UNIVERSITY OF WASHINGTON

Department of Civil and Environmental Engineering

Washington's water resources in a changing climate

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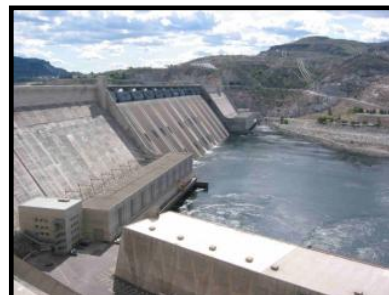
for

2009 University of Washington Water Center Annual Review of Research

Seattle

February 18, 2009



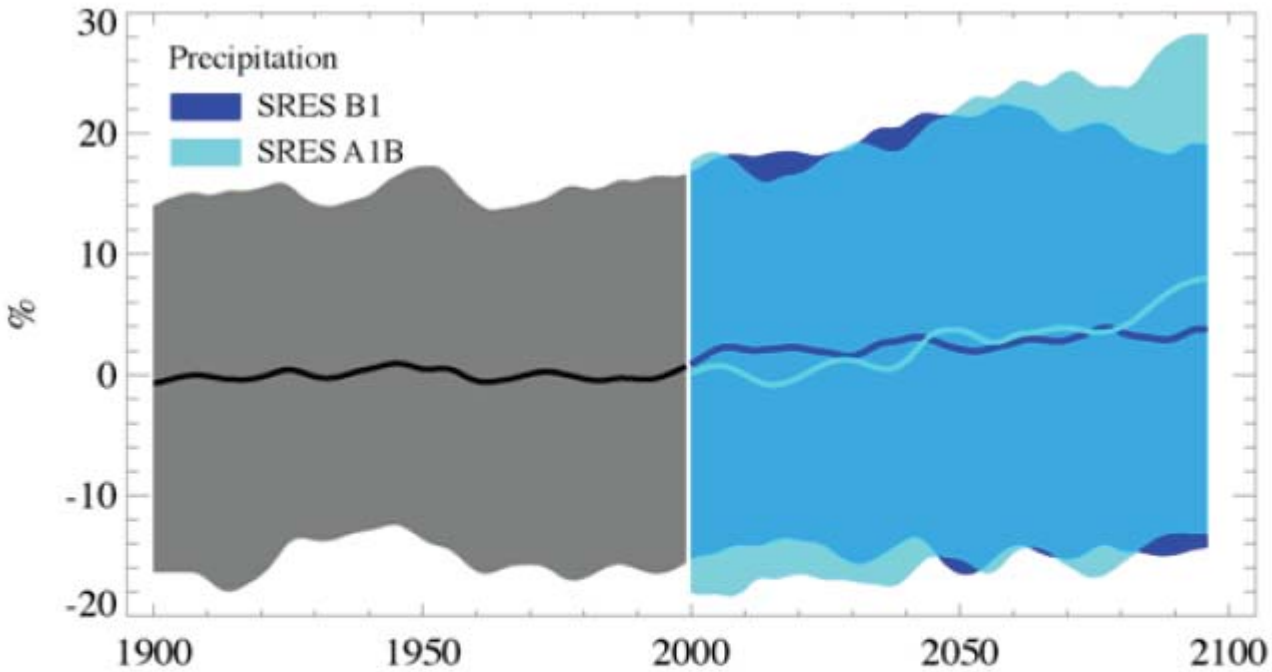
Washington State Climate Change Impacts Assessment:

- **April 20, 2007: State Legislature of Washington passed HB 1303 which mandated *the preparation of a comprehensive assessment of the impacts of climate change on the State of Washington* to be performed by the UW Climate Impacts Group**

- **The assessment was to be focused on the impacts of global warming generally, and specifically in relation to:**

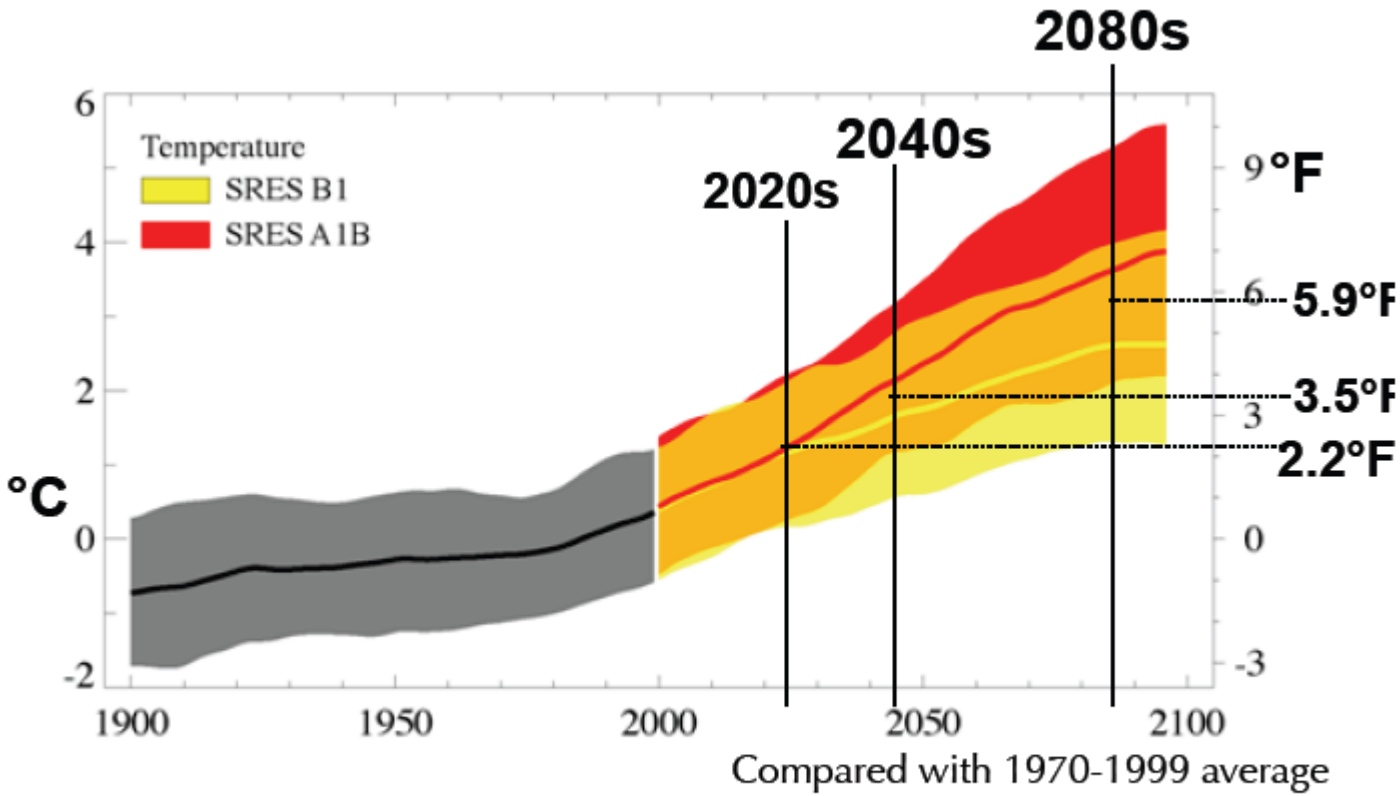
  - public health,
  - Agriculture (partner: WSU)
  - the coastal zone
  - forestry
  - **Infrastructure (specifically stormwater)**
  - **water supply and management (partner: PNNL)**
  - **Salmon and ecosystems**
  - **energy**

Projected annual changes in precipitation for PNW (averaged over 111° – 124° W, 41.5° – 49.5° N)

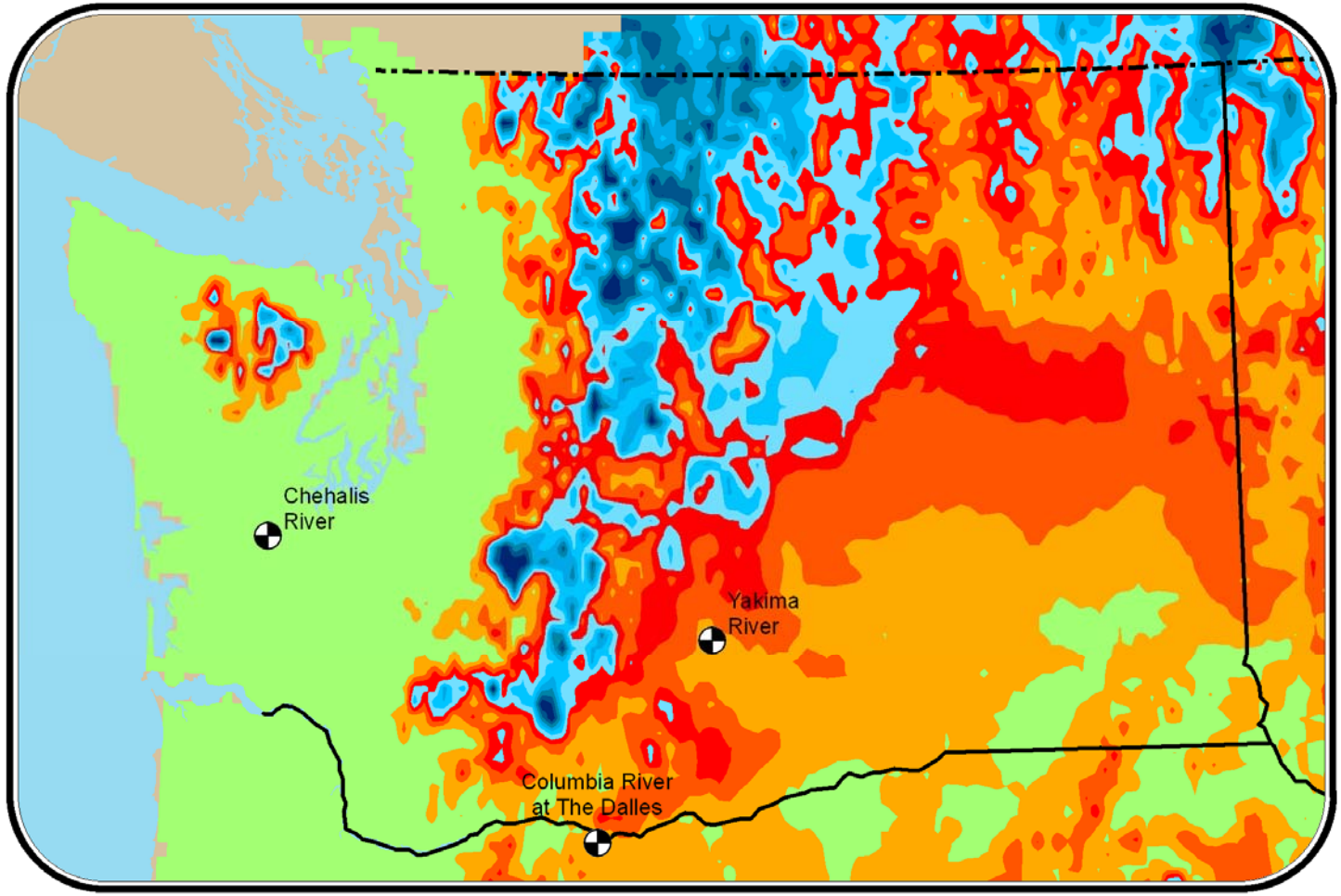


Changes in annual precipitation averaged over all models are small but some models show large seasonal changes, especially toward ***wetter autumns and winters*** and ***drier summers.***

Projected annual changes in surface air temperature for PNW (averaged over 111° – 124° W, 41.5° – 49.5° N)



Assessment Overview: Study Region



Ratio of Peak Snow-Water Equivalent to October-March Precipitation

Rain dominant -- Transition -- ----- Snow dominant -----

0.0 - 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Global Climate Models

2 different emissions scenarios
20 models using A1B (medium scenario)
19 models using B1 (low scenario)

Downscaled to regional projections of P and T for the 2020s , 2040s, 2080s

Hydrologic Models

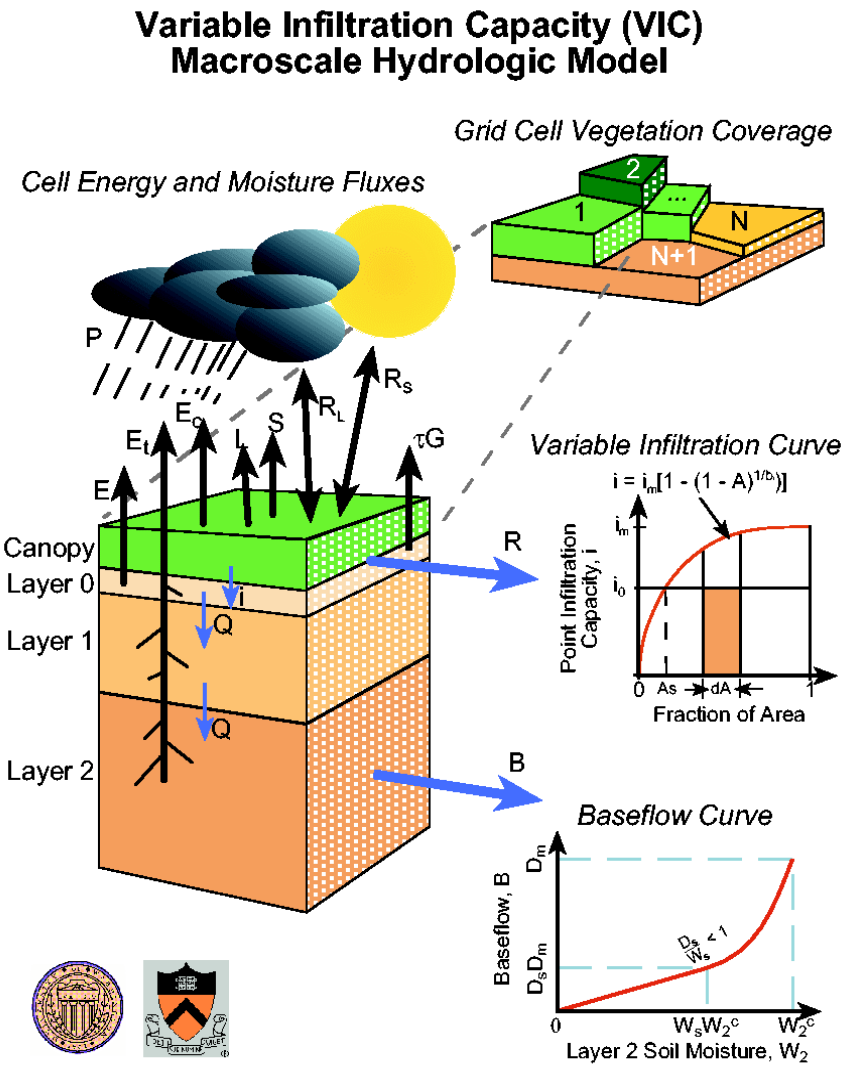
Projections of future changes in snowpack, streamflow, soil moisture, etc.

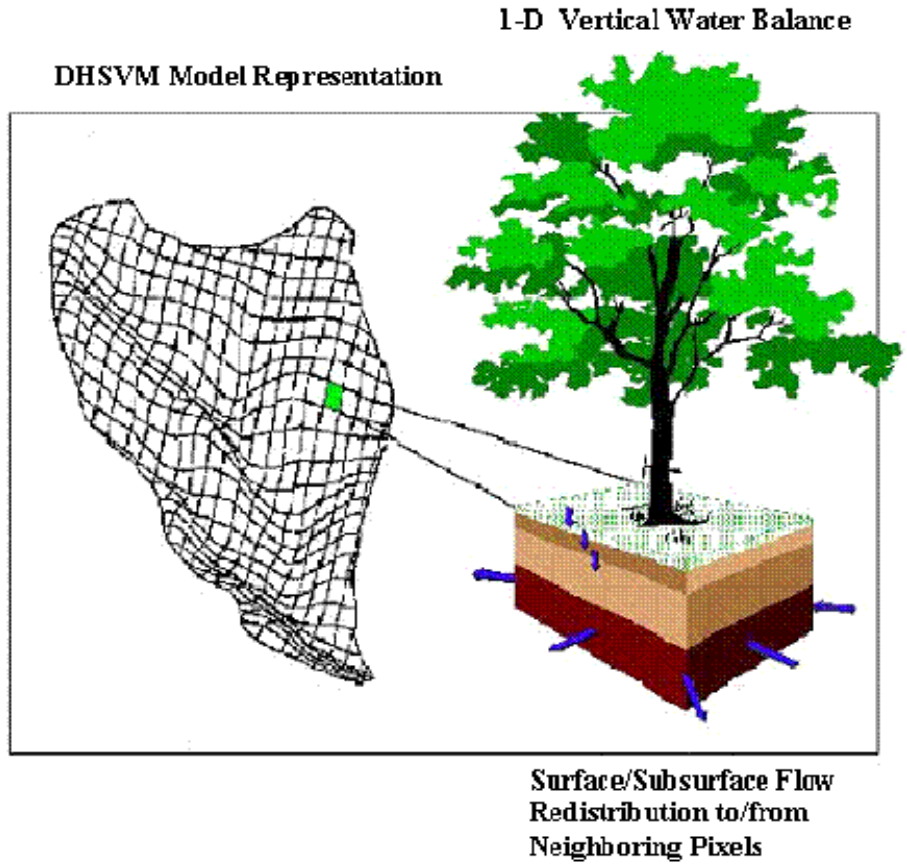
Energy

Salmon

Forests **Water Management** **Infrastructure** **Agriculture**

Hydrologic Simulations





Large Scale Model (VIC)
~12mi² per cell

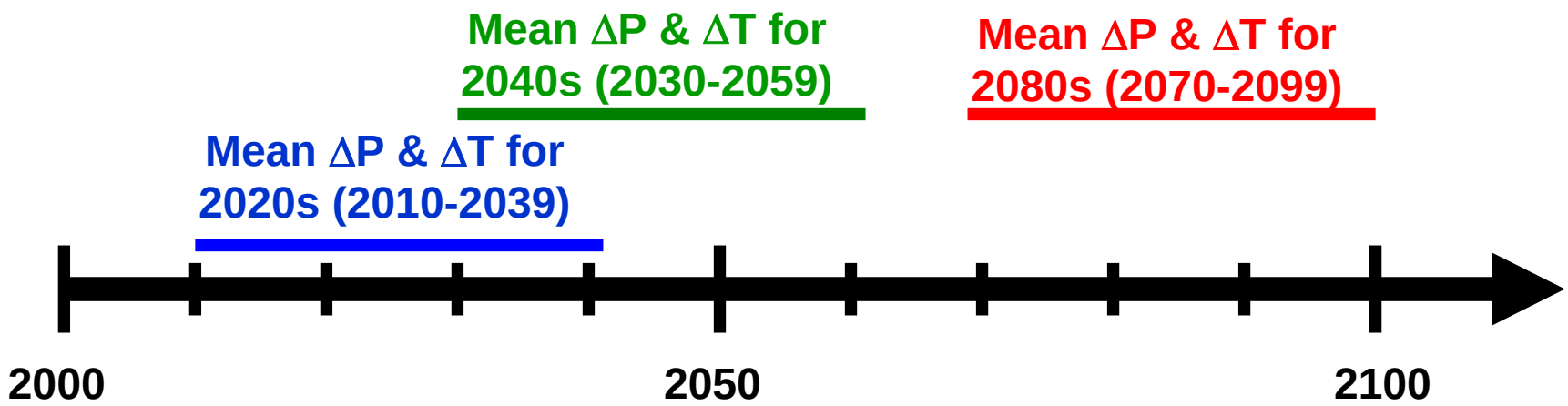
Fine Scale Model (DHSVM)
~6 acres per cell

Climate Change Projections (using "delta method")

39 Climate Change Scenarios

- each is a monthly timeseries of P and T from 2000-2099

3 chosen projection windows



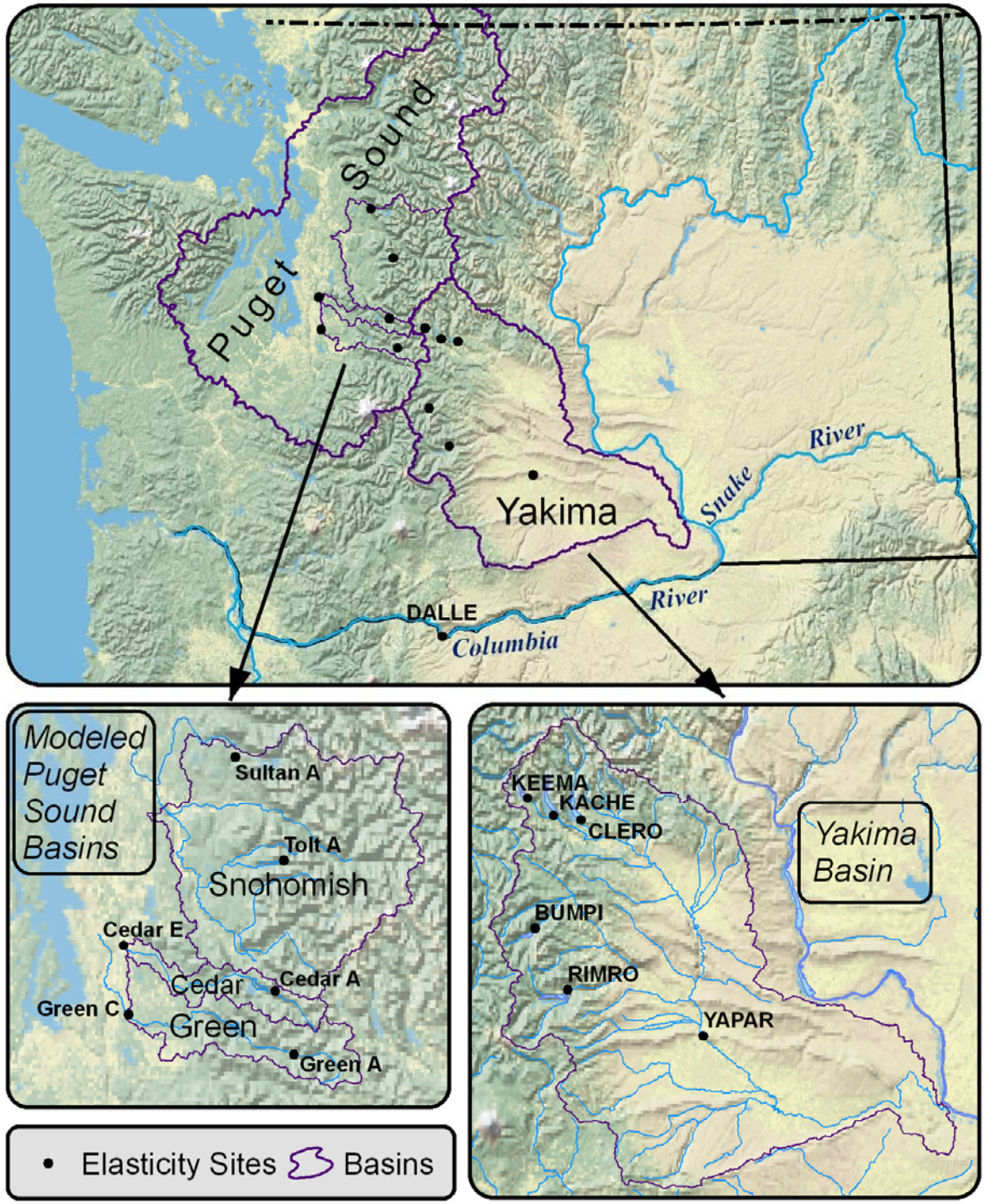
Historical daily timeseries (1916-2006) perturbed by mean monthly ΔP & ΔT

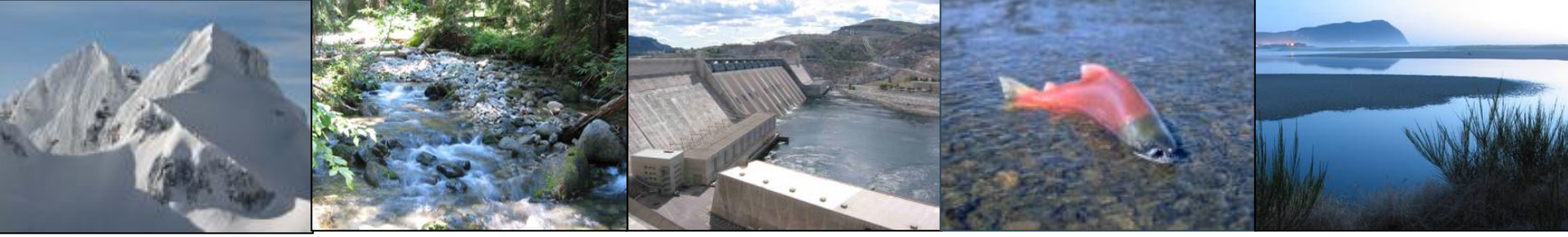
(same mean ΔP and ΔT applied to each day in a given month)

New daily timeseries which incorporates historical daily patterns and future projections of precipitation and temperature

Focus Watersheds

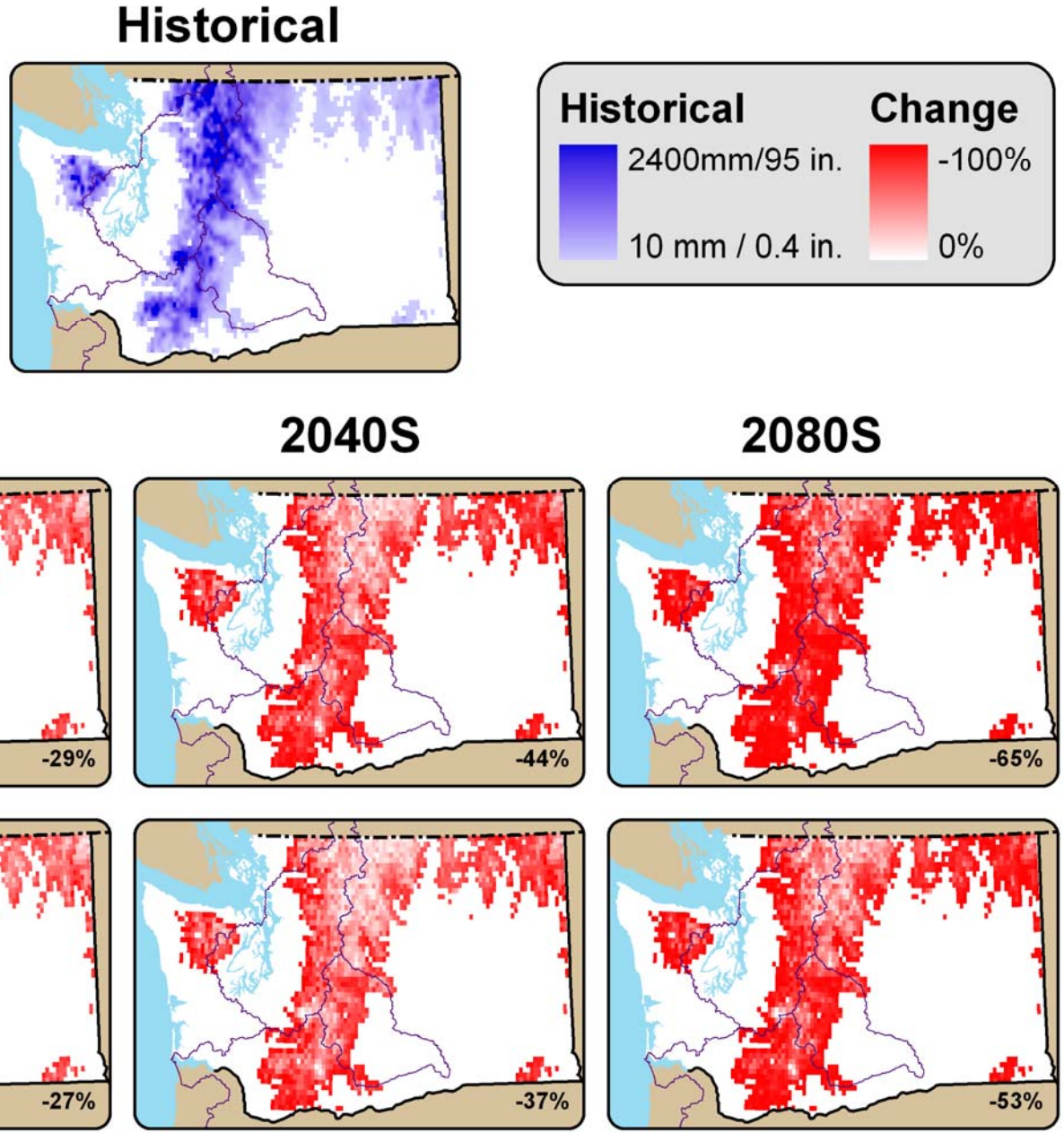
- Columbia River
  - Washington portion
- Puget Sound
  - Green River
  - Snohomish River
  - Cedar River
  - Tolt River
- Yakima River





Implications of 21st century climate change on Washington's watersheds

April 1 Snow-Water Equivalent

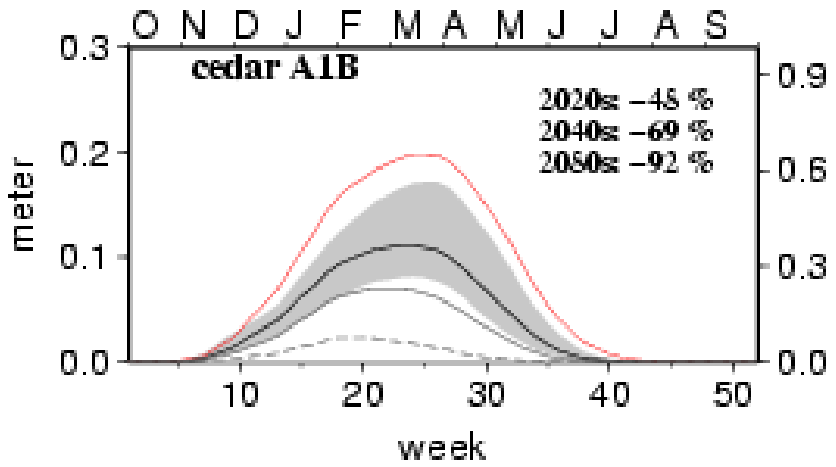


Elsner, M.M. et al. 2009: Implications of 21st Century climate change for the hydrology of Washington State (in review)

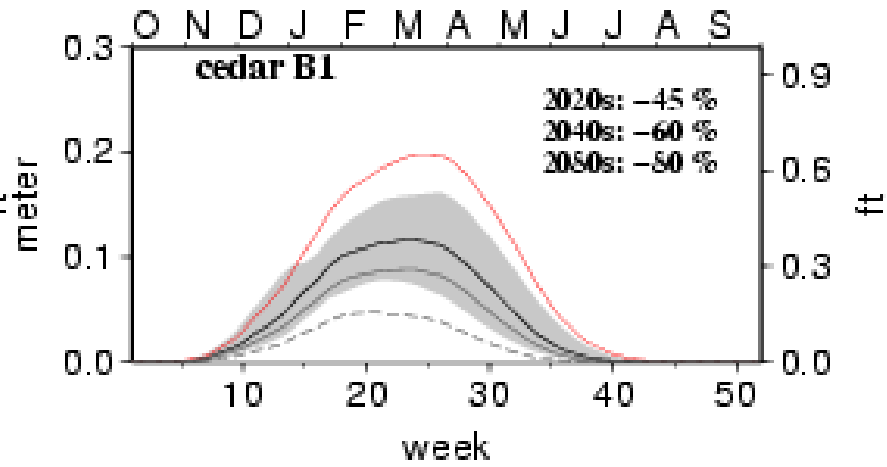
Weekly Snowpack Projections

Cedar River

Medium

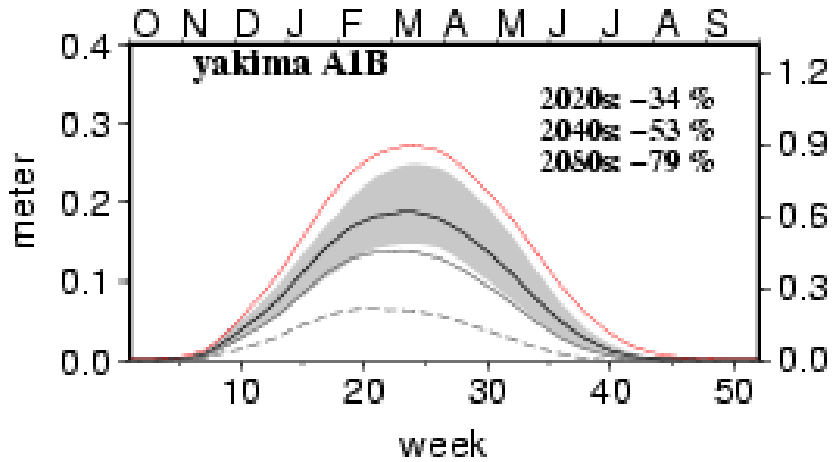


Low

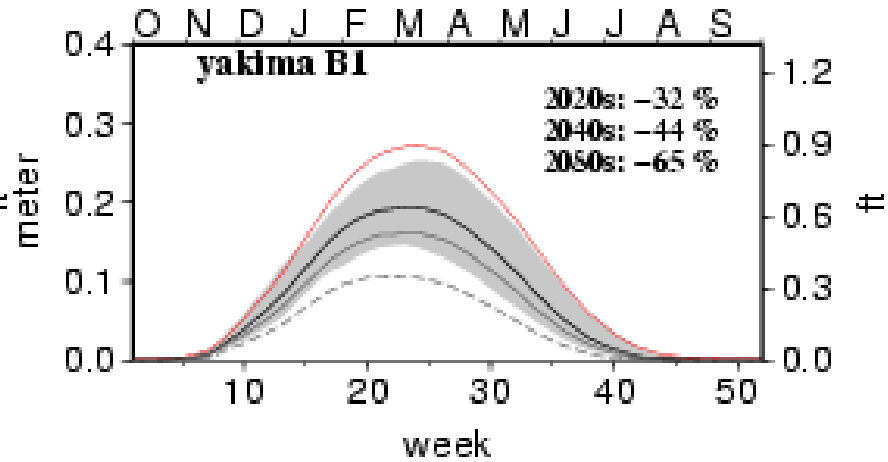


Yakima River

Medium

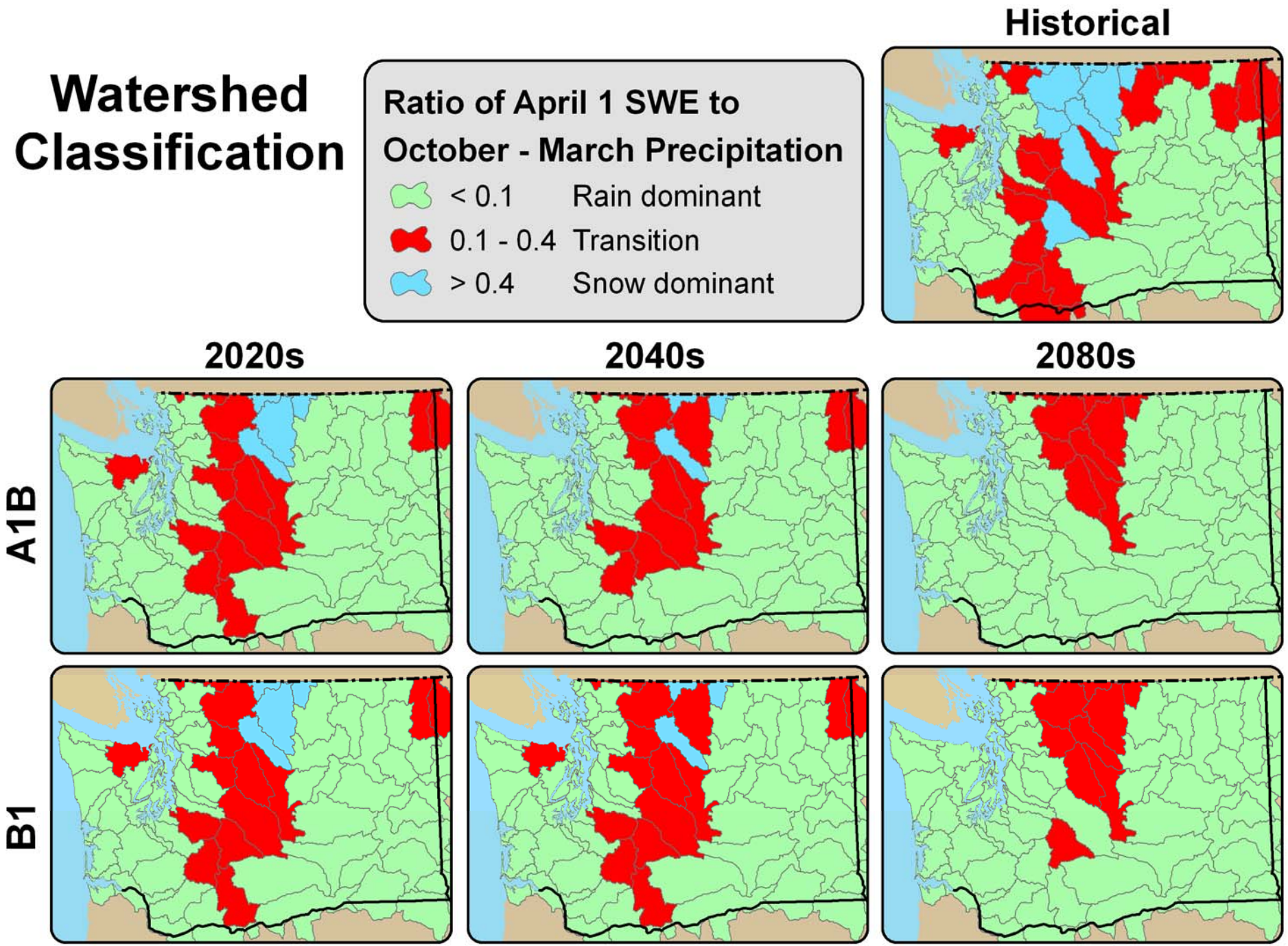


Low



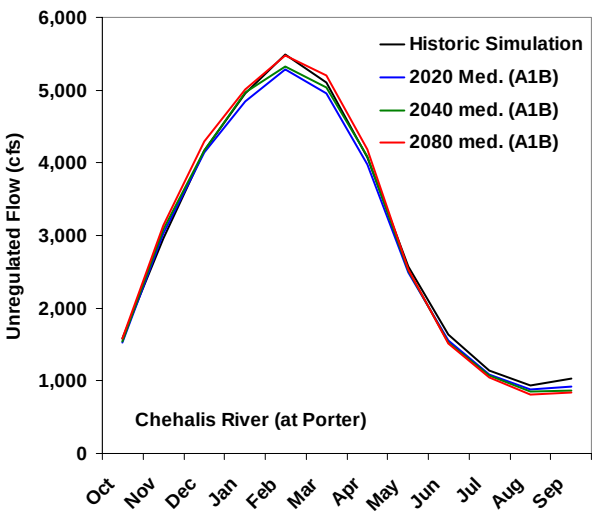
hist. 2020s 2040s 2080s 2020s range

Watershed Classification

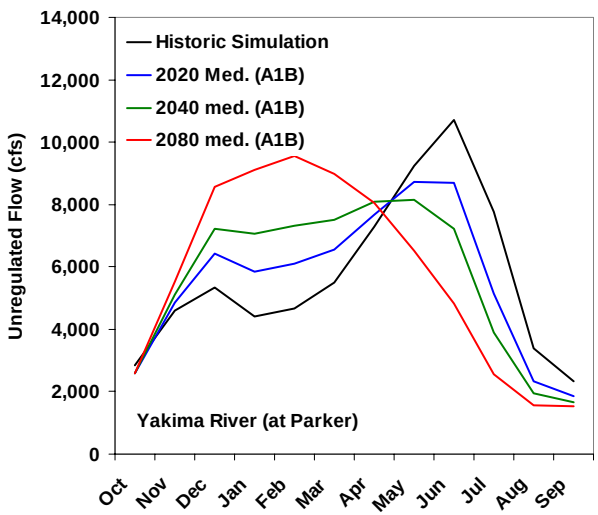


Monthly Streamflow Projections

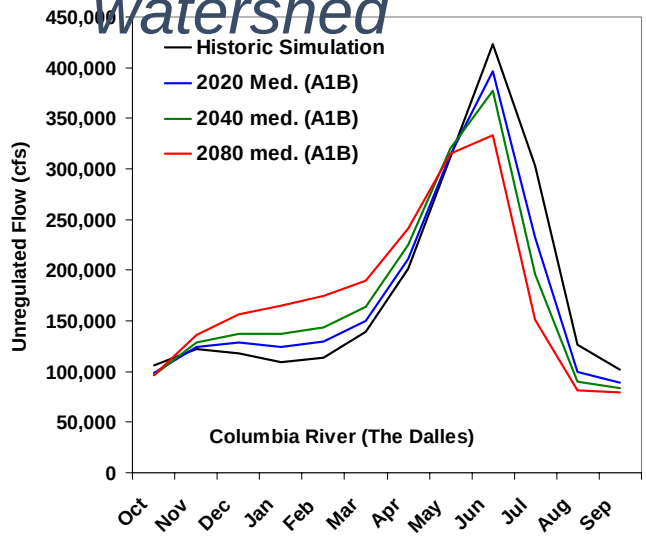
Rain dominant watershed



Transient rain-snow watershed

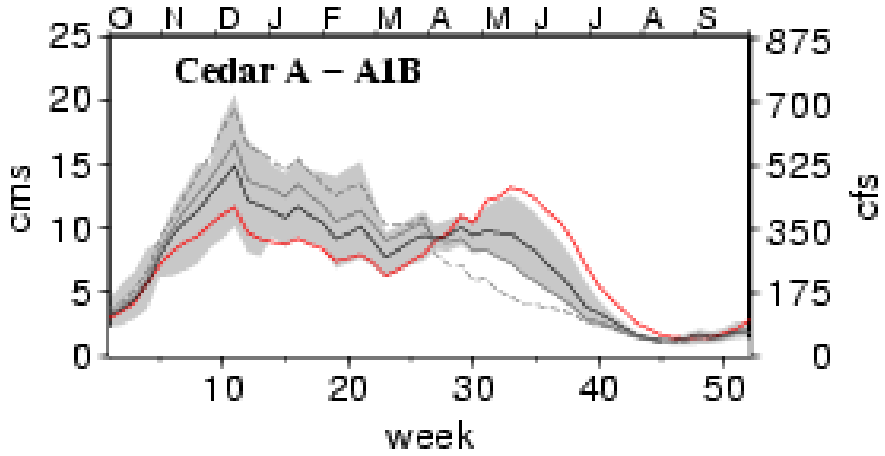


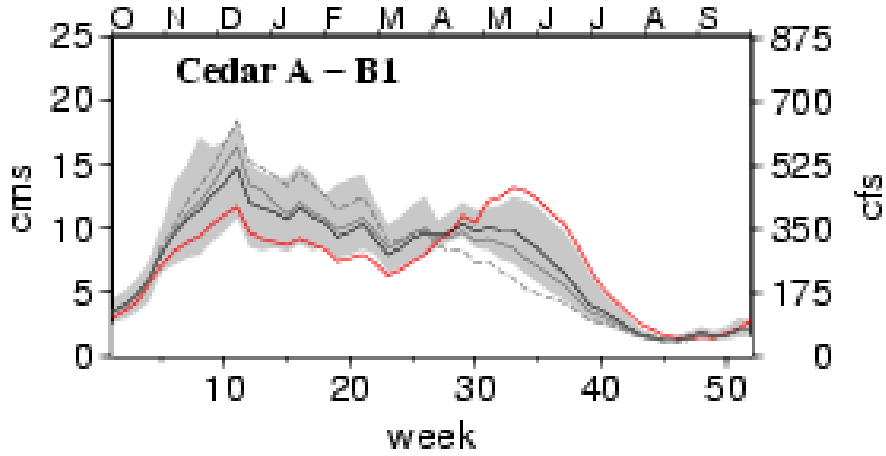
Snowmelt dominant watershed



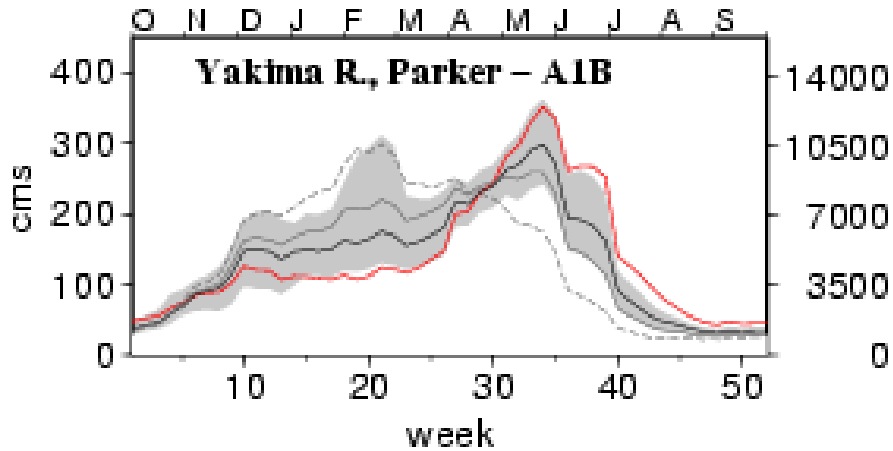
Weekly Streamflow Projections

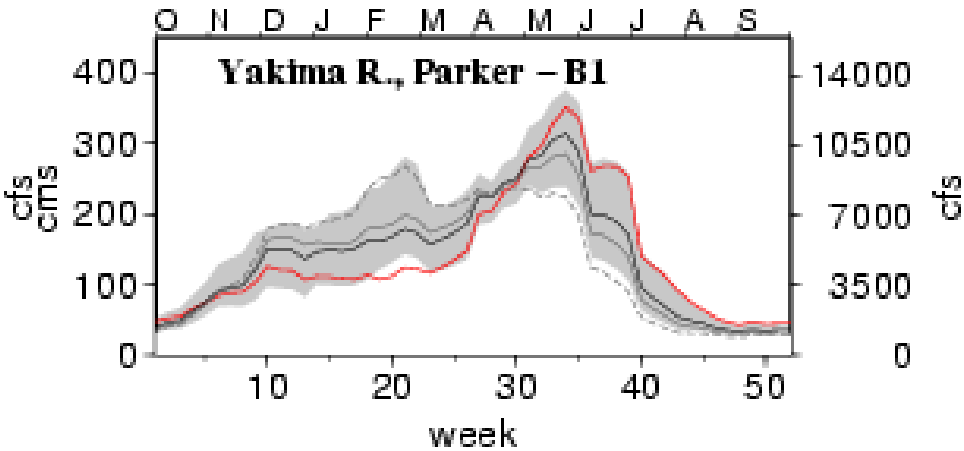
Cedar River - inflow to Chester Morse Reservoir





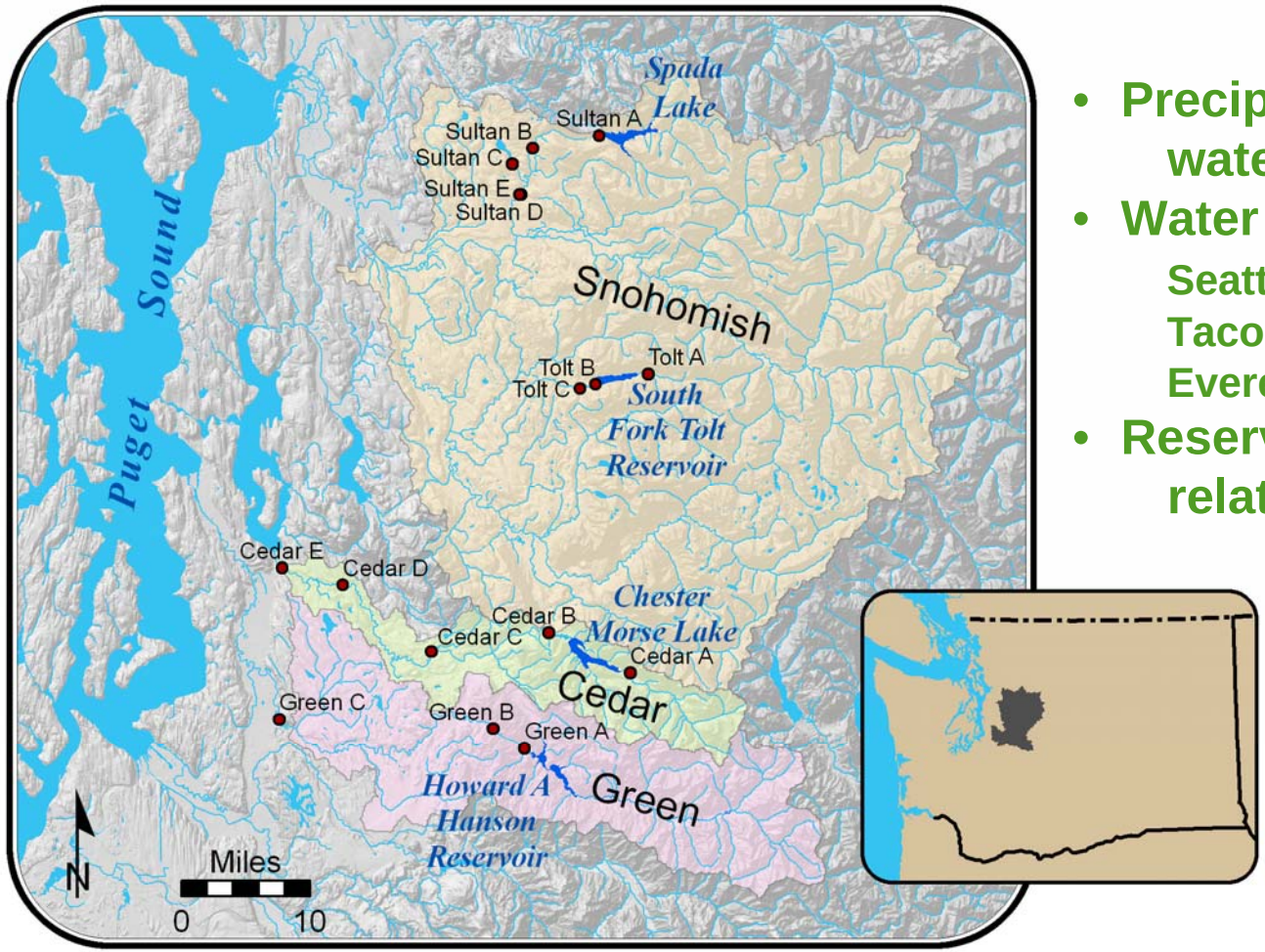
Yakima River at Parker





2020s | 2020s range | 2040s | 2080s | historical

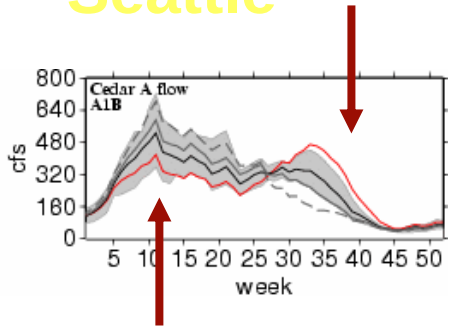
Case study 1: Puget Sound Basin

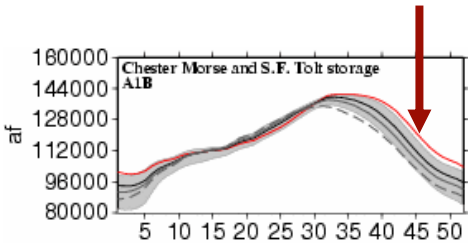


- **Precipitation in fall-winter, water demand in summer**
- **Water management systems:**
  - **Seattle - municipal, fish**
  - **Tacoma - municipal, flood control**
  - **Everett - municipal, hydropower**
- **Reservoir capacities small relative to annual flow**

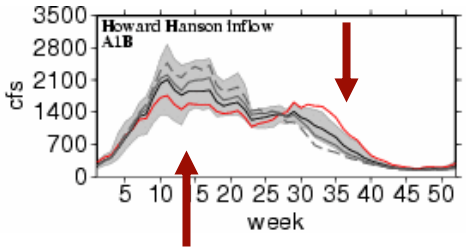
Puget Sound Basin

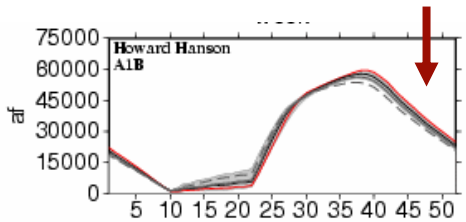
Seattle



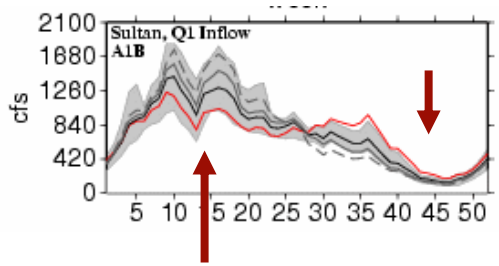


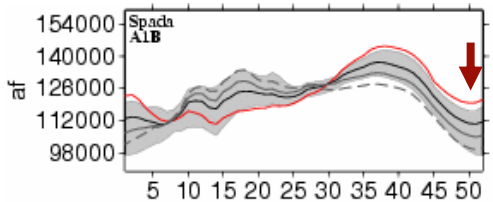
Tacoma





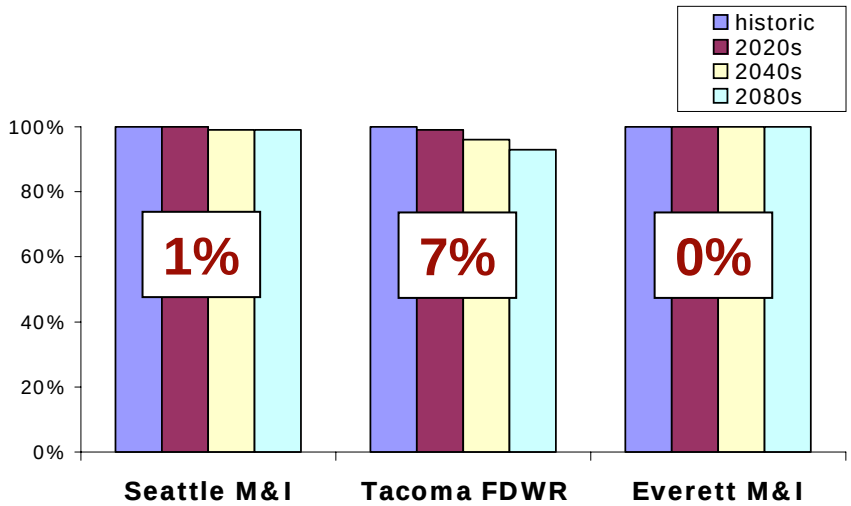
Everett





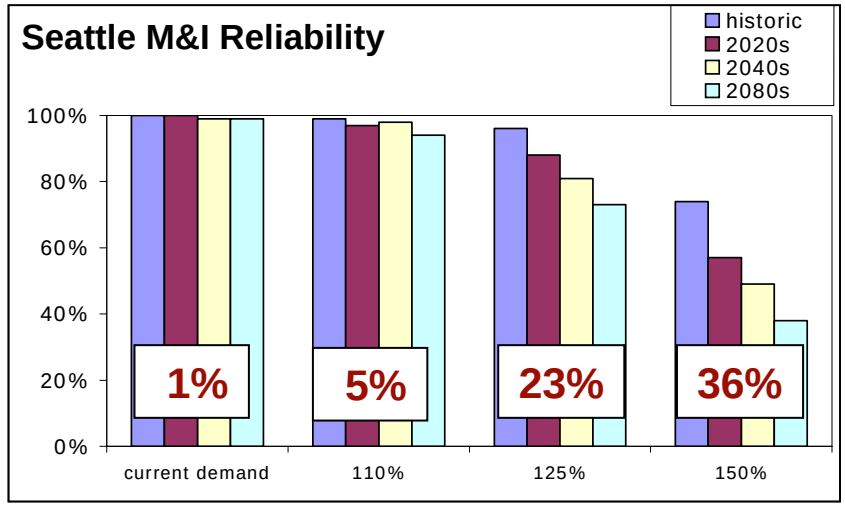
Puget Sound Basin

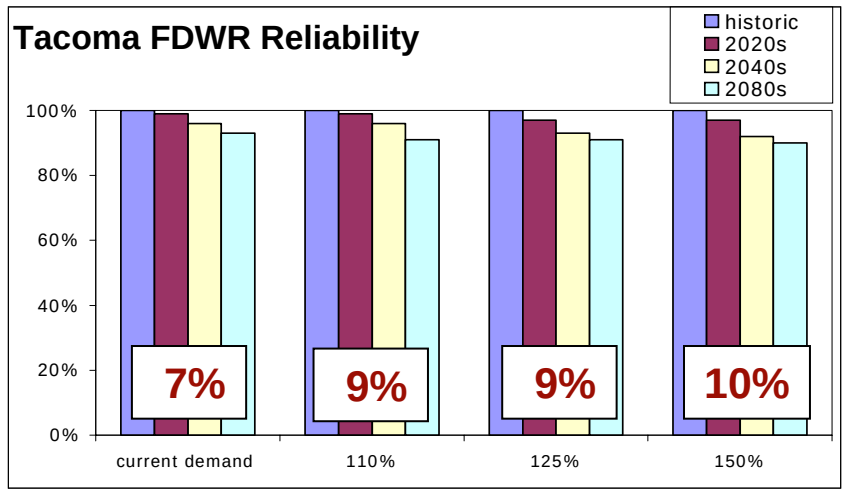
municipal supply - current demand



Puget Sound Basin

municipal supply - changing demand



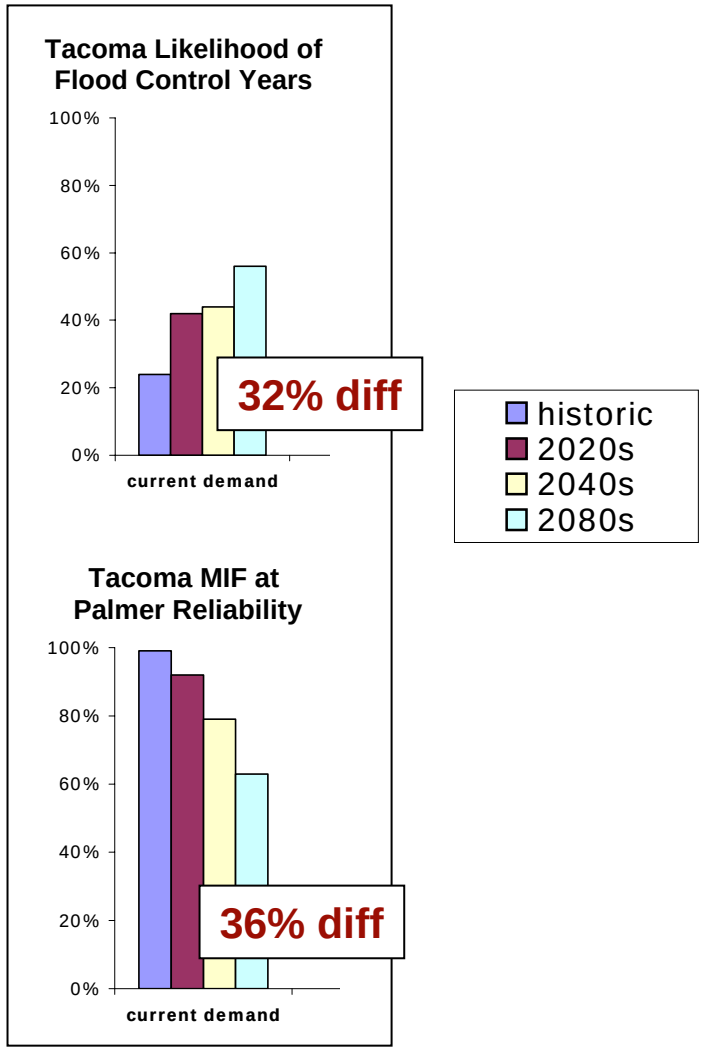


Everett M&I Reliability

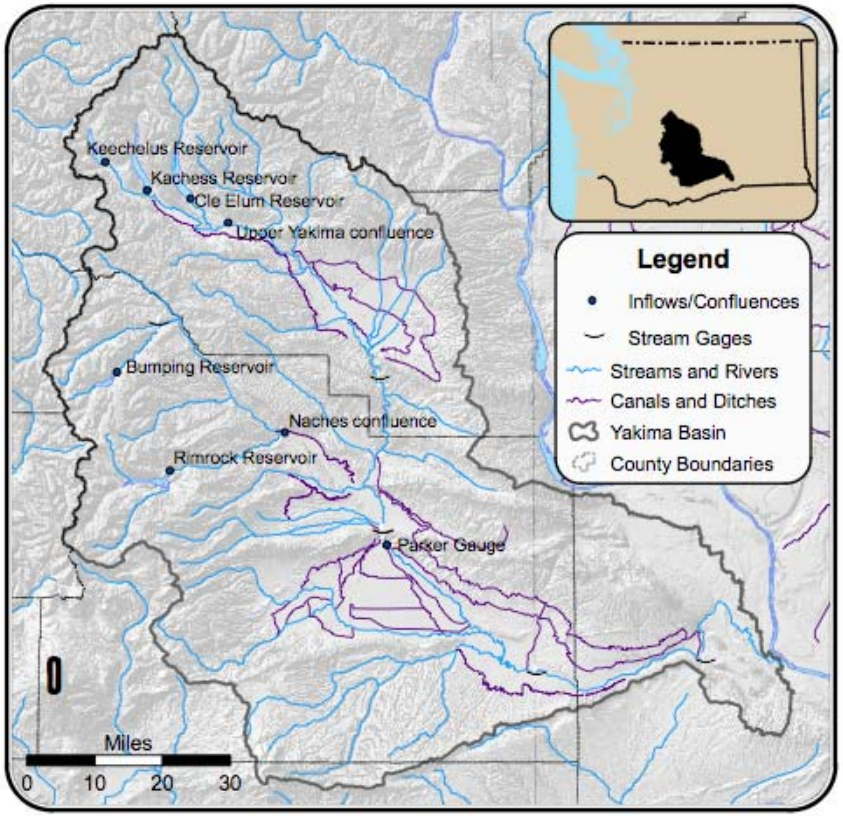
0% diff, all 100%

Puget Sound Basin

operations beyond municipal supply



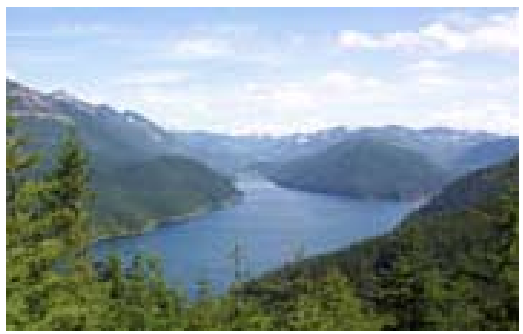
Case study 2: Yakima River Basin



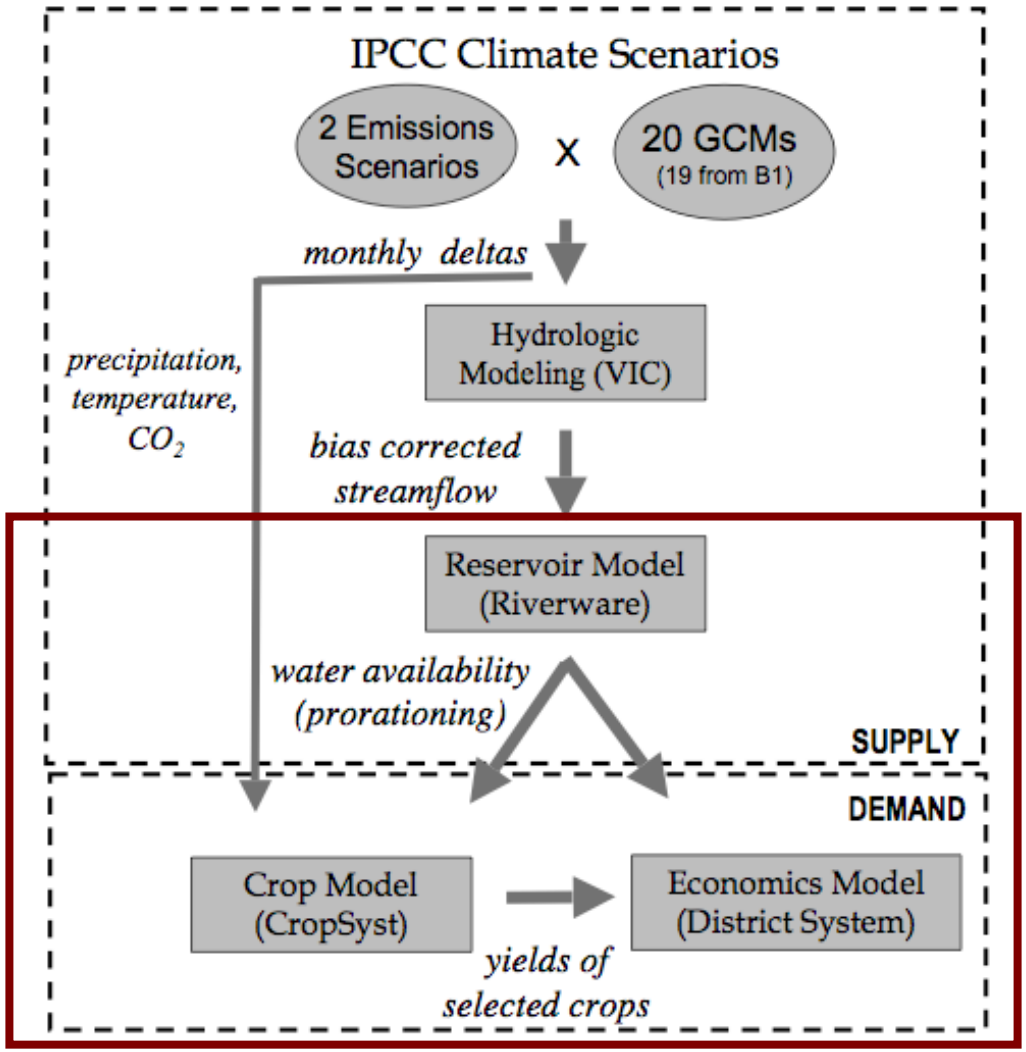
- Irrigated crops largest agriculture value in the state
- Precipitation (fall-winter), growing season (spring-summer)
- Five USBR reservoirs with storage capacity of ~1 million acre-ft, ~30% unregulated annual runoff
- Snowpack sixth reservoir
- Water-short years impact water entitlements

Key Findings: Puget Sound Basin

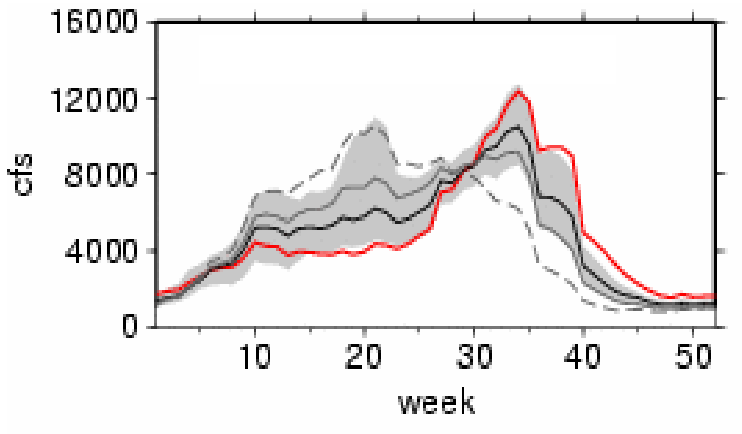
1) **Primary impacts of climate change will be a shift on average in the timing of peak river flow from late spring to winter**
2) **With current demands, system reliability able to accommodate changes**
3) **With demand increases, system reliability reduced, conservation measures matter**
4) **Other aspects of system performance complicate management decisions such as environmental flows, flood control, and hydropower**



Yakima Basin Methods

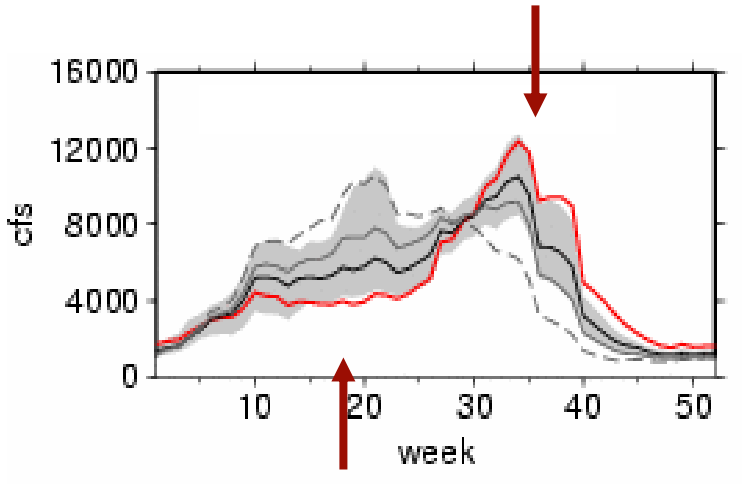


Yakima River Basin



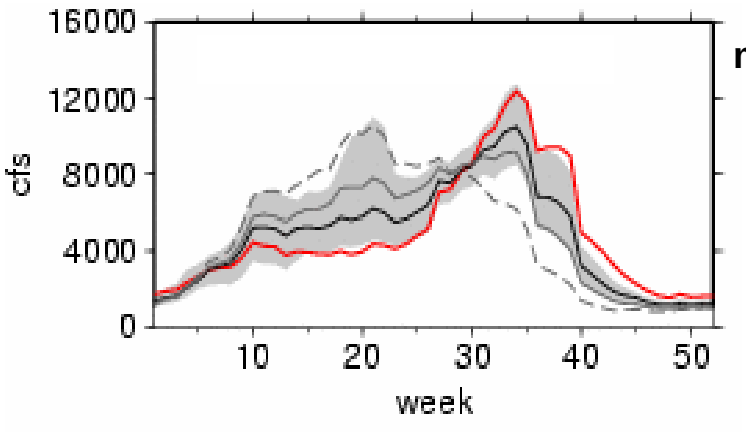
Unregulated

Yakima River Basin



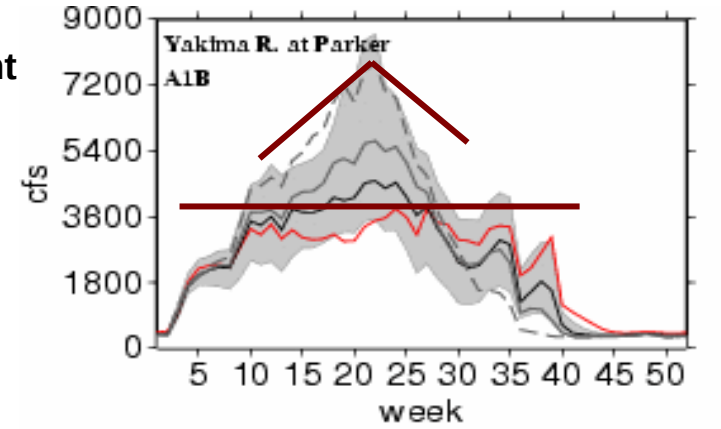
Unregulated

Yakima River Basin



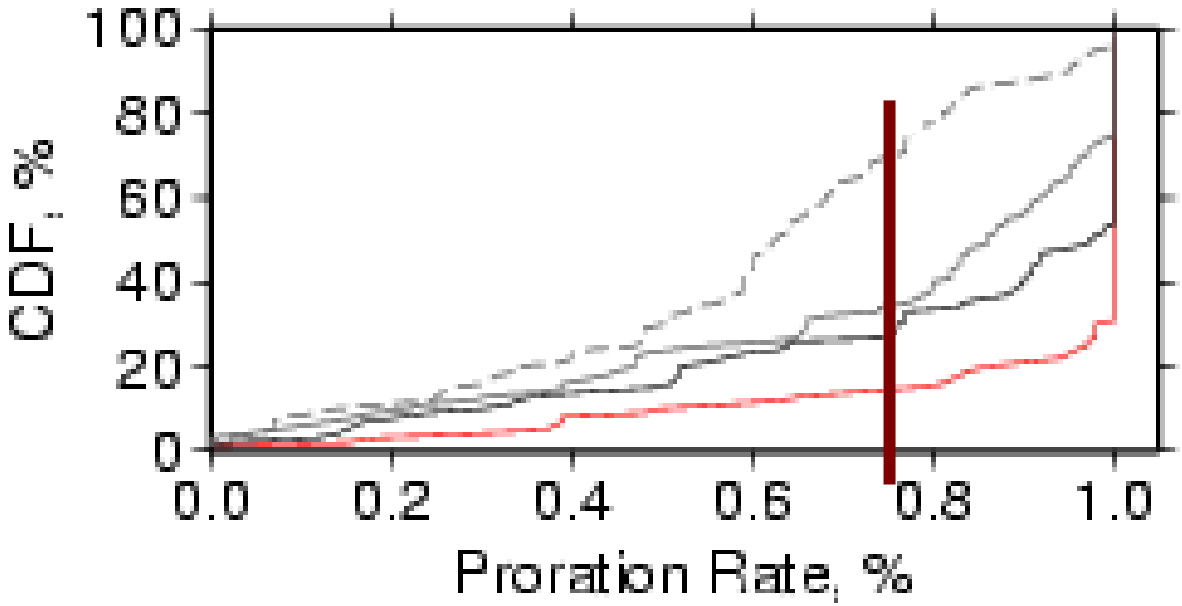
Unregulated

management model

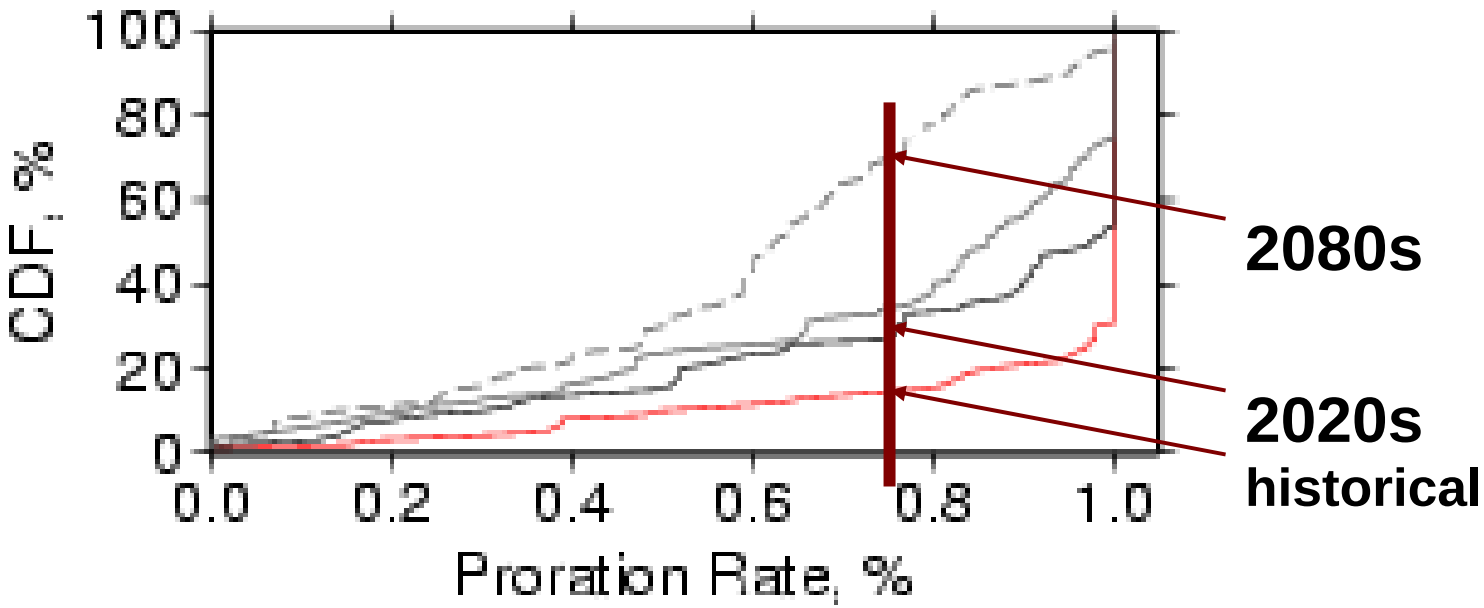


Regulated

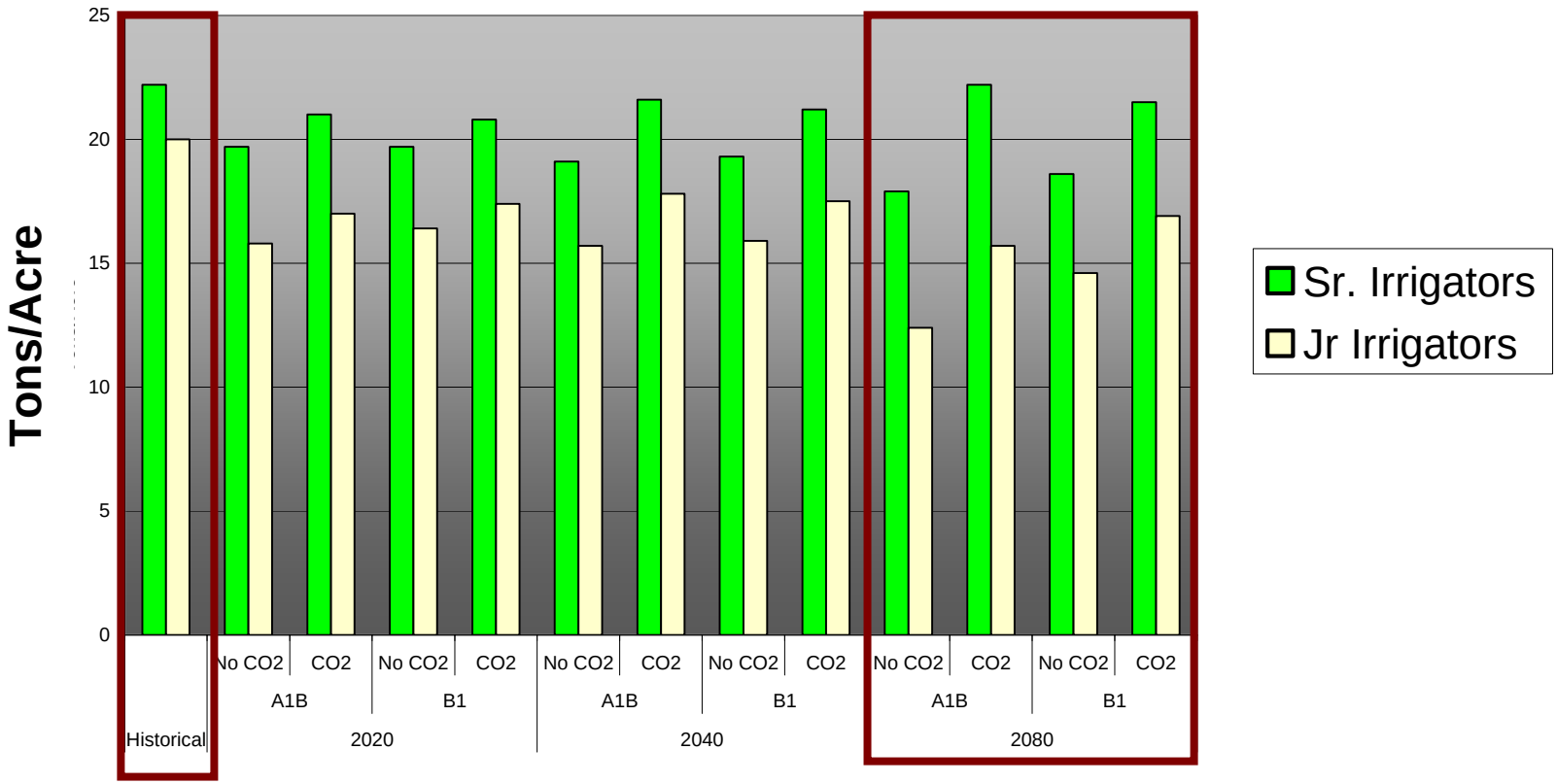
Yakima River Basin



Yakima River Basin



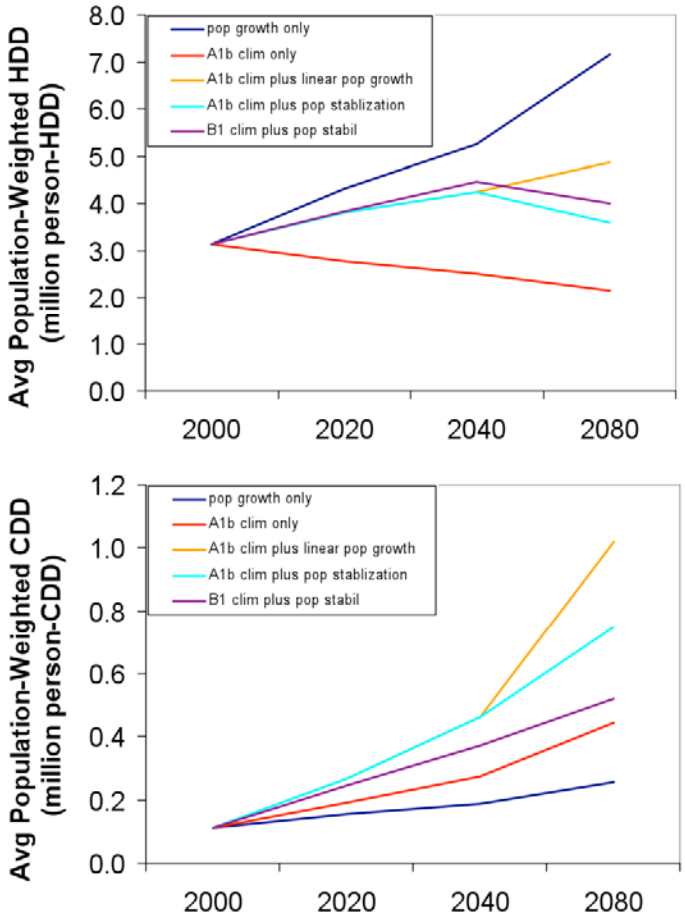
Crop Model - Apple Yields

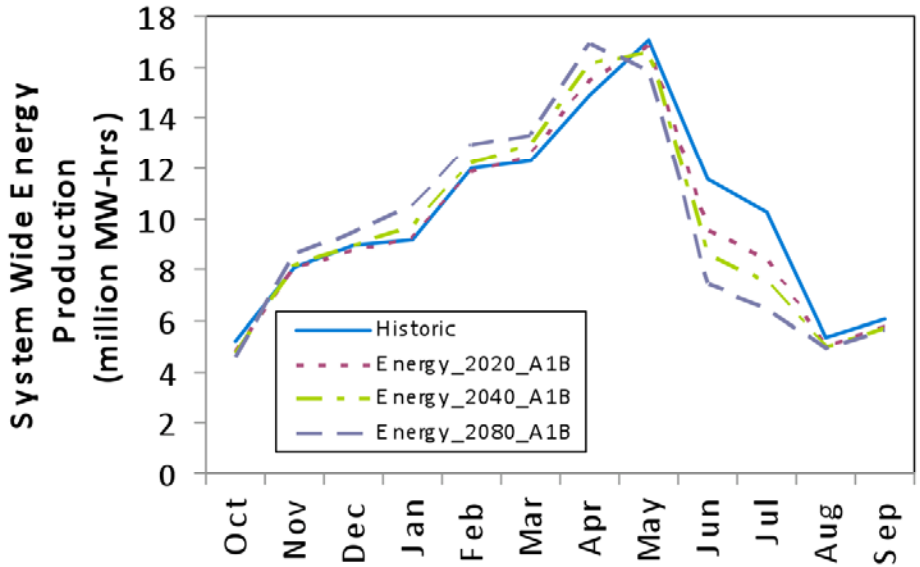


Key Findings
Yakima River Basin

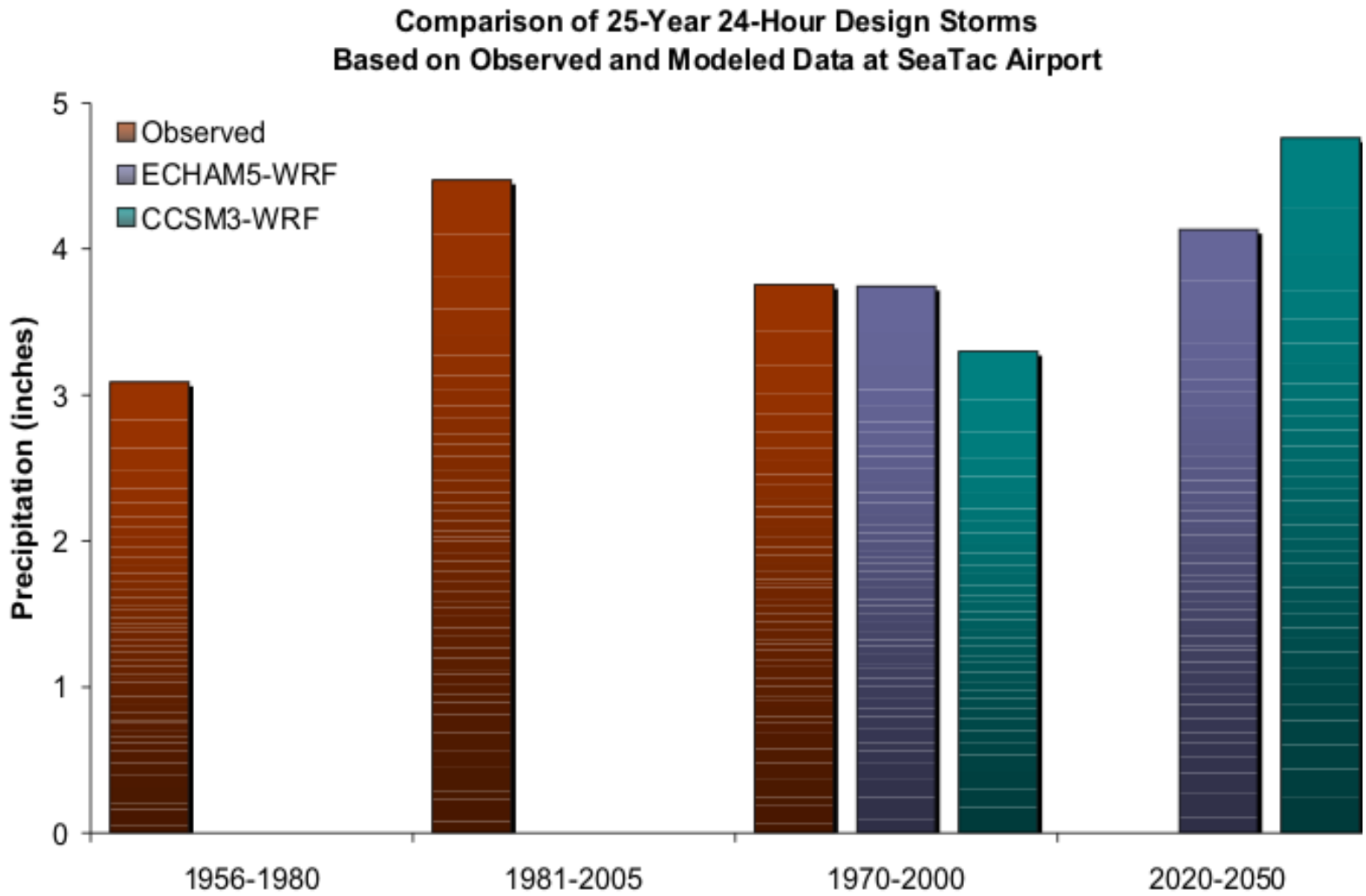
1) **Future projections indicated that reservoir system will be less able to supply water to all users, especially those with junior water rights**
2) **Earlier and shorter growing season - apples 12 days earlier, cherries 22 days earlier season start, month earlier harvest**
3) **Yields decline - under A1B emissions scenario, average apple and cherry yield are likely to decline by 20% to 25% (2020s) and 40% to 50% (2080s) for junior water holders**
4) **Crop values decline - value of apple and cherry production is likely to decline by 5% ($20 million) in 2020s,16% ($70 million) in the 2080s**

Shifts in energy production and demand

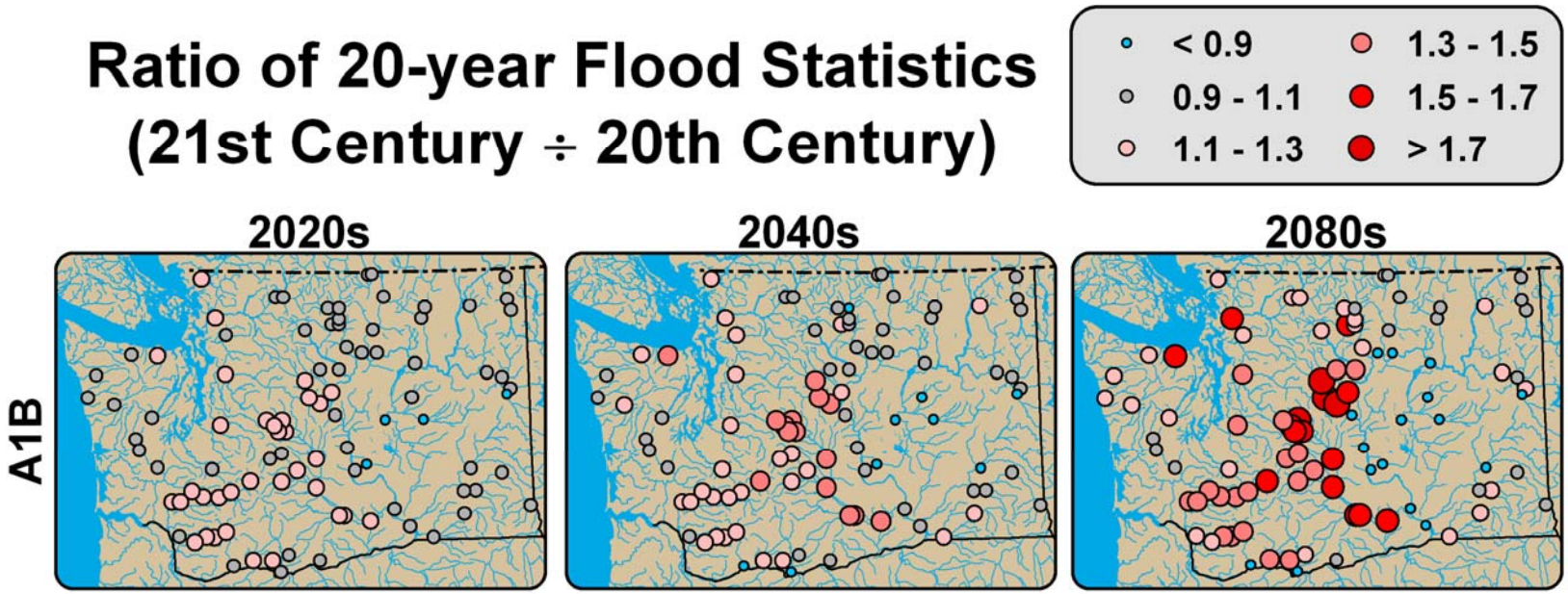




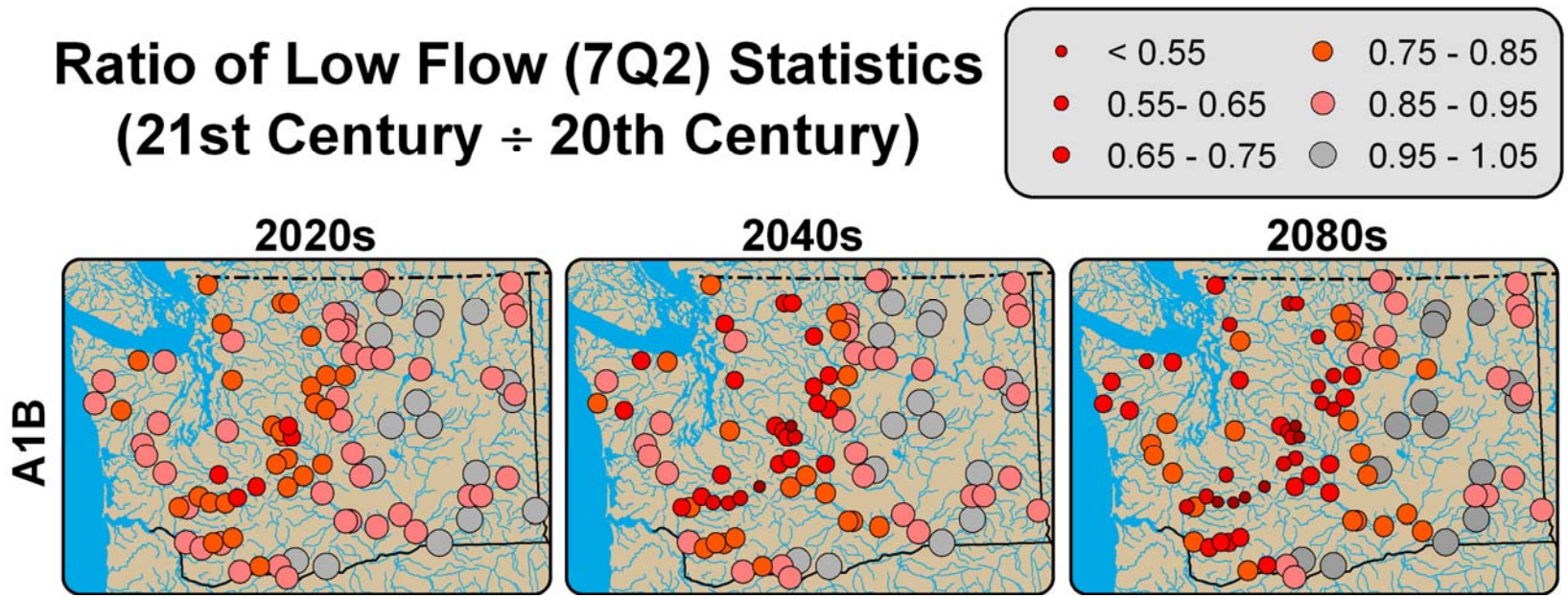
Changes in precipitation maxima



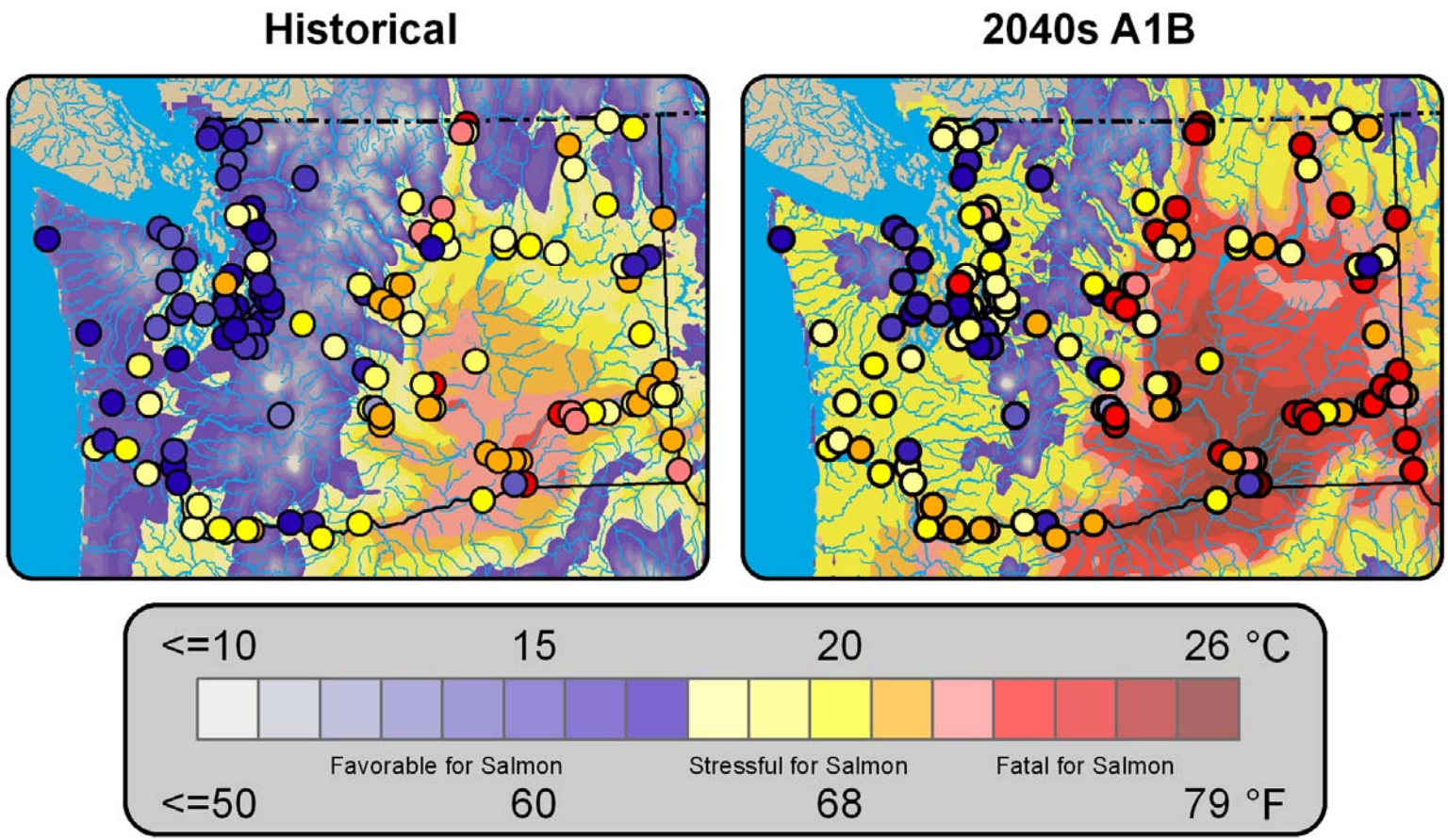
- Models project **more winter flooding** in sensitive "transient runoff" river basins that are common in the Cascades
  - Likely reducing survival rates for incubating eggs and rearing parr



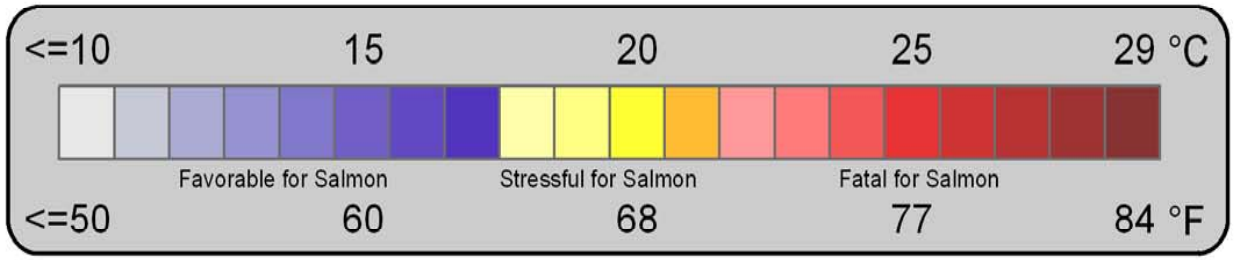
- **Summer base flows are projected to drop substantially** (5 to 50%) for most streams in western WA and the Cascades
  - The **duration of the summer low flow season is also projected to increase in snowmelt and transient runoff rivers**, and this reduces rearing habitat



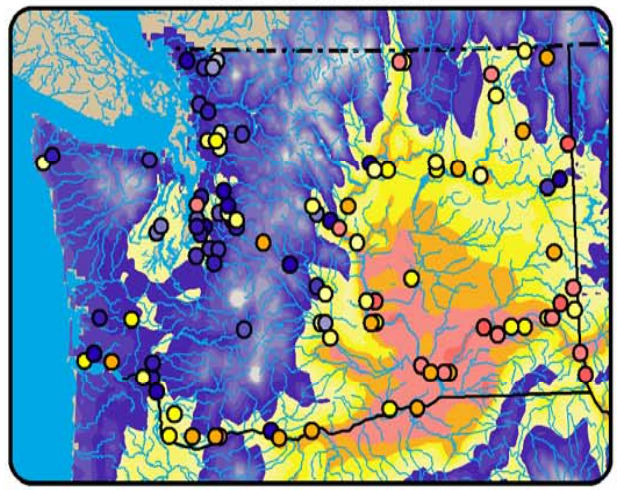
Warming trends of air and water temperatures across Washington State



August Mean Surface Air Temperature and Maximum Stream Temperature



Historical



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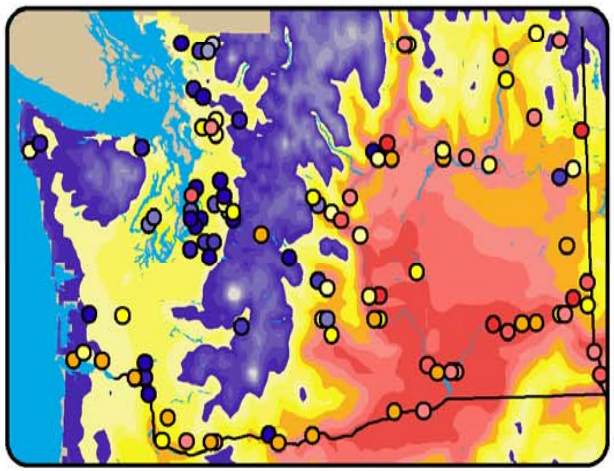
2020s



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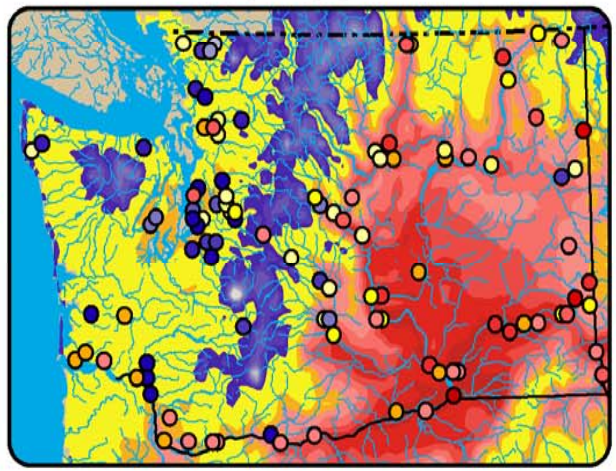
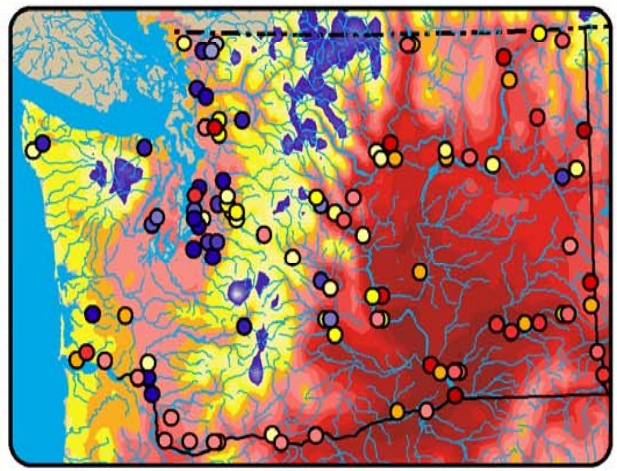
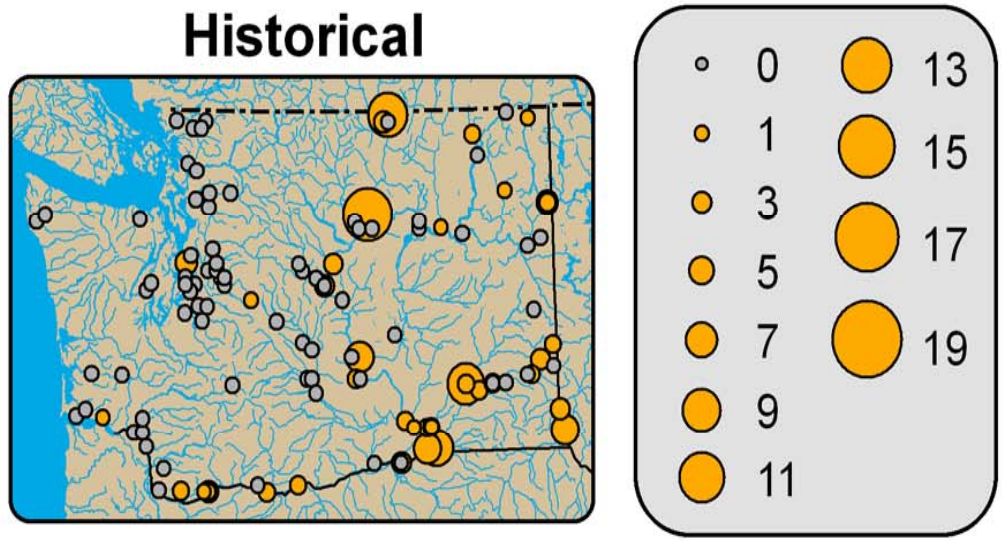


2080s



Average Number of Weeks per Year Stream Temperatures Exceed 21°C/70°F



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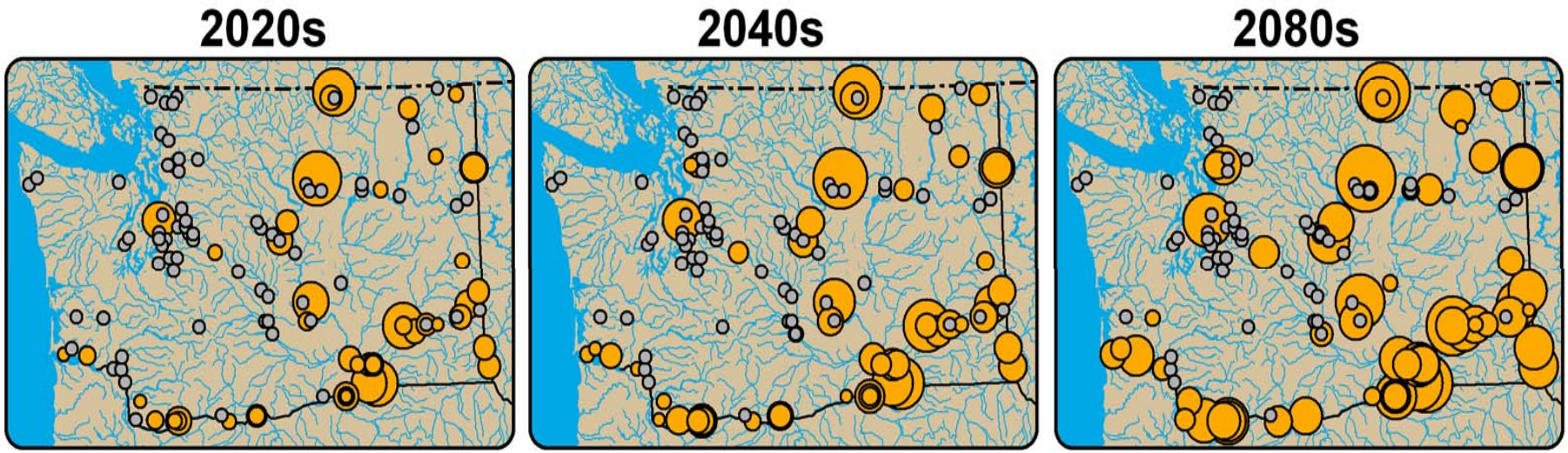

Conclusions

- Broad consensus among models that PNW temperatures will rise, continuing (and amplifying) 20th C trends
- Precipitation changes less clear, both historically and projected, although some indication of slightly wetter conditions in coming decades, esp. in winter
- Dominant hydrologic signal is reduction in SWE, and streamflow timing shifts – esp. in transient basins
- Direct effects of warming on western WA water supply systems are nonetheless modest, mostly because of demand reductions achieved over last ~10-20 years
- Impacts on the already-overallocated Yakima basin are more severe than on westside water systems
- Other water-related sectors (fish habitat, energy, infrastructure) are generally negatively impacted, although specifics vary