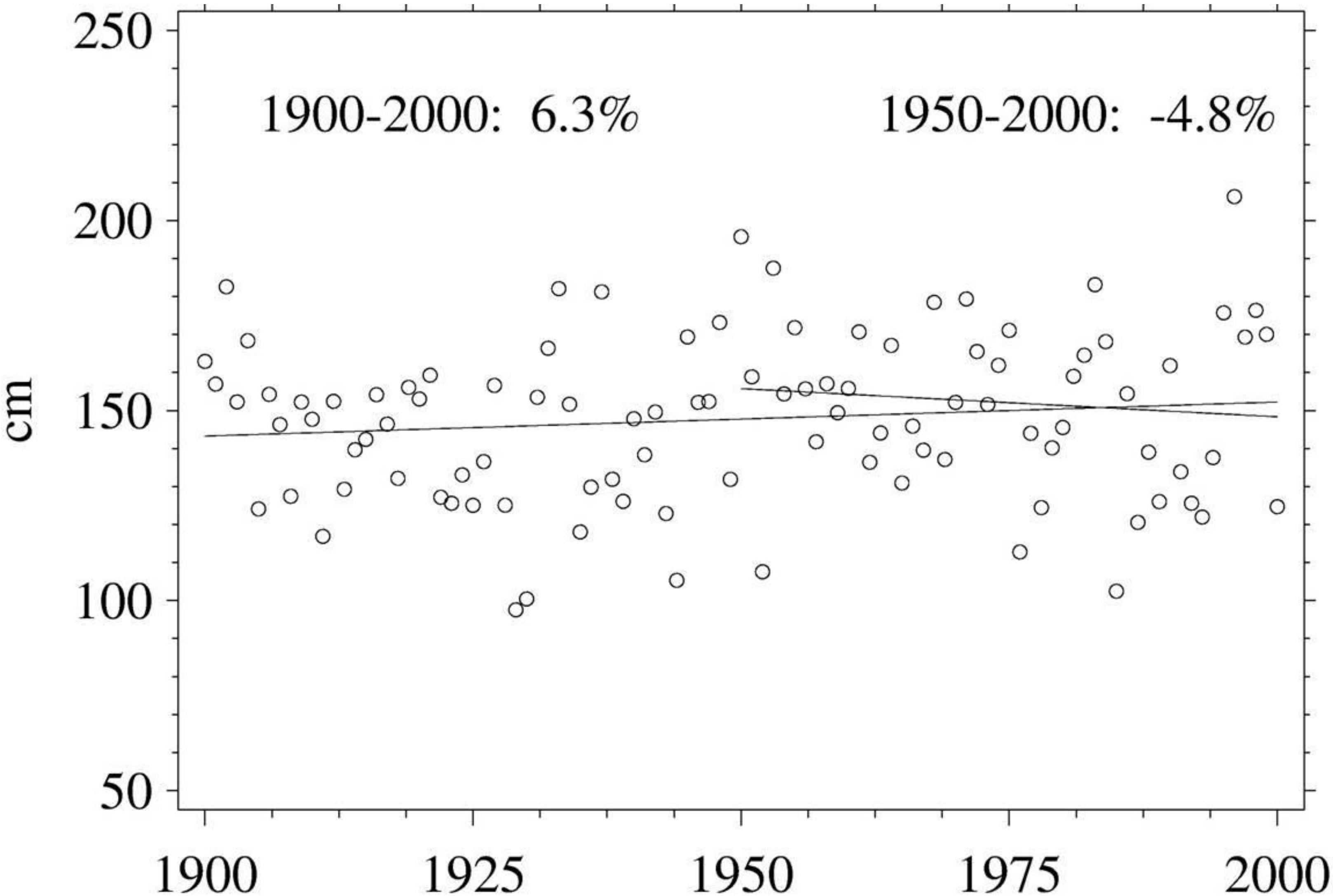




Temperature trends (°F per century) since 1920

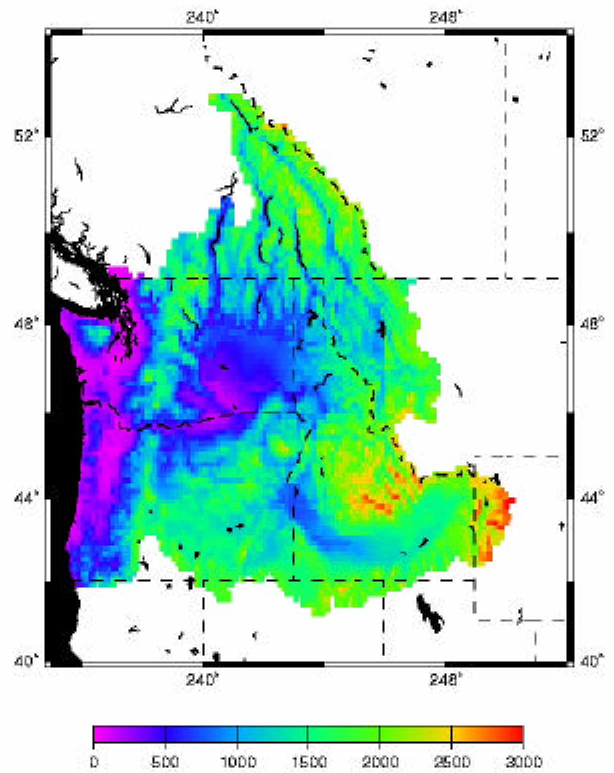


Annual Precipitation
(Western WA, OR, BC)



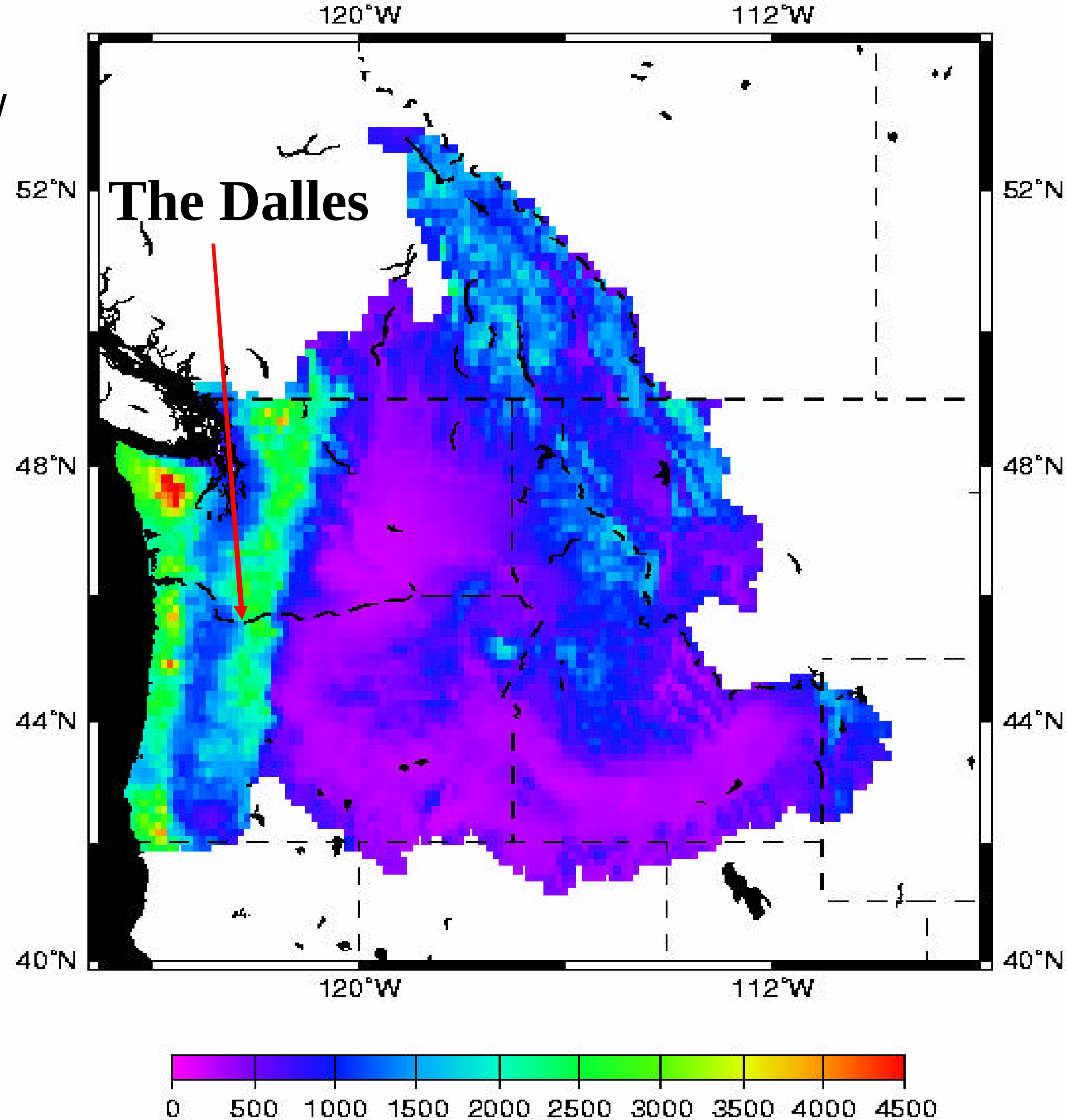
Hydroclimatology of the Pacific Northwest

Columbia River Basin
Useable Storage ~35 MAF
~50% of storage is in Canada
~Storage is 30% of annual flow
Snowpack functions as a natural reservoir



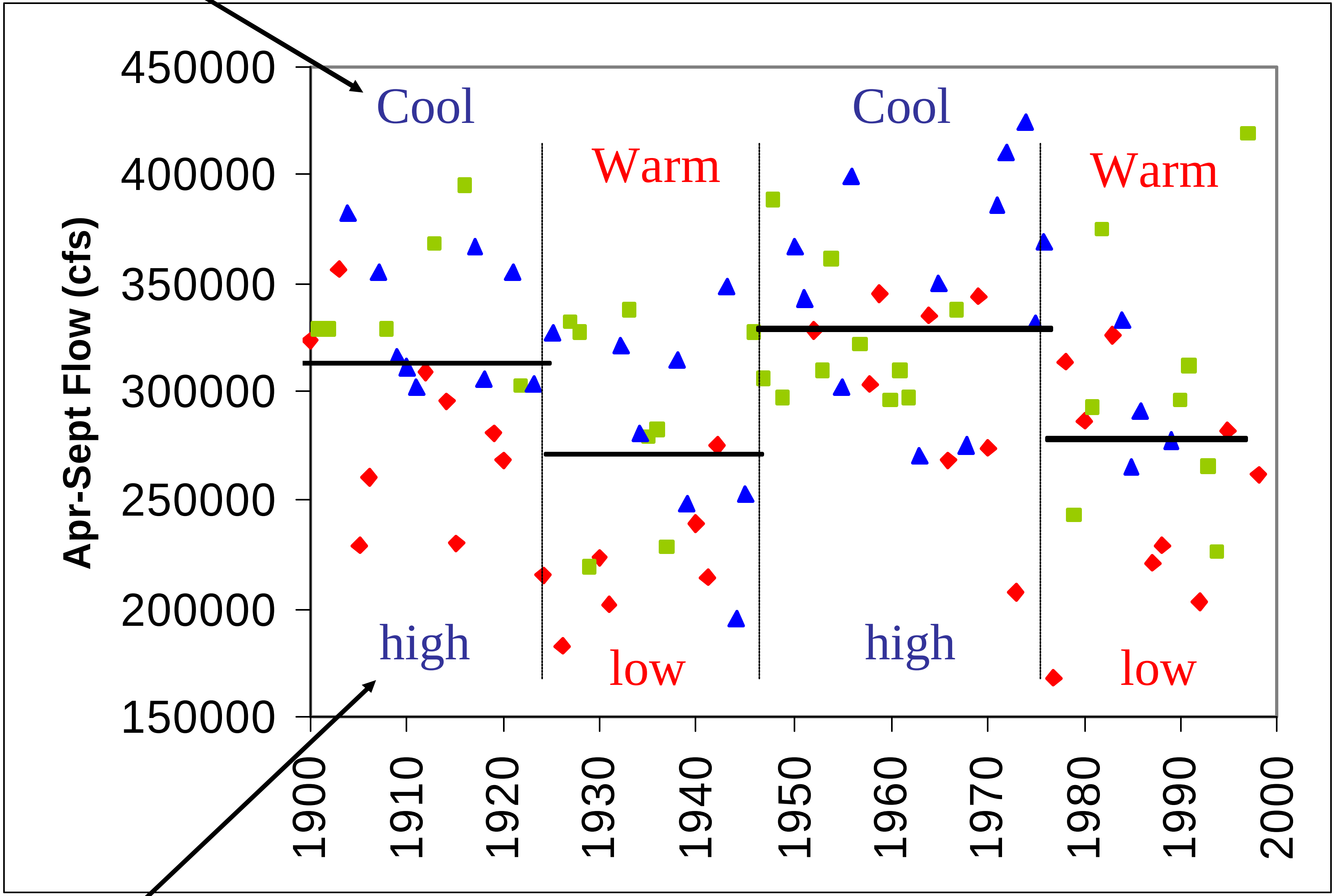
Elevation (m)

Annual PNW Precipitation (mm)



Effects of the PDO and ENSO on Columbia River Summer Streamflows

PDO

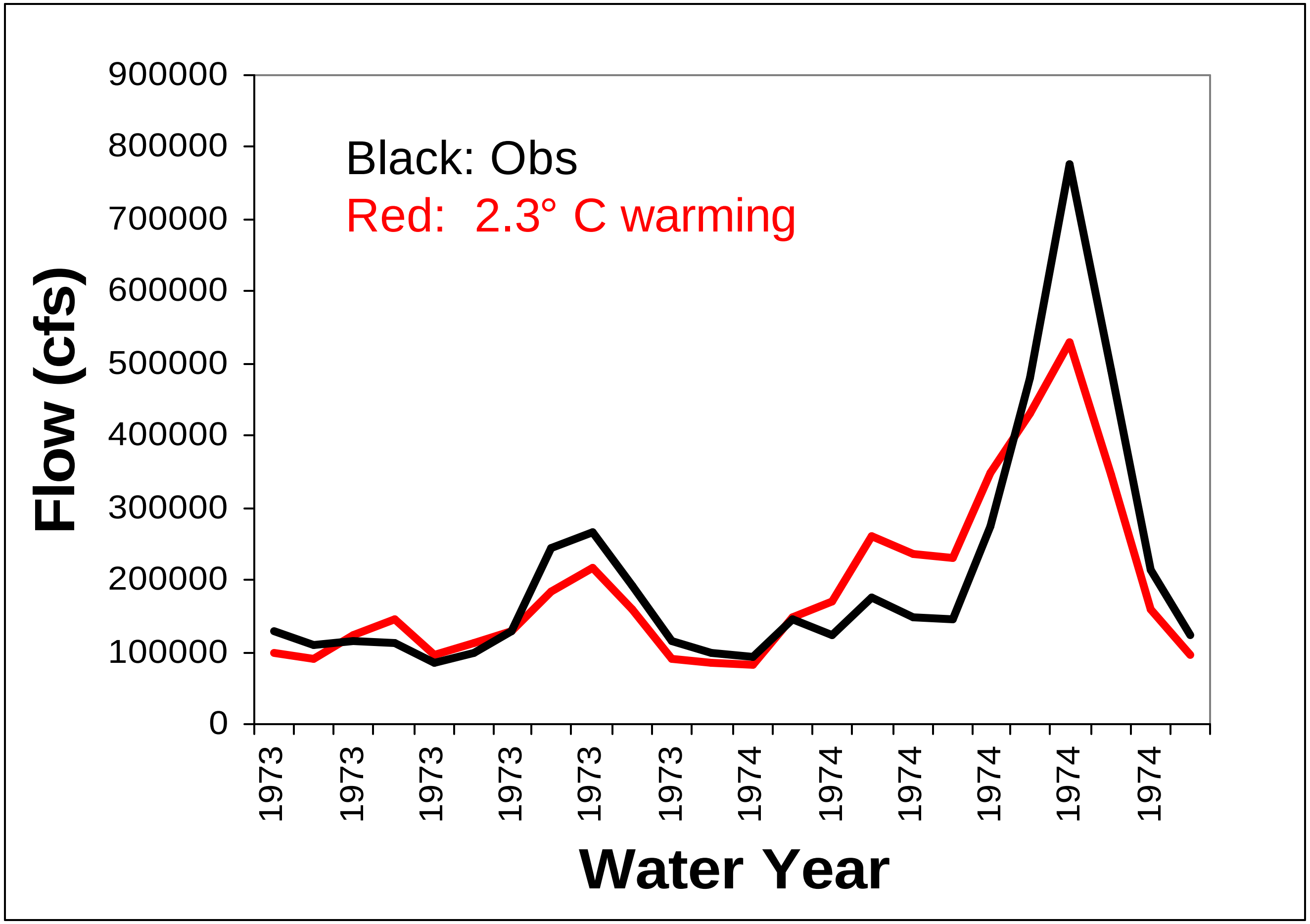


Ocean Productivity

Warming Affects Streamflow *Timing*

Temperature warms, precipitation unaltered:

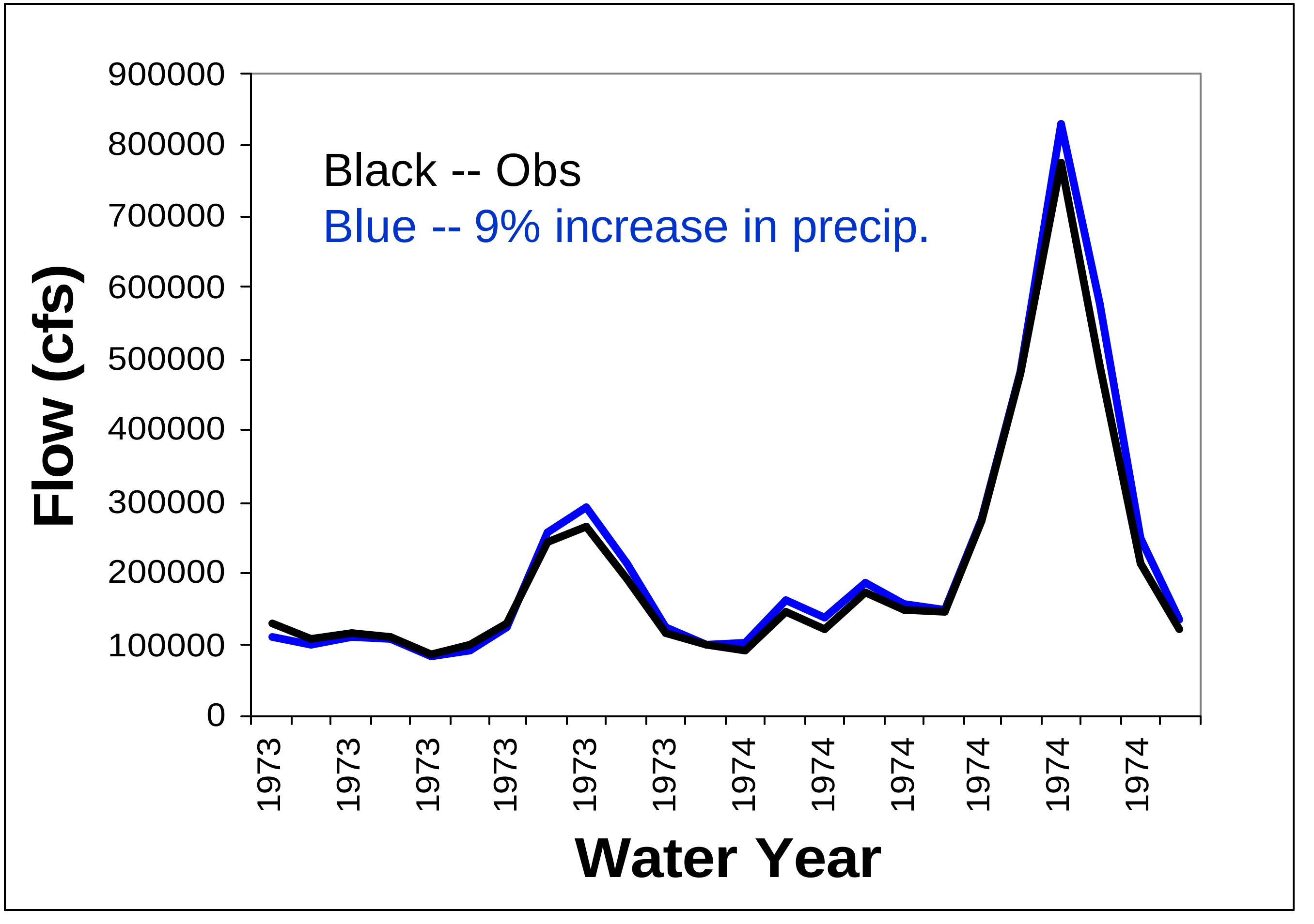
- Streamflow timing is altered
- Annual volume may be somewhat lower due to increased ET



Precipitation Affects Streamflow *Volume*

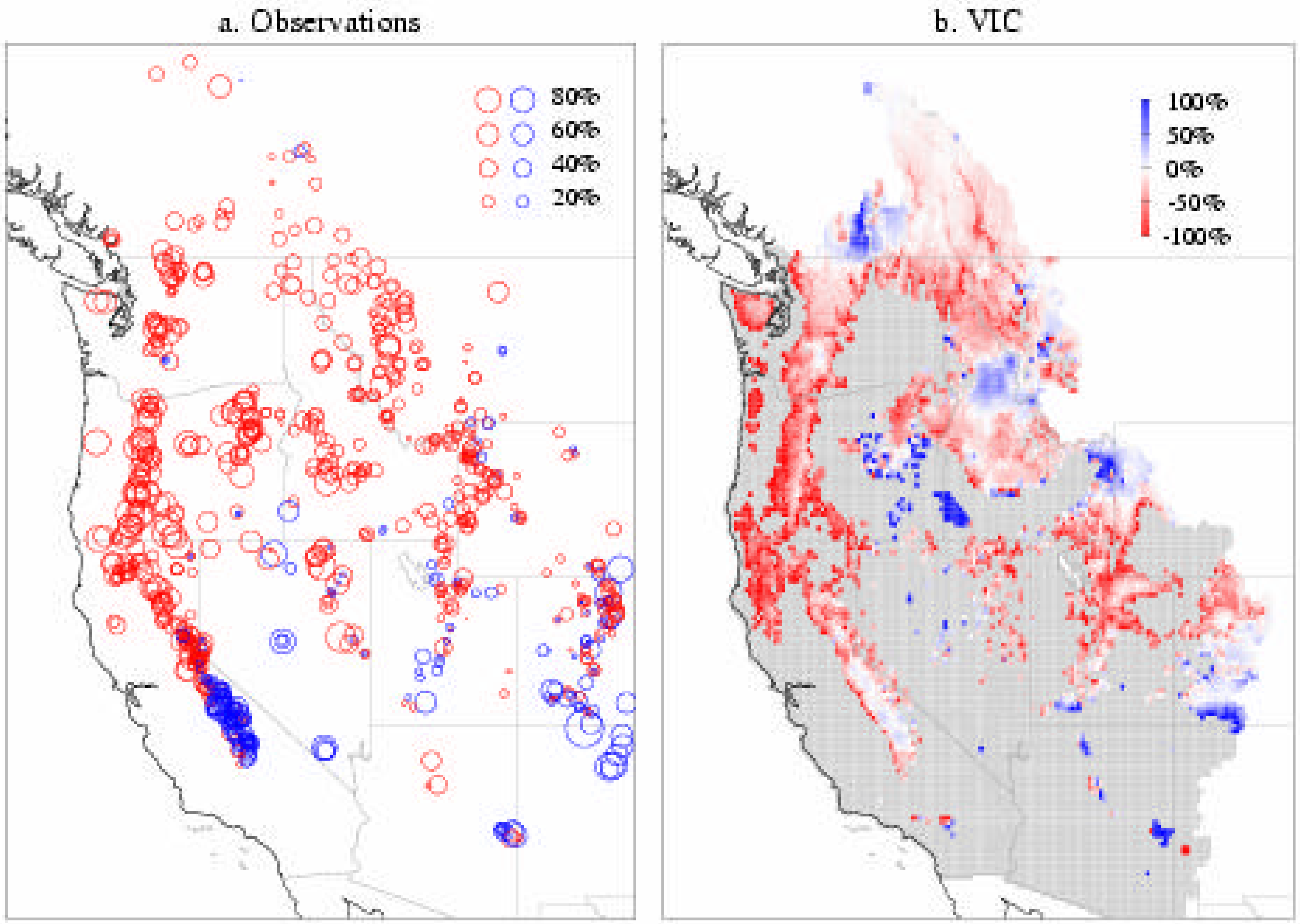
Precipitation increases, temperature unaltered:

•Streamflow timing stays about the same
•Annual volume is altered

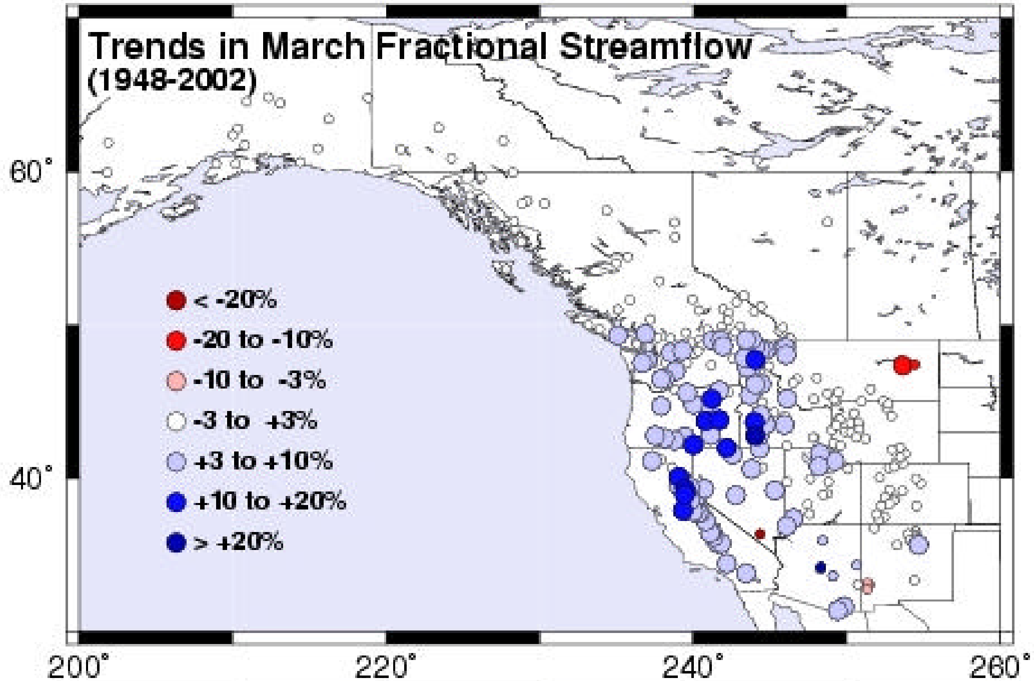


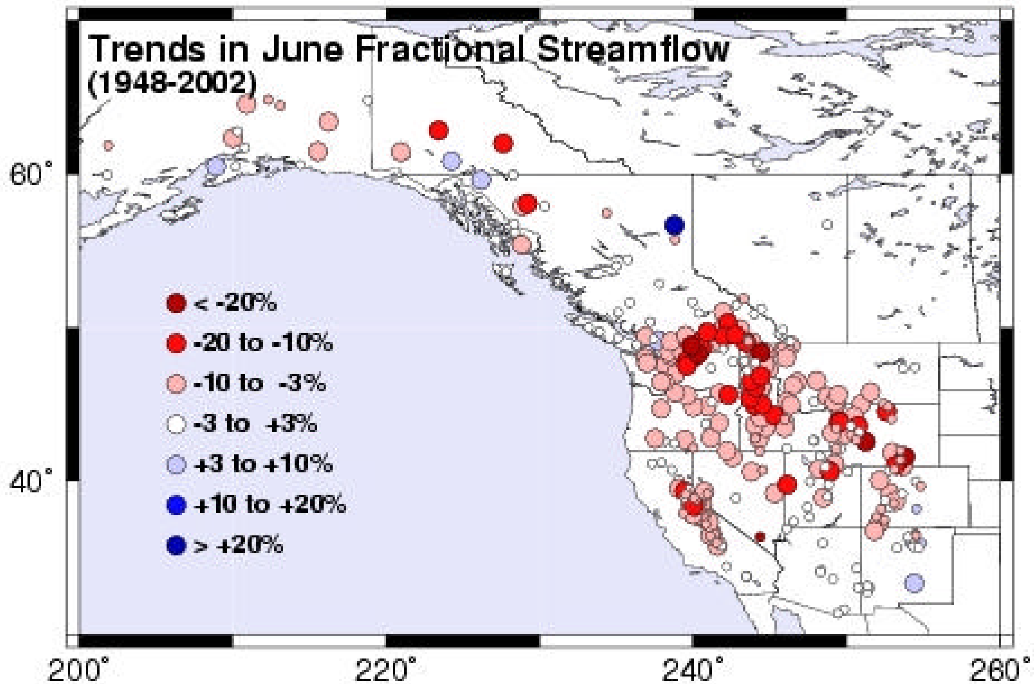
Observed Hydrologic Changes

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 (in press)



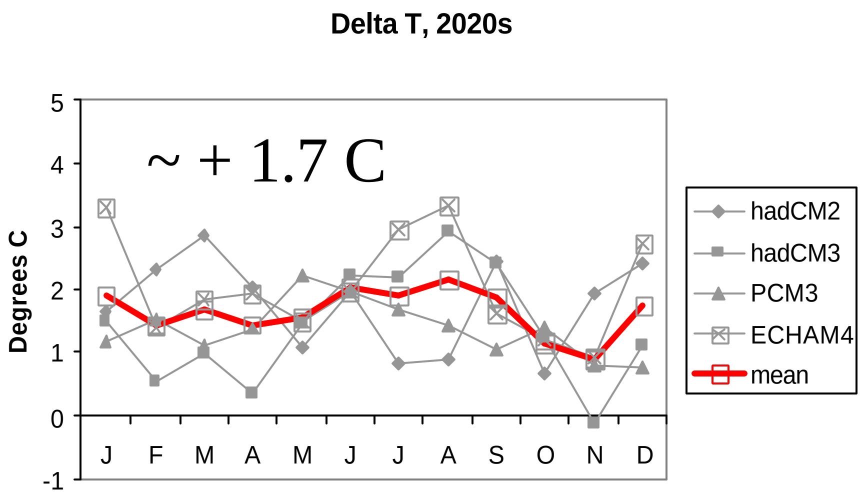


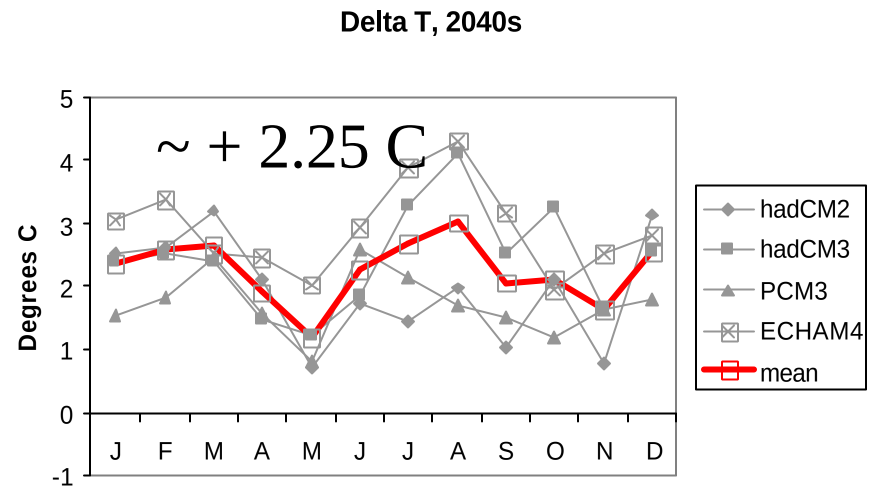
As the West warms, spring flows rise and summer flows drop

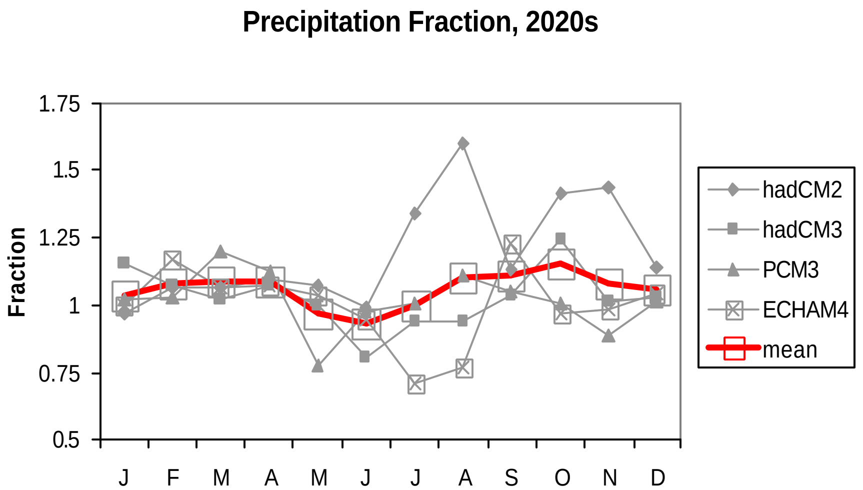
Stewart IT, Cayan DR, Dettinger MD, 2005: Changes toward earlier streamflow timing across western North America, J. Climate, 18 (8): 1136-1155

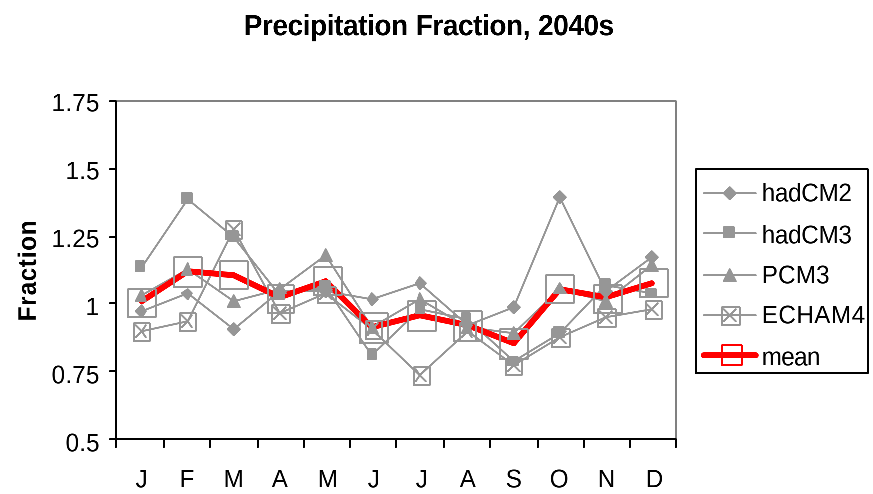
Global Climate Change Scenarios and Hydrologic Impacts for the PNW

Four Delta Method Climate Change Scenarios for the PNW

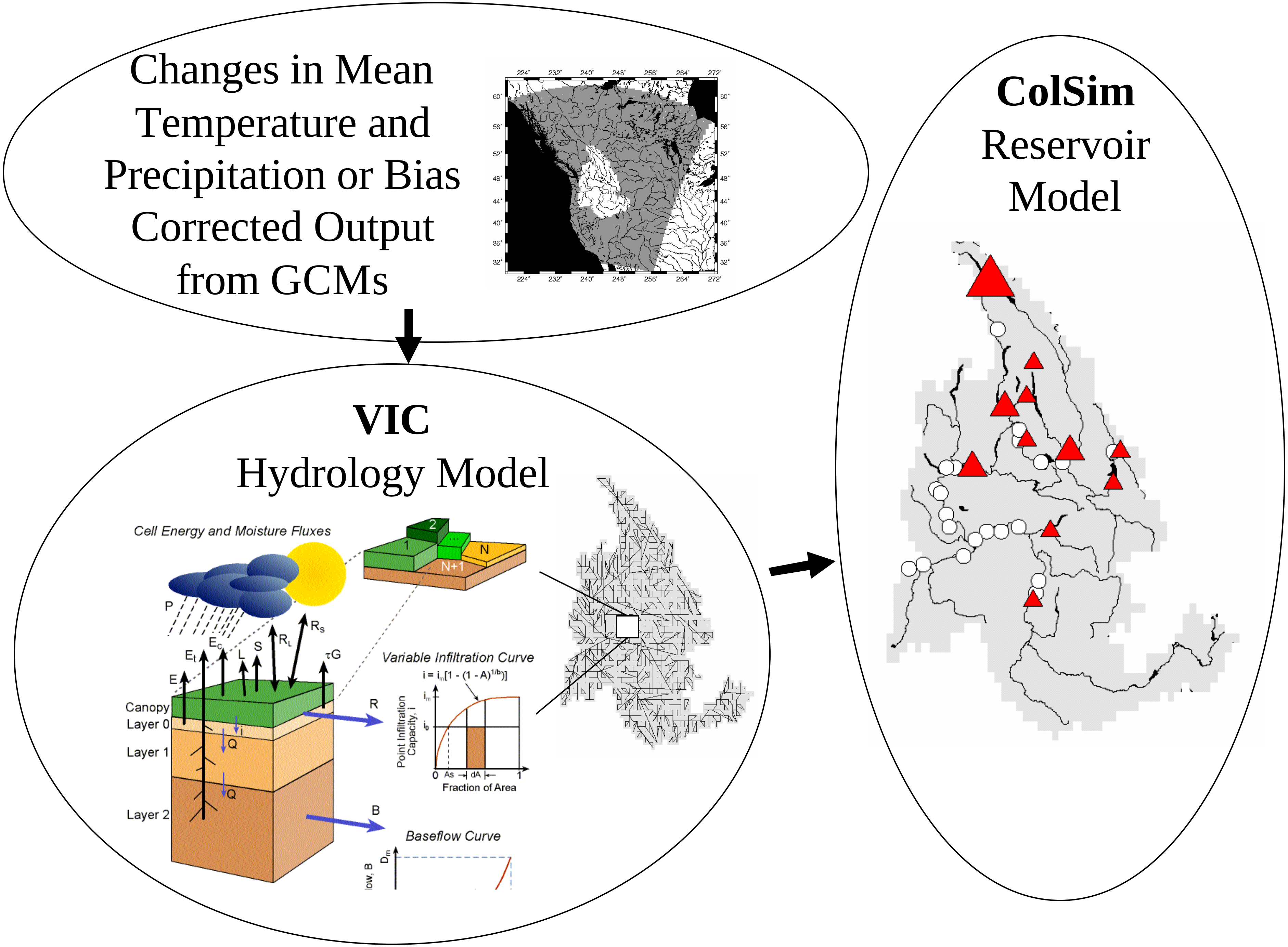




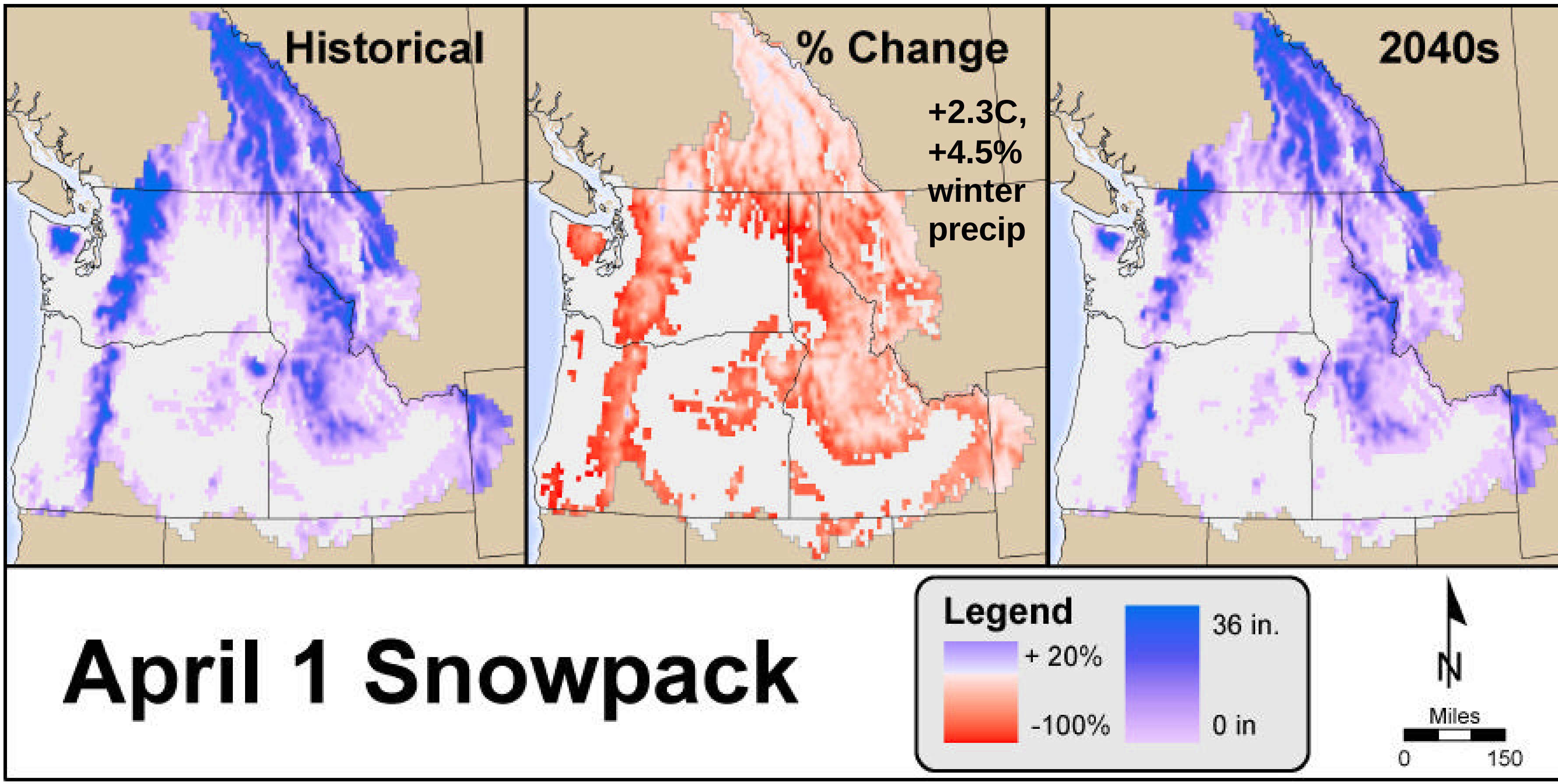




Somewhat wetter winters and perhaps somewhat dryer summers

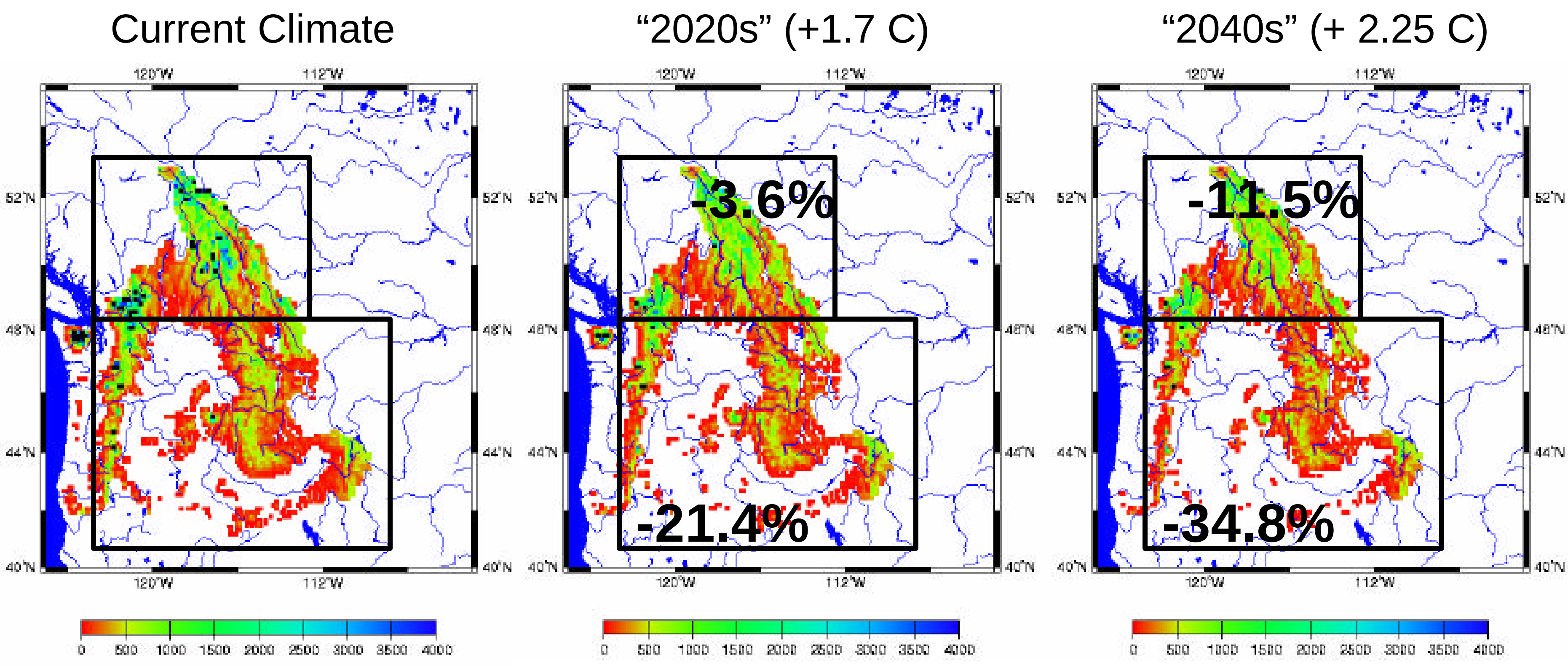

Changes in Mean Temperature and Precipitation or Bias Corrected Output from GCMs
VIC
Hydrology Model
Cell Energy and Moisture Fluxes
Variable Infiltration Curve
Point Infiltration Capacity, i
Fraction of Area
Baseflow Curve
Canopy
Layer 0
Layer 1
Layer 2
ColSim
Reservoir
Model

The warmest locations are most sensitive to warming



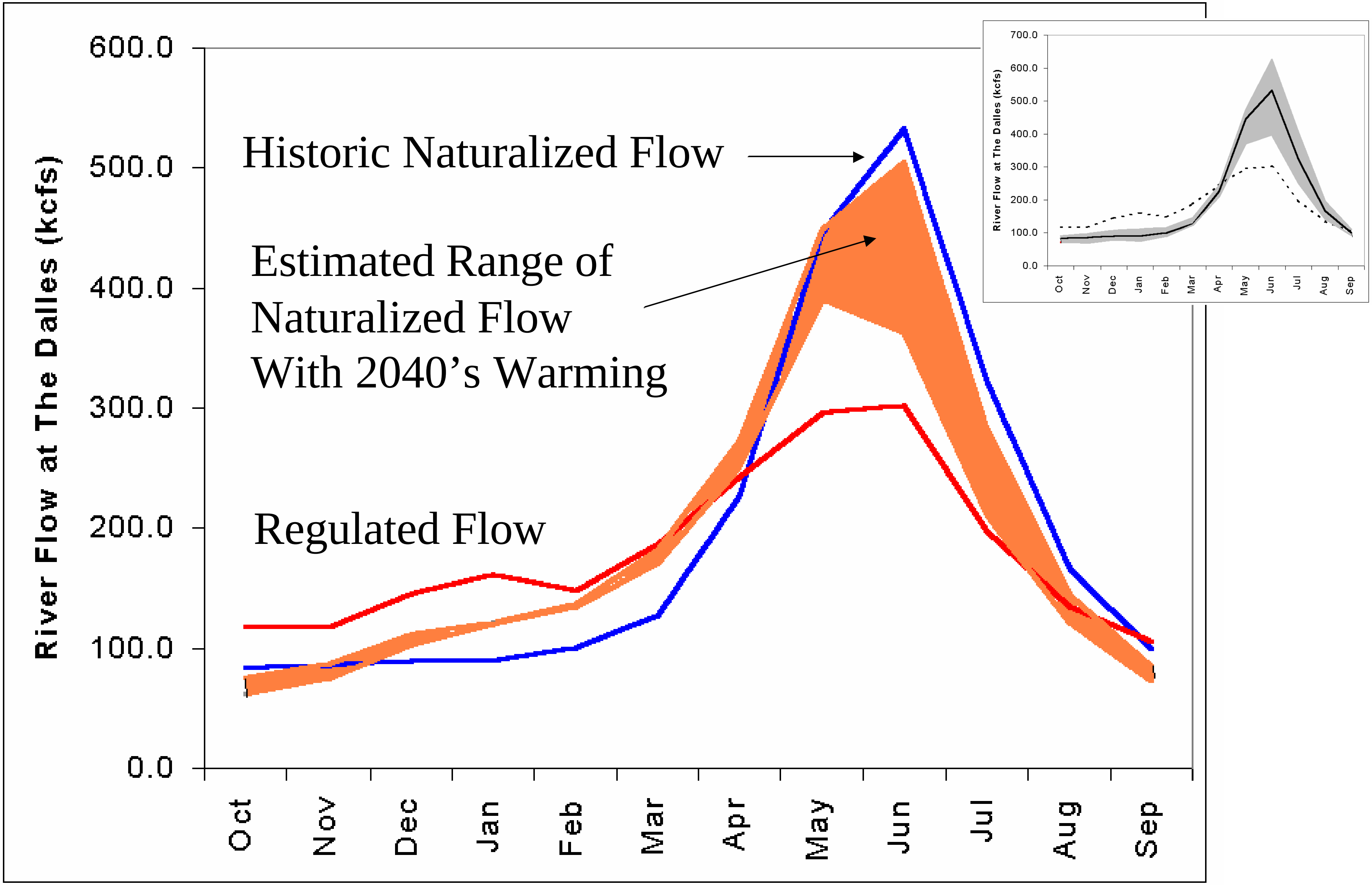
Changes in Simulated April 1 Snowpack for the Canadian and U.S. portions of the Columbia River basin

(% change relative to current climate)



April 1 SWE (mm)

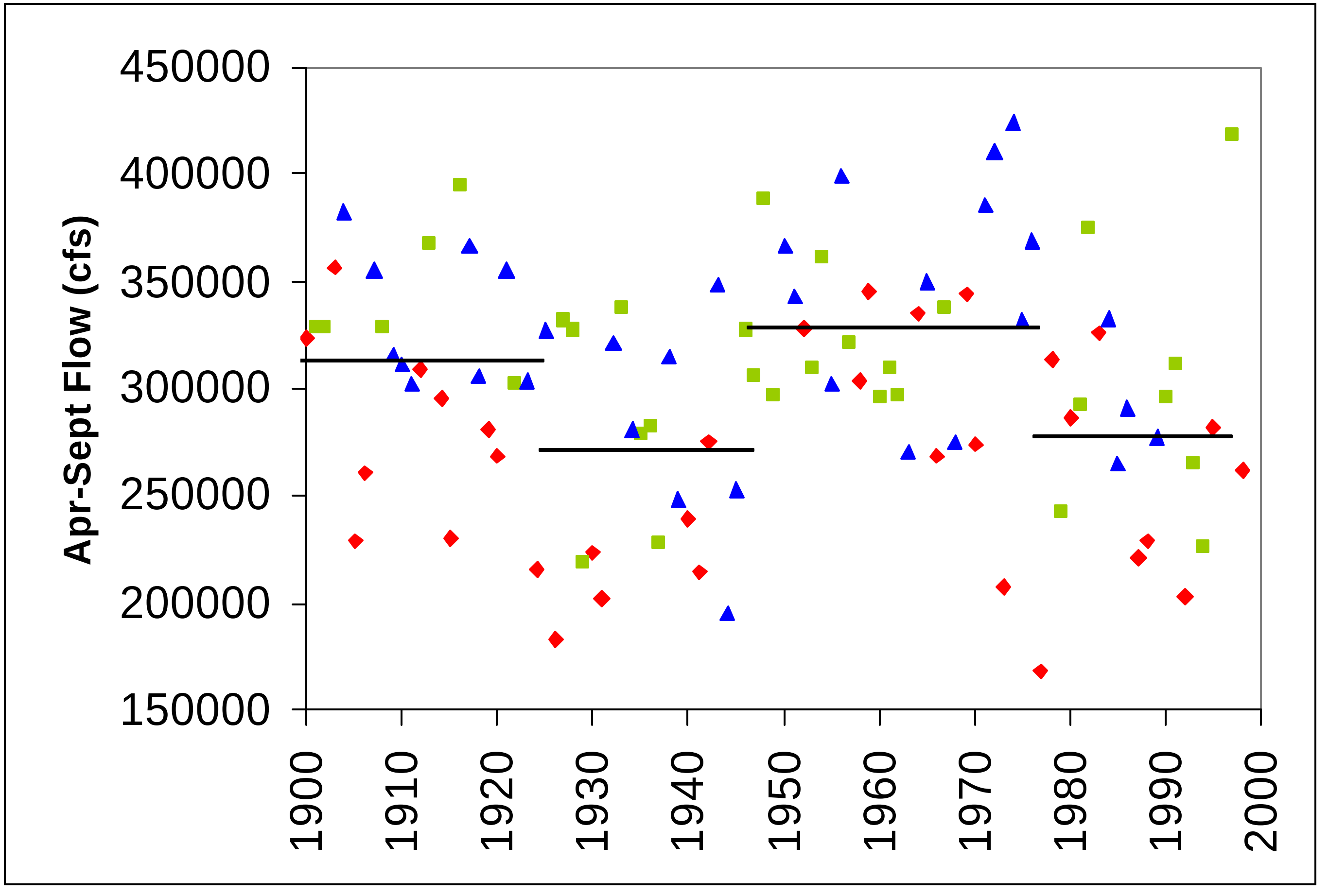
Naturalized Flow for Historic and Global Warming Scenarios Compared to Effects of Regulation at 1990 Level Development



Decadal Climate Variability and Climate Change

Will Global Warming be “Warm and Wet” or “Warm and Dry”?

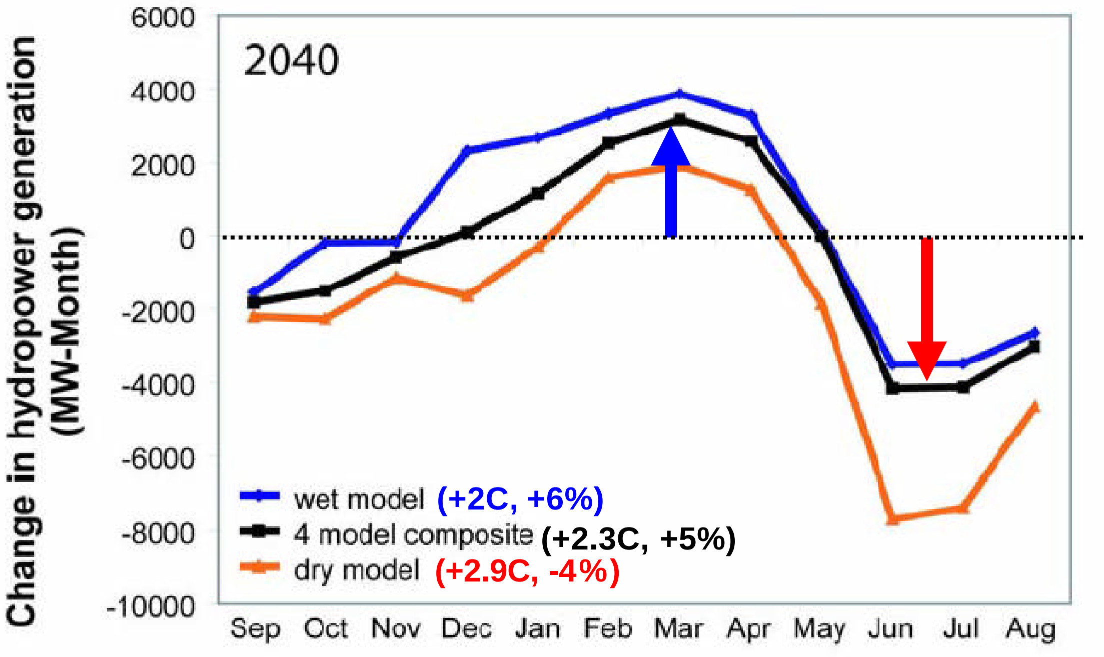
Answer: Probably BOTH!



Water Resources Implications for the Columbia River Basin

Impacts on Columbia Basin hydropower supplies

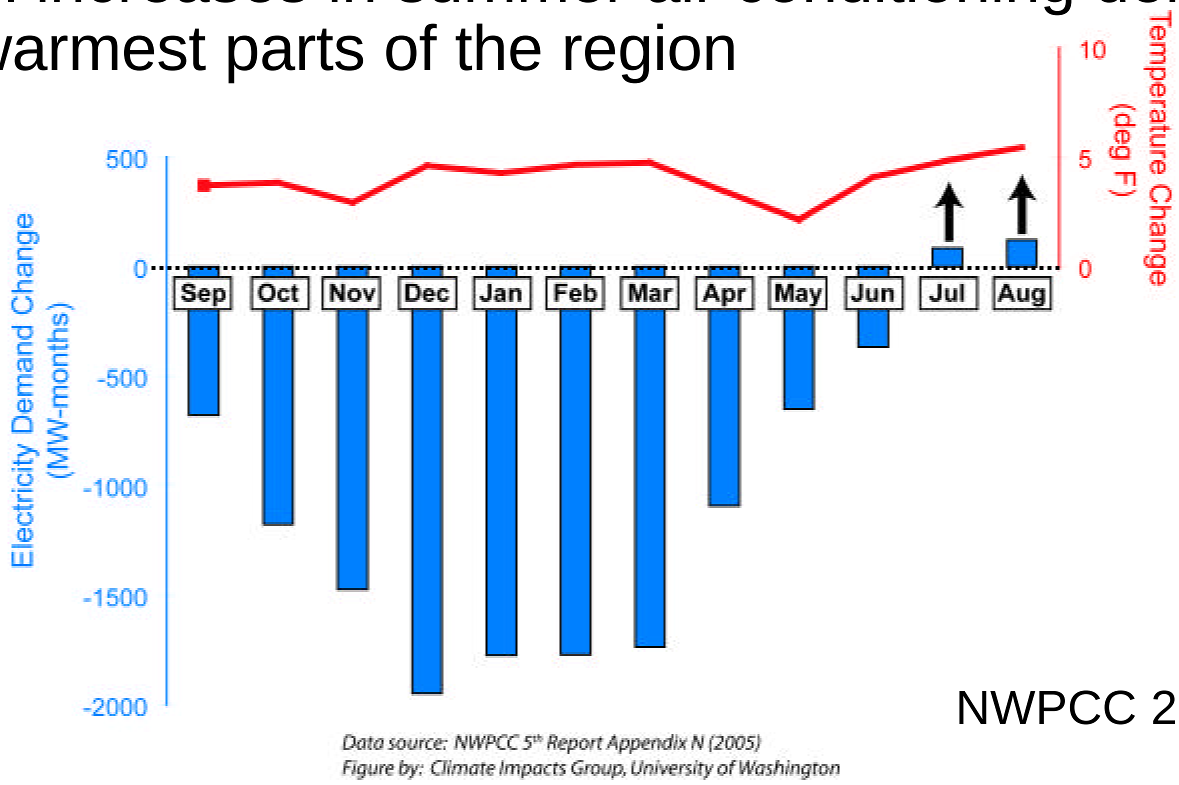
- **Winter and Spring:** increased generation
- **Summer:** decreased generation
- **Annual:** total production will depend primarily on annual precipitation



NWPCC (2005)

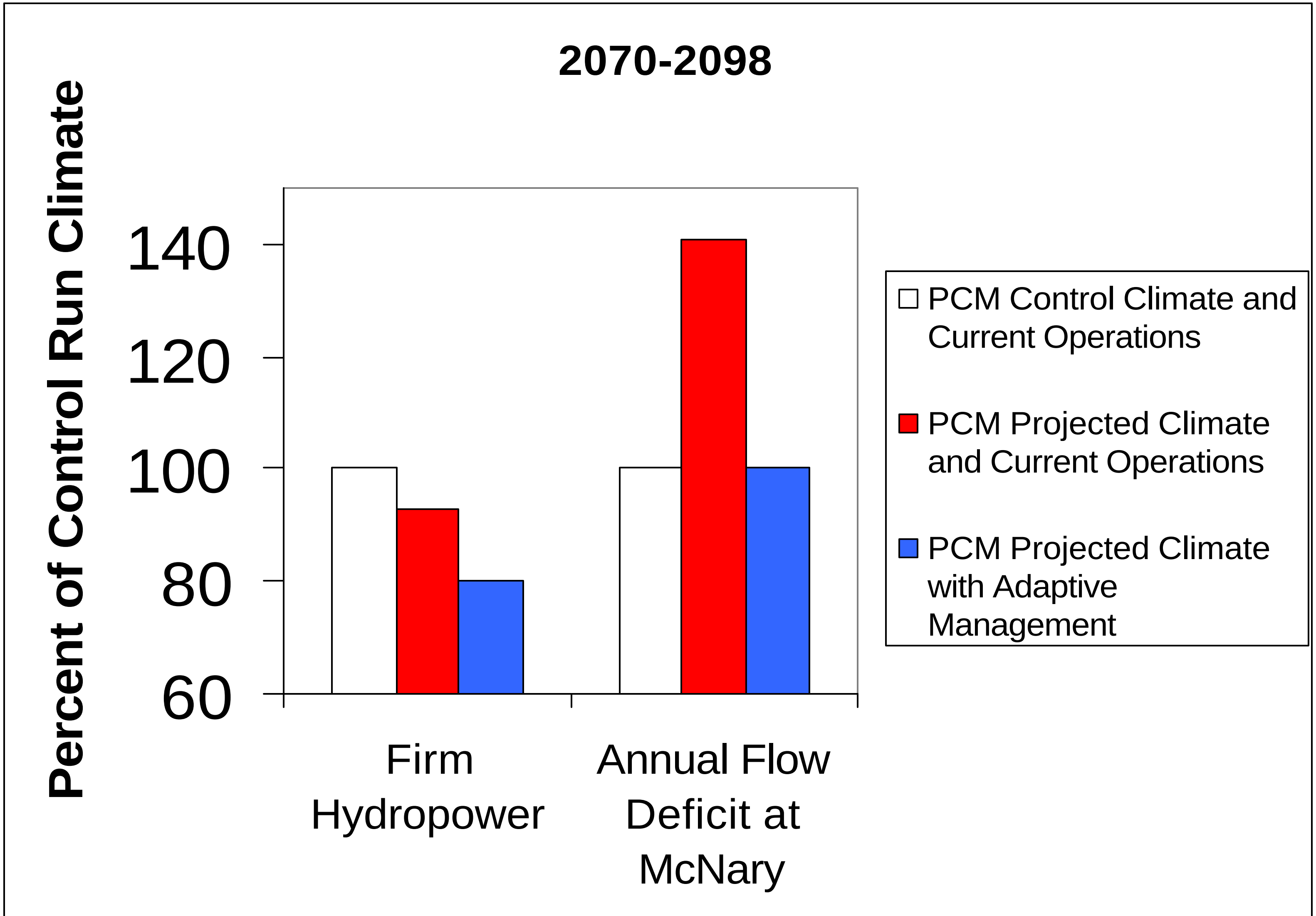
Warming climate impacts on electricity demand

- Reductions in winter heating demand
- Small increases in summer air conditioning demand in the warmest parts of the region



NWPCC 2005

Adaptation to climate change will require complex tradeoffs between ecosystem protection and hydropower operations



Source: Payne, J.T., A.W. Wood, A.F. Hamlet, R.N. Palmer, and D.P. Lettenmaier, 2004, Mitigating the effects of climate change on the water resources of the Columbia River basin, Climatic Change, Vol. 62, Issue 1-3, 233-256

Flood Control vs. Refill

Maintaining an appropriate balance between flood protection and the reliability of reservoir refill is crucial to many water resources objectives in the Columbia Basin.

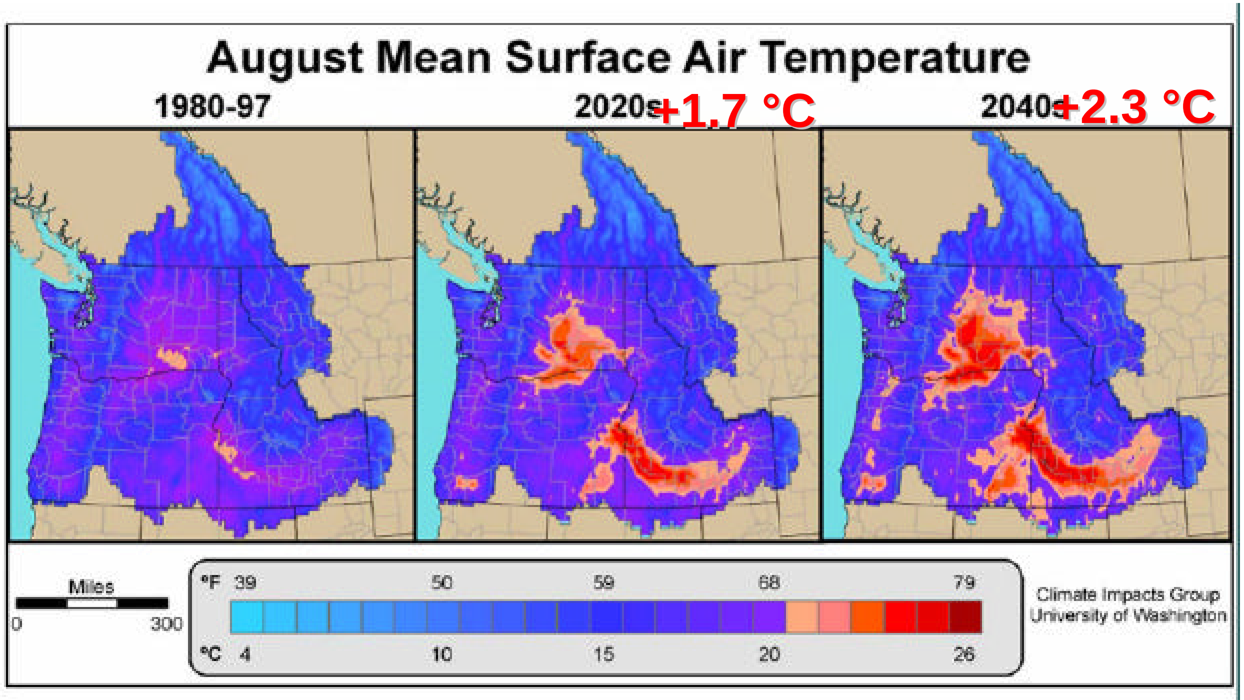
As streamflow timing shifts move peak flows earlier in the year, flood evacuation schedules may need to be revised both to protect against early season flooding and to begin refill earlier to capture the (smaller) spring freshet.

Model experiments (see Payne et al. 2004) have shown that moving flood evacuation two weeks to one month earlier in the year helps mitigate reductions in refill reliability associated with streamflow timing shifts.

Payne, J.T., A.W. Wood, A.F. Hamlet, R.N. Palmer, and D.P. Lettenmaier, 2004, Mitigating the effects of climate change on the water resources of the Columbia River basin, Climatic Change, Vol. 62, Issue 1-3, 233-256

Temperature thresholds for coldwater fish in freshwater

- **Warming temperatures will increasingly stress coldwater fish in the warmest parts of our region**
  - A monthly average temperature of 68ºF (20ºC) has been used as an upper limit for resident cold water fish habitat, and is known to stress Pacific salmon during periods of freshwater migration, spawning, and rearing



Implications for Transboundary Agreements

- Snowpack in the BC portion of the Columbia basin is much less sensitive to warming in comparison with portions of the basin in the U.S. and streamflow timing shifts will also be smaller in Canada.

- As warming progresses, Canada will have an increasing fraction of the snowpack contributing to summer streamflow volumes in the Columbia basin.

- These differing impacts in the two countries have the potential to "unbalance" the current coordination agreements, and will present serious challenges to meeting instream flows on the U.S. side.

- Changes in flood control, hydropower production, and instream flow augmentation will all be needed.

- Long-range planning is needed to address these issues.

Conclusions

•Climate change will result in significant hydrologic changes in the Columbia River and its tributaries.

•These changes will not be equally distributed throughout the region or between different water management objectives.

•With hydrologic changes, there will come a need to “rebalance” the system to compensate for these different impacts in each sector.

•This “rebalancing” will take time and will involve complex (and contentious) tradeoffs between different management objectives.

•We have the tools that we need to begin planning for a warmer future.

•We should begin to include climate information in planning now to reduce the severity of future impacts as much as possible.

Selected References and URL's

Climate Impacts Group Website

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

White Papers, Agenda, Presentations for CIG 2001 Climate Change Workshop

http://jisao.washington.edu/PNWimpacts/Workshops/Skamania2001/WP01_agenda.htm

Climate Change Streamflow Scenarios for Water Planning Studies

http://www.ce.washington.edu/~hamleaf/climate_change_streamflows/CR_cc.htm

Northwest Power and Conservation Council Columbia Basin Hydropower Study

http://www.nwppc.org/energy/powerplan/plan/Default.htm

Refs on Climate Variability and Climate Change

http://www.ce.washington.edu/~hamleaf/hamlet/publications.html