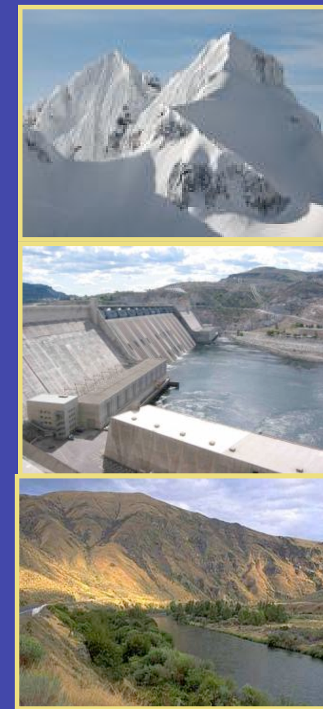
Impacts of climate change on water management in the state of Washington



Julie Vano[A,B]

in collaboration with **Nathalie Voisin[B], Michael Scott[C], Lan Cuo[A,B], Marketa McGuire Elsner[B] , Alan Hamlet[A,B], Kristian Mickelson[B], Richard Palmer[B,D], Austin Polebitski[B,D], Claudio Stockle[E], Dennis Lettenmaier[A,B]**

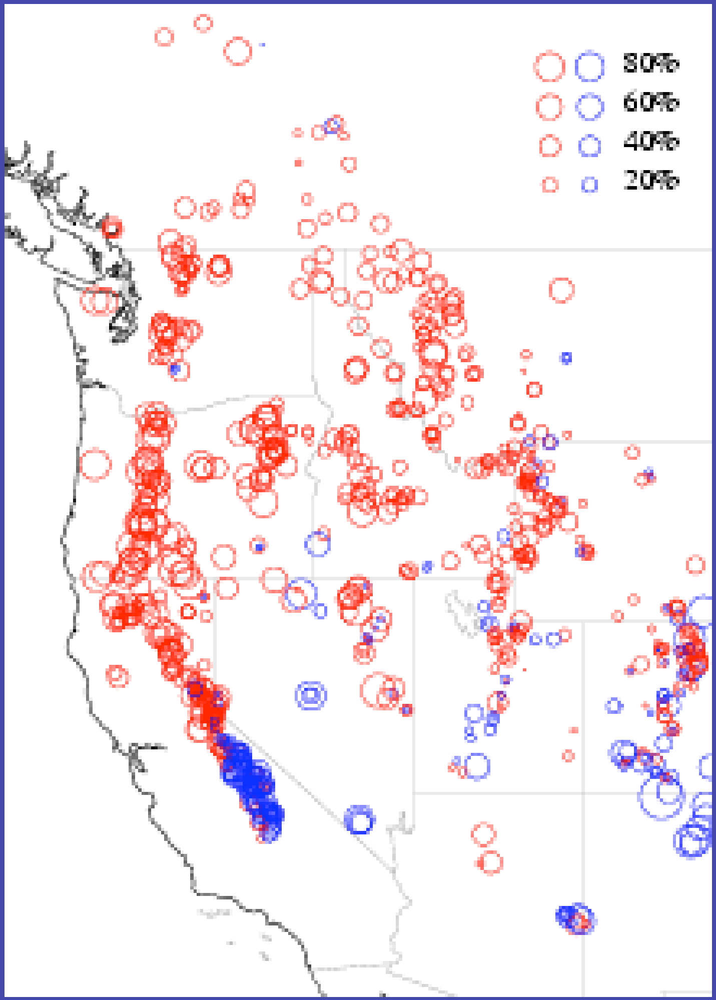
[A]Climate Impacts Group
[B]Dept of Civil and Environmental Engineering, U of Washington
[C]Pacific Northwest National Laboratory, Richland, WA
[D]Dept of Civil and Environmental Engineering, U of Massachusetts-Amherst
[E]Dept of Biological Systems Engineering, Washington State University

April 17, 2009
Graduate Climate Conference, Pack Forest

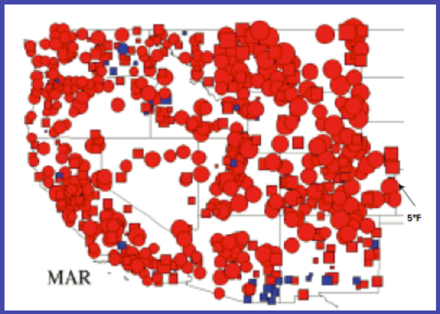
CLIMATE IMPACTS GROUP

Climate science in the public interest

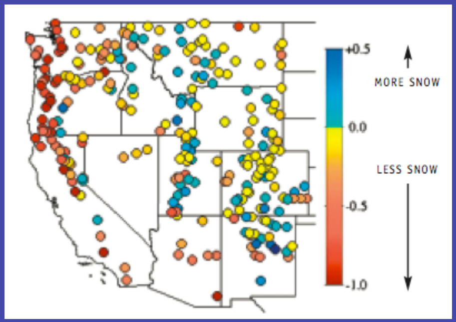
Current Climate Trends



Observed April 1 snow water equivalents, 1950-1997



March Average Min Temp on Days with Precipitation (1949-2004)



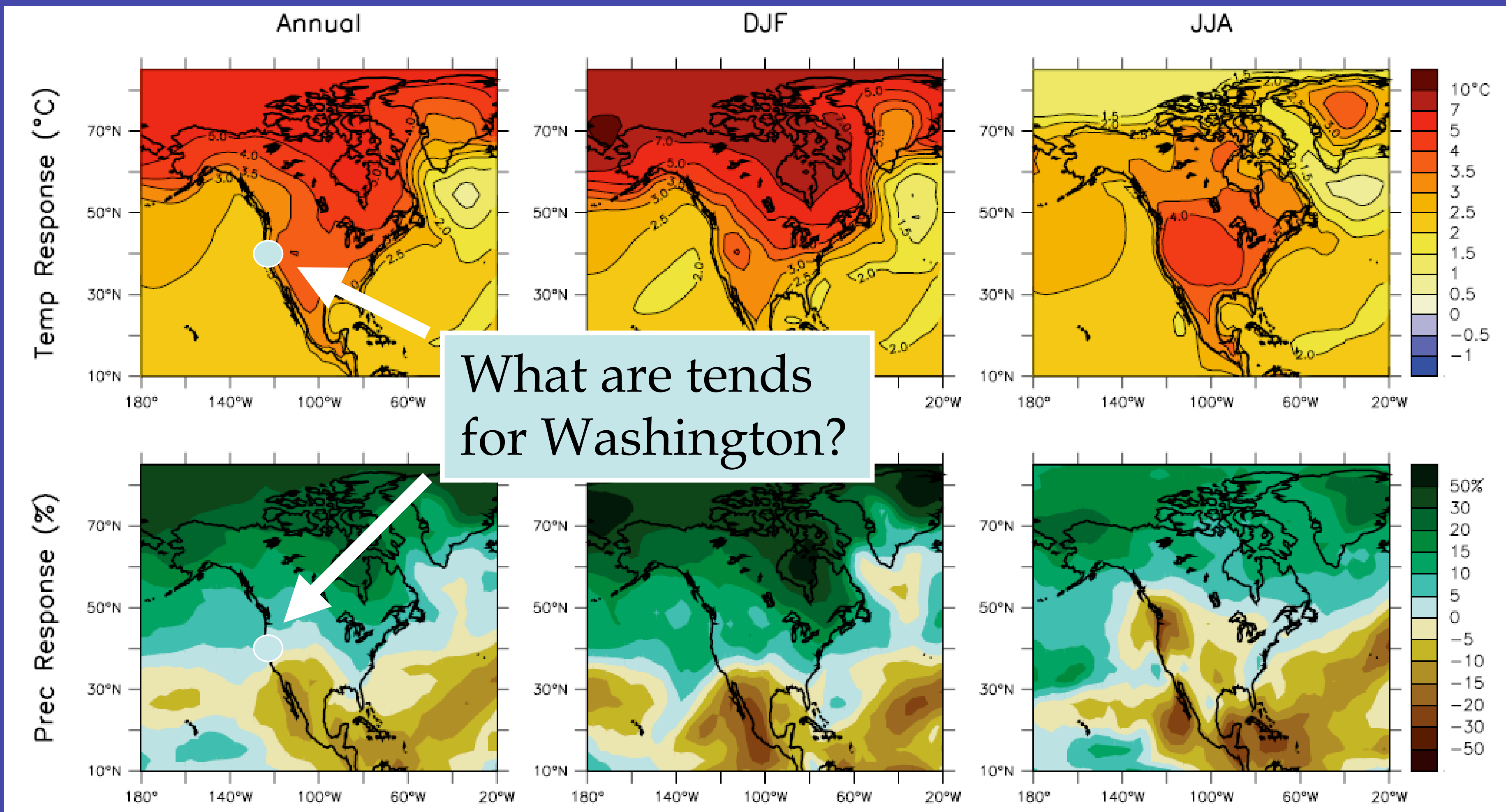
Trends in Snow vs. Rain in Winter (1949-2004)

and many more…

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

Knowles, N., Dettinger, M.D., and D.R. Cayan, 2006, Trends in Snowfall verse Rainfall in the Western United States, Journal of Climate 19: 4545-4559.

International Panel on Climate Change (IPCC) 2007



Consensus Forecasts of Temperature and Precipitation Changes from IPCC AR4 GCMs

Research Objectives

1) Is the scale (space, time) of the information provided by future forecasts relevant to water management decisions?
2) If planning relies on past variability, how does this change when we can no longer assume stationarity?
3) How can we account for uncertainty in these forecasts?
4) How can we change planning and management to account for this non-stationarity, uncertainty, and risk?

Photo courtesy of http://www.usbr.gov/dataweb/html/yakima.html

Washington State Climate Impacts Assessment

Agriculture/Economics

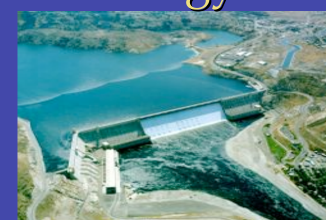
A comprehensive climate change impacts assessment for Washington State

Water Resources

Coasts

Funding Source: Clean Air/Clean Fuels House Bill 1303

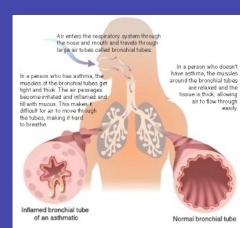
Energy



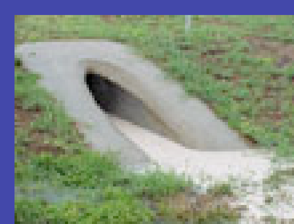
Forest Resources

Salmon

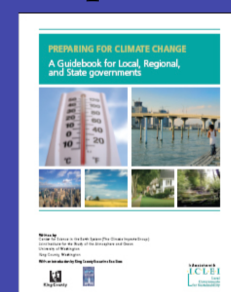
Human Health



Infrastructure



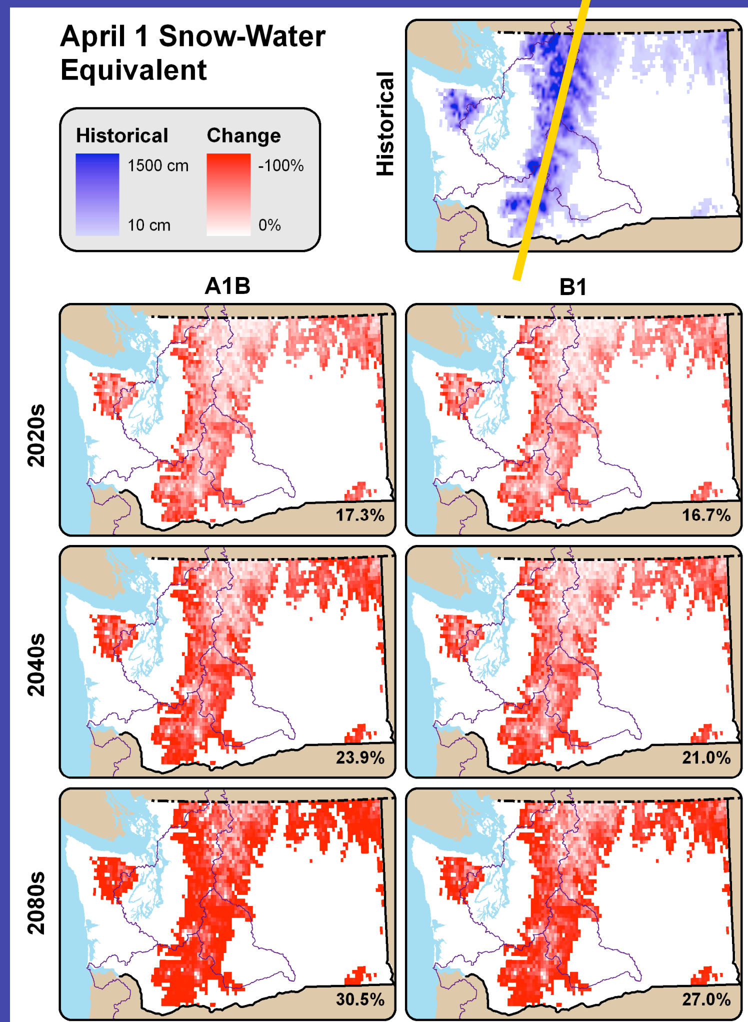
Adaptation



Washington Water Resources

Reduced snowpack and changes in soil moisture will occur.

Declines in April 1 SWE vary between 21-24% for the 2040s, depending on the emissions scenario.



Case study 1:
Yakima R basin
irrigated agriculture

Case study 2:
Puget Sound basin
municipal

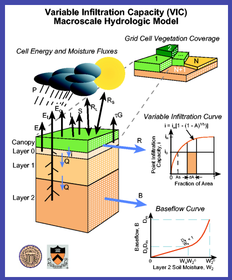
Data Needs to Support a 21st Century Planning Framework Incorporating Climate Information, Uncertainty, and Risk

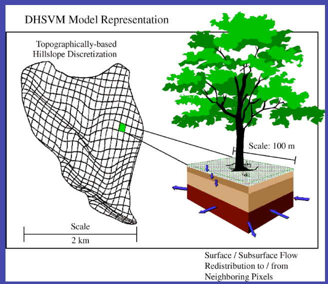
2 Emissions Scenarios X 20 GCMs

IPCC Climate Scenarios

downscaling

Hydrology Modeling





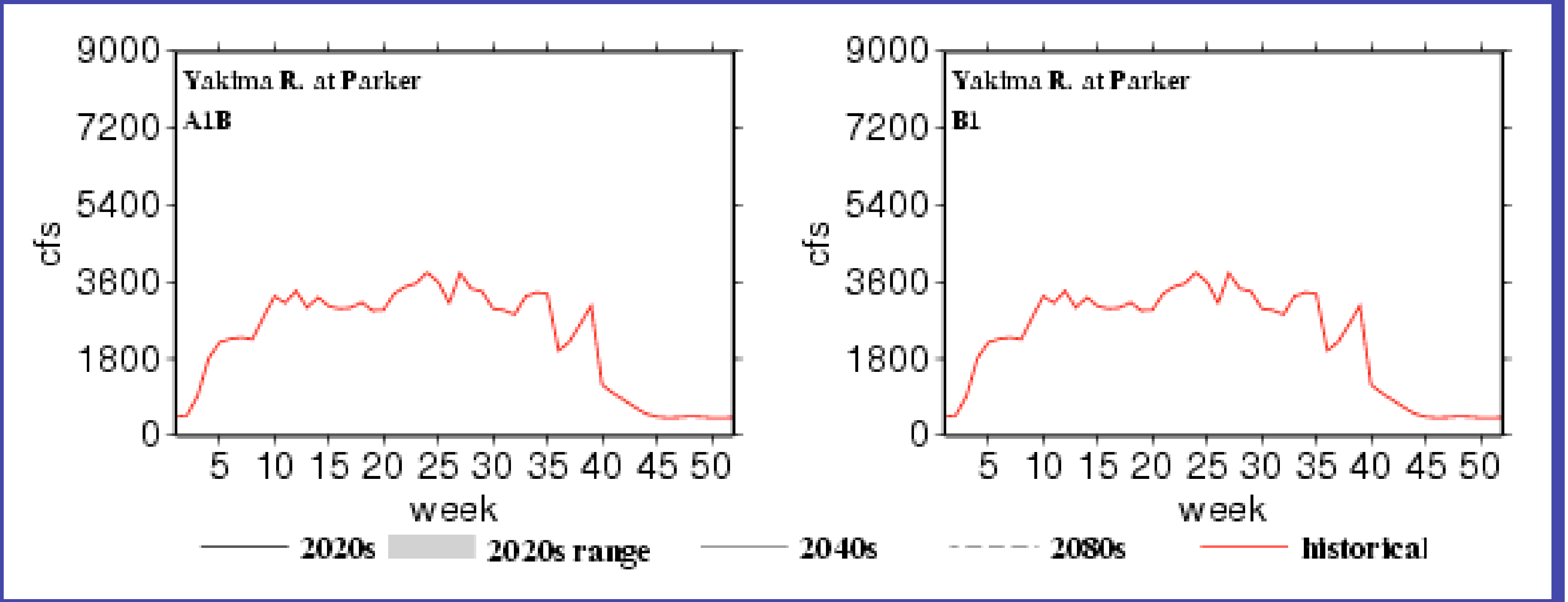
stream routing, bias correcting

Reservoir Models (Riverware, GoldSim)

Approach provides ensemble of variables that can be used to evaluate impacts of climate change

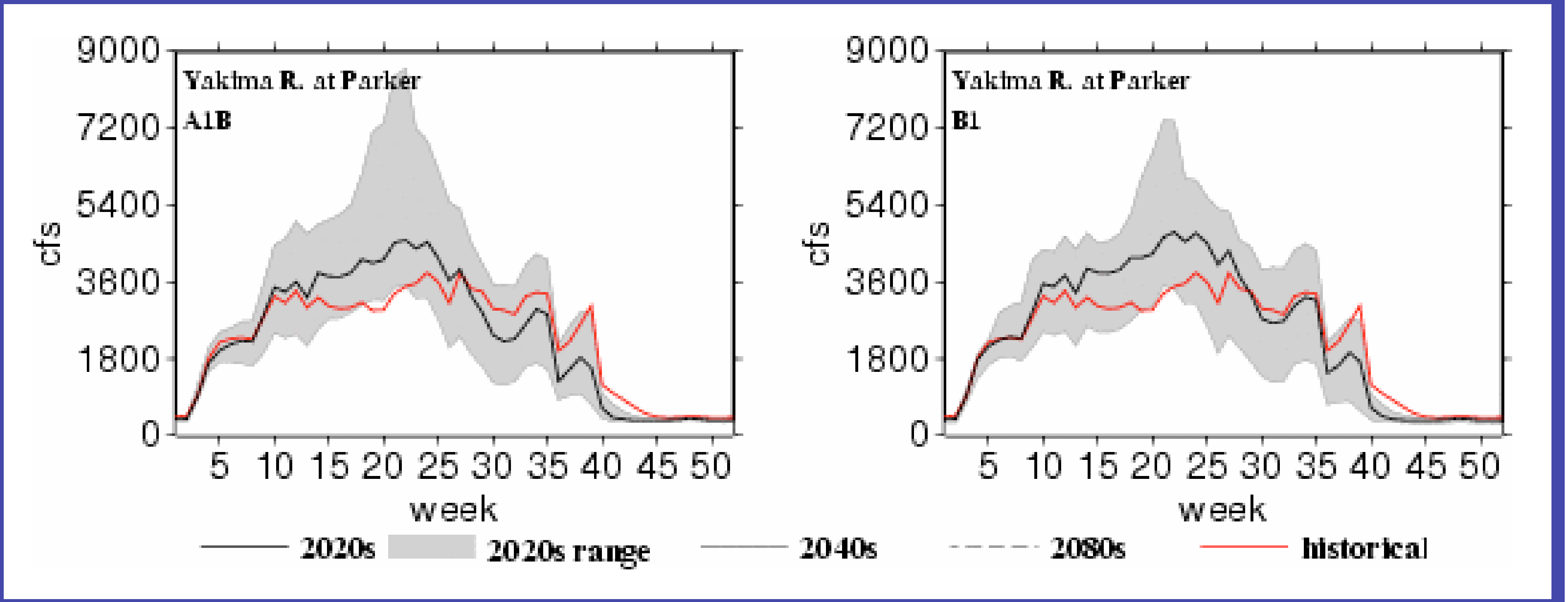
- Precipitation
- Air Temperature
- Streamflow
- Soil Moisture
- Evapotranspiration
- Anticipated Storage
- System reliability
- Water prorationing
- And more

Example of ensemble method



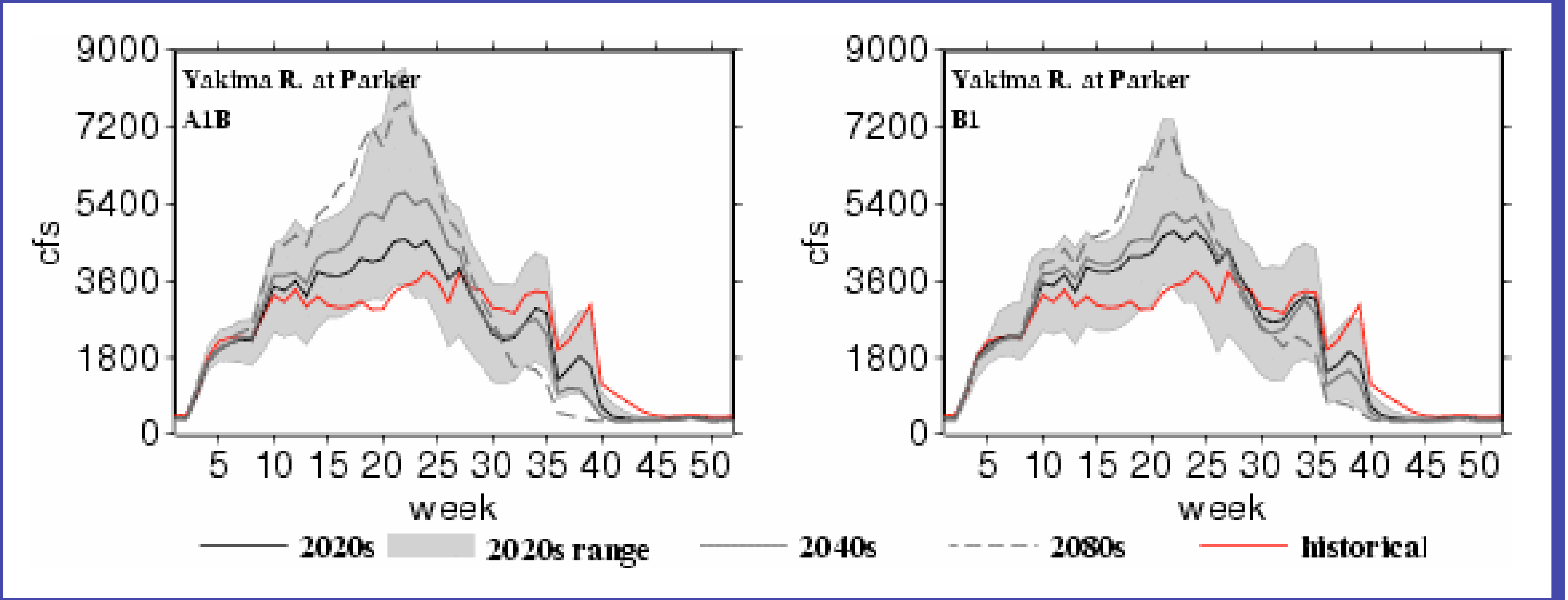
- Historical (1917-2006), weekly averages start Oct 1

Example of ensemble method



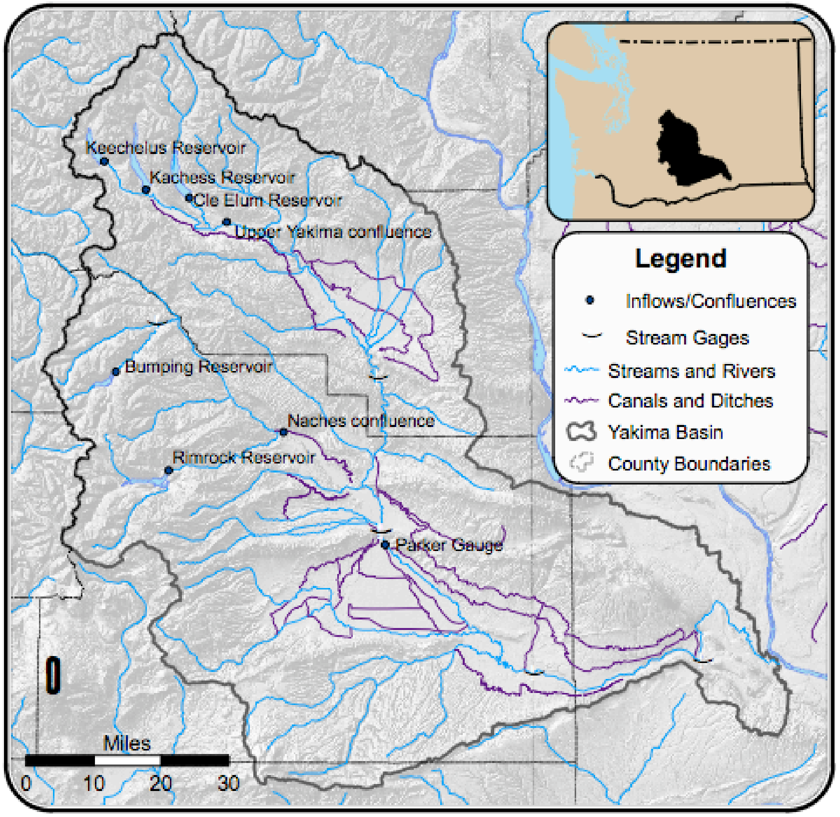
- Historical (1917-2006), weekly averages start Oct 1
- 2020s ensembles of 20 A1B and 19 B1, delta method produce 90 years with a climate resembling 2005 to 2035
- 2020s composite of A1B and B1 (2005-2035)

Example of ensemble method



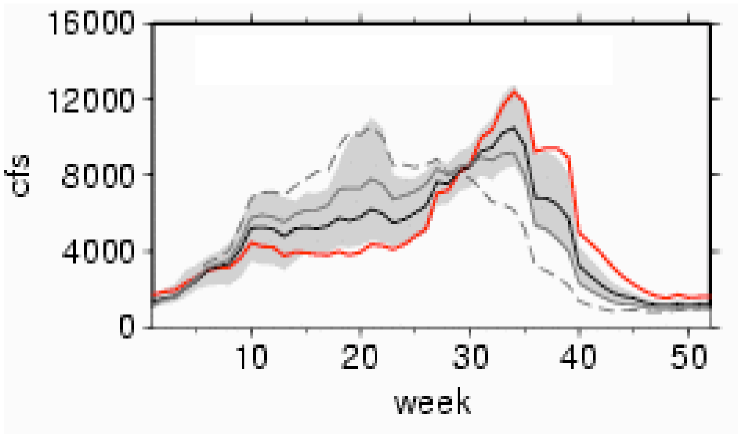
- Historical (1917-2006), weekly averages start Oct 1
- 2020s ensembles of 20 A1B and 19 B1, delta method produce 90 years with a climate resembling 2005 to 2035
- 2020s composite of A1B and B1 (2005-2035)
- 2040s composite of A1B and B1 (2025-2055)
- 2080s composite of A1B and B1 (2065-2095)

Case study 1: Yakima River Basin



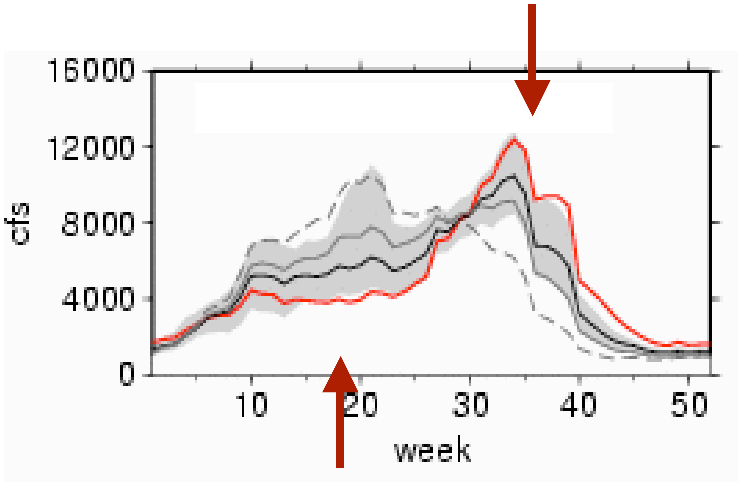
- Irrigated crops largest agriculture value in the state
- Precipitation (fall-winter), growing season (spring-summer)
- Five USBR reservoirs with storage capacity of ~1 million acre-ft, ~30% unregulated annual runoff
- Snowpack sixth reservoir
- Water-short years impact water entitlements

Yakima River Basin



Unregulated

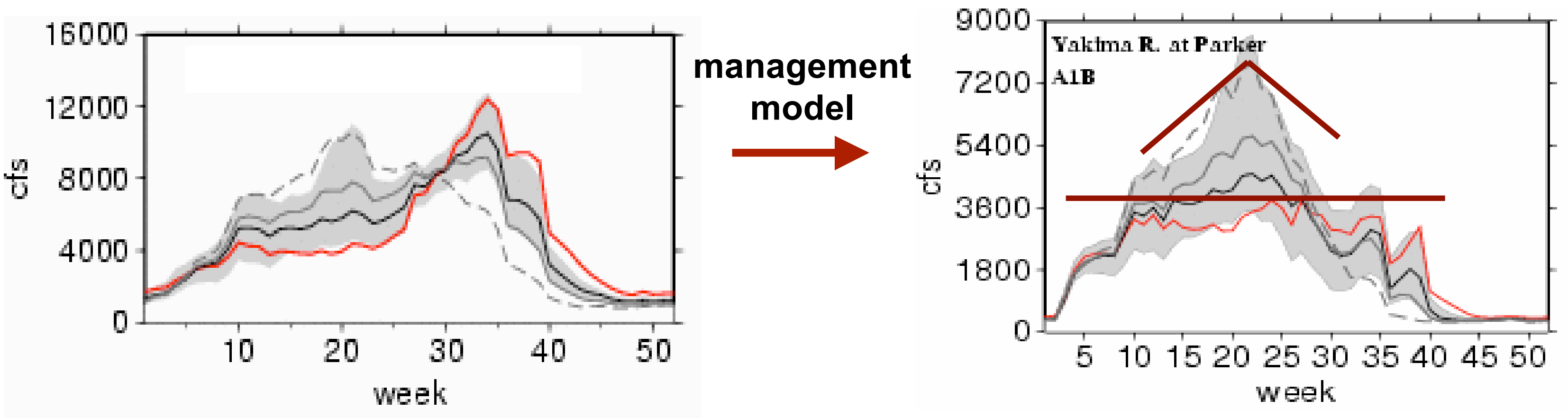
Yakima River Basin



Unregulated

- Basin shifts from snow to more rain dominant

Yakima River Basin

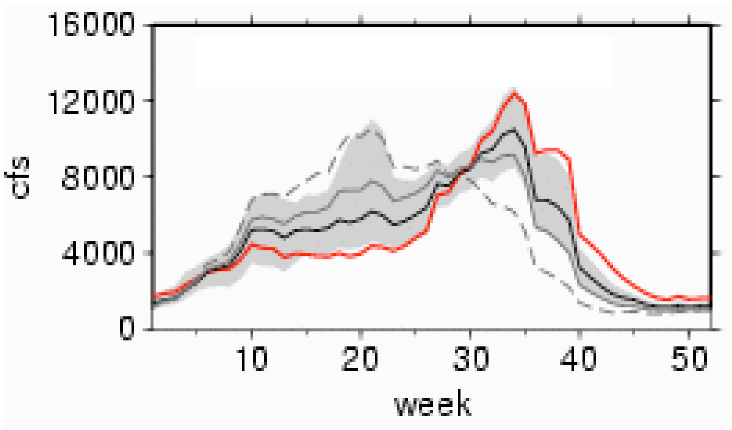


Unregulated

Regulated

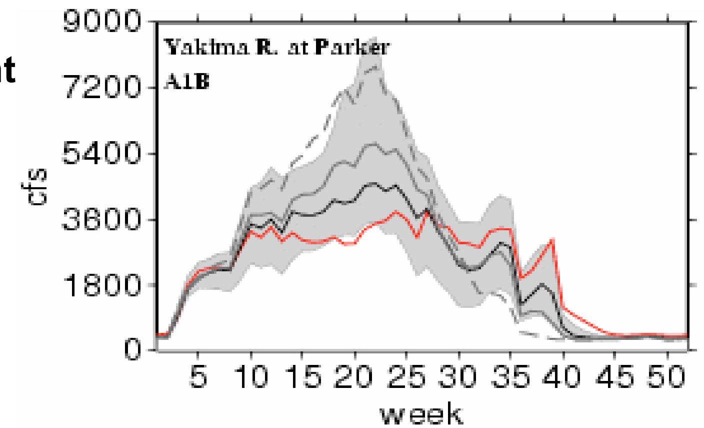
- Basin shifts from snow to more rain dominant
- Water prorating, junior water users receive 75% of allocation
- Junior irrigators less than 75% prorating (current operations):
  - 14% historically
  - 32% in 2020s A1B (15% to 54% range of ensemble members)
  - 36% in 2040s A1B
  - 77% in 2080s A1B

Yakima River Basin



Unregulated

management model



Regulated

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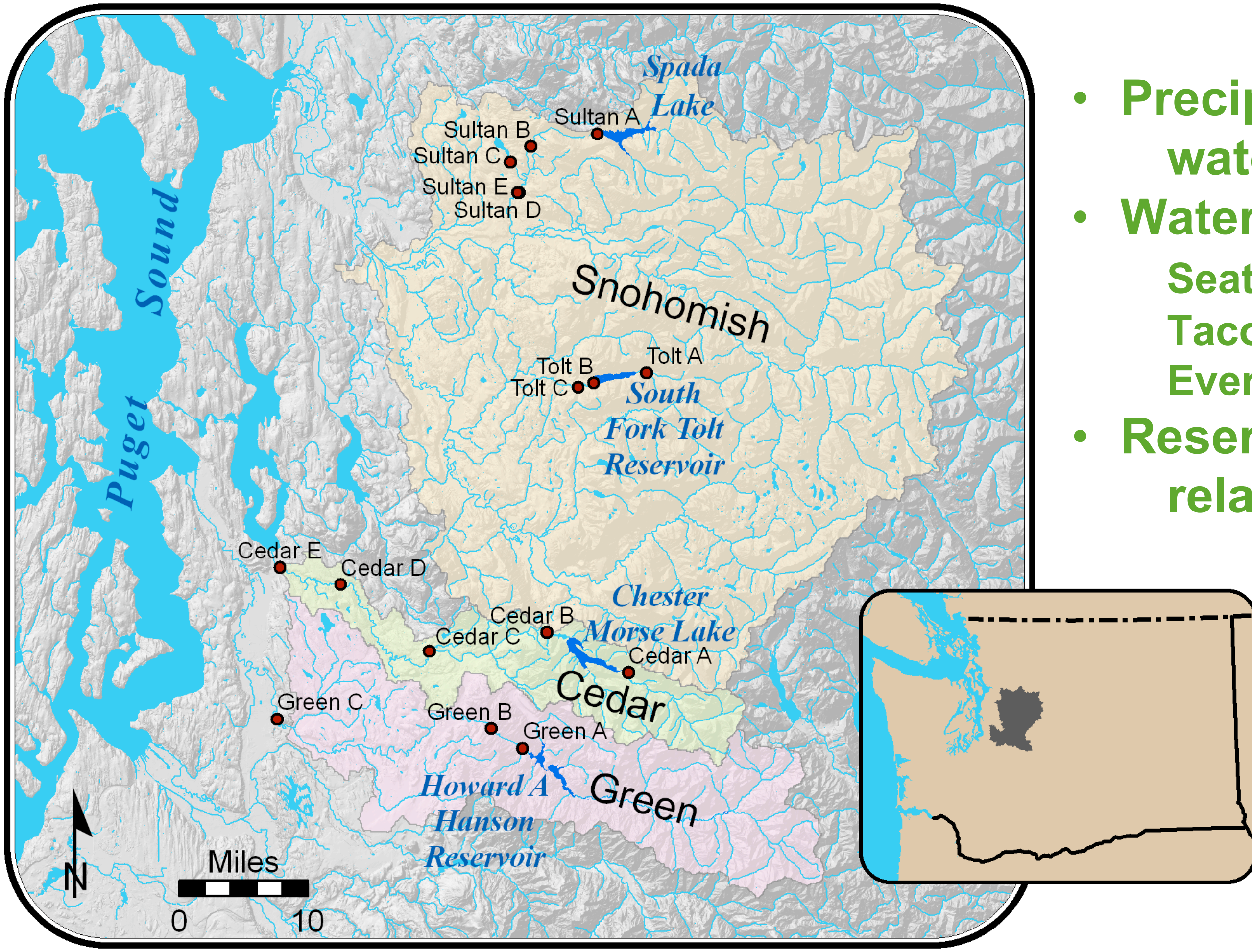
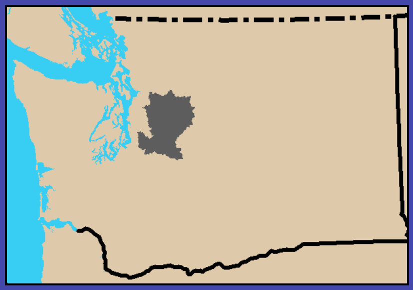
  - 14% historically
  - 32% in 2020s A1B (15% to 54% range of ensemble members)
  - 36% in 2040s A1B
  - 77% in 2080s A1B
- Reductions in apple and cherry production is likely to decline by 5% ($20 million) in 2020s,16% ($70 million) in the 2080s

Case study 2: Puget Sound Basin

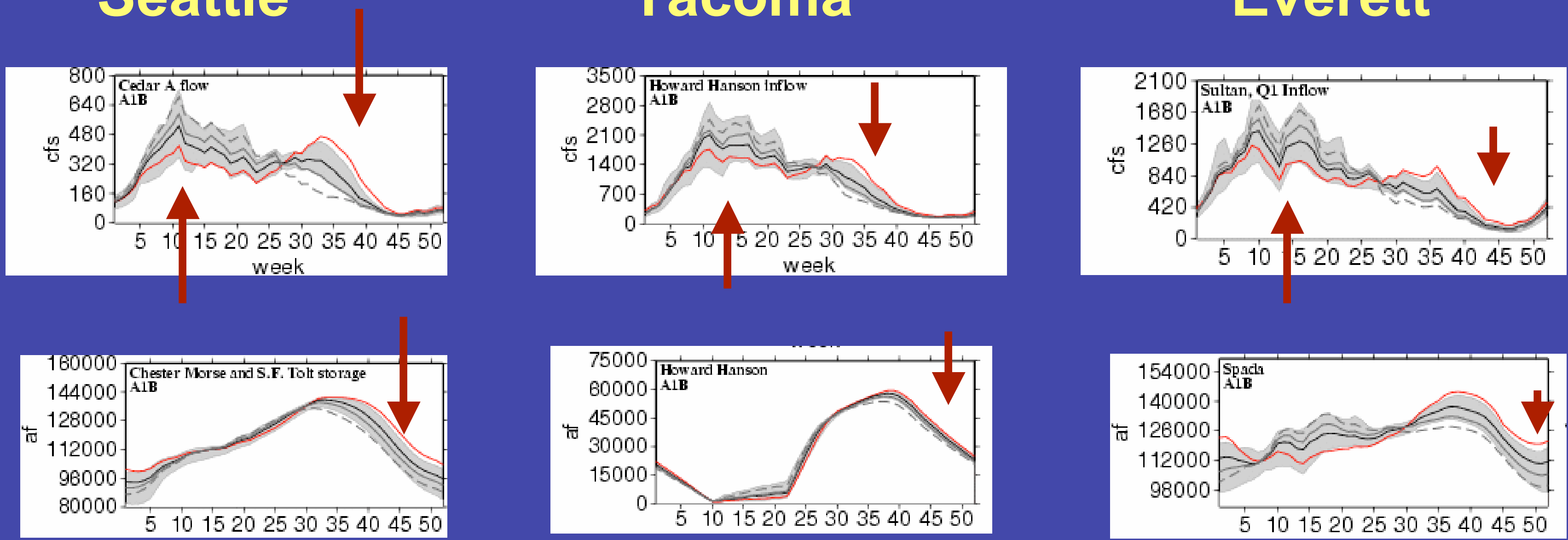


- Precipitation in fall-winter, water demand in summer
- Water management systems:
  - Seattle - municipal, fish
  - Tacoma - municipal, flood control
  - Everett - municipal, hydropower
- Reservoir capacities small relative to annual flow



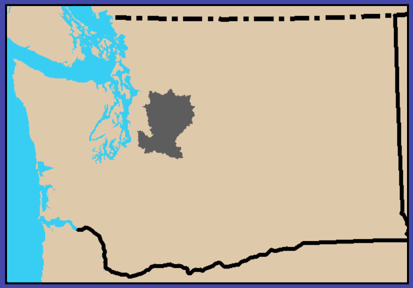
Puget Sound Basin

Seattle | **Tacoma** | **Everett**



Variations in impacts within and between systems (A1B)

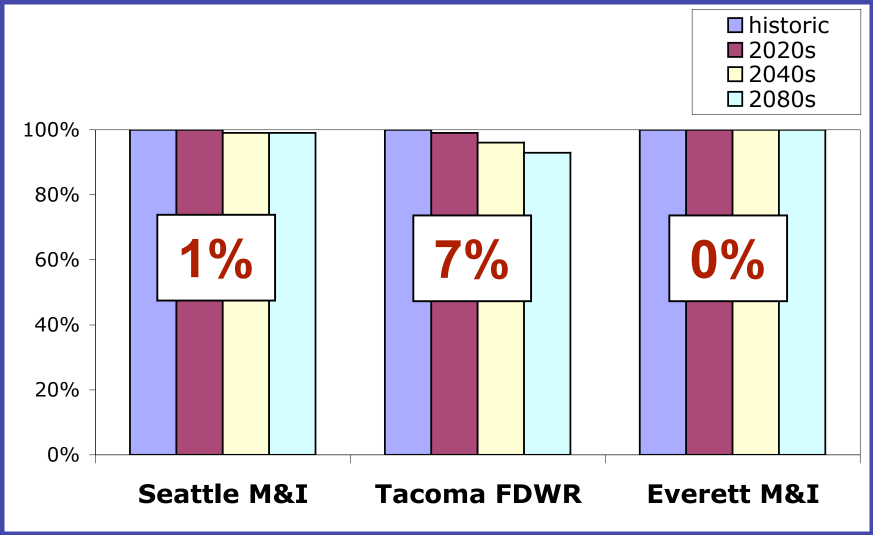
- **Seattle, M&I and environmental flows**
- **Tacoma, flood control, more constrained storage**
- **Everett, hydropower, more interannual variability**

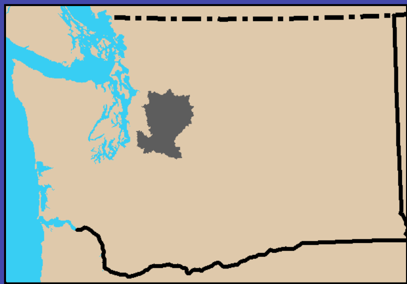


Puget Sound Basin

municipal supply - current demand

- M&I reliability measures, differ for all systems
- Current demand, reliability little impact from future change (A1B)
- Tacoma, water allocations closer to current system capacity
- Everett, largest system capacity
- Note: simulations prior to adaptations

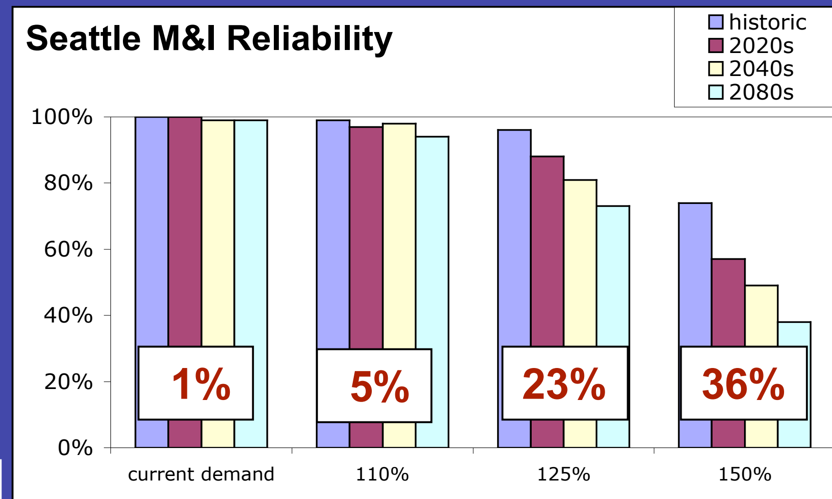


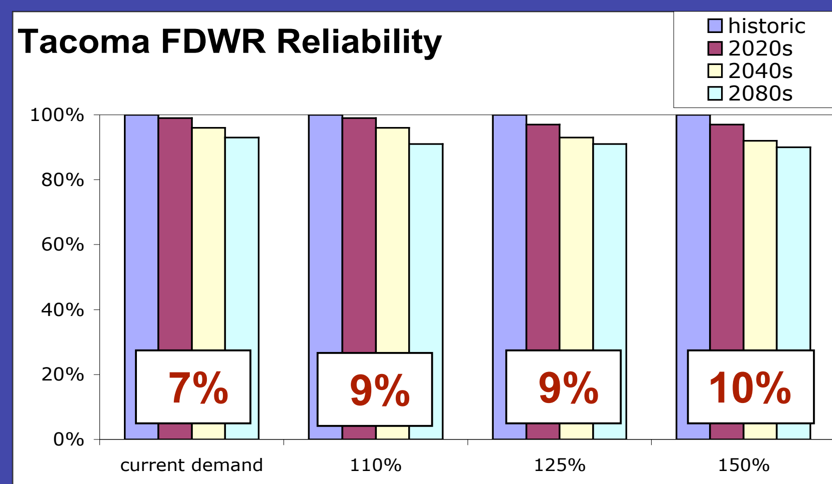


Puget Sound Basin

municipal supply - changing demand

- With demand increases, climate change has more impact reliability
- Importance of conservation measures/reduced demand
- Systems respond different depending on storage capacity, basin transitions, system demands, adaptive capacity
- Note: simulations prior to adaptations





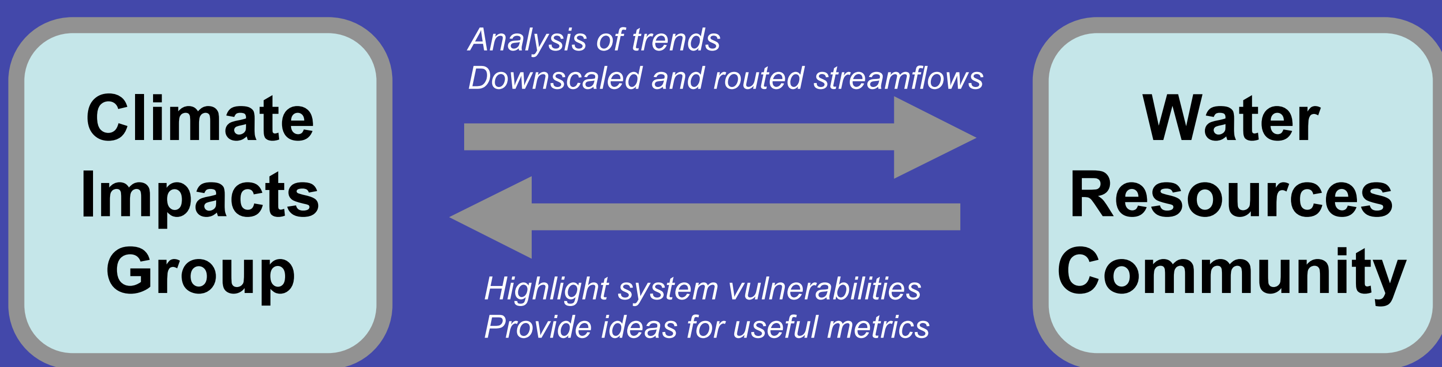
Everett M&I Reliability — 0% diff, all 100%

Specific findings for the state of Washington

1) Primary impacts of climate change will be a shift on average in the timing of peak river flow from late spring to winter
2) In Yakima, future projections indicated that reservoir system will be less able to supply water to all users, especially those with junior water rights
3) In Puget Sound, with current demands, systems able to accommodate changes from future climate. With demand increases, systems less able to accommodate changes from future climate, conservation measures matter
4) Other aspects of system performance complicate management decisions such as environmental flows, flood control, and hydropower

General findings

1) Is the scale (space, time) of the information provided by future forecasts relevant to decisions?
   Relevant, basin-specific information and metrics
2) If planning relies on past variability, how does this change when we can no longer assume stationarity?
   Scenarios of a transient climate
3) How can we account for uncertainty in these forecasts?
   Ensemble estimations
4) How can we change planning and management to account for this non-stationarity uncertainty, and risk?
   Adaptive responses and agreements



Acknowledgements

- Chris Lynch, US Bureau of Reclamation, Yakima Project
- Lance Vail and Andre Coleman, Pacific Northwest National Lab
- Seattle Public Utilities
- Tacoma Water
- US Army Corps of Engineers, Howard Hanson Project
- City of Everett
- Snohomish County Public Utility District

The Climate Impacts Group

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