From the Global to the Local: Managing Climate Change Impacts across Scales

Edward L. Miles

School of Marine Affairs

Climate Impacts Group

Center for Science in the Earth System (CSES), JISAO

University of Washington

Seattle, WA. 98195

Acknowledgements

- Ze'ev Gedalof - Forest Resources, UW & CIG
- Alan Hamlet - Civil & Environmental Eng.,CSES/ CIG
- Dennis Lettenmaier - Civil & Environmental Eng.,CSES/ CIG
- Nathan Mantua - Assoc. Dir. CSES/CIG; Assoc. Prof. SAFS
- Philip Mote -CSES/ CIG, State Climatologist
- Richard Palmer = Civil & Env. Eng. &CSES/CIG
- Eric Salathe - CSES/CIG
- Amy Snover - Asst. Dir. CSES/CIG
- Matthew Wiley - Civil & Envir. Eng. & CSES/CIG

Outline

- The Framework: Linking the Global to the Local.
- Serious Implications for Planning & Policy.
- The Context: Mega-Regional & Regional Drivers & Impacts.
- Projections of Climate Change & its Impacts.
- Summary:Trends & the Take-Away Message

The Framework:

Linking the Global to the Local

On Panarchies, Nonlinearities, Thresholds, Vulnerability, & Resilience

- Social-Ecological Systems (SESs) exist as Panarchies, i.e., adaptive cycles interacting across multiple spatiotemporal scales (Holling, 1973;Walker et al. 2004). Condition of great significance for dynamics.
- Resilience = Capacity of system to absorb disturbance & reorganize while undergoing change. Problem that systems consist of nested dynamics operating at particular org scales; latter not always congruent.
- C.C. Impacts present difficulties because require mgmt of changing rates of change @ multiple space/time scales.

Panarchies, cont'd.

- Resilience contains 4 faces:
- Latitude = max amt disturbance before losing ability to recover (the failure threshold).
- Resistance = ease or difficulty of changing the system.
- Precariousness = how close system may be to failure threshold.
- Panarchies contain nonlinearities $\Rightarrow$ surprises in resilience, resistance, & precariousness.
- Adaptability both autonomous (homeostatic) or learned (deliberate).

Global Climate Change as a Unique Policy Problem :Critical Limiting Conditions for Societal Response

Table 1	
Residence Times of Greenhouse Gases in the Atmosphere	
GHG	Residence Times
Carbon Dioxide (CO_2)	50-200 Years (The range varies with sources and sinks and depends on the equilibration times between atmospheric CO_2 and terrestrial and oceanic reserves.)
Methane (CH_4)	12 years
Nitrous Oxides (N_2O)	120 years
Chlorofluorocarbons	
CFC-11	50 years
HCFC-22	12 years
Perfluorocarbon (CF_4)	50,000 years

Source: IPCC. 1990. *Climate Change: The Scientific Assessment*, Working Group 1.

Critical Limiting Conditions for Societal Response

Table 2

Timescales of the Global Carbon Cycle as Determined by Exchange Between the Atmosphere and the Ocean

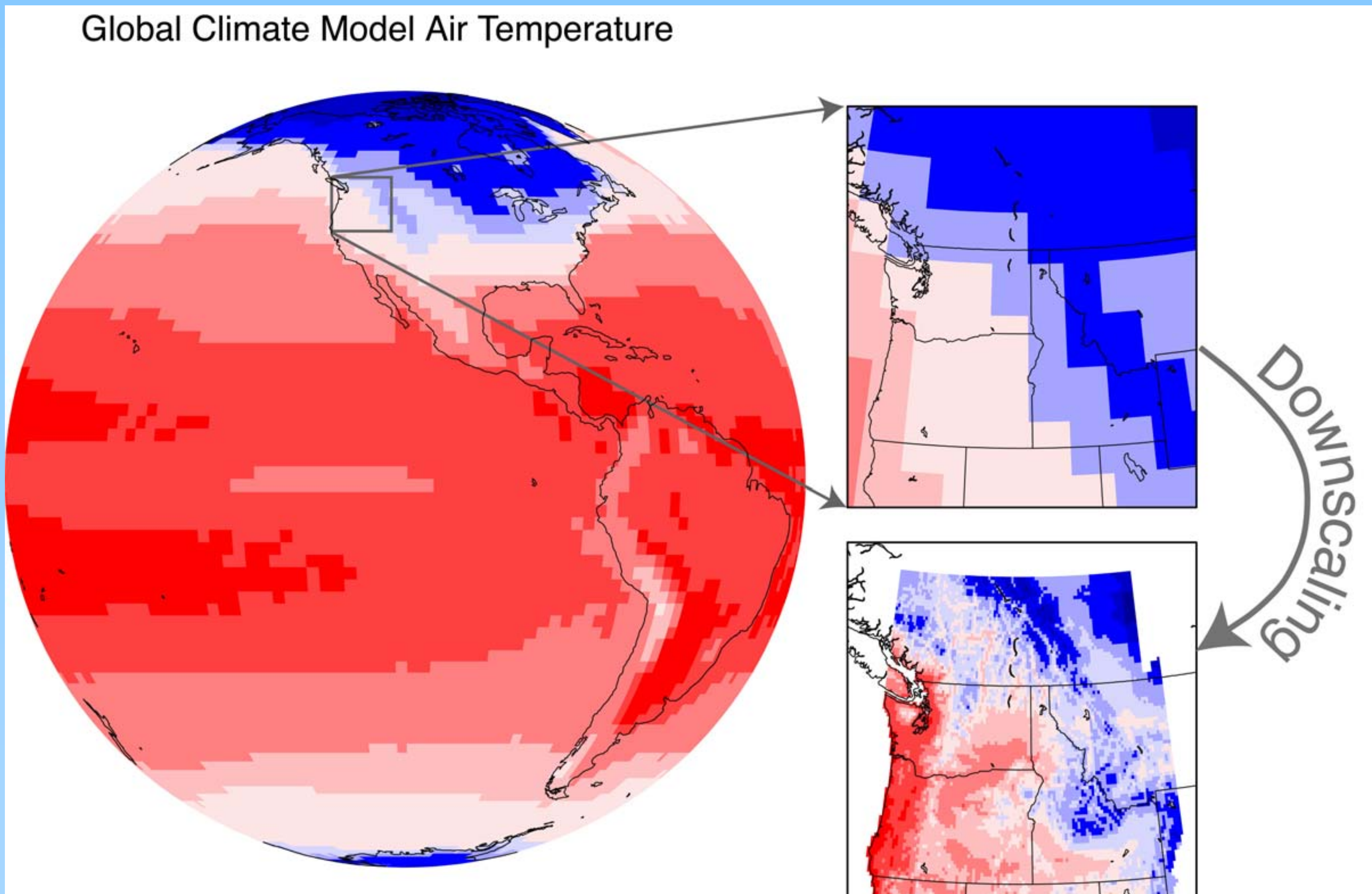
Mechanism	Time Required
Troposphere (lower atmosphere) mixing alone	1 year
Atmosphere to surface ocean layer	4 years
Surface ocean layer to intermediate layer below the thermocline	50-200 years
Venting from ocean above thermocline to atmosphere	100 years
Turnover time of deep ocean basins	1000 years

Source: IPCC 1990 *Climate Change: The Scientific Assessment*

Linking the Global to the Mega-Regional, the Regional, and the Local

Techniques & Drivers

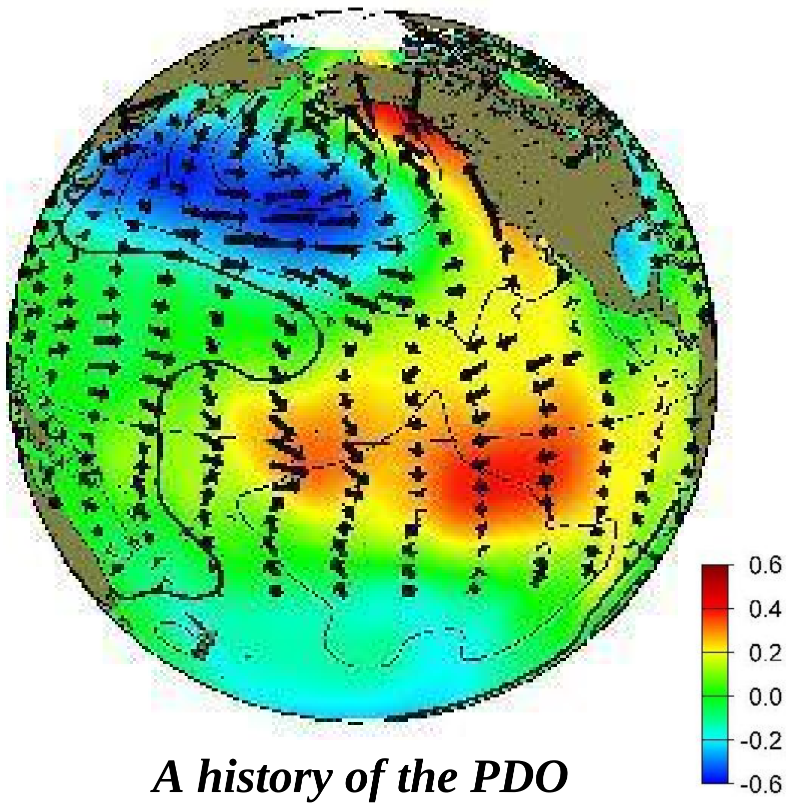
Global models must be downscaled for regional studies



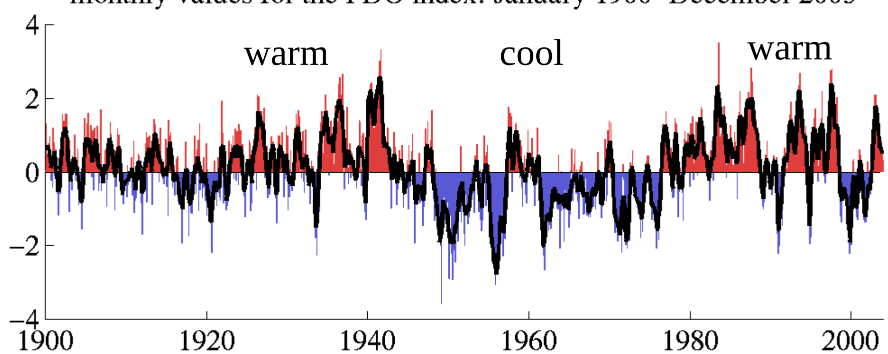
Salathe, 2006

Two Important Patterns of PNW Climate Variability

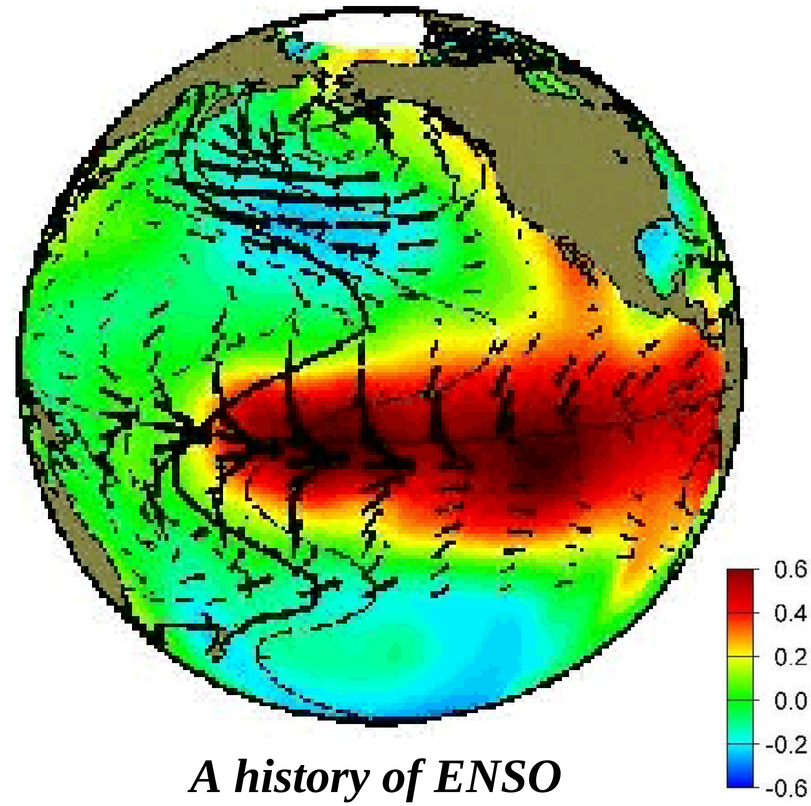
The Pacific Decadal Oscillation



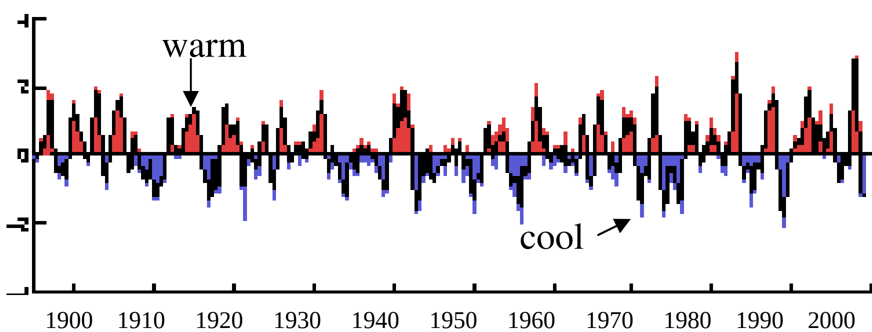
A history of the PDO

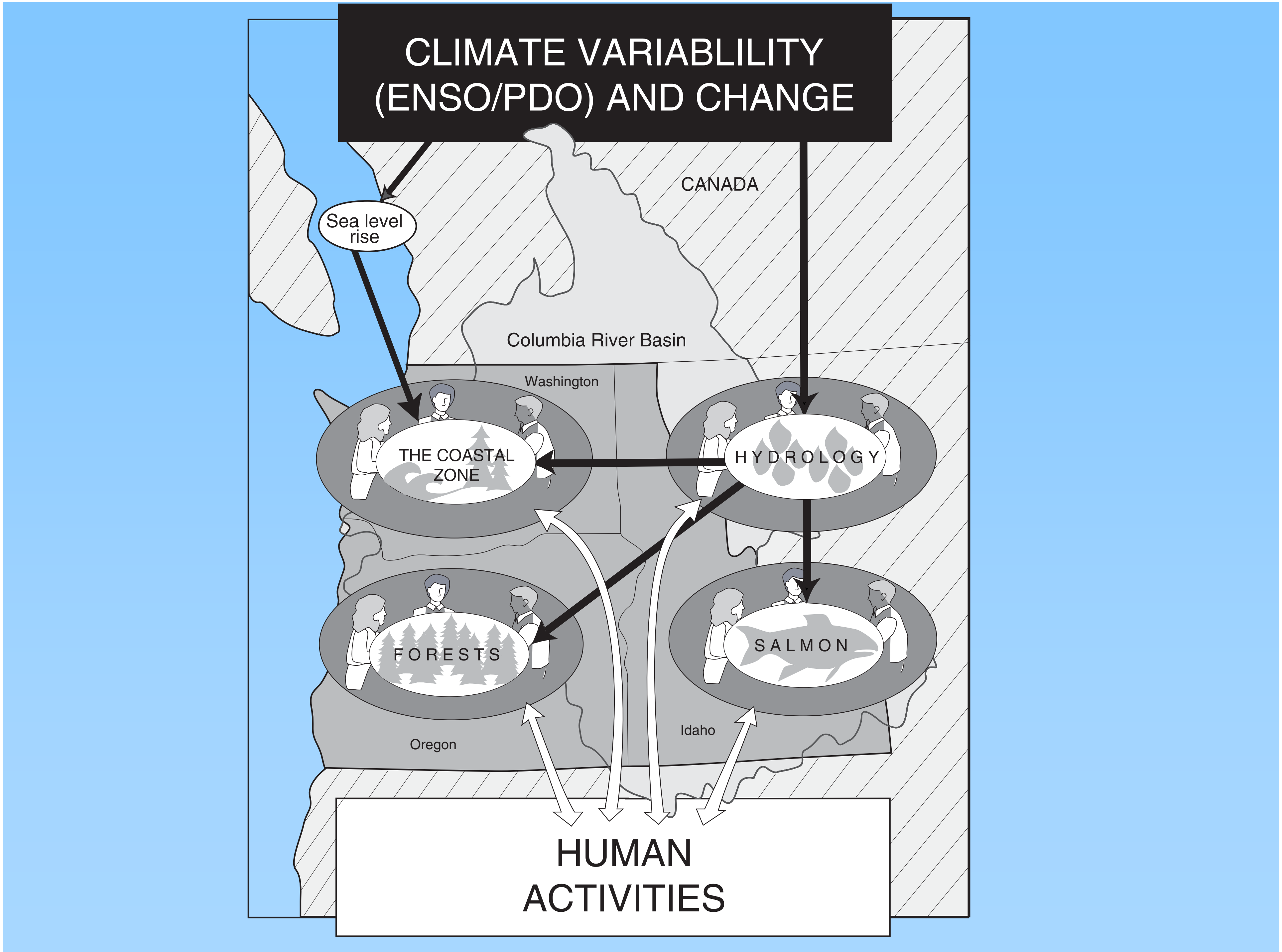


El Niño/Southern Oscillation



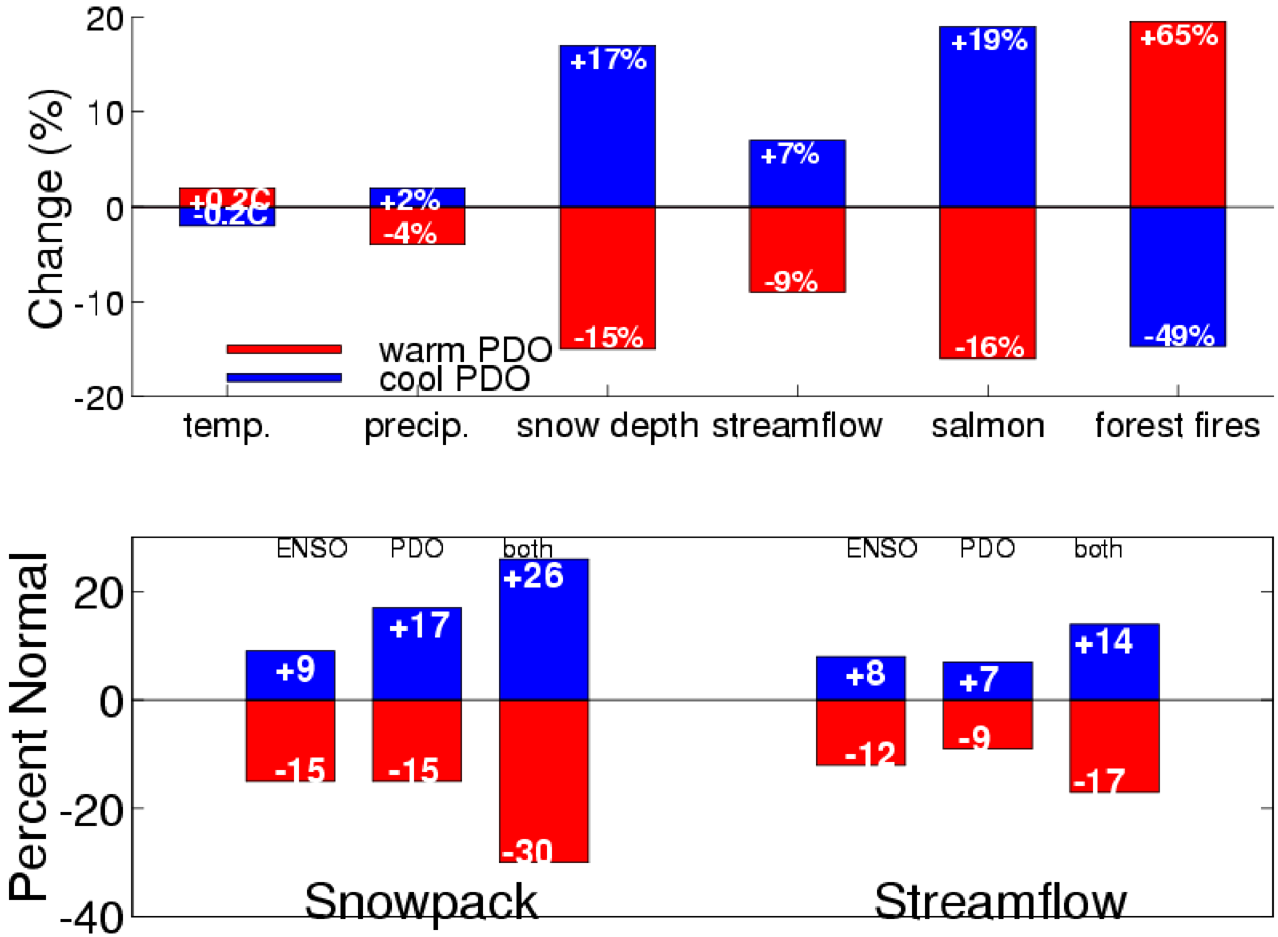
A history of ENSO





CLIMATE VARIABLILITY
(ENSO/PDO) AND CHANGE
Sea level rise
CANADA
Columbia River Basin
Washington
THE COASTAL ZONE
HYDROLOGY
FORESTS
SALMON
Oregon
Idaho
HUMAN ACTIVITIES

Regional impacts of the PDO

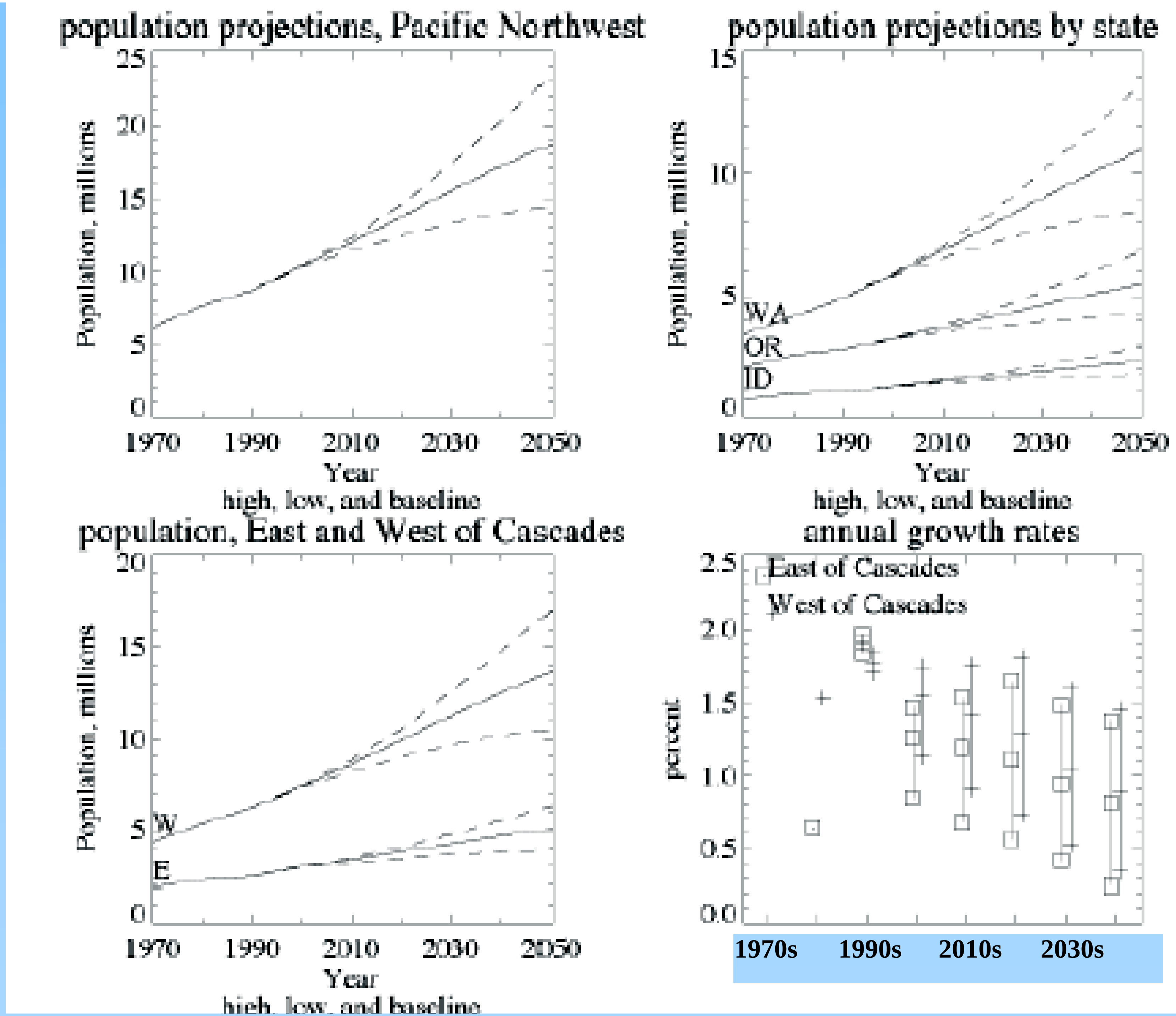


The Context

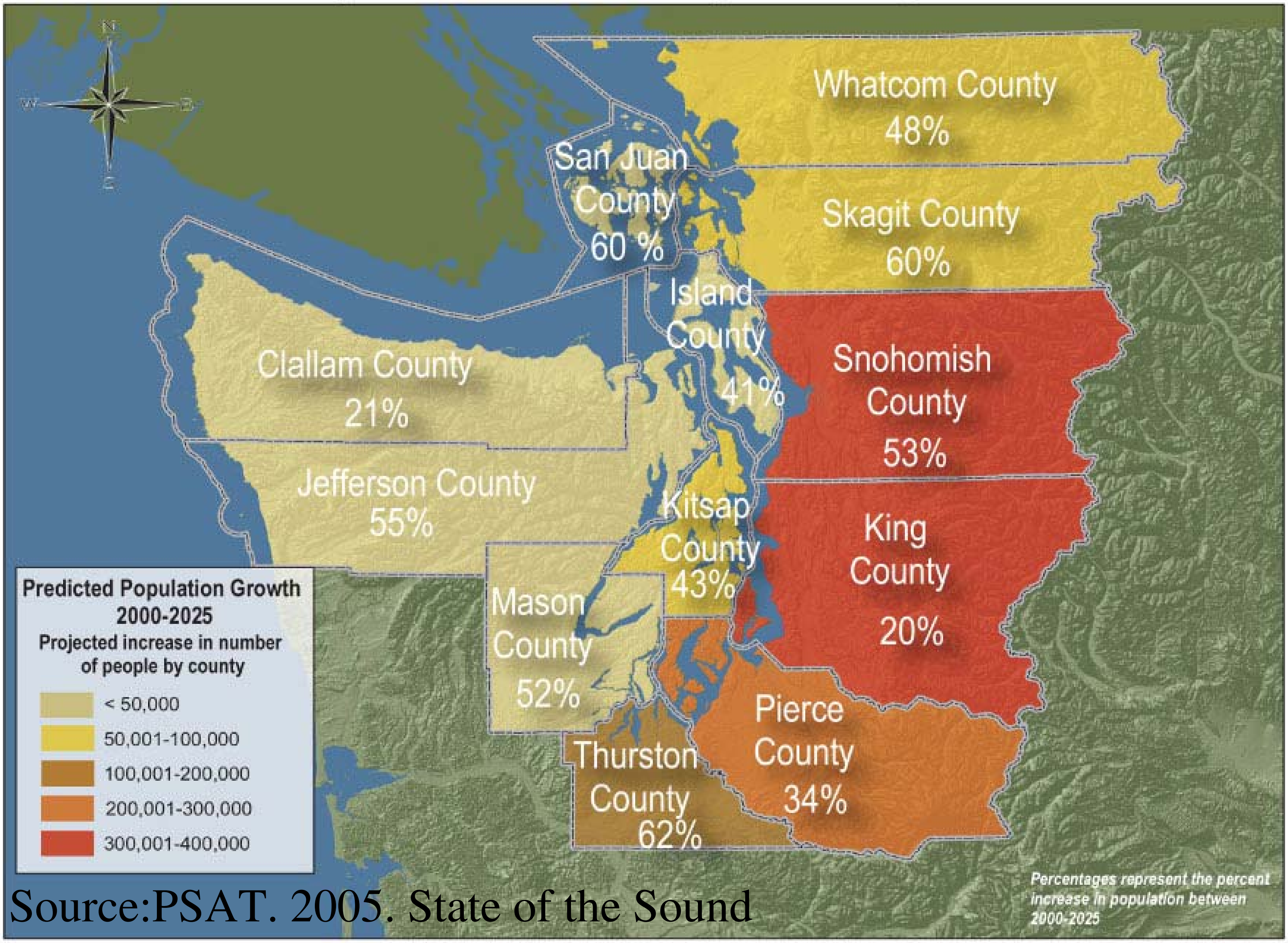
- Strong regional coherence in variability of PNW climate combined with heterogeneity in microclimates & ecosystems as result of topography.
- **The East-West divide really important re P/T differences.**
- Variations in time more important than variations in space re P/T but P/T uncorrelated.

The Context, cont'd.

- Current impacts of CV a function largely of past human choices about mgmt. strategies, institutions, & technologies.
- Future impacts of CC also depend on similar choices people make today.
- Vulnerability determined by interplay among climate, natural systems, & human choices.


population projections, Pacific Northwest
Population, millions
Year
high, low, and baseline
population projections by state
WA
OR
ID
Population, millions
Year
high, low, and baseline
population, East and West of Cascades
W
E
Population, millions
Year
high, low, and baseline
annual growth rates
East of Cascades
West of Cascades
percent
1970s
1990s
2010s
2030s

Predicted Population Growth in the Puget Sound Region: 2000-2025

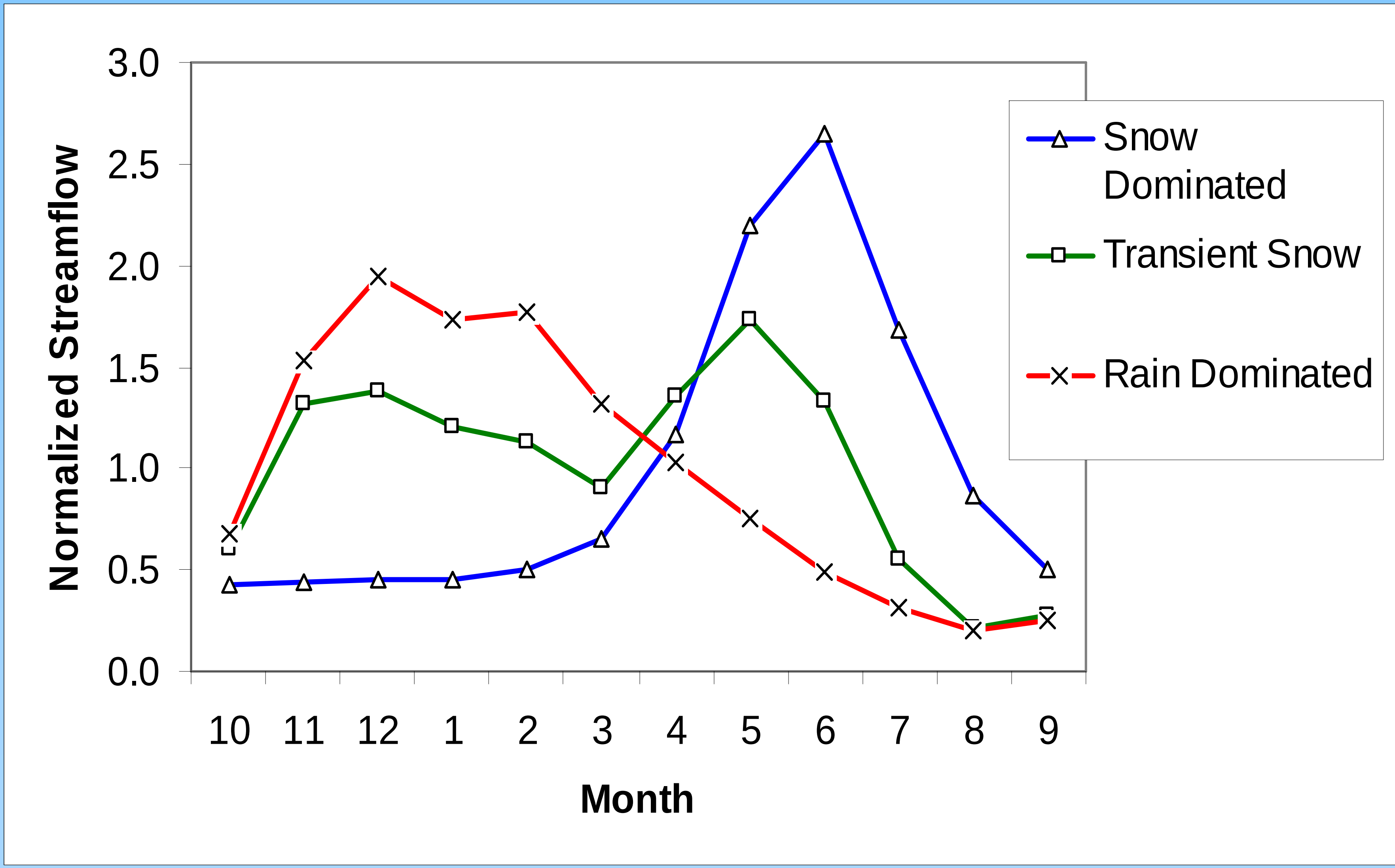


Source:PSAT. 2005. State of the Sound

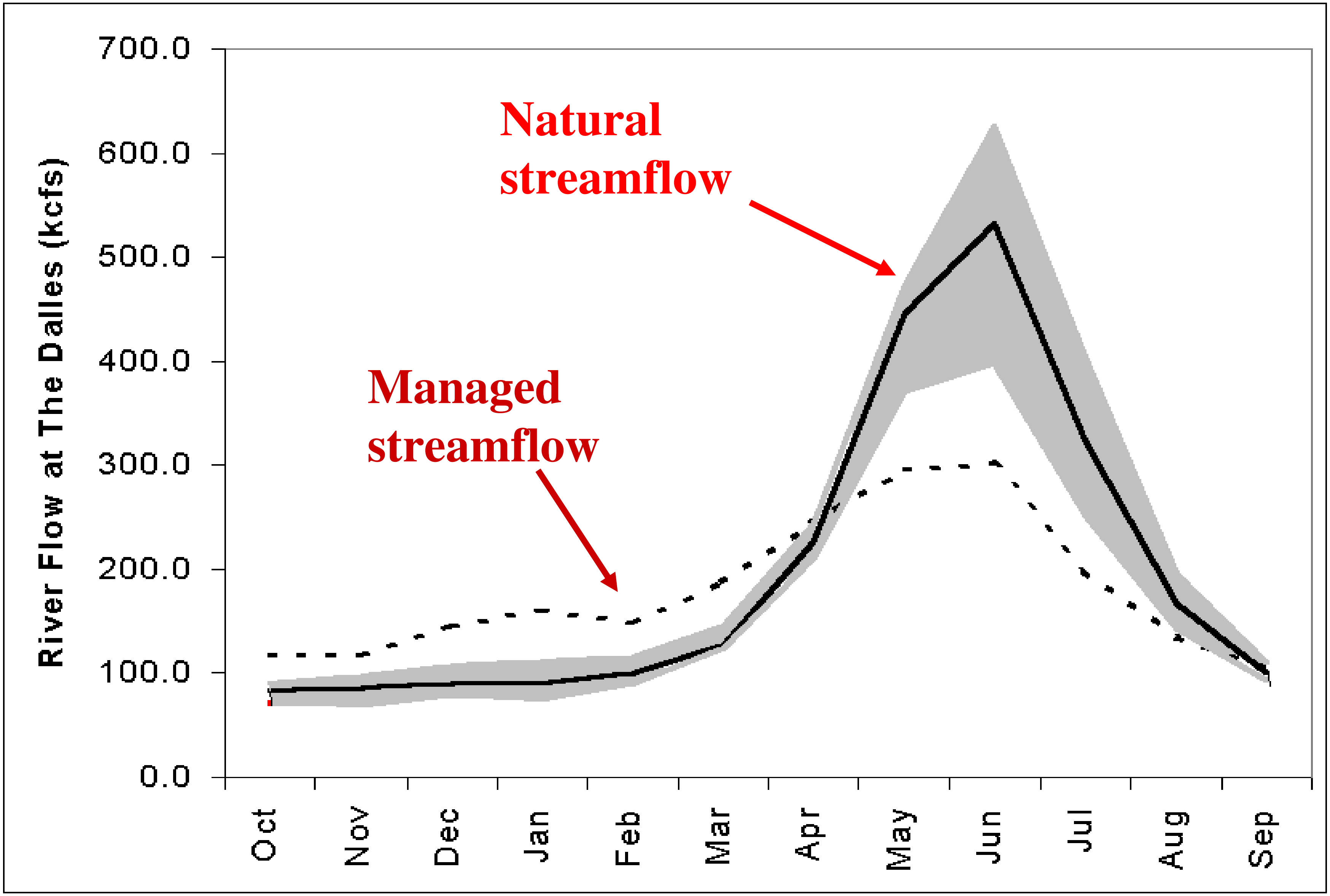
Recently Updated Population Growth Estimates for Puget Sound Region to 2040, OFM, June 2007

- Puget Sound = 5 million (2007 = 3.5m)
- Snohomish = 1.052m (2007 = 672K)
- King = 2.46m (2007 = 1.8m)
- Pierce = 1.094m (2007 = 773.5K)
- Kitsap = 380K (2007 = 243K)
- Whole State current pop. 6.5m; previous pop. est. to 2050 = 11m

Hydrologic Characteristics of PNW Rivers



The Columbia Basin Hydrosystem



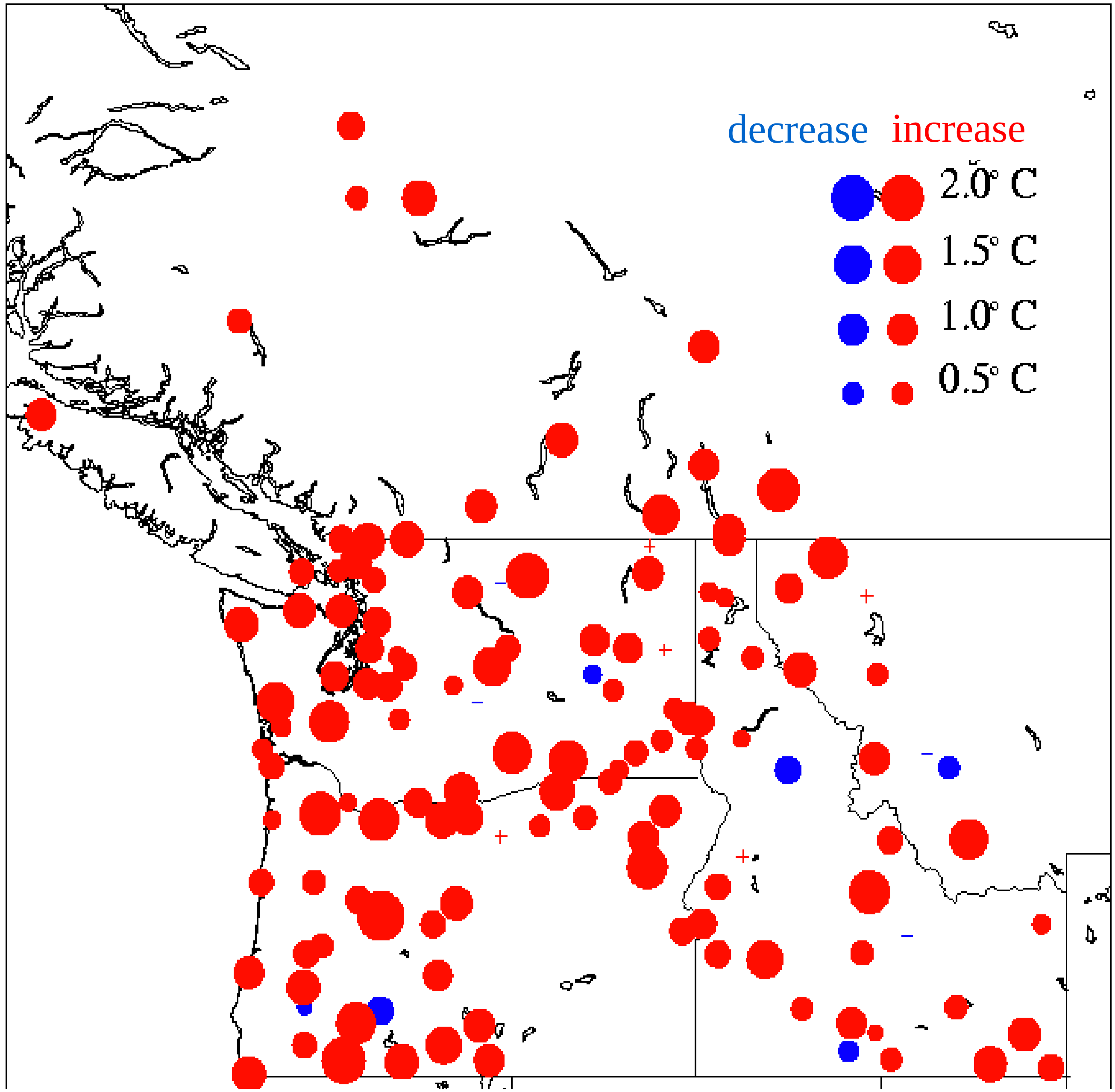
Observed Regional Climate Change in the Mega-Region: The American West

Trends in 20th Century PNW Temperature

Almost every station – urban and rural – shows **warming**

PNW climate is already changing, possibly due (in part) to climate change

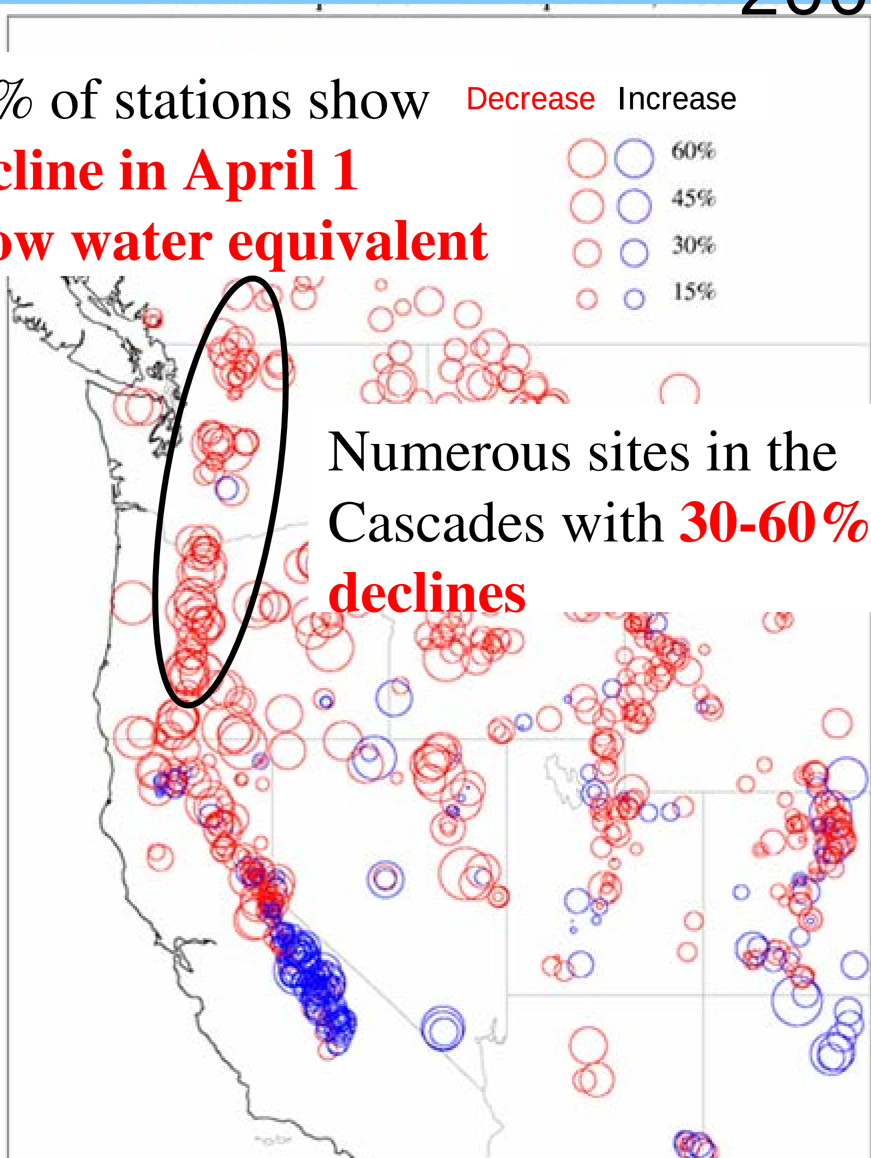
Temperature trends (°C per century), since 1920



Source: Mote, P. W. 2003. Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. *Northwest Science* 77(4): 271-282.

Snow water equivalent trends, 1950-2000

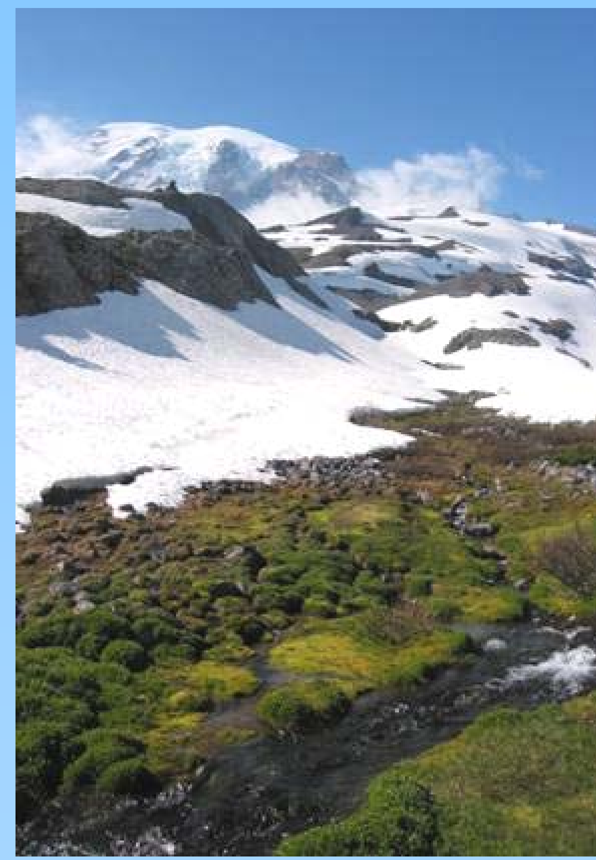
73% of stations show **decline in April 1 snow water equivalent**



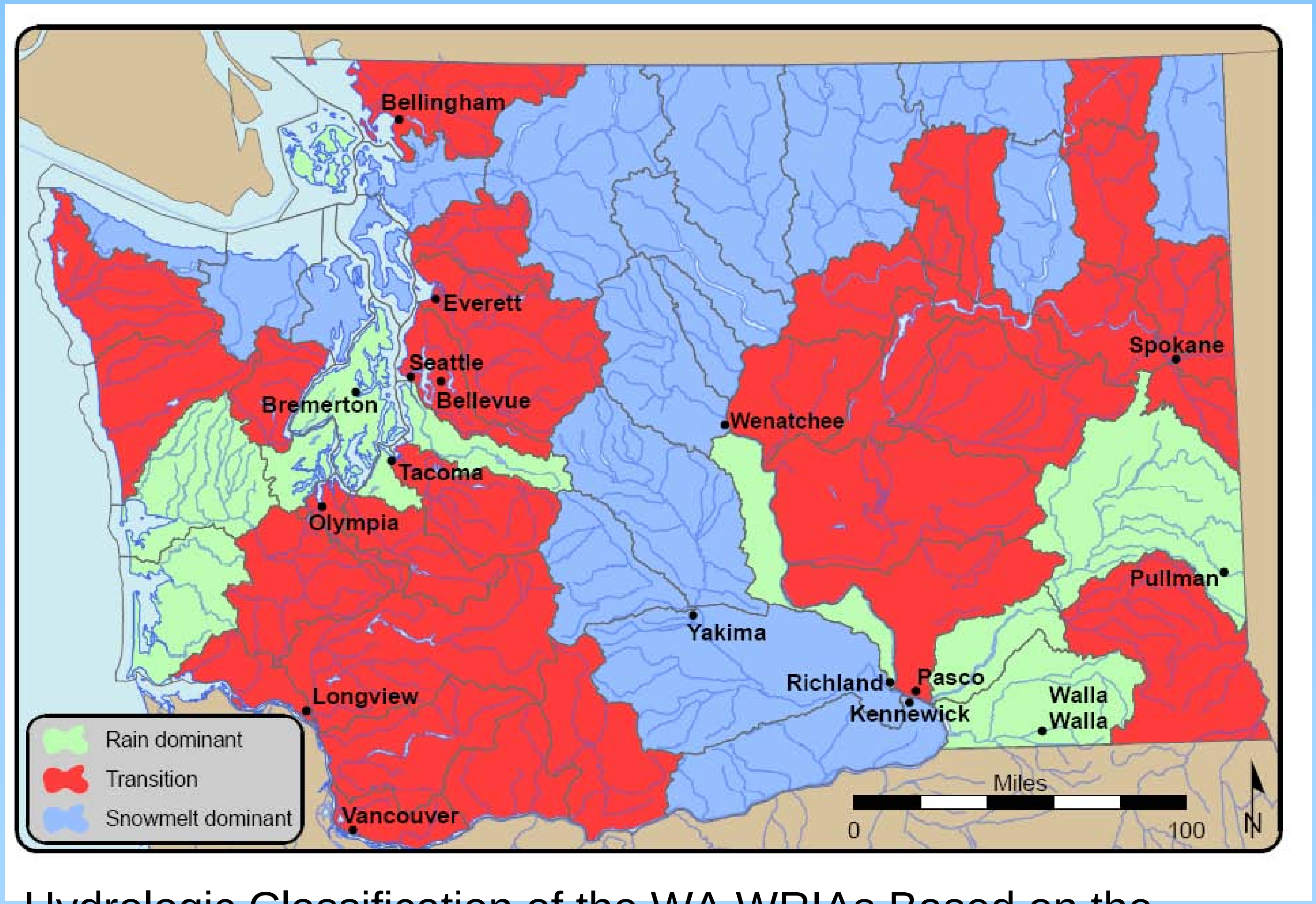
Numerous sites in the Cascades with **30-60% declines**

Trends in April 1 SWE, 1950-2000

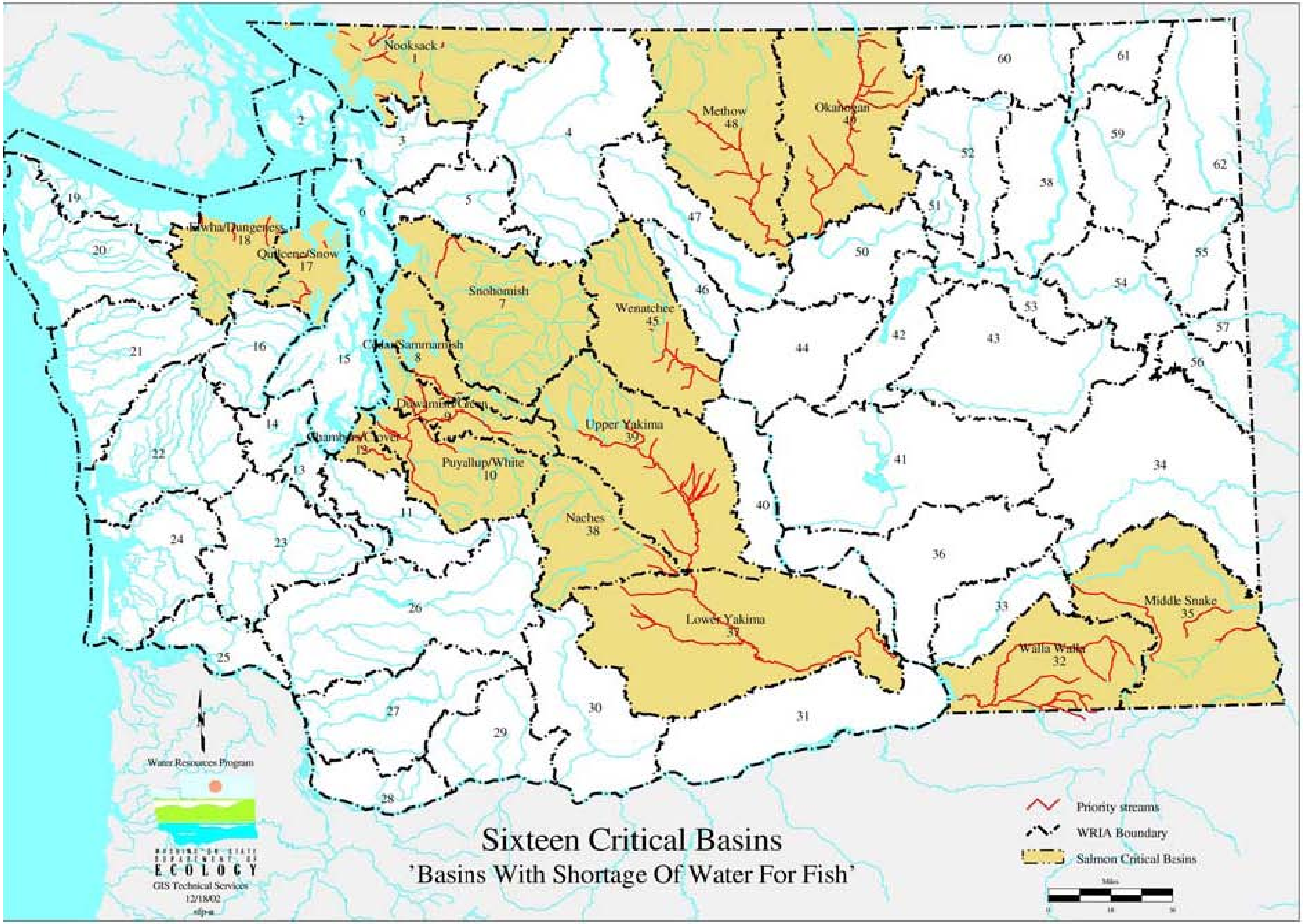
Mote 2003(b)



BASIN SENSITIVITY TO WARMING



Hydrologic Classification of the WA WRIAs Based on the Fraction of Oct-Mar Precipitation Stored in the Peak SWE for the 1950 Temperature Regime

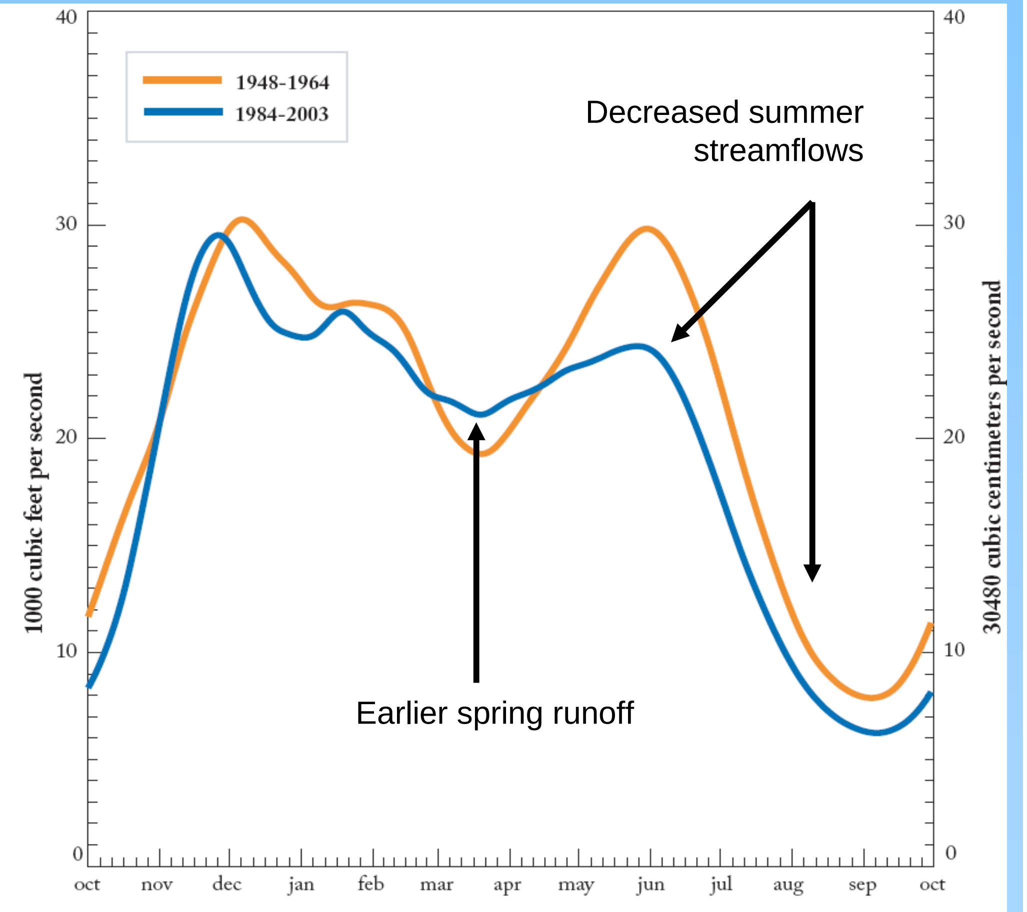


Sixteen Critical Basins
'Basins With Shortage Of Water For Fish'

20th Century Changes in Snowpack and Streamflow: Puget Sound

Since 1950, Puget Sound snowpack and stream flows are changing in ways consistent with projected climate change impacts:

- April 1 snowpack has been declining. Losses are largest in mid- and lower elevations
- Snowmelt is occurring earlier : 2.1 days/decade; total 12.
- Summer freshwater inflows have decreased 18%.
- Probability of extremes is changing (prob. for both unusually low and high daily inflow has increased)



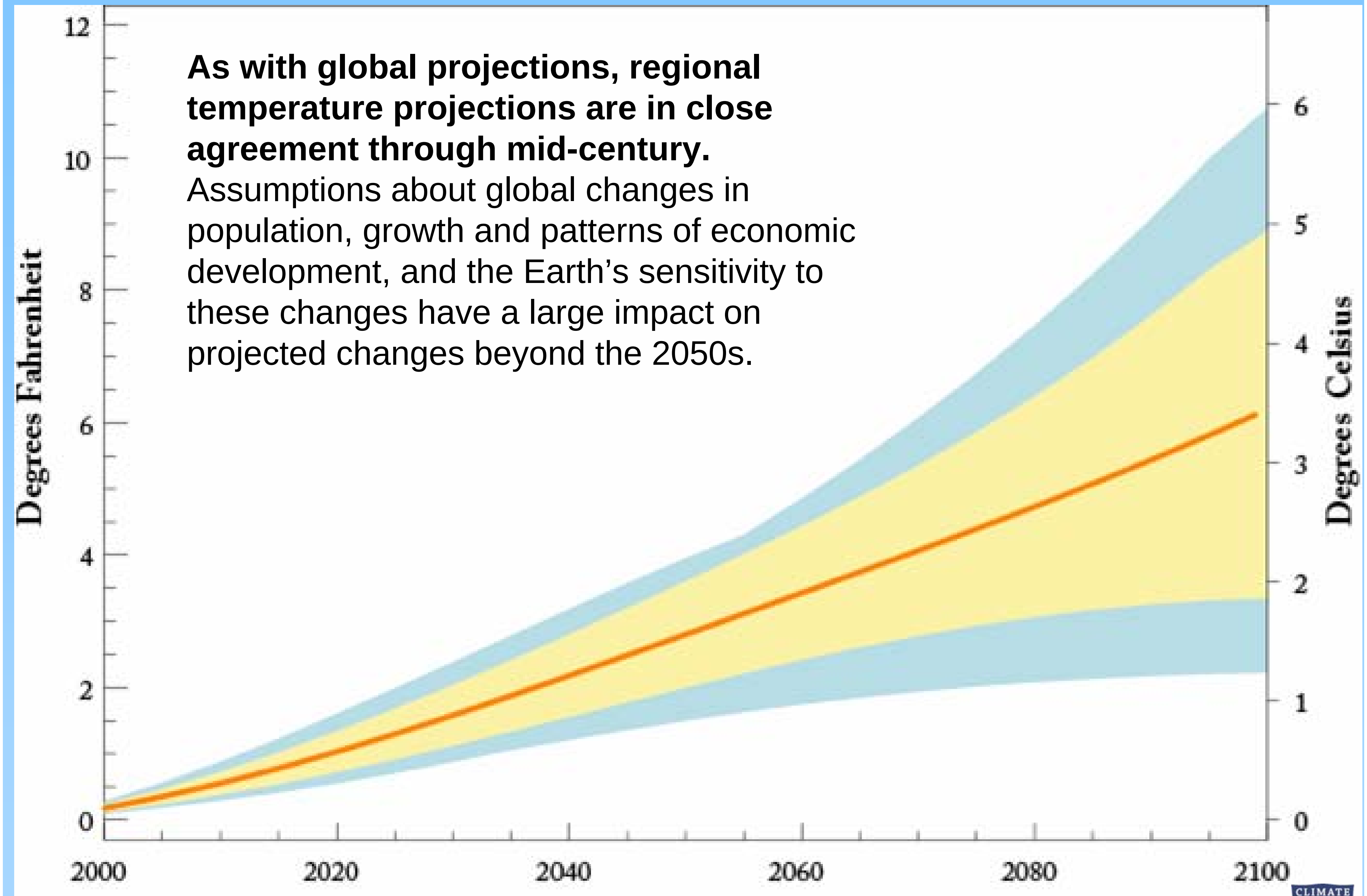
Average Daily Freshwater Flow into Puget Sound

Scenarios of Climate Change in the Pacific Northwest

Climate Impacts Group

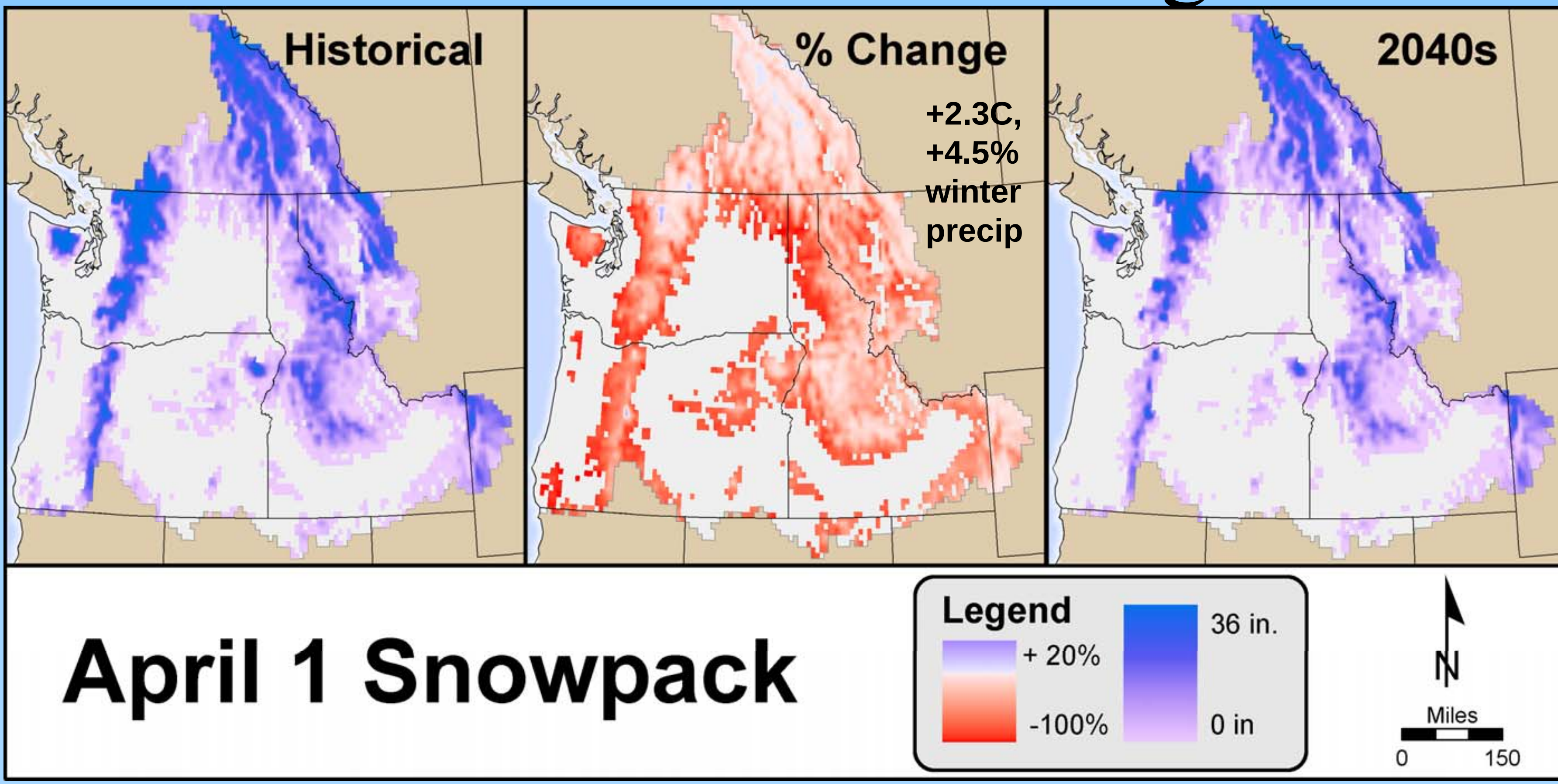
2001 & 2005

As with global projections, regional temperature projections are in close agreement through mid-century. Assumptions about global changes in population, growth and patterns of economic development, and the Earth's sensitivity to these changes have a large impact on projected changes beyond the 2050s.

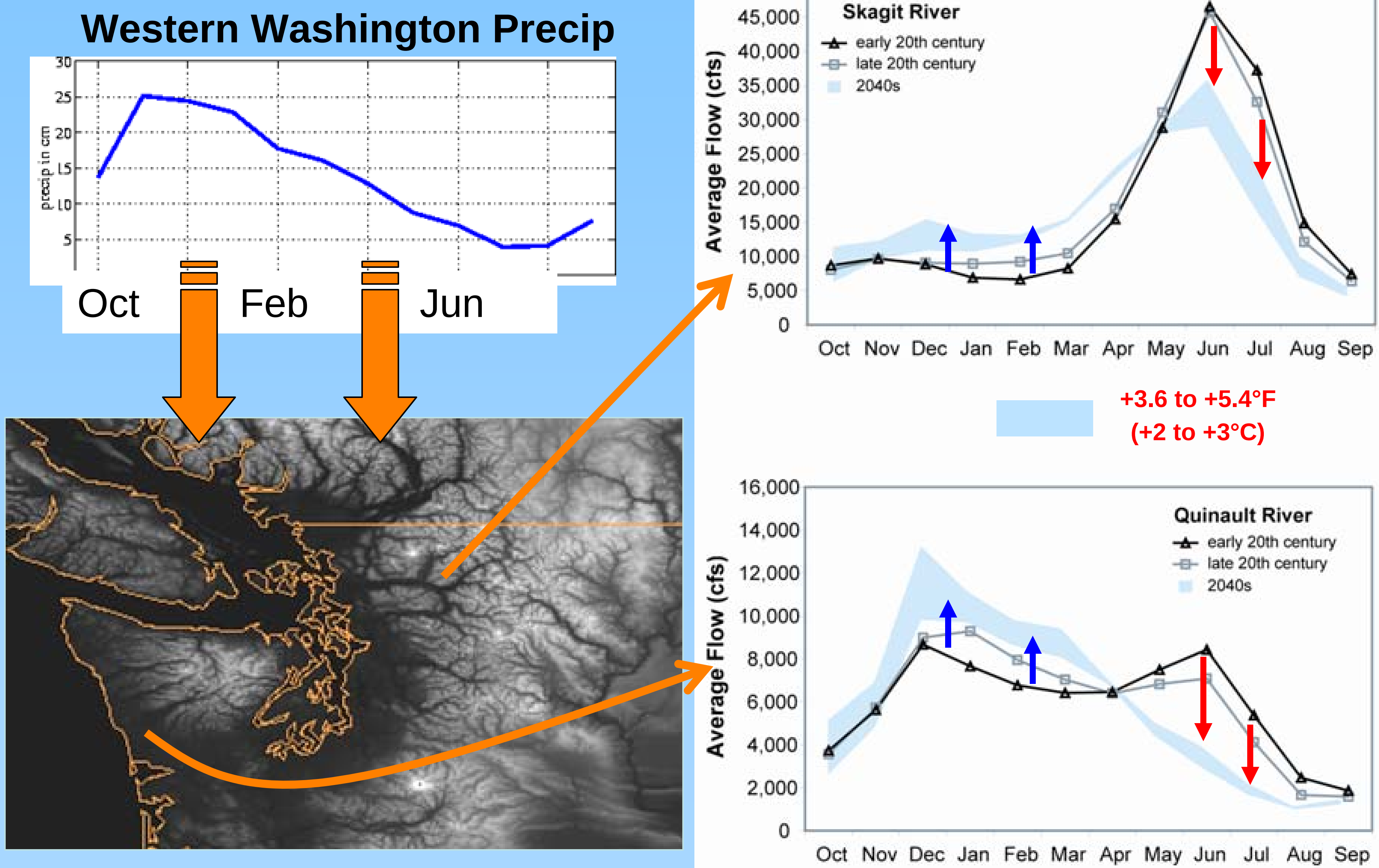


21st Century Pacific Northwest Warming Trends

The coldest locations are less sensitive to warming

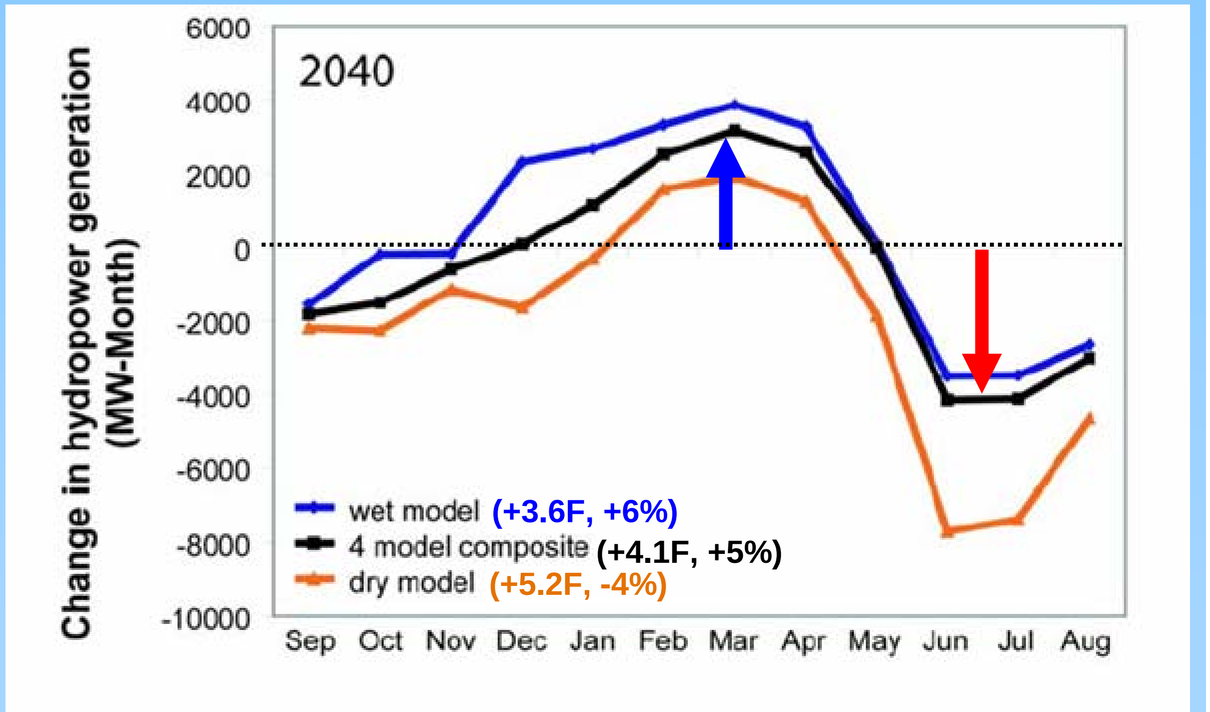


Streamflow patterns are temperature dependent



Impacts on Columbia Basin hydropower supplies

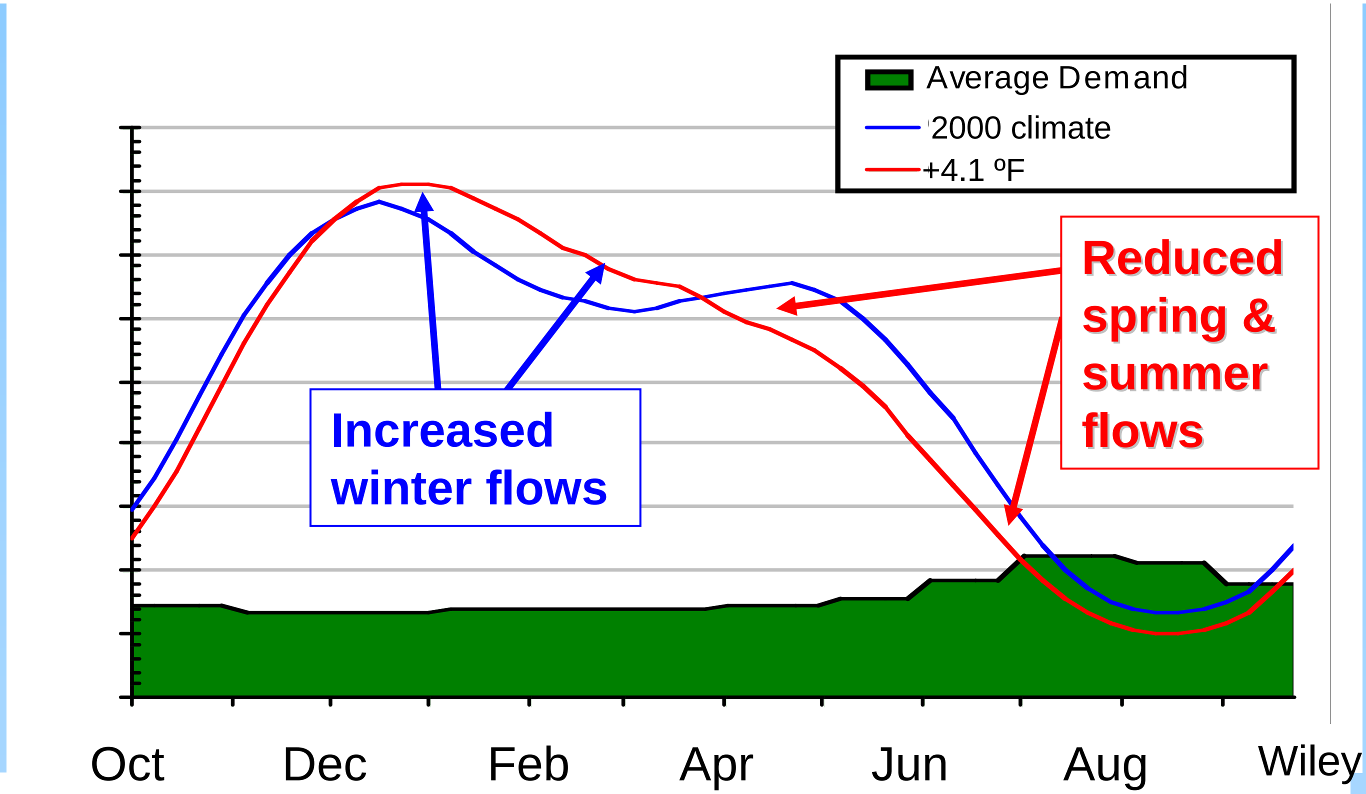
- **Winter and Spring:** increased generation
- **Summer:** decreased generation
- **Annual:** total production will depend on annual precipitation
- **Plus:** impacts on electricity demand
    - ↓ in winter
    - ↑ in summer



NWPCC (2005)

Impacts on Seattle's water supply

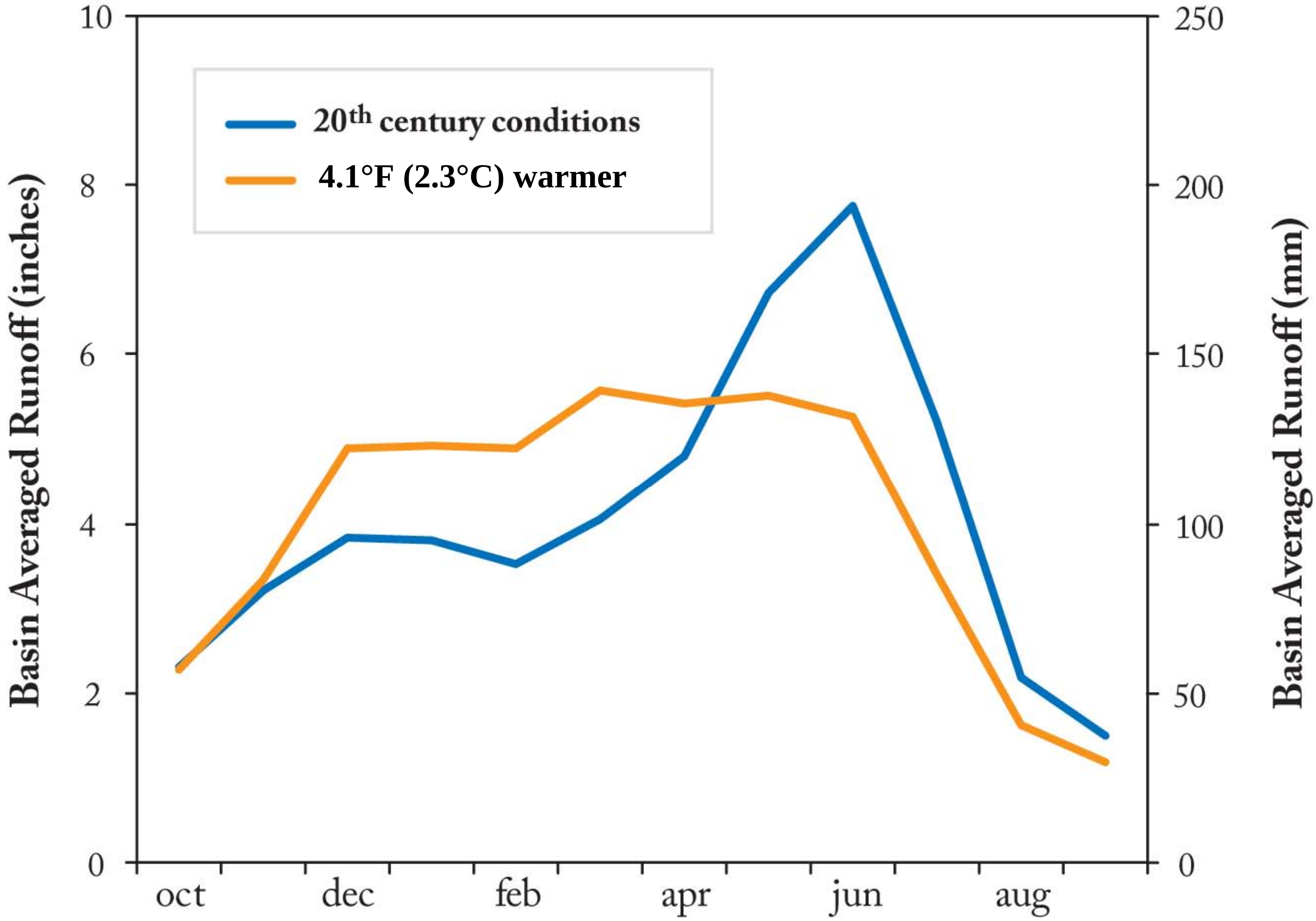
- **reduced summertime inflows, increasing the size and extending the time of the summertime inflow-demand deficit**
  - this is common to all our region's municipal (surface) water supplies



Wiley (2004)

Caution

- Cannot attribute these changes solely to global warming; land-use & flow regulation play role as well.
- Some changes consistent with global warming; total annual declines may be associated with PDO.



Simulated Average Runoff for the Puget Sound Basin

Simulated 21st Century Snowpack & Streamflow: Puget Sound

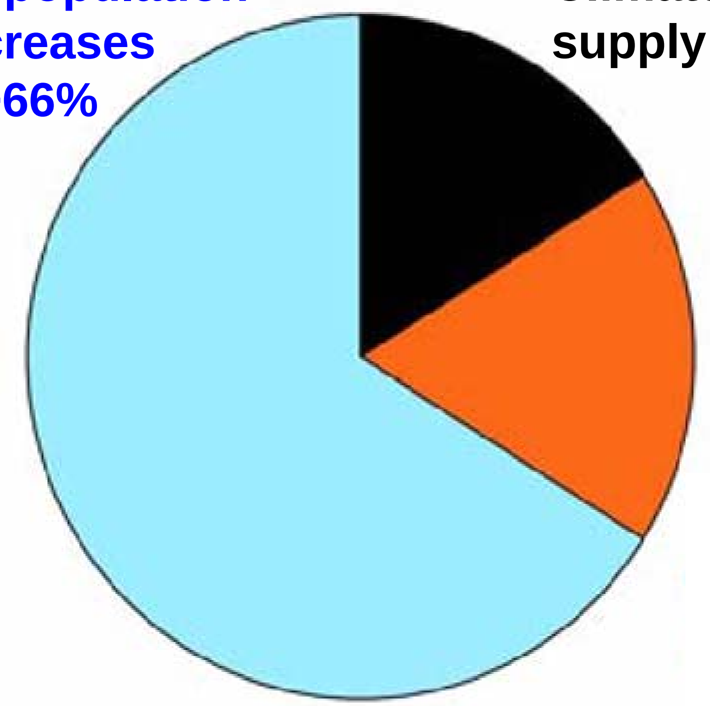
- For warming of 2.3°C (4.1°F), 2040s or later, Oct-March runoff increases by c.25% & April-Sept runoff decreases by c.21%.
- Reduced MT. snowpack.
- Greater winter streamflow ⇒ more P as rain =flooding.
- Earlier peak flows.
- Reduced summer flows.

A warmer climate and flooding, stormwater & wastewater management

- At mid-elevations more precipitation will fall as rain and less as snow, leading to an increased frequency of river flooding
- At high elevations there are competing factors:
  - reduced snowpack may reduce flood risks in spring
  - elevated spring soil moisture may increase vulnerability to flooding during spring storms

- **a warmer atmosphere holds more moisture:** theory and climate models suggest an increased intensity of precipitation
  - if WA precipitation events become more intense, it will increase the risk of urban flooding and combined sewer overflows

Factors driving Portland Oregon's future water supply



Palmer and Hahn (2004)

Including the 2040s scenario for climate change impacts increases projected future supply needs by ~50% of the amount needed to meet population growth alone.

Institutional Resistance to Change

The Problem: The System is Already Taxed

Increasing Scarcity and Conflict
2000-2020

- **Little or no room for growth in supply for the Columbia River and much of the PNW**. Patterns of year-to-year and decade-to-decade climate variability may exacerbate or ameliorate potential impacts.

- **Level of water scarcity is relatively new.** Demands on water systems are growing, but supplies remain essentially fixed. *Less margin of safety available to cope with the unexpected.*

- ***Region in severe difficulty even if climate doesn't change***

- **Management system inadequate to task, 2000-2020:**
  - Highly fragmented;
  - No one management entity in charge re droughts;
  - Little or no inter-use coordination;
  - Inconsistent standards, re: water quantity and quality across basins;
  - Conflicting management practices: international, federal, states, counties, private, tribal lands;
  - Large number of largely uncoordinated planning efforts;
  - No official incorporation of climate change scenarios in planning.

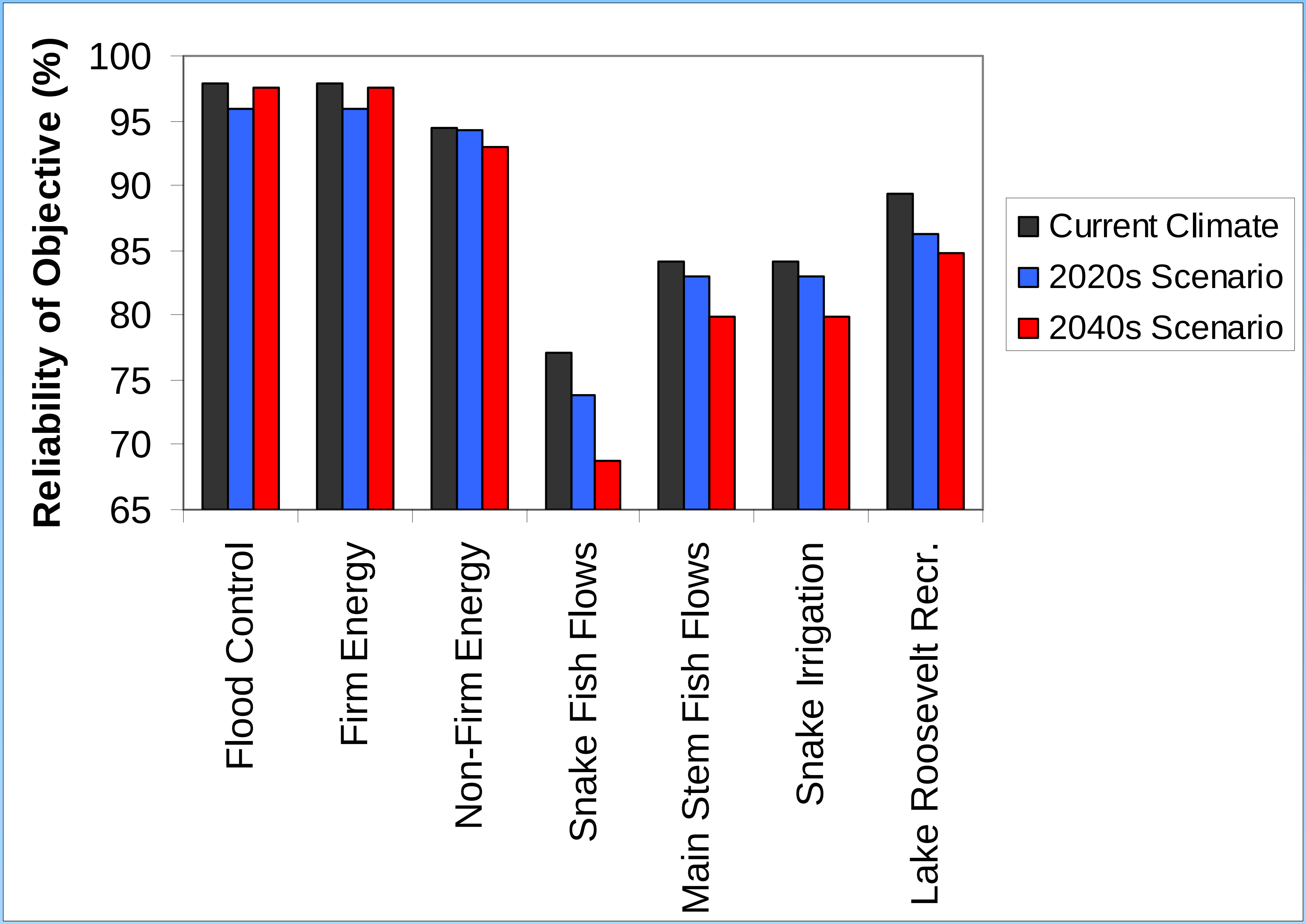
Policy Hurdles (Resistance)

- Increasing intensity to trade-off conflicts:
  - East Side trade-offs - Hydro/Fish/Agriculture
  - West Side trade-offs – Municipal & Industrial/Hydro/Fish
  - East Side vs. West Side conflict
- Heavy emphasis on State sovereignty
- Differences Idaho vs. Oregon & Washington
  - *re: application of Prior Appropriation rule.*

Policy Hurdles (cont'd)

- System is top-down. Technical level cannot determine own planning scenarios.
- System currently includes only population growth & ESA applications in long term planning. [Slowly moving towards including CC scenarios & effects].
- Policy level in 2001 said they unlikely to face up to climate change challenge without leadership from white House & U.S. Congress (i.e., system is top-down for them too). Situation now changed--Western & Eastern states out in front.

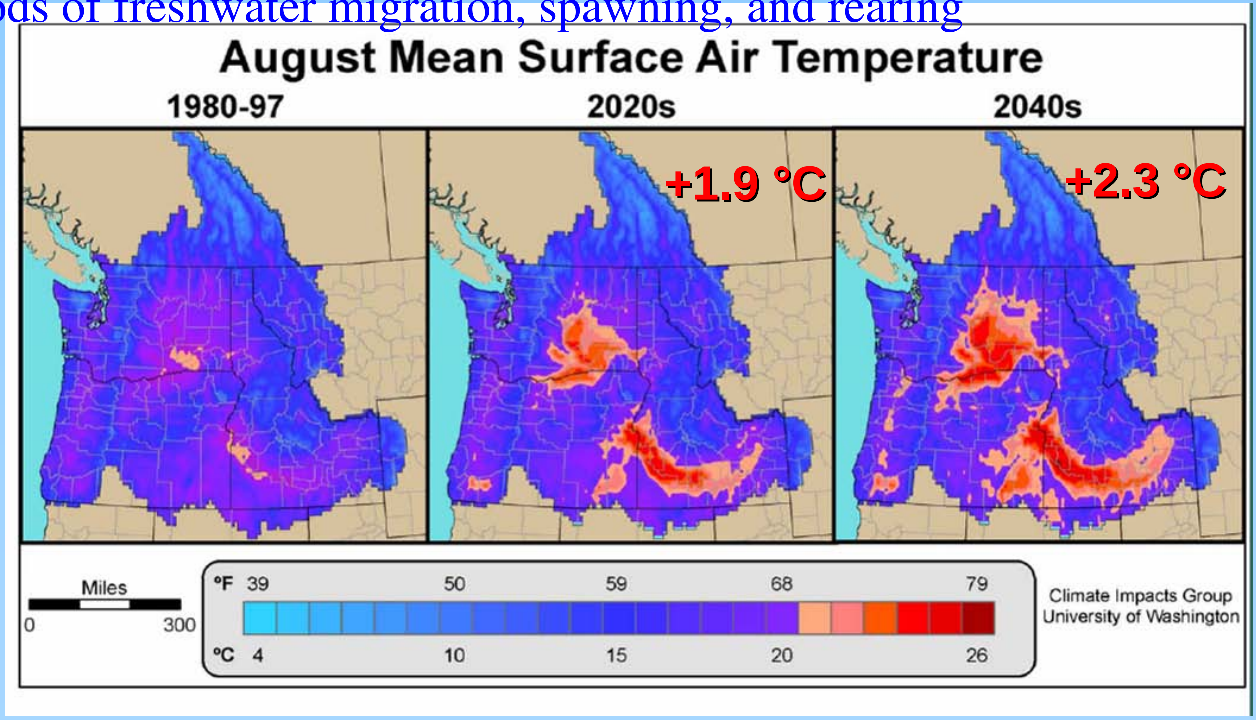
Simulated Reliability of Water Resources Objectives for “Middle-of-the-Road” Scenarios

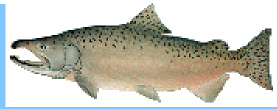


Climate change will force resource managers and planners to deal with increasingly complex trade-offs between different management objectives.

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





Climate Impacts & Consequences/Snohomish

- Climate Impacts- Increasing temp, less summer precipitation
- Hydrologic – Increasing winter peaks lower summer runoff, higher water temperatures
- Salmon Impacts -
  - 15-39% reduction in Chinook #'s without restoration
  - 5-23% reduction in Chinook #'s with restoration.
- Restoration efforts offset climate impacts
- Planning without climate change may result in overly optimistic estimate of benefits

Battin et al. 2007

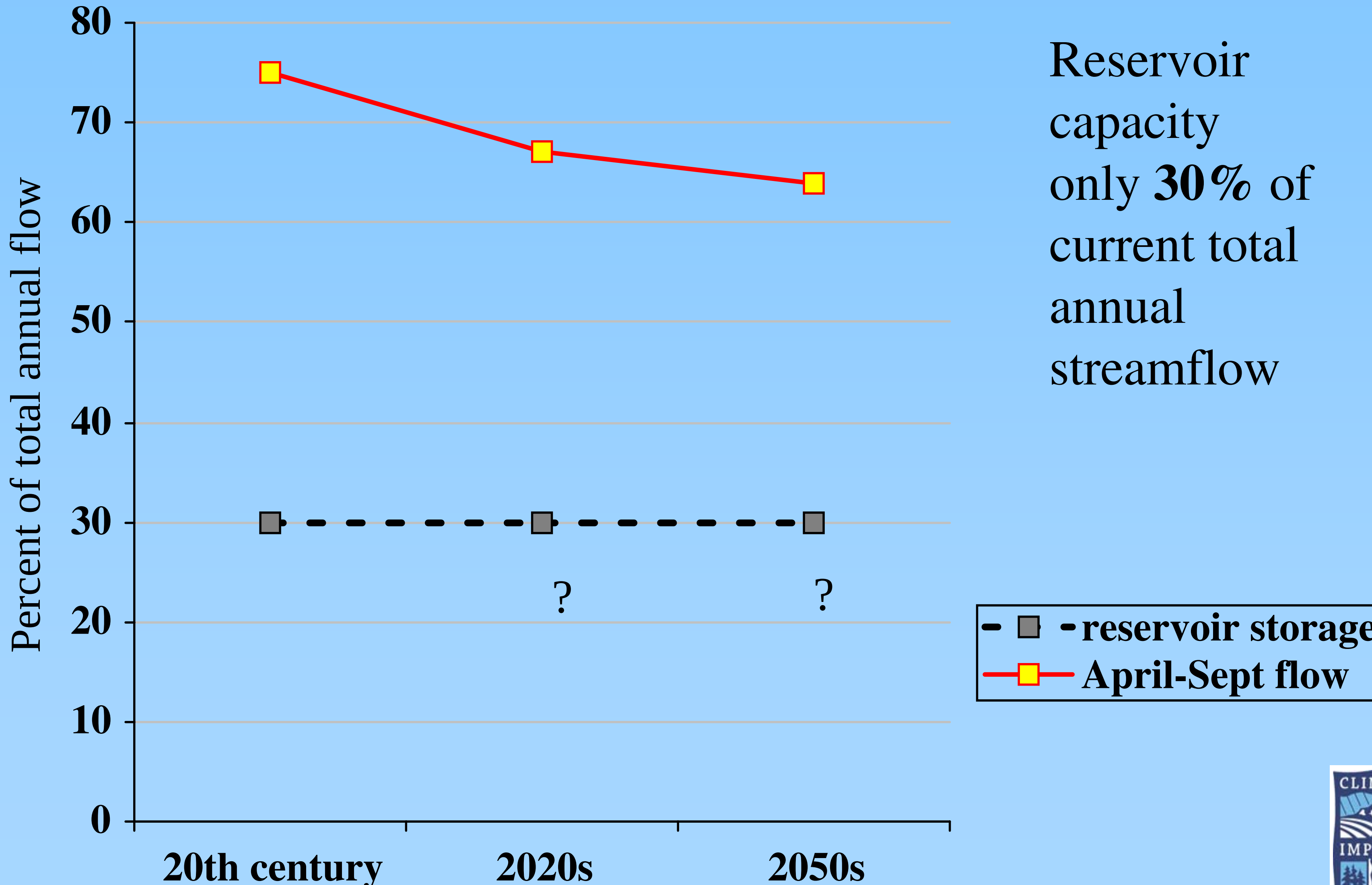
What Are the Greatest Vulnerabilities to Regional Climate Change?

Drought, Multi-year Drought, and Decadal Megadrought

Multi-year Drought in PNW

- The greatest climate-related vulnerability of the region.
- Snowmelt-driven system in which human-engineered storage capacity limited & majority of storage in Columbia Basin in winter snowpack.
- Capacity to manage drought limited because authority highly fragmented & degree of control very constrained.
- Drought in PNW displays high spatial variability on East side of OR./WA. Cascades & East-West divide also important re availability of water.

Storage of Columbia River Water



Reservoir capacity only **30%** of current total annual streamflow

Hydrosystem Capacity in PNW

- **Columbia Basin:Multi-use system**. Demands exceed needs in any year streamflow less than long term average (0.9σ). The longer the drought, the more intense the zero sum conflicts among users. Substantial efficiencies available if system were to be operated more flexibly (change rule curves), but major organizational, political barriers in WA. & Or. Unable to copy Idaho example on large scale re water markets, water banks, & water rentals.
- **Snake Basin:Multi-use system.** System highly sensitive to drought, but existence of large aquifer managed conjunctively with surface water a significant buffer even in face of multiyear drought. Authority to manage relatively centralized & considerable flexibility in experimentation to manage water resources more efficiently in order to decrease vulnerability imposed by nature.
- **Yakima Basin: Single-use system (Irrigation).** Sufficient storage to withstand 2-year drought, but not 3. System "breaks" & severe pro-rationing imposed. Junior right holders pay for water that they never receive. High vulnerability to multi-year drought/limited buffering capacity.
- **Klamath Basin: Single-use system (Irrigation).** Severe buffering limitations to even 1-year intense drought episodes. System very brittle. Easily "breaks". Intensely zero sum conflict between farmers vs tribes & downstream commercial fishing communities.

The Take Away Message

Guiding Principles for Planning

- The future will not be like the past.
- Familiarize yourself with climate change impacts
- Take actions to increase the resilience of regional systems
- Monitor regional climate and resources for ongoing change
- Design for surprises. Policies & management practices should be flexible.
  - *Develop new approaches based on risk management.*

Picasso – The Acrobat (1930)

www.georgetown.edu

The PNW Climate Change Panarchy

- How resilient? Picture mixed. West side in general more than East side. But even on East side, leadership & institutional design make significant differences, viz. Idaho.
- Latitude greater on West side--gift of nature: more P, significant additional storage possible in Seattle & Portland; but also significant leadership & innovation in SPU re gains in efficiency, restraints on demand growth, & sophisticated risk mgmt strategies.
- At same time, a lot of vulnerability socially constructed & institutions very resistant to change--fragmentation & confusion combined with policy constraints imposed by vested interests.
- However, high sensitivity to CC in many sectors means that changing rates of change will force policy innovation over time as sensitivity increases to vulnerability.

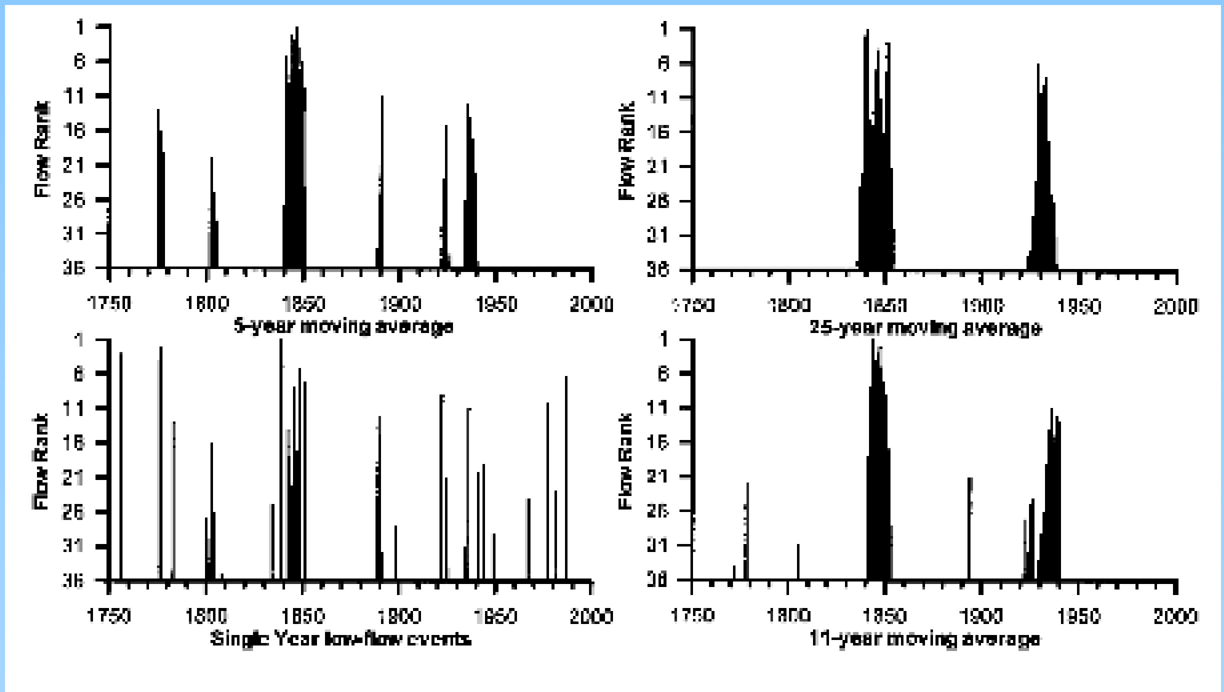
The PNW Climate Change Panarchy, cont'd.

- Is the region in a precarious condition?
- Not in general. West side has margin of 3-4(?) decades; real issue is how or whether West side can manage growth effectively.
- East side has much less margin, so less resilient *under present operational rules of regional hydro-system.* If latter changed with different choices, resilience can increase. And wise management with supportive institutions (Idaho) will continue to make a difference.
- But some places are in a precarious position, *vide* Yakima & the Klamath Basin .

Are there Nonlinearities &Thresholds?

- Yes, many--known and unknown:
- Precipitation quantity and intensity.
- Increasing temperature effects on wildfire, pests, pathogens & the scale of primary, secondary, & tertiary effects.
- What happens when human-caused warming surpasses the range of natural variability of the last 10K years?
- So emphasis on policy innovation to increase resilience & to mitigate the problem sooner rather than later.
- Turn to risk and vulnerability assessment/mgmt as general response, especially re greatest vulnerability.

Columbia Basin multiyear drought since 1750



- Since 1750, the most intense multiyear drought occurred in the 1840s; the 2nd worst was in the late 1920s to mid-1930s

Type of Risk, 2020's

	Type	Magnitude	Probability
1	Increased flooding West-side unmanaged rivers	Limited in area & severity	High
2	4-6 weeks additional summer drought	Severe East-side re: ag. & fish	High
		M&I implications (?)	?
		Supply & quality problems re: M&I and fish West-side (?)	Med. (?)
3	Increased frequency/intensity forest fires & pest infestations	Region-wide. Severe.	High
4	Increased frequency multi-year drought El Niño/PDO in phase	Region-wide. Very severe.	Med.-High (?)
5	Increased coastal erosion/inundation combined effect sea level rise & increased intensity winter storms, esp. El Niño years.	WA/OR coastal regions	High