
January 2053...
I DON'T CARE WHAT THEY SAY, THIS GLOBAL WARMING SCARE IS JUST A BUNCH OF LOONY LEFT-WING ENVIRONMENTALIST ANTI-GROWTH HYPE!
SO, IS THIS YOUR FIRST WINTER HERE IN JUNEAU?
HORSEY

Global Warming Scenarios for the Pacific Northwest and their implications for Northwest Salmonids

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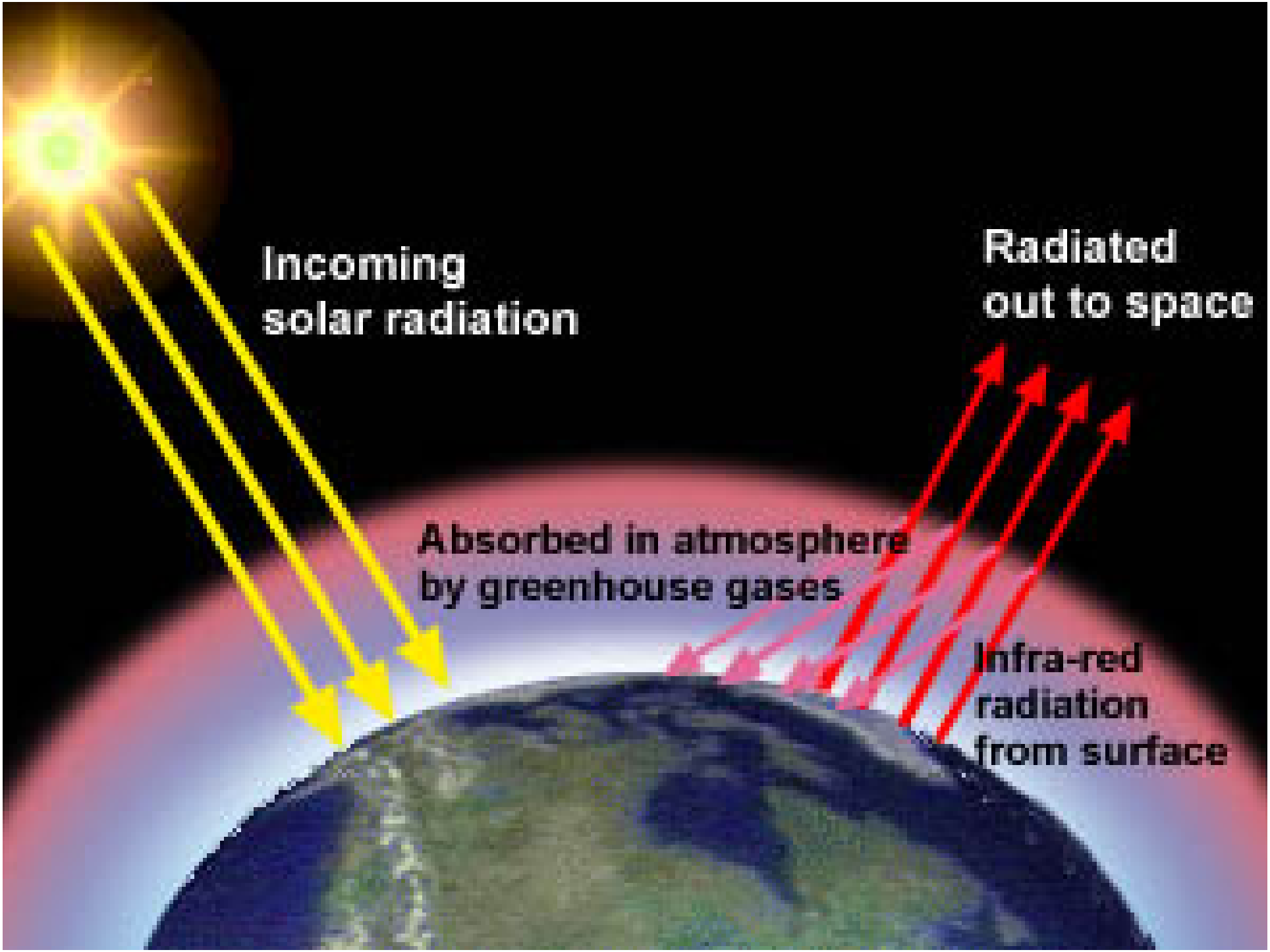
CLIMATE IMPACTS GROUP

Climate Science in the Public Interest


Incoming
solar radiation
Radiated
out to space
Absorbed in atmosphere
by greenhouse gases
Infra-red
radiation
from surface

Some facts

- Earth's natural greenhouse effect warms surface temperatures by ~33ºC (60 º F)
- H_2O vapor the most powerful greenhouse gas (GG)
- other important GG's are CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6 …
  - Human caused emissions of these GG's are increasing the natural greenhouse effect; since 1700's CO_2 concentrations have increased ~33%, and CH_4 concentrations have increased ~150%
  - Without drastic changes in current emissions trends, GG concentrations will increase dramatically in the next few centuries

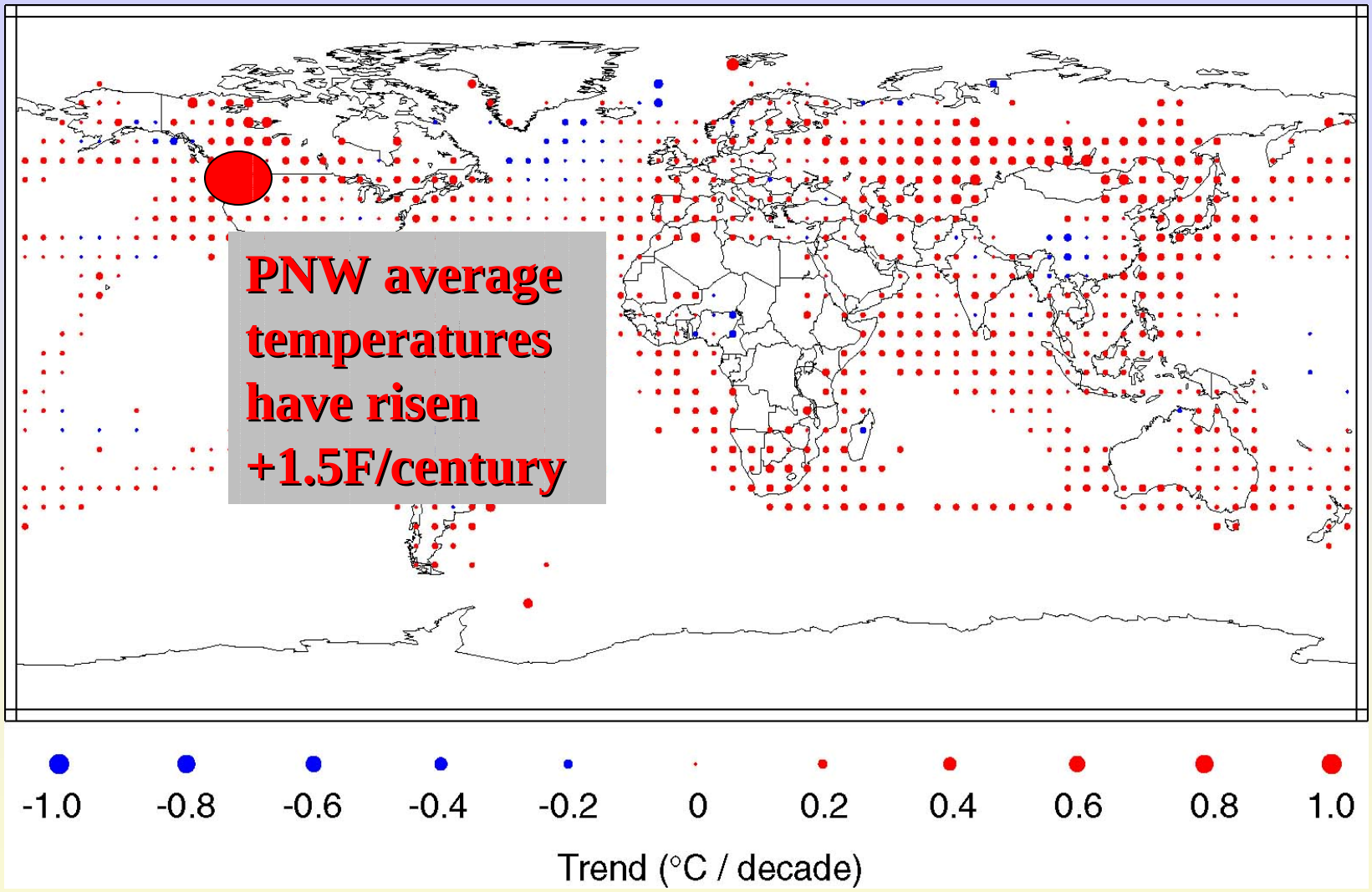
Science of climate change

- Thousands of peer-reviewed scientific papers
- **Intergovernmental Panel on Climate Change (IPCC)**
  - Major reports in 1990, 1996, 2001, 2007
  - 2001 report involved 637 contributing authors, 420 peer-reviews, then another review by government experts and policy-makers
- Conclusions from the IPCC's 2001 assessment:
  - "An increasing body of observations gives a collective picture of a warming world and other changes in the climate system."
  - "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."

At the request of President Bush, the IPCC's conclusions were reviewed and confirmed by the US National Academy of Sciences in 2001

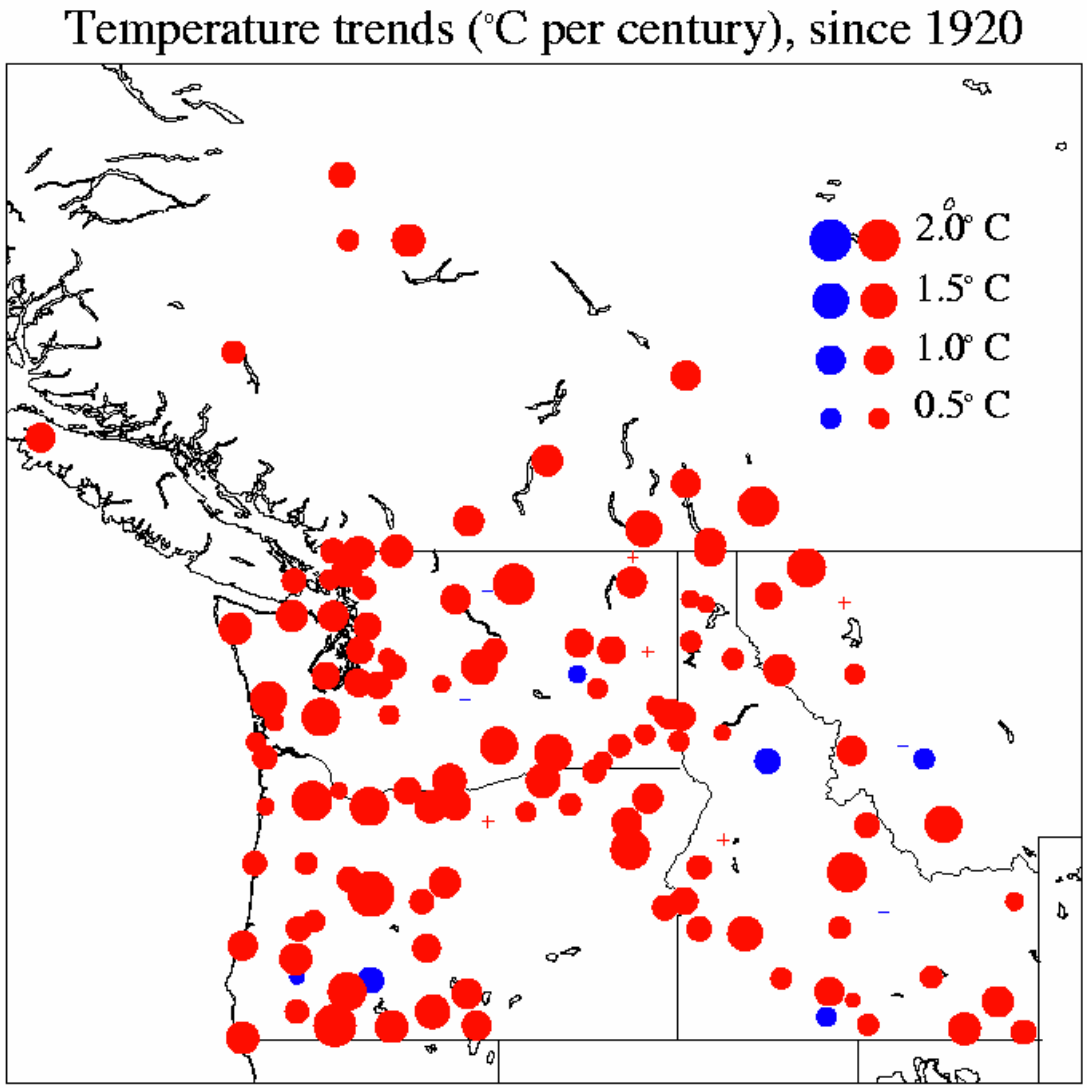
There was global warming in the 20th Century

Annual Temperature Trends, (°C / century) 1901-1999



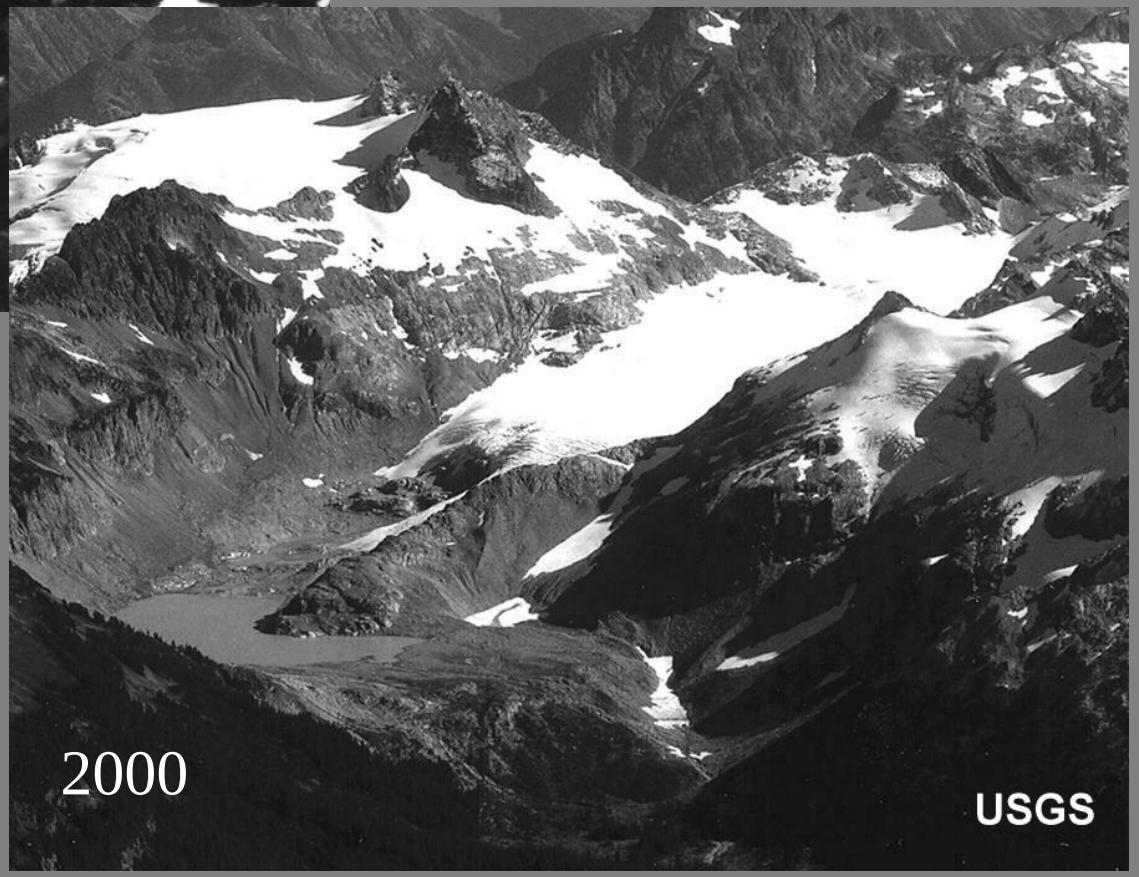
Source: P. Jones, et. al. 2000.

- In the Pacific Northwest, most stations show 20th century temperatures warmed at a rate of ~0.5 to 2 °C per century (a bit faster than the global average rate of warming)
- It is <u>not</u> clear how much of the regional warming is due to human-caused global warming



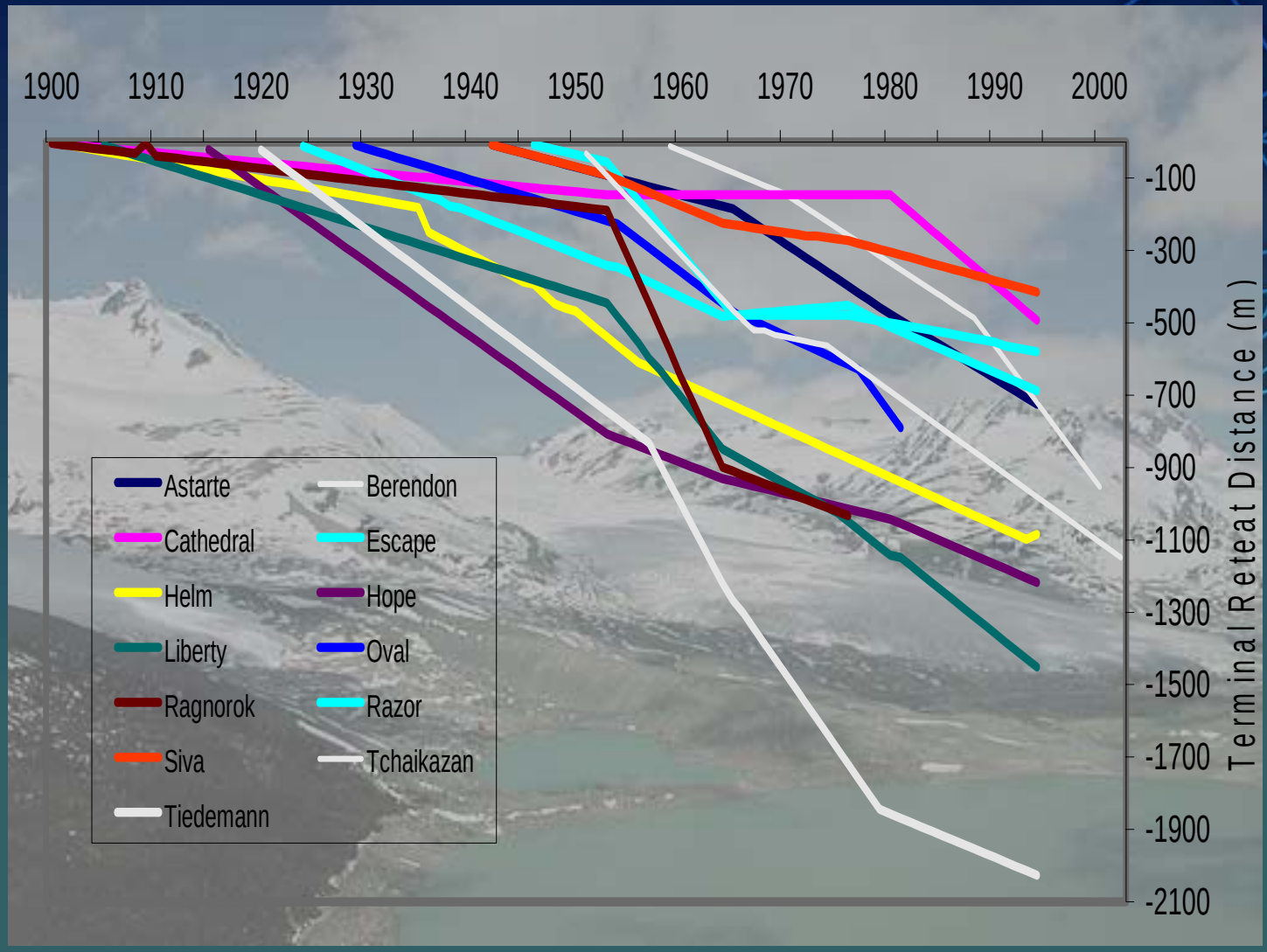
Mote, 2003: Northwest Science, vol 77

The South Cascade glacier retreated dramatically in the 20th century



Courtesy of the USGS glacier group

Historical terminus retreat in the British Columbia Coast Mountains



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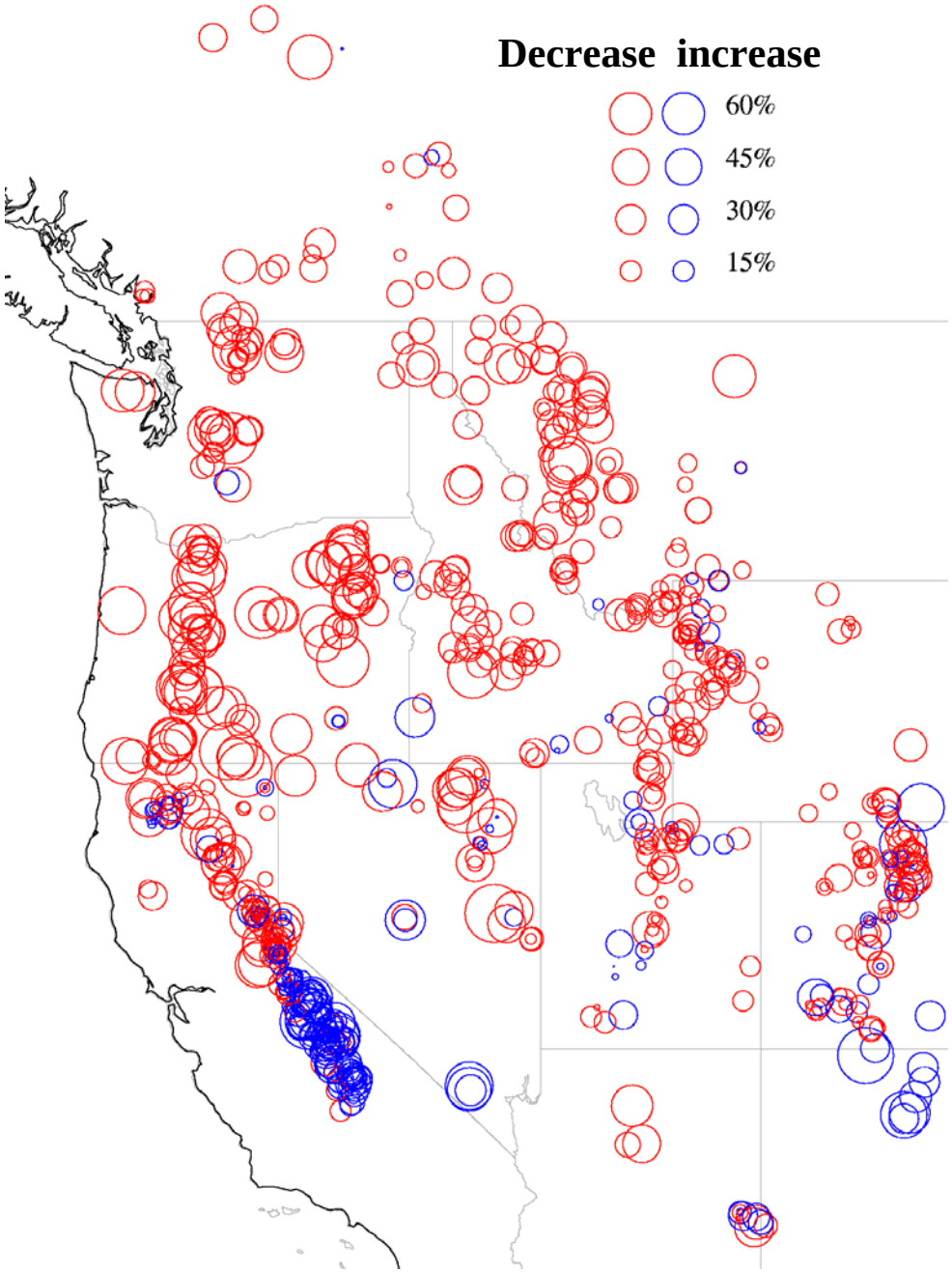
GEOGRAPHY

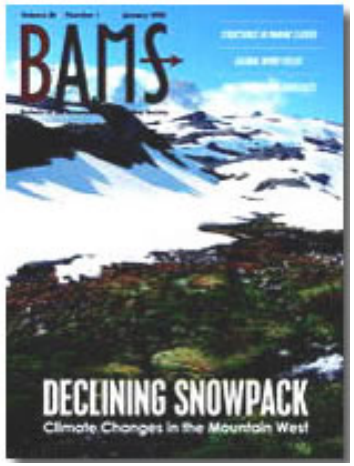


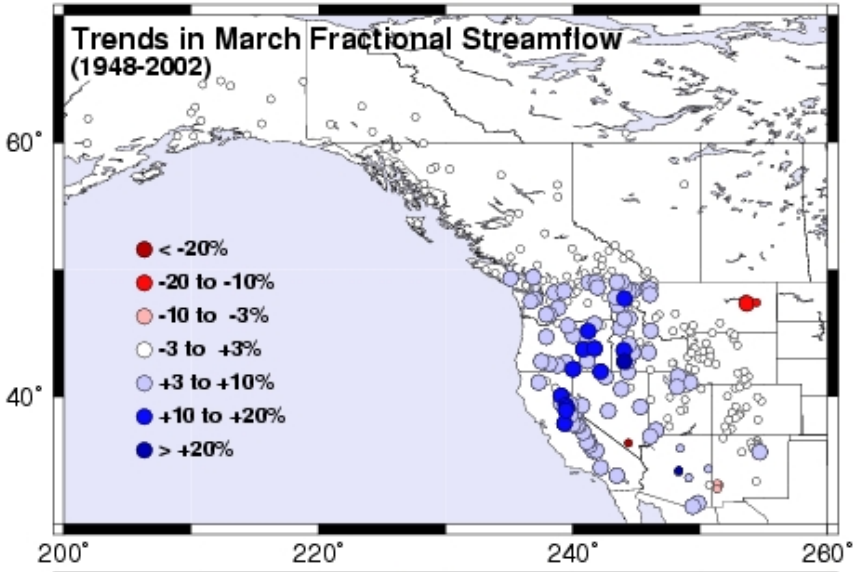
Trends in April 1 Snowpack

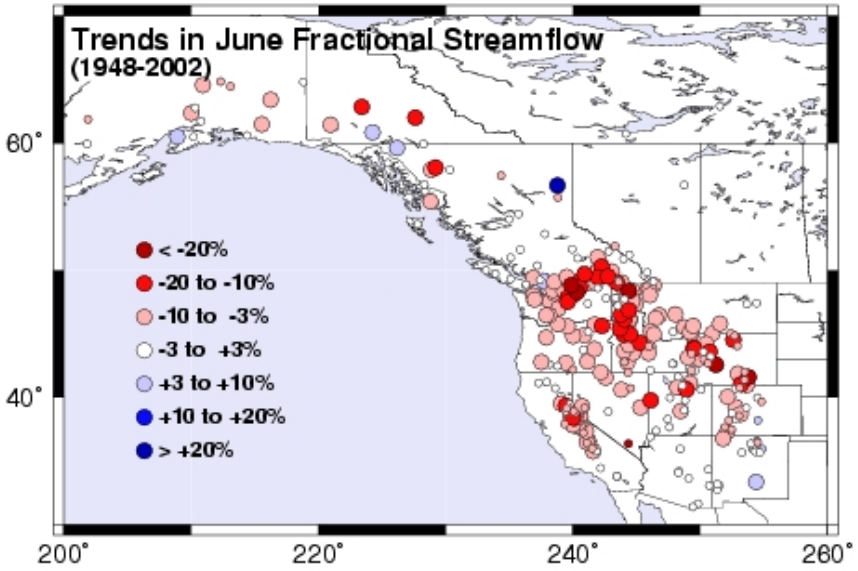
("snow-water-equivalent)
1950-2000
Relative to 1950 value

73% – trends
Large – trends PNW
Some + trends SW

Mote et al. 2005: BAMS



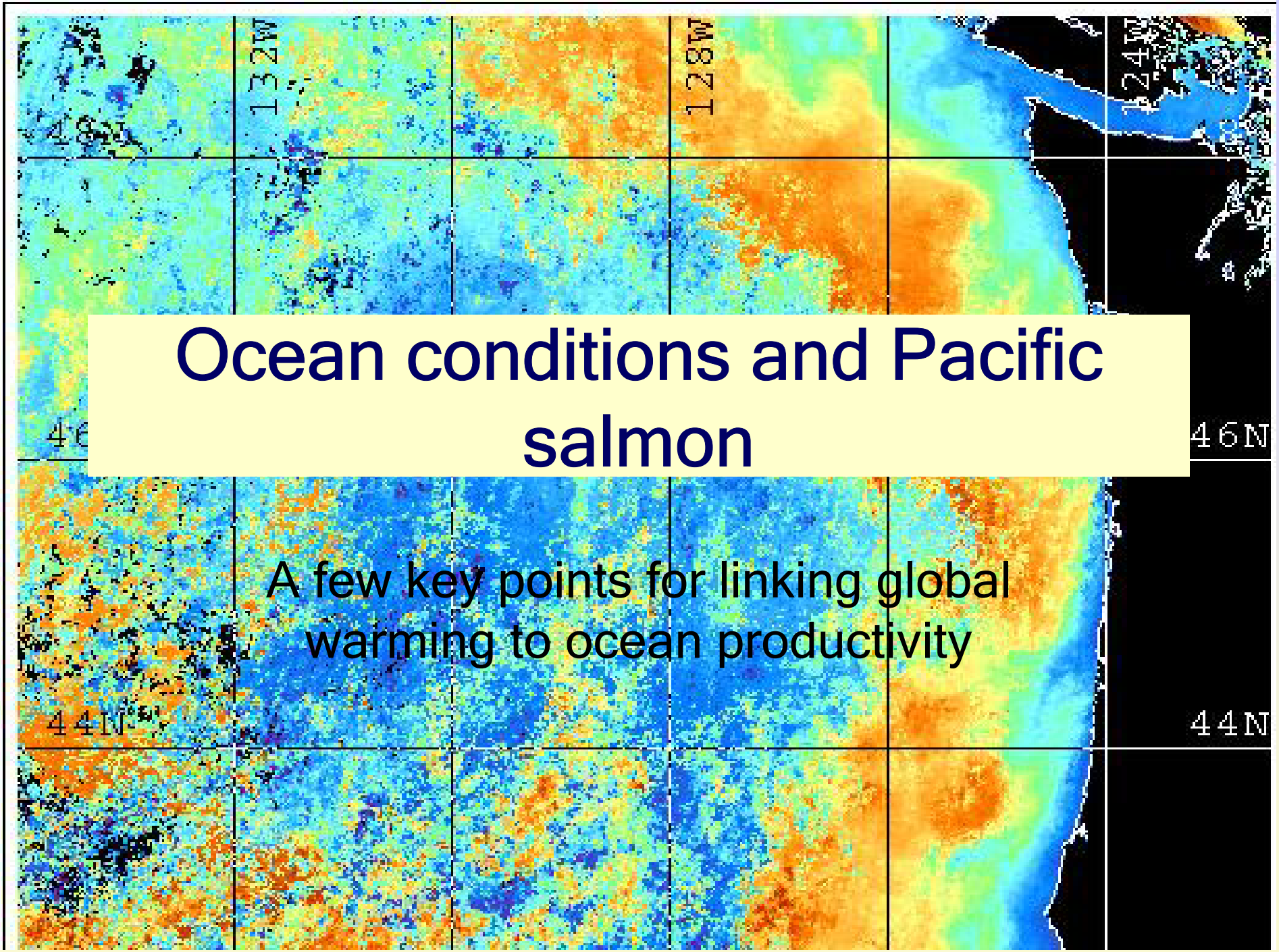




from:
Stewart, I.T., D.R. Cayan, and M.D. Dettinger (2004)
Changes toward earlier streamflow timing across western North America
J. Climate, in review

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

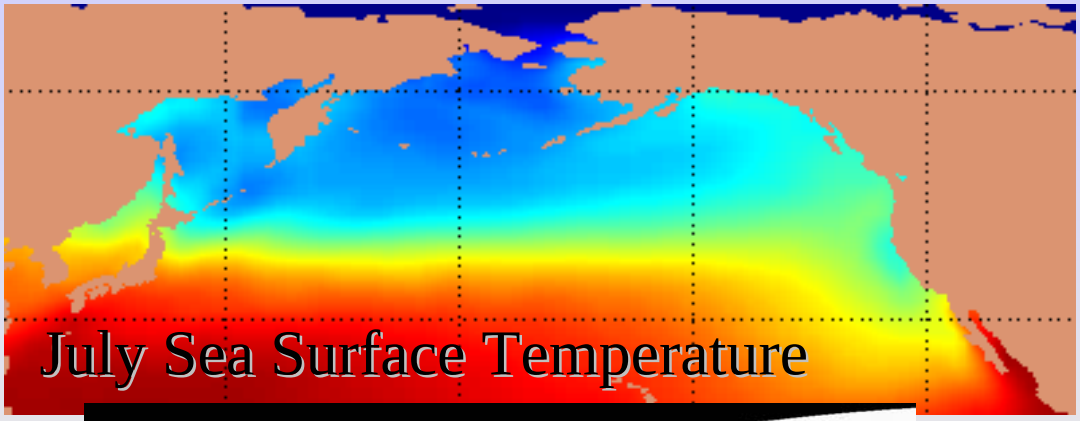
Figure by Iris Stewart, Scripps Inst. of Oceanog. (UC San Diego)

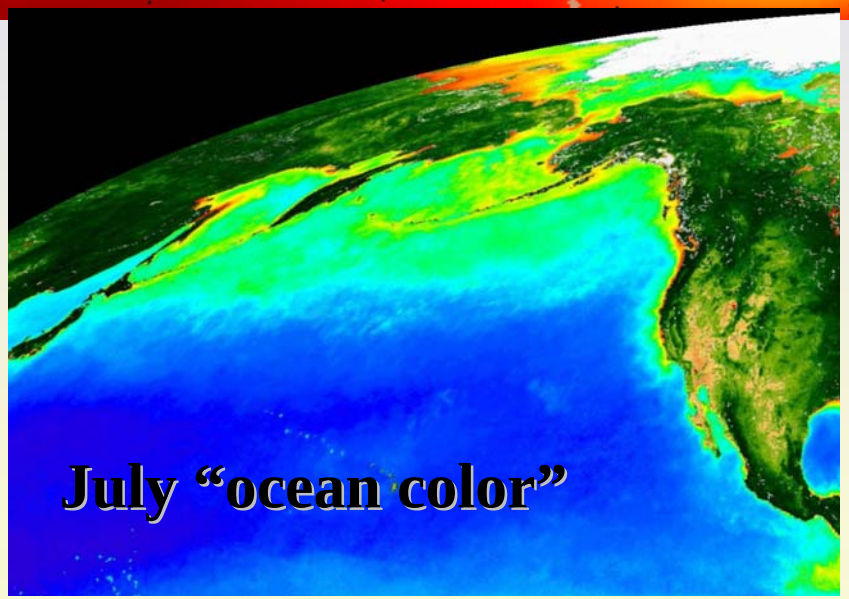


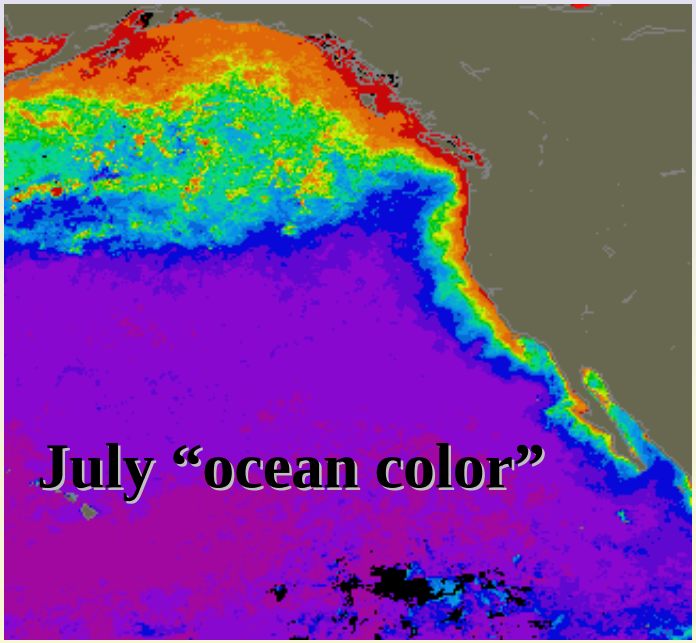
Ocean conditions and Pacific salmon

A few key points for linking global warming to ocean productivity

Pacific salmon habitat: productive sub-arctic (cool-fresh-nutrient rich) waters from Japan to California -- coastal upwelling extends this habitat south to S. Cal.



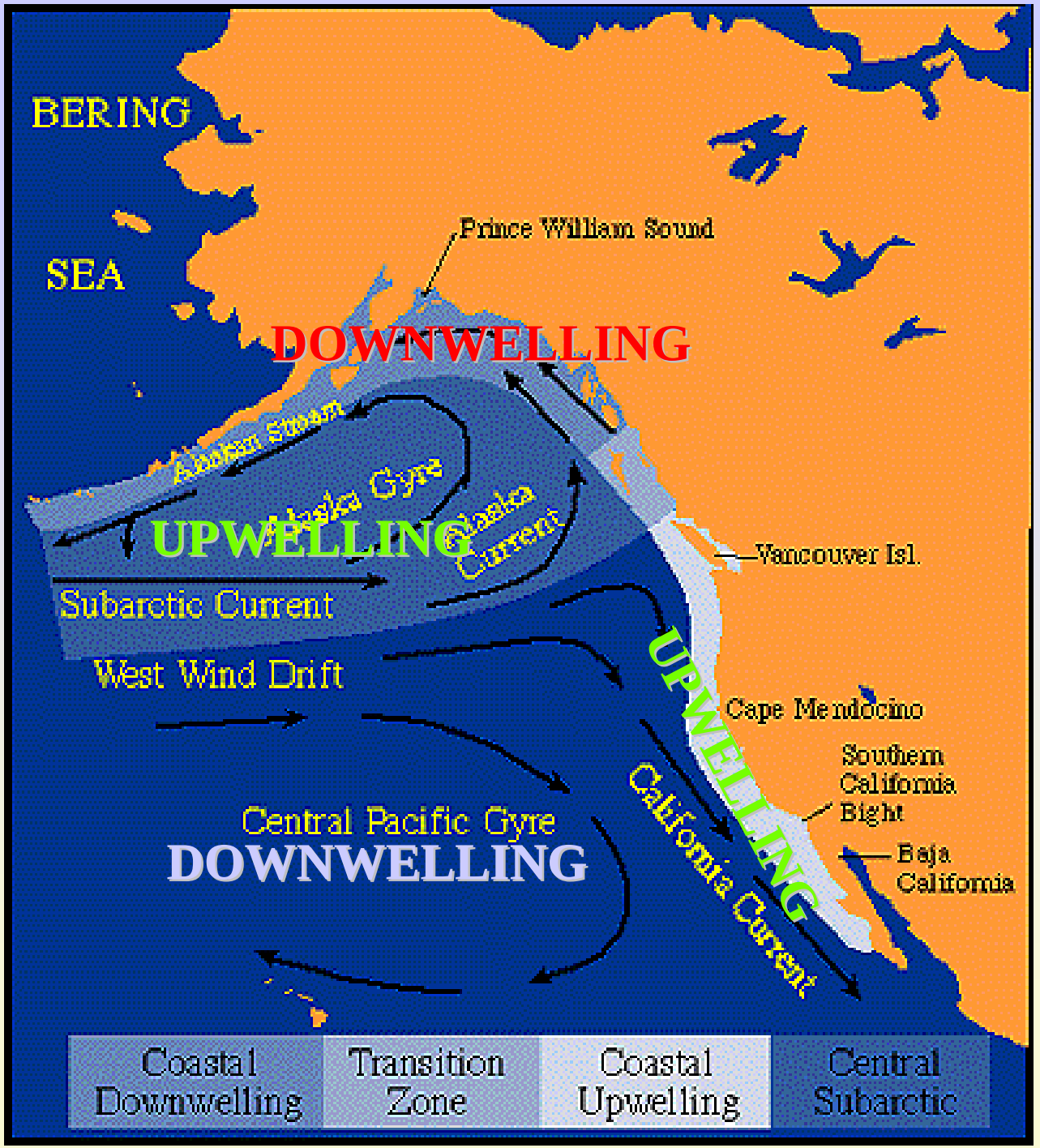




SeaWiFS images from NASA’s Goddard Space Flight Center
http://seawifs.gsfc.nasa.gov/SEAWIFS.html

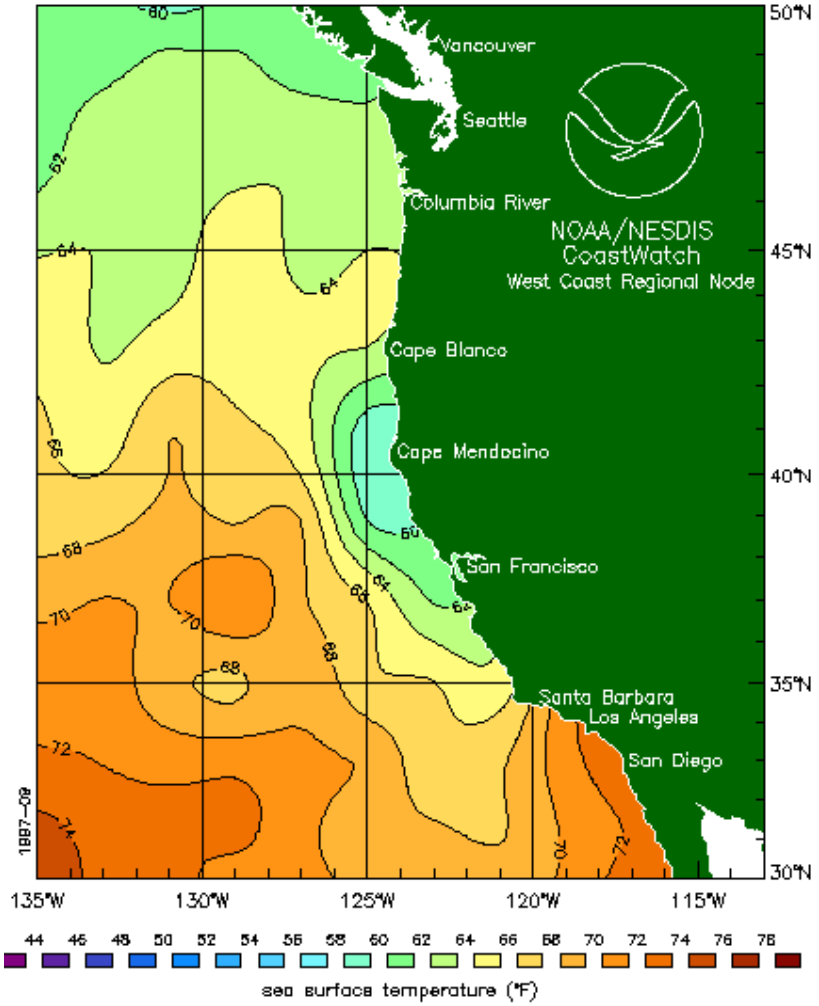
Ocean habitat domains are closely linked to wind and current patterns

(from Ware and McFarlane, 1989)

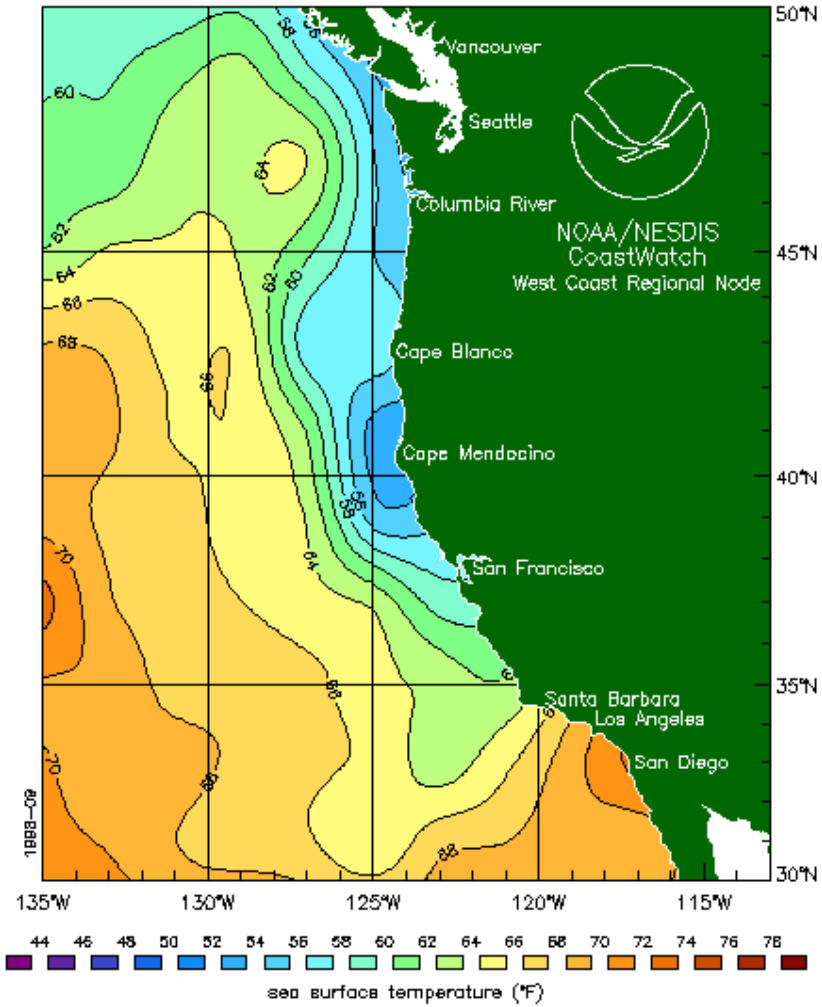


West-coast sub-arctic habitat is dynamic and sensitive to changing wind patterns (El Niño, La Niña, the Pacific Decadal Oscillation (PDO), and other)

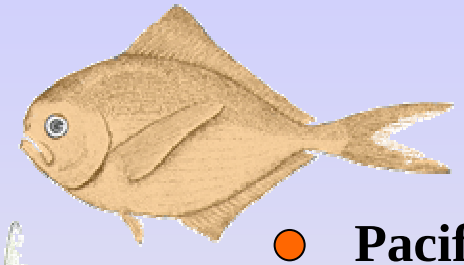
Sept 1997 El Niño



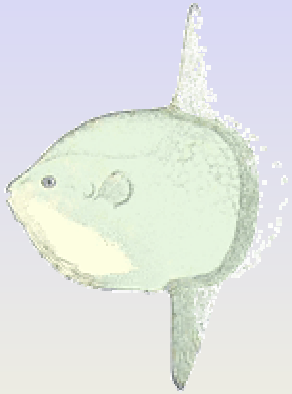
Sept 1998 La Niña



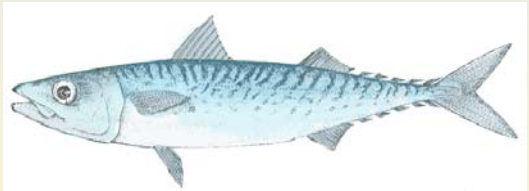
Exotic Species Sightings off the BC Coast
During 1983, an extreme El Niño year (J. Fulton, P.B.S.)



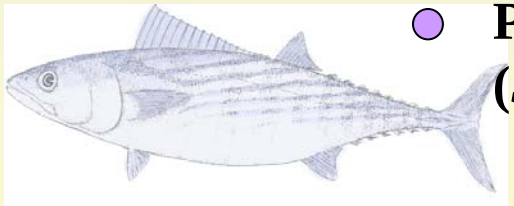
Pacific Pomfret
(*Brama japonica*)



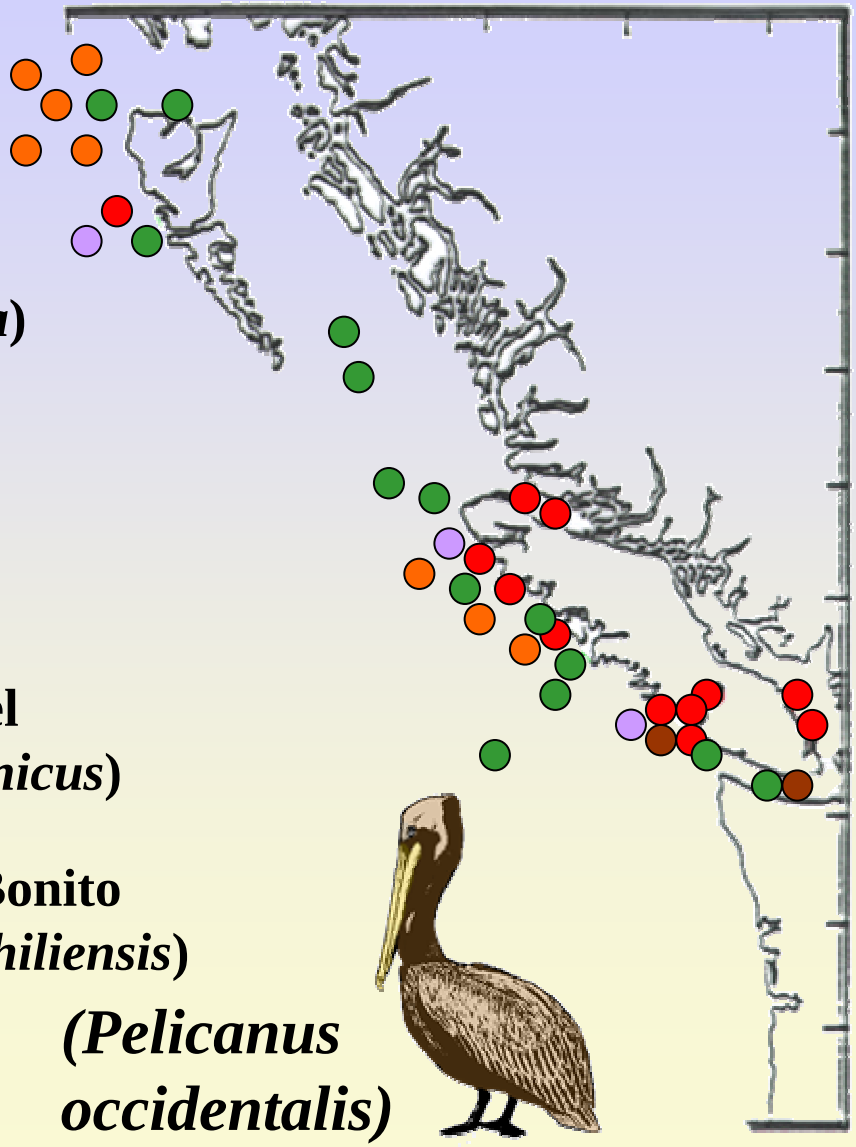
Ocean Sunfish
(*Mola mola*)



Chub mackerel
(*Scomber japonicus*)



Pacific Bonito
(*Sarda chiliensis*)



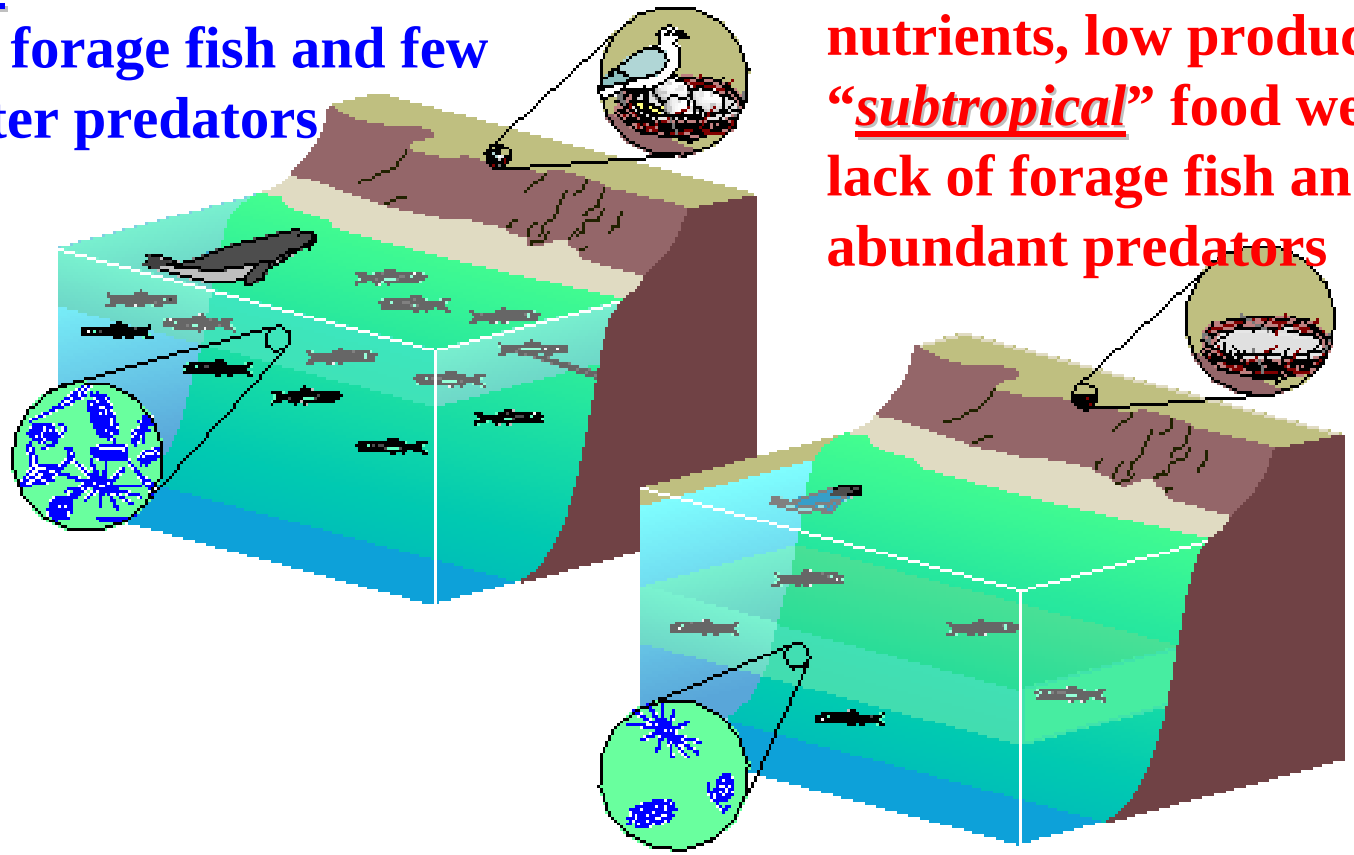
(Pelicanus occidentalis)

Slide provided by Kim Hyatt, DFO

upwelling food webs in our coastal ocean

Cool water, weak stratification high nutrients, a productive "*subarctic*" food-chain with abundant forage fish and few warm water predators

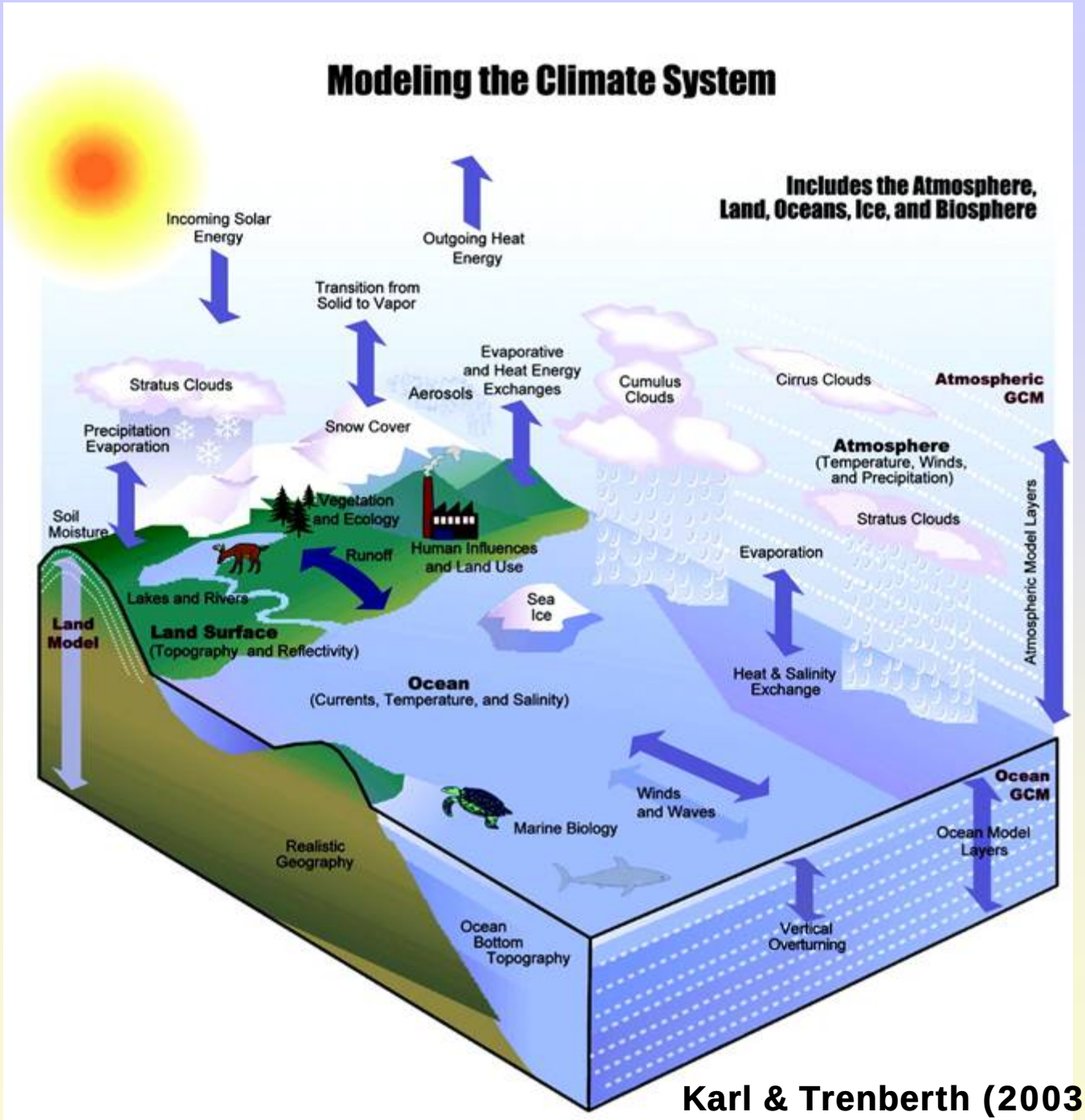
Warm stratified ocean, few nutrients, low productivity "*subtropical*" food web, a lack of forage fish and abundant predators



Peering into the future

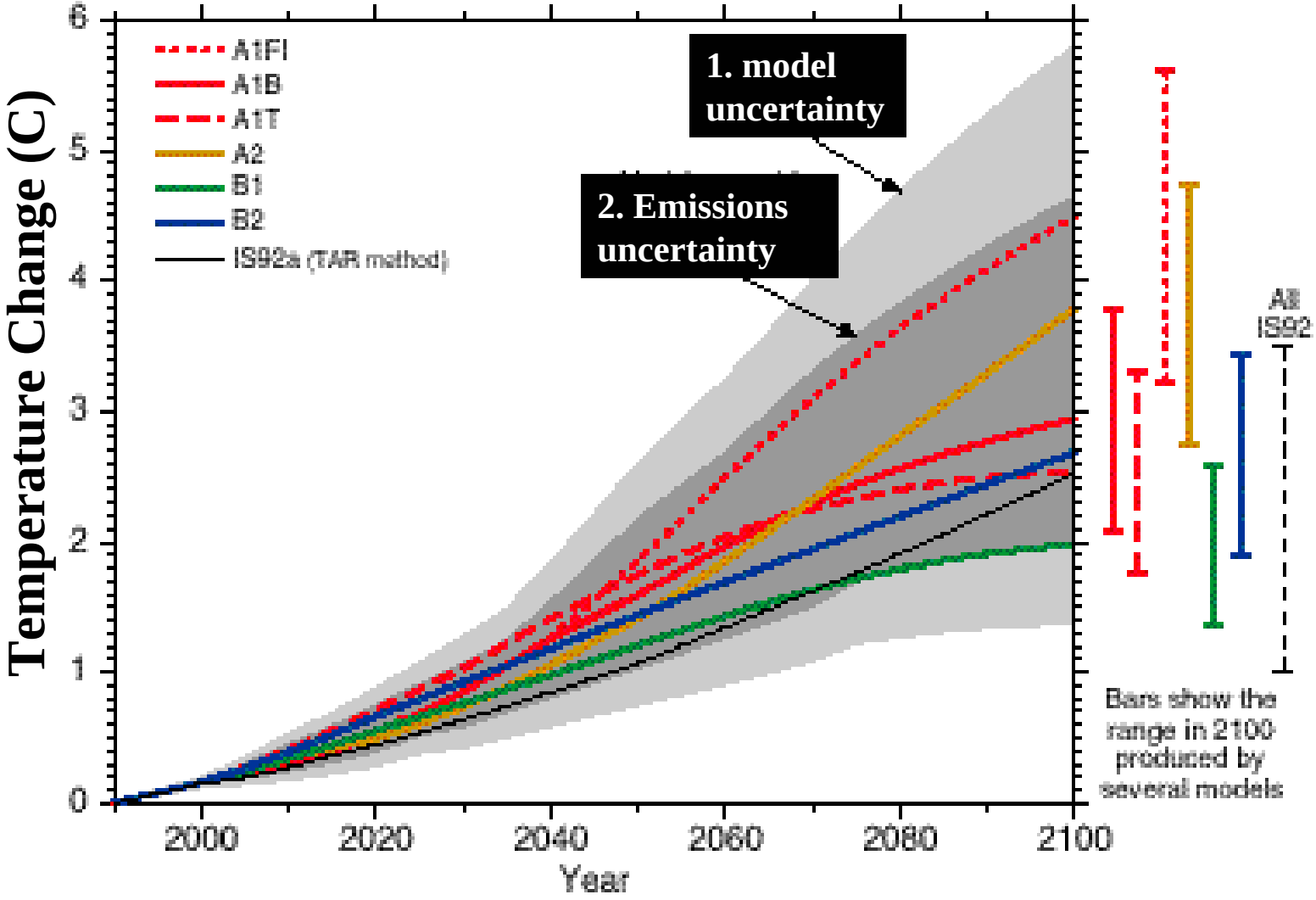
What are the consequences of increasing nature's greenhouse effect?

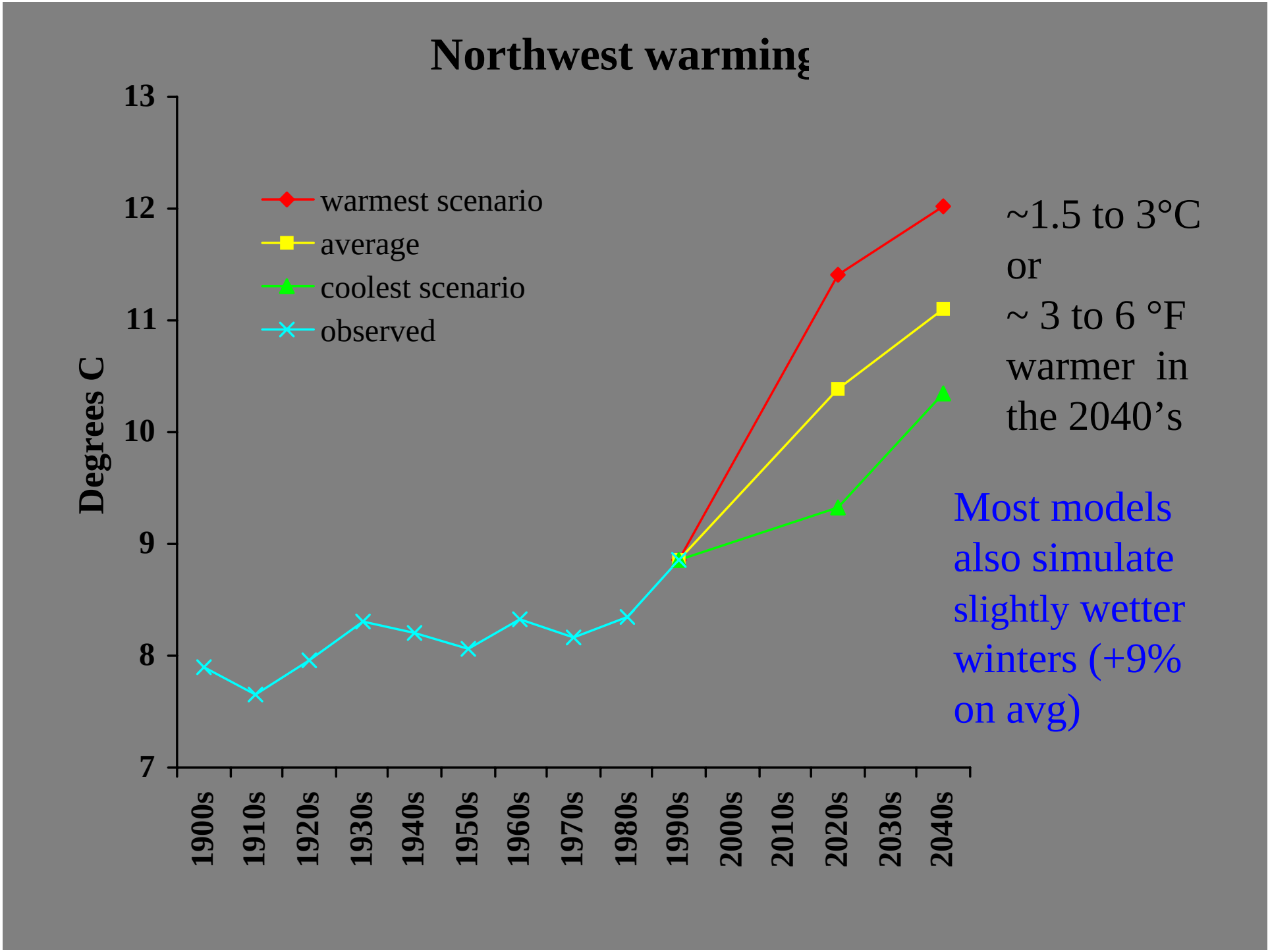
To answer this question, scientists are using climate system simulation models and future greenhouse gas emission scenarios



Karl & Trenberth (2003) Science

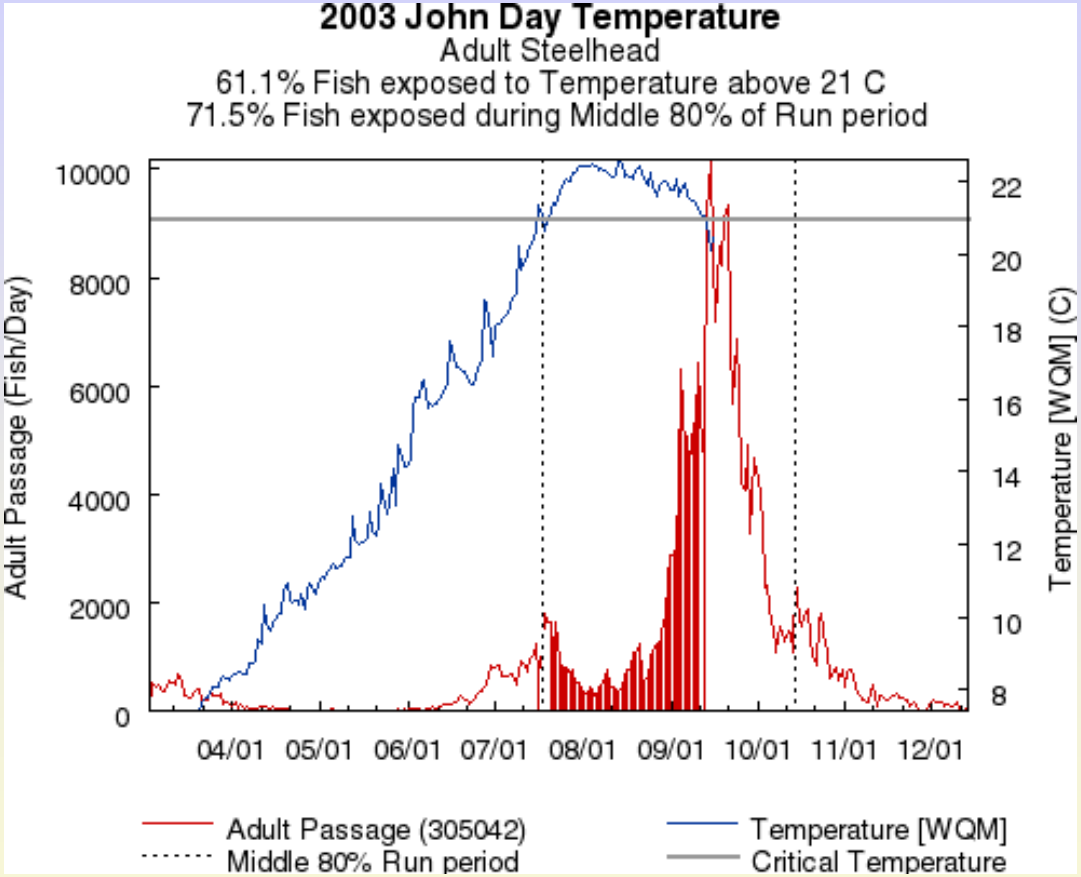
future climate scenarios: different model - emissions combinations give different answers




Northwest warming
Degrees C
13
12
11
10
9
8
7
warmest scenario
average
coolest scenario
observed
1900s
1910s
1920s
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s
2010s
2020s
2030s
2040s
~1.5 to 3°C
or
~ 3 to 6 °F
warmer in
the 2040's
Most models
also simulate
slightly wetter
winters (+9%
on avg)

Adult migrations and water temperature in the Lower Columbia River

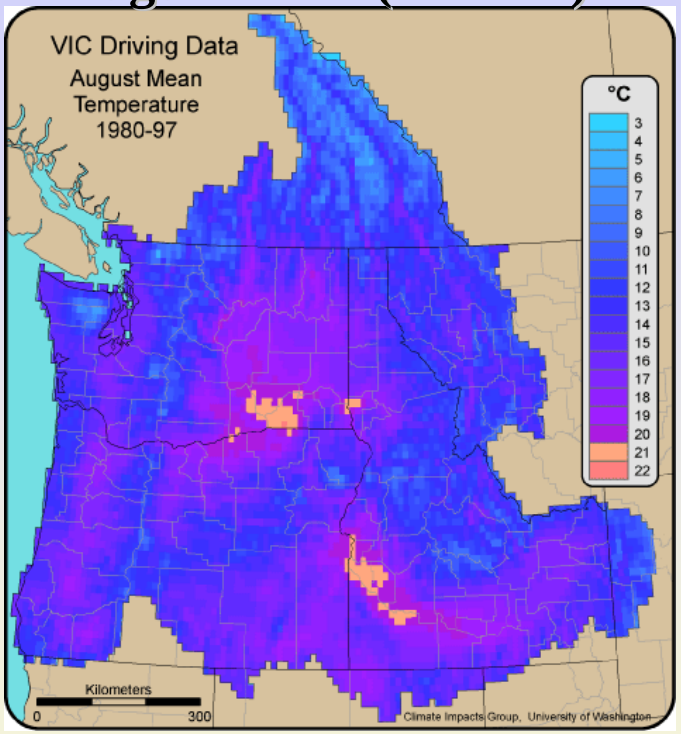
- Adult migrations are sensitive to water temperatures > ~21ºC



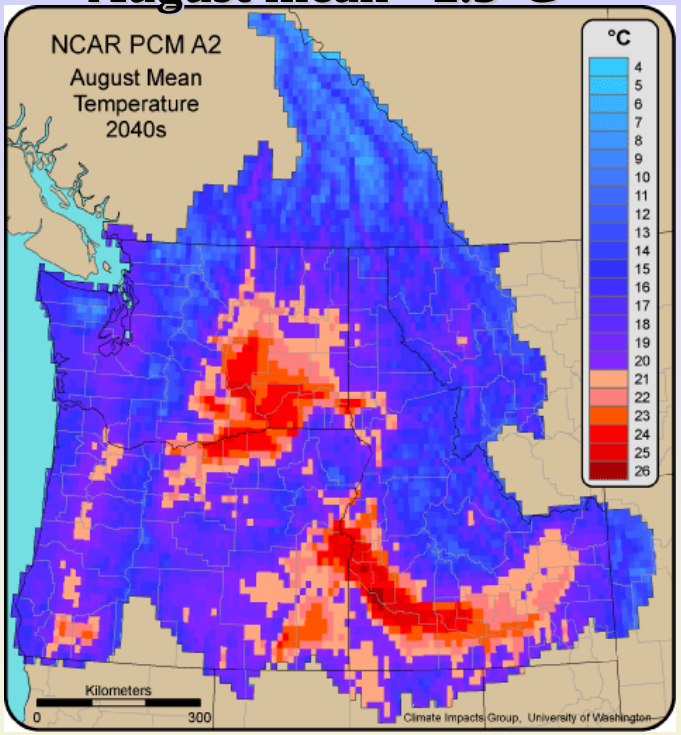
UW SAFS Columbia Basin DART: http://www.cqs.washington.edu/

A ***Plausible Warming*** and the 21°C threshold

August mean (1980-97)



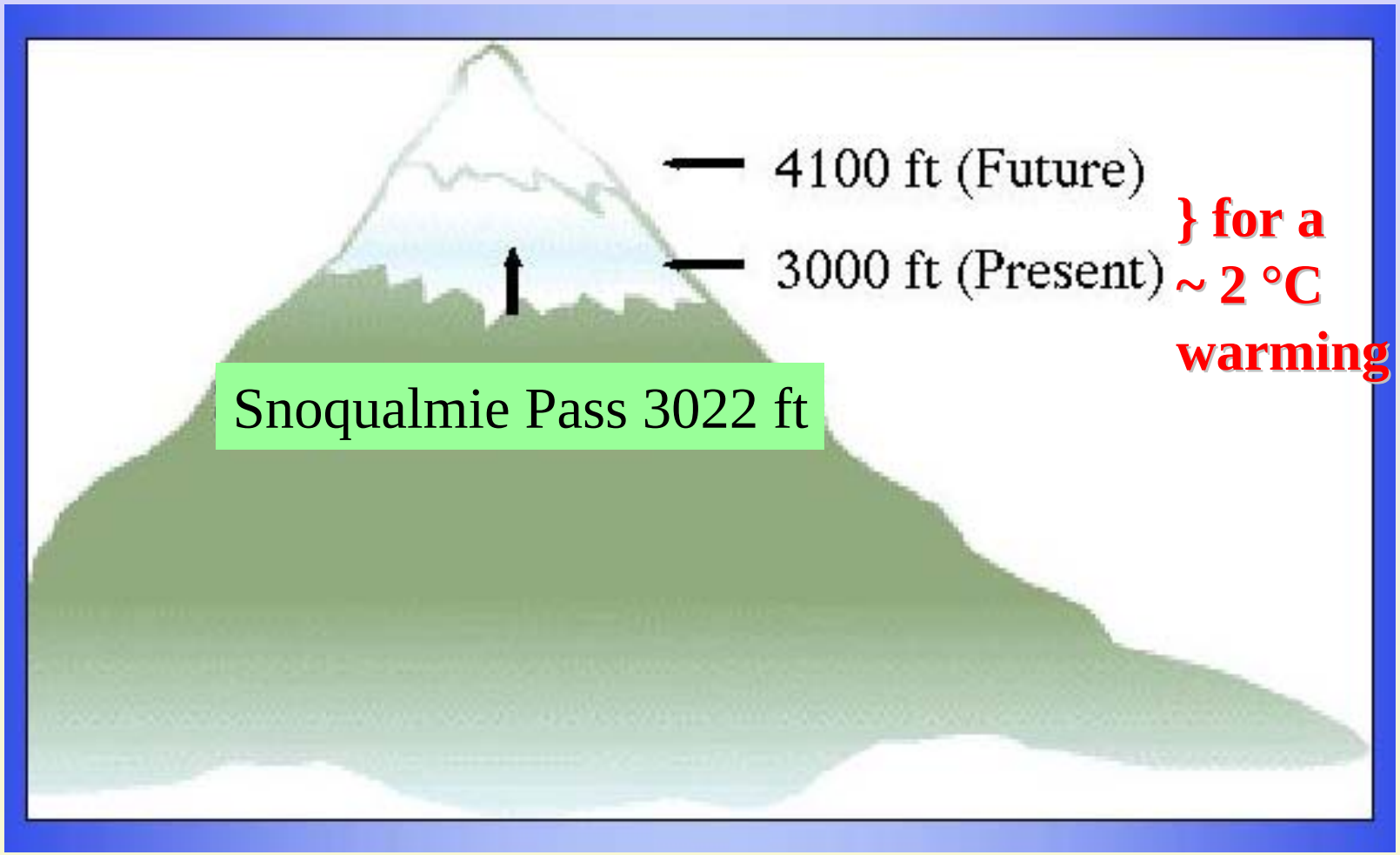
August mean +2.3°C



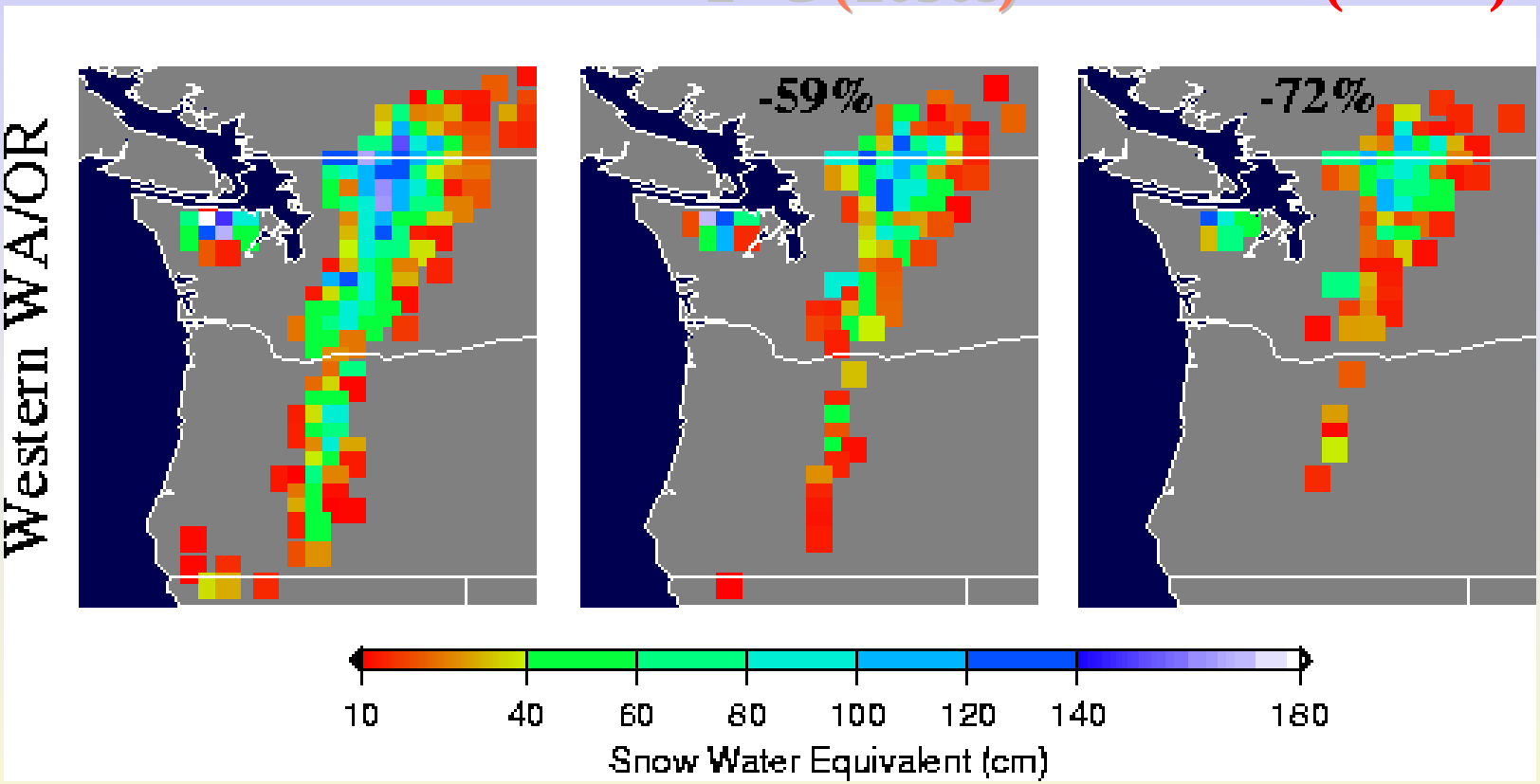
- With a 2.3 °C warming, ~ 20% of the region has August average temperatures > 21 °C (compared with an average of < 2% for 1980-97)

VIC driving data are described by Hamlet et al., *J. Hydrometeor.* (in press)

The main impact: less snow

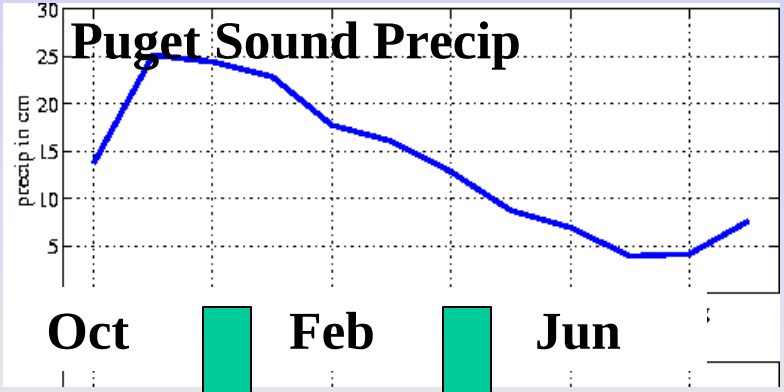


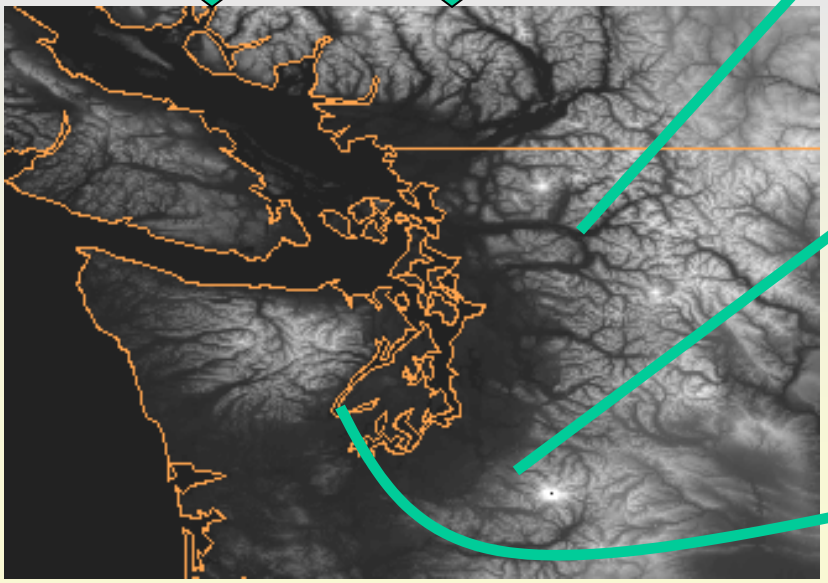
April 1st Snowpack simulations based on “plausible” warming scenarios

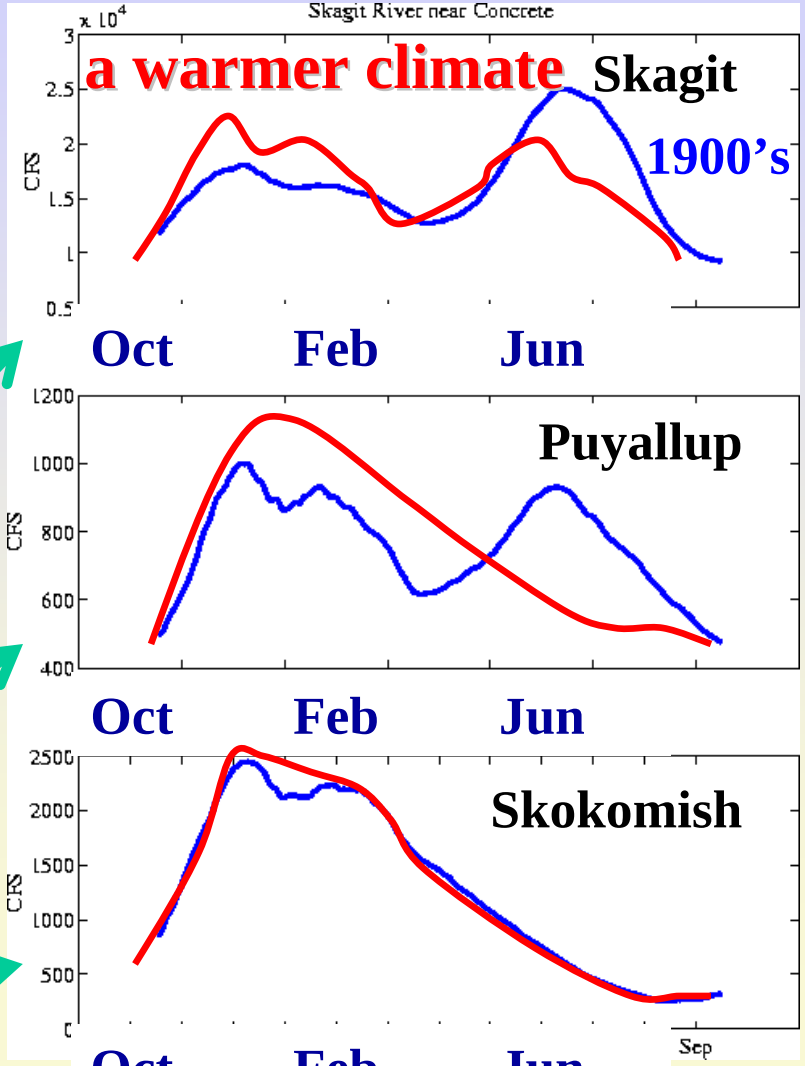


Provided by Dennis Lettenmaier and Andy Wood, UW Civil Engineering
Accelerated Climate Prediction Initiative, a UW-SIO-PNNL collaboration

Runoff patterns are temperature and elevation dependent



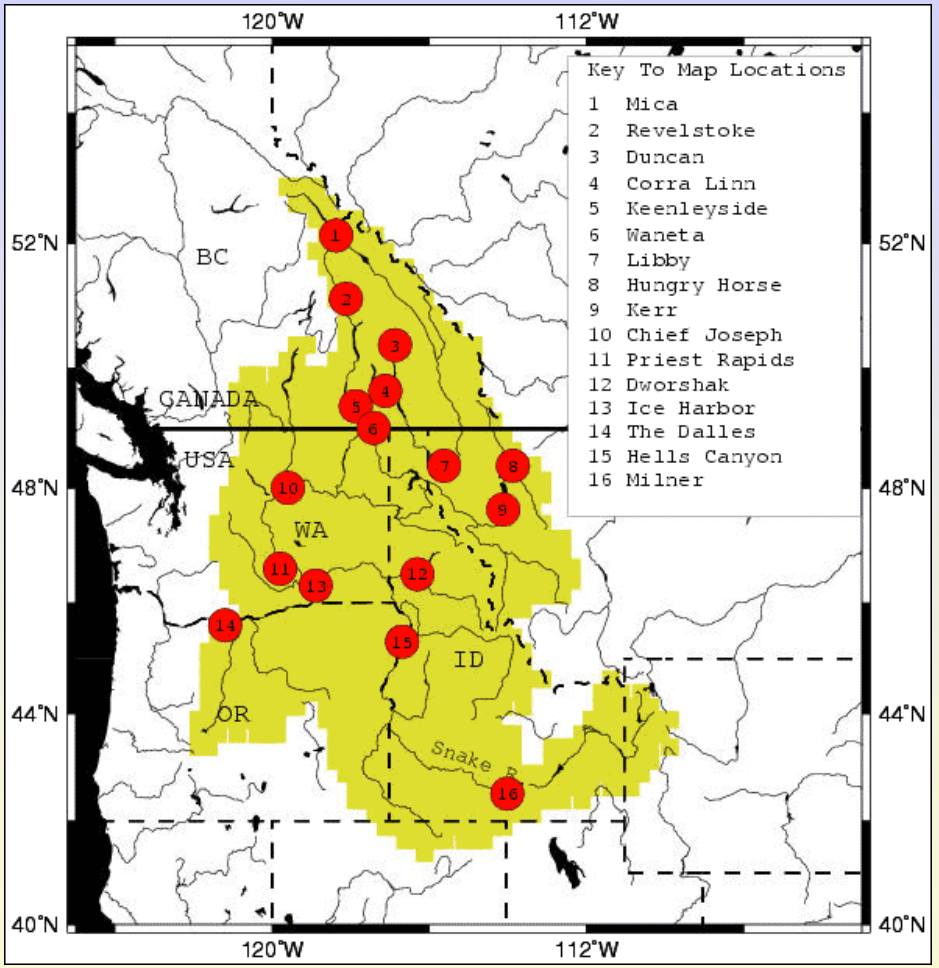




Global warming streamflow scenarios

- Combining a mid-range global warming scenario (+2.3 C by 2040s, + ~10% annual precip.) with observed weather for 1950-89, *40-yr records for global warming streamflow are simulated* using an 1/8 degree hydrology model for the Columbia River Basin
- Data are freely available off our web-site

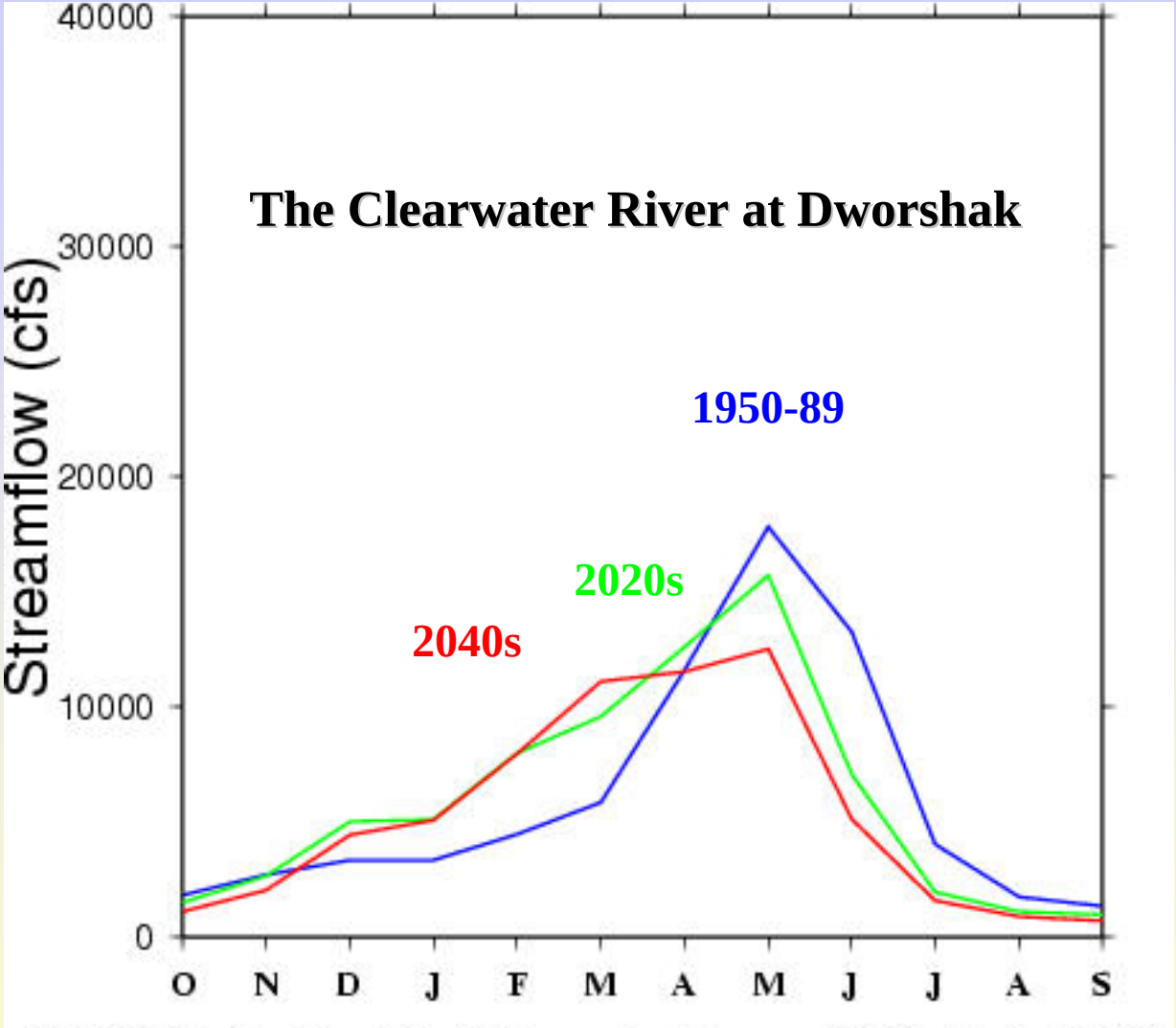
  cses.washington.edu/cig



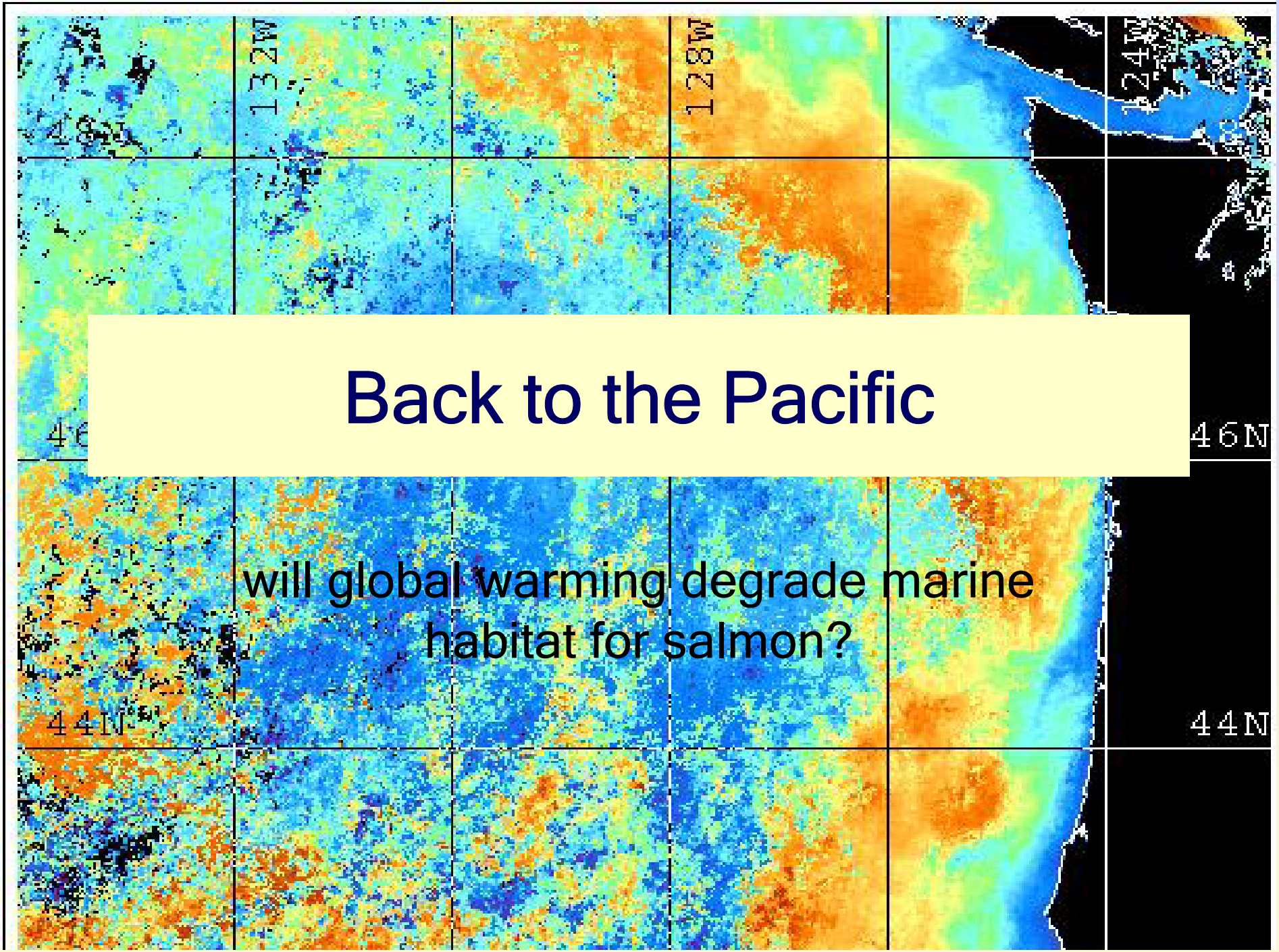
Also see Snover et al. 2003, BAMS, vol. 84

global warming natural runoff scenarios show major timing shifts in response to rising temperatures

cses.washington.edu/cig



Snover et al. 2003, BAMS, vol. 84



Back to the Pacific

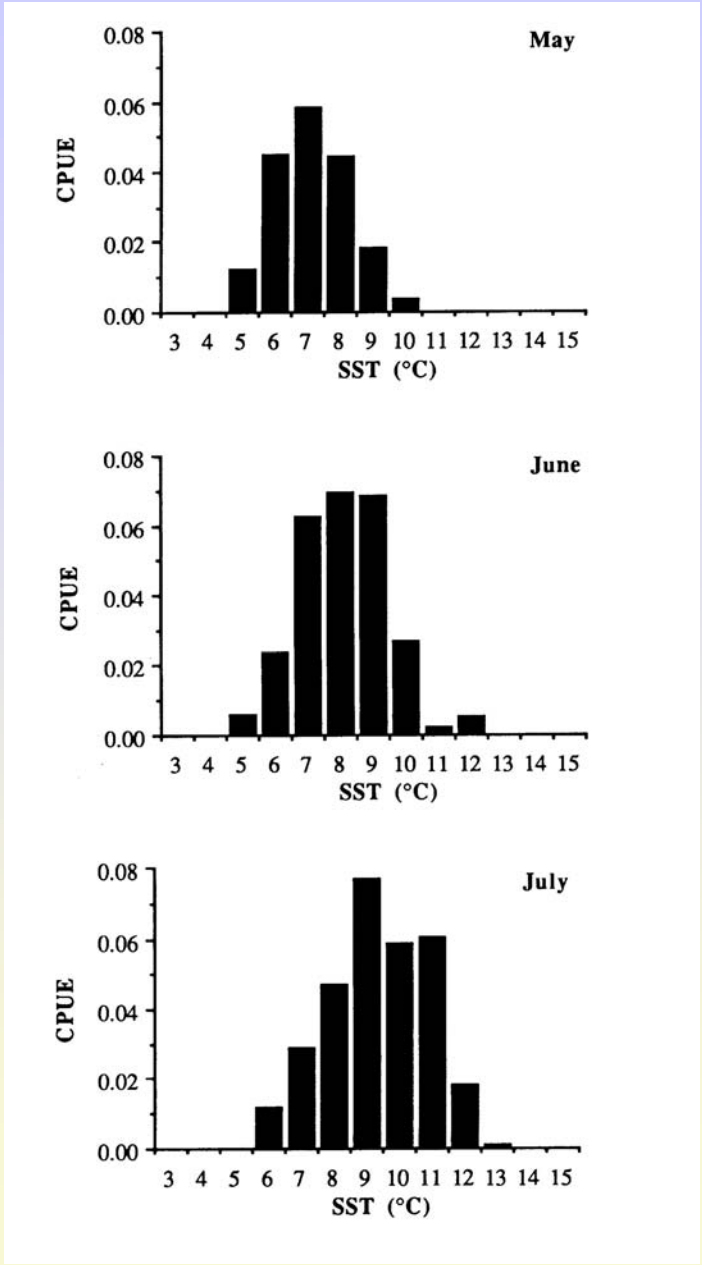
will global warming degrade marine habitat for salmon?

High Seas Habitat?

Sea surface temperatures and catch-per-unit-effort (cpue) for steelhead (*O. mykiss*) on the high seas:

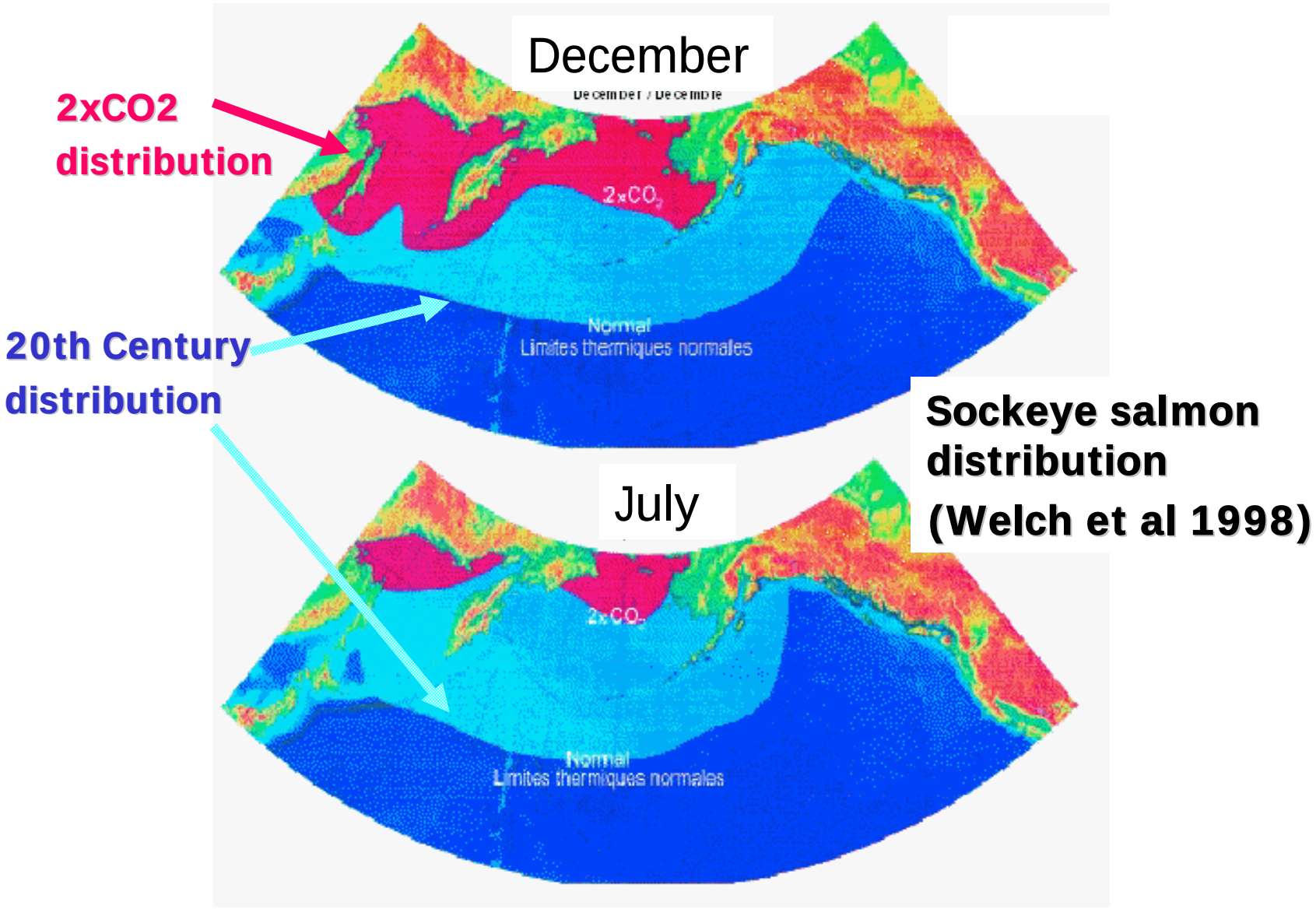
cpue peaks between 6 and 11ºC

(Burgner et al. 1992, INPFC)

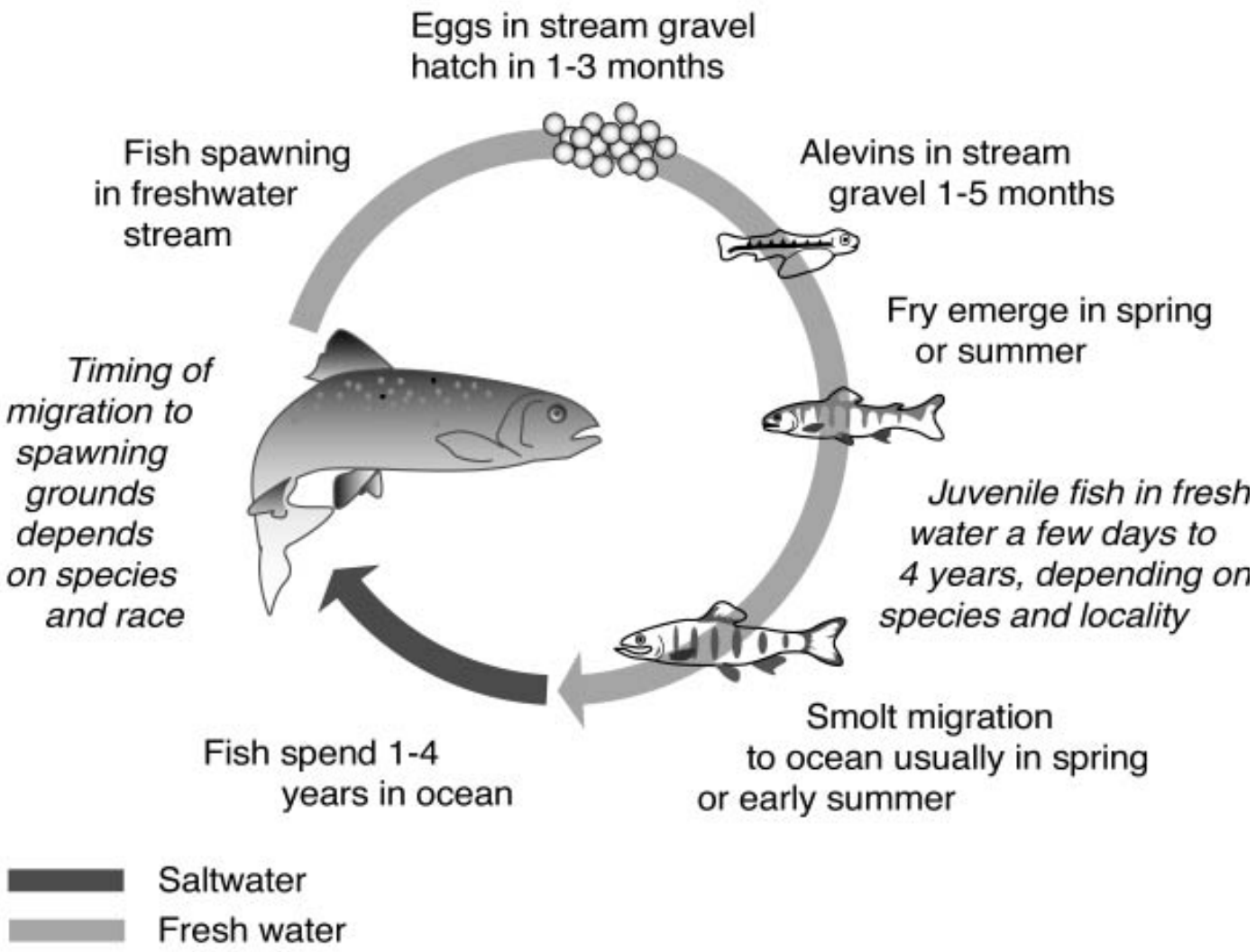


Welch et al's (1998) *Thermal Limits*

1. Salmon and steelhead are surface oriented at sea
2. They are metabolically constrained by surface ocean temperatures
3. Surface ocean warming will force salmon (sockeye and steelhead) out of the Pacific and into cooler northern oceans as metabolic rates accelerate with warming

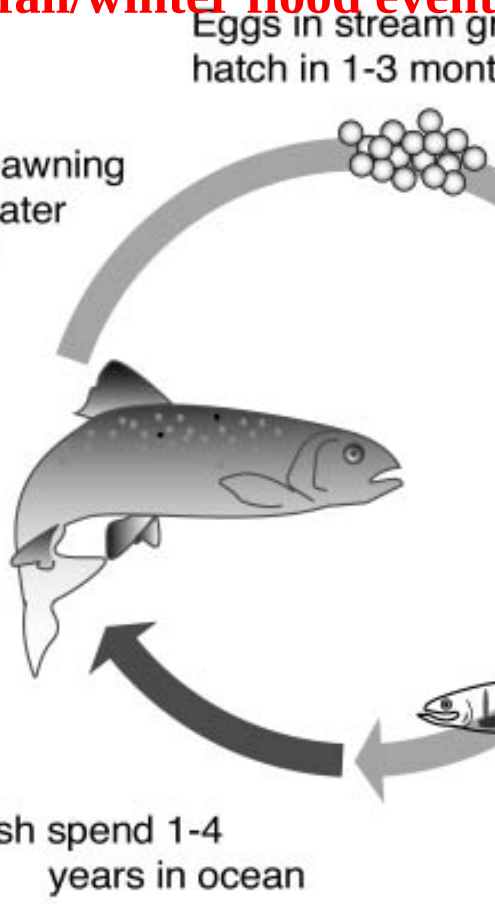

December
2xCO2
distribution
2xCO2
Normal
Limites thermiques normales
20th Century
distribution
July
2xCO2
Normal
Limites thermiques normales
Sockeye salmon
distribution
(Welch et al 1998)

Salmon Life Cycle



The salmon life cycle and climate warming

Increased fall/winter flood events in snow melt basins



Thermal barriers to spawning migrations

higher summer stream temps

Thermal limits?

- **will intensified upwelling winds sustain subarctic habitat?**

earlier spring snowmelt

- **will smolt migration timing shifts match timing shifts in the spring transition in coastal upwelling?**

Concluding thoughts

- Higher temperatures and changes in stream flow timing will exacerbate existing stresses on salmonids in freshwater and estuaries
  - *Without significant efforts to restore and protect instream flows, migration corridors, and thermal refugia, climate warming may be the straw that breaks the salmon's back in some (many?) basins*

- Global warming impacts on ocean conditions are now highly uncertain, yet 20th Century observations suggest that many PNW stocks suffer low ocean productivity during periods of warmer than average ocean temperatures

For more information

- The Intergovernmental Panel on Climate Change

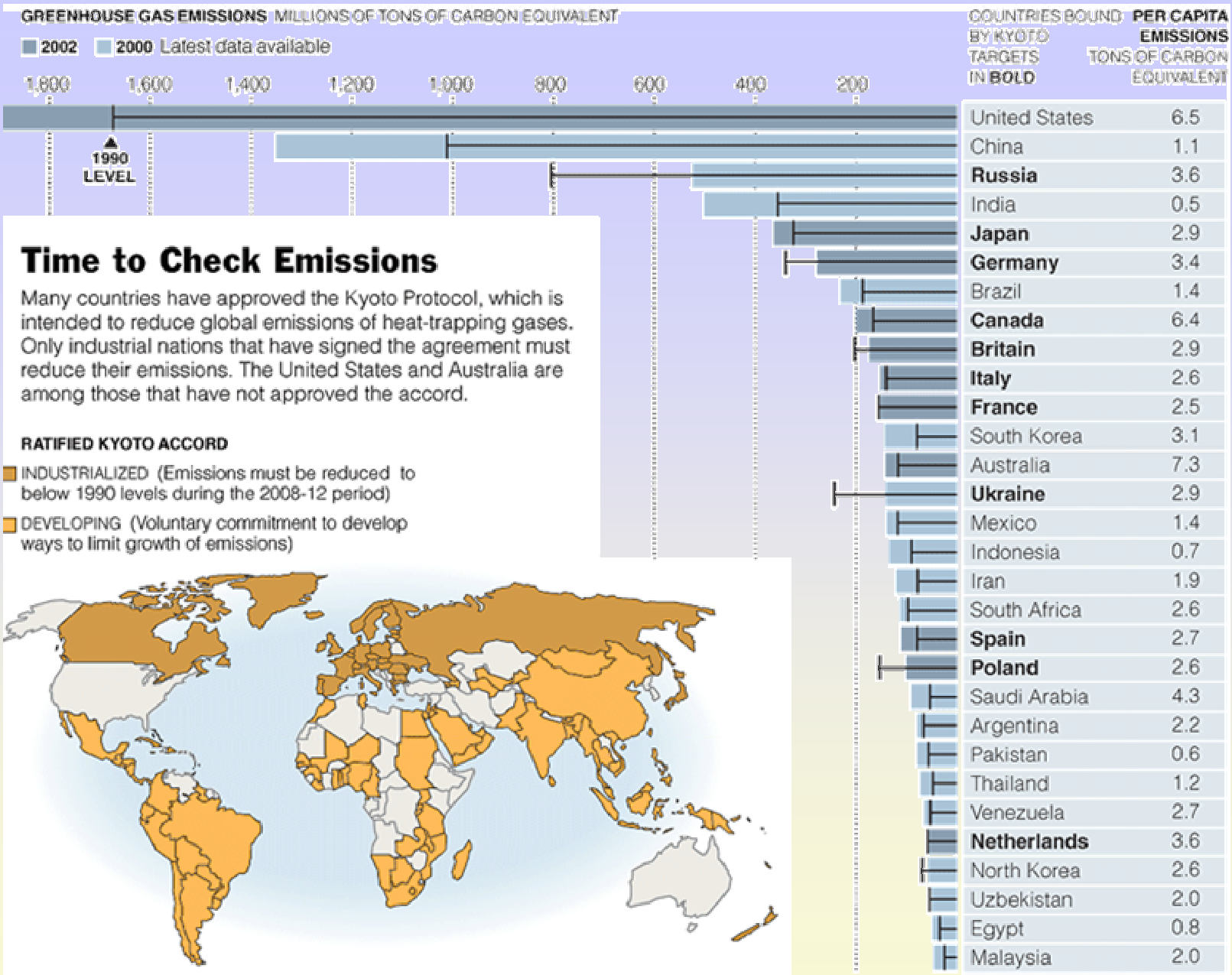
  http://www.ipcc.ch

- The UW Climate Impacts Group

  http://cses.washington.edu/cig

- RealClimate -- a “no spin zone” on climate science

  http://realclimate.org

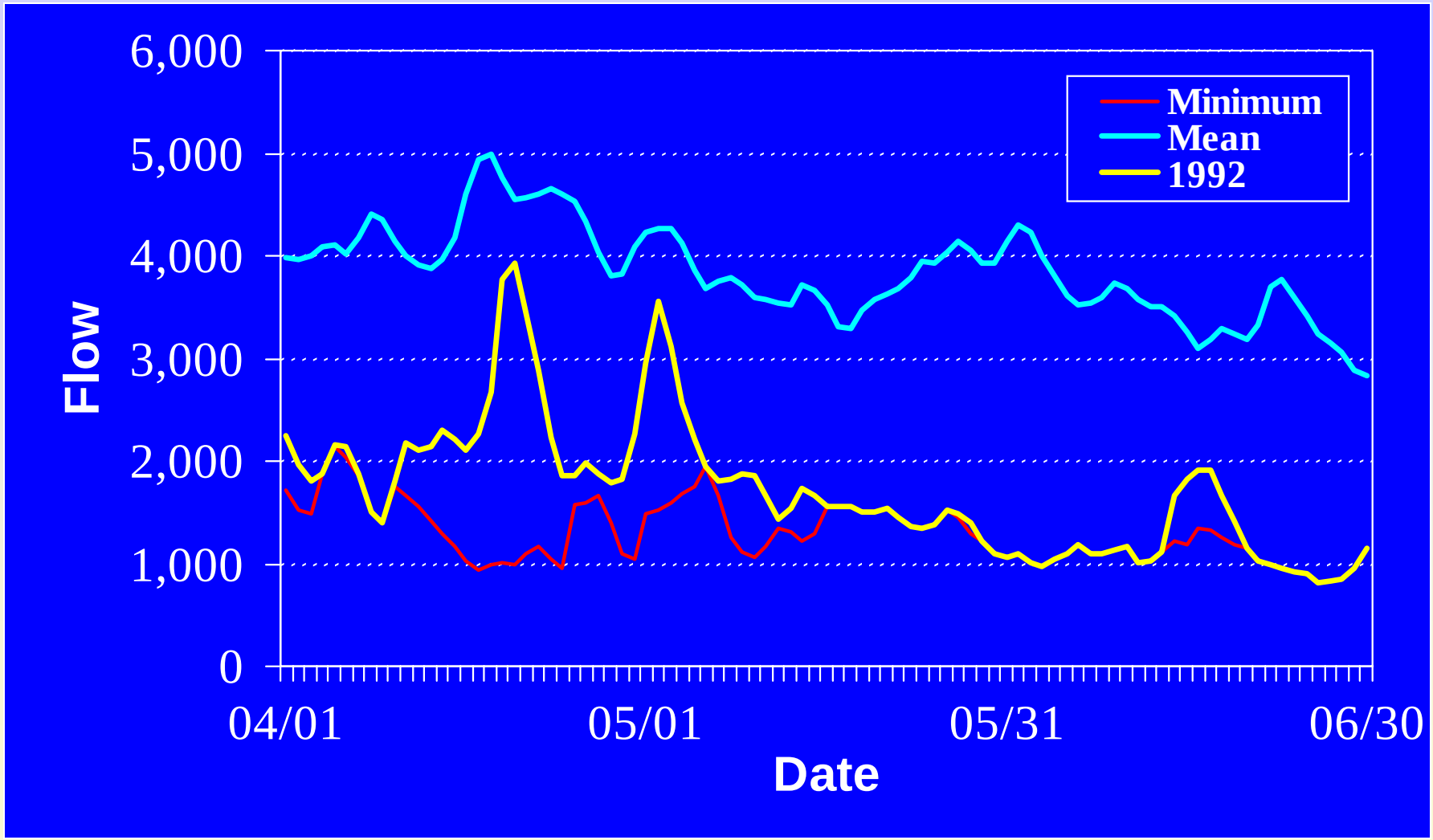


Emissions figures include carbon dioxide, methane, nitrous oxide and three fluorinated greenhouse gases. Figures exclude carbon dioxide emissions resulting from land use change and deforestation. If included, the amounts would probably rise significantly for Brazil, Indonesia and Malaysia.

Source: Climate Analysis Indicators Tool from the World Resources Institute

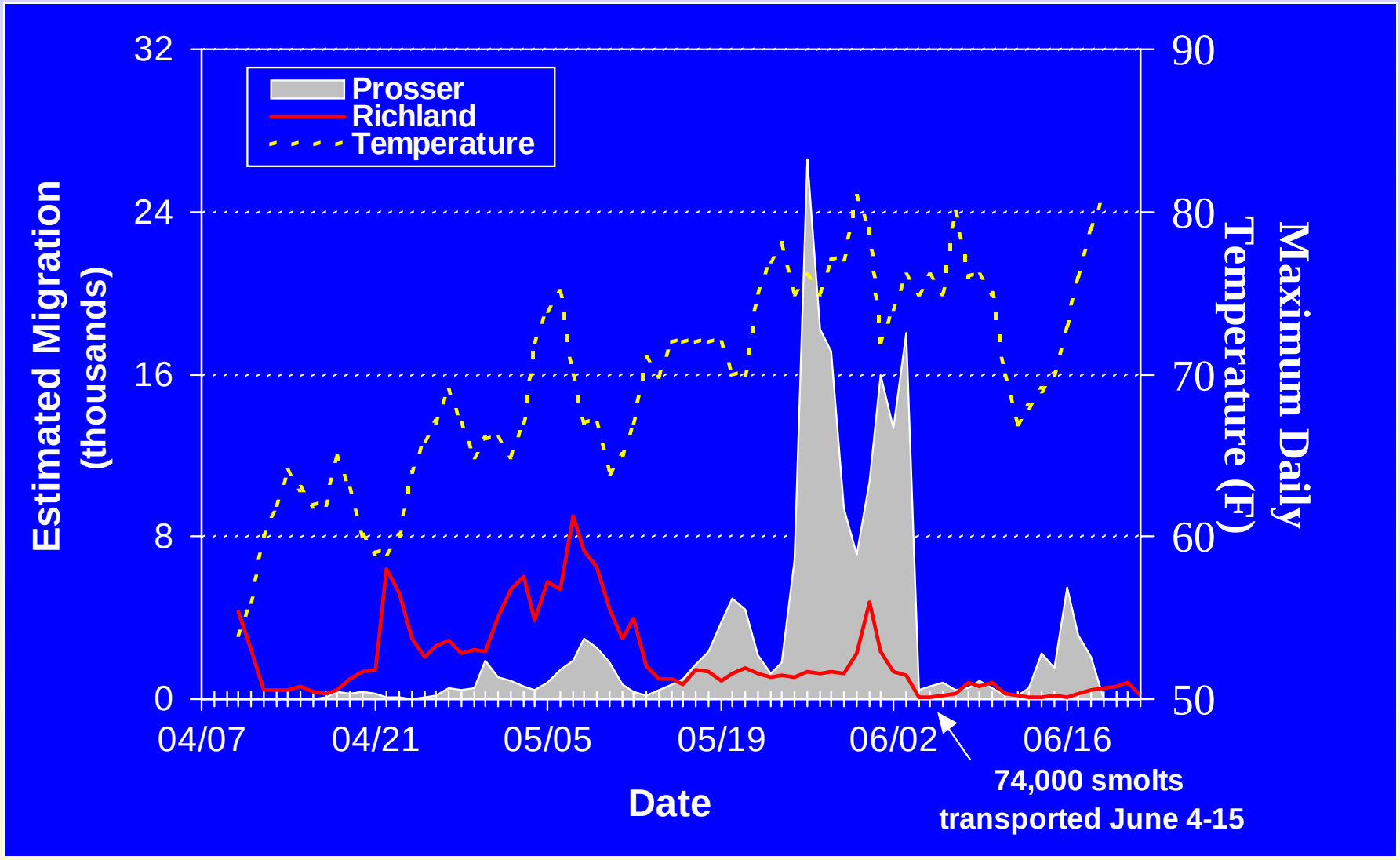
The New York Times

Yakima River Flow Range at Prosser During Fall Chinook Smolt Migration



Fall Chinook Smolt Migration Past Prosser & West Richland

and Stream Temperature, Yakima River 1992



Projected PNW Climate Change

Projected changes in **average annual PNW temperature and precipitation** for the decades of the 2020s and 2040s

high confidence ↓ lower confidence ↓

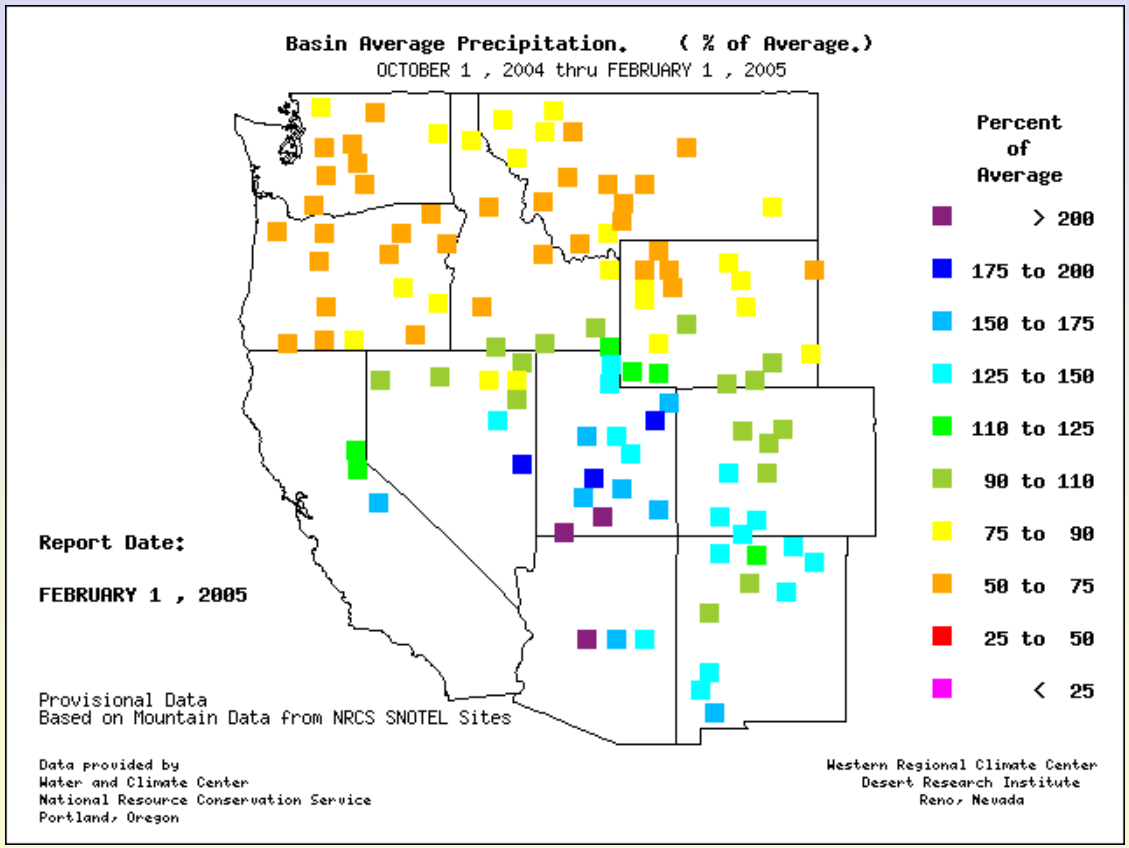
2020s	Temperature	Precipitation
Low	+ 0.8°F	+ 2 %
Mean	*+ 2.5°F*	*+ 7%*
High	+ 3.4°F	+ 14 %

2040s	Temperature	Precipitation
Low	+ 2.7°F	- 3 %
Mean	*+4.0°F*	*+ 7%*
High	+ 4.9°F	+ 14 %

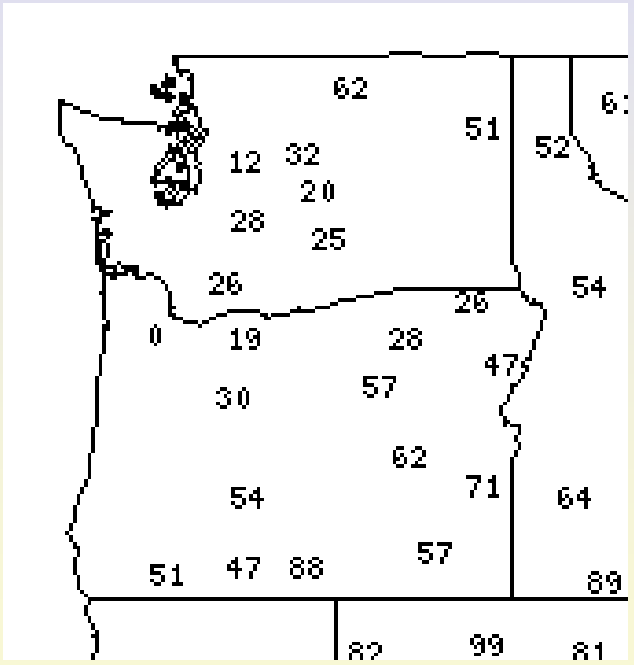
Based on an increase in equivalent CO_2 of 1% per year. Benchmarked to the decade of the 1990s.

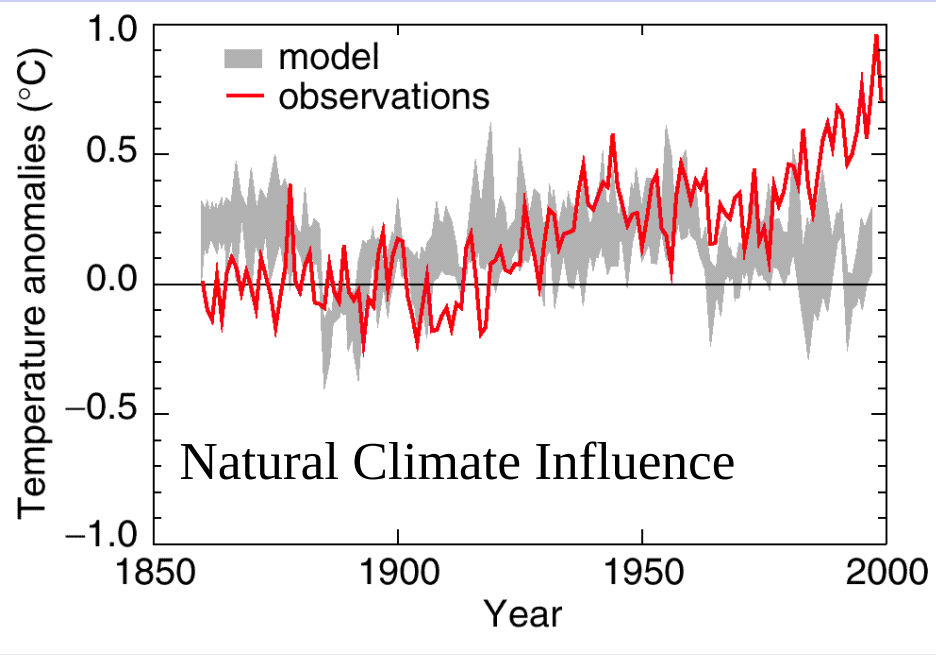
Oct 1 to Feb 1 Precipitation and snowpack (from SNOTEL sites)

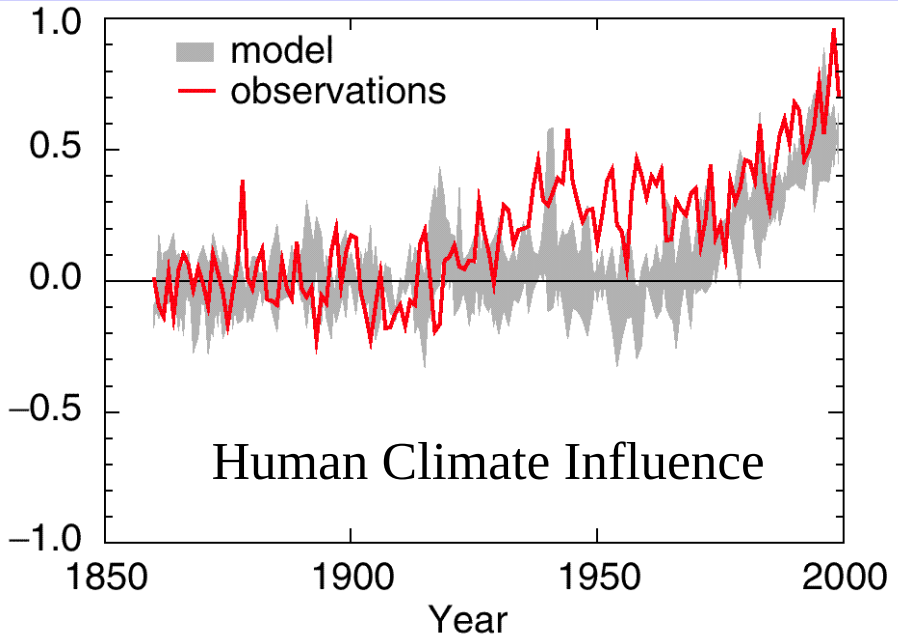
Basin average precip (% avg)

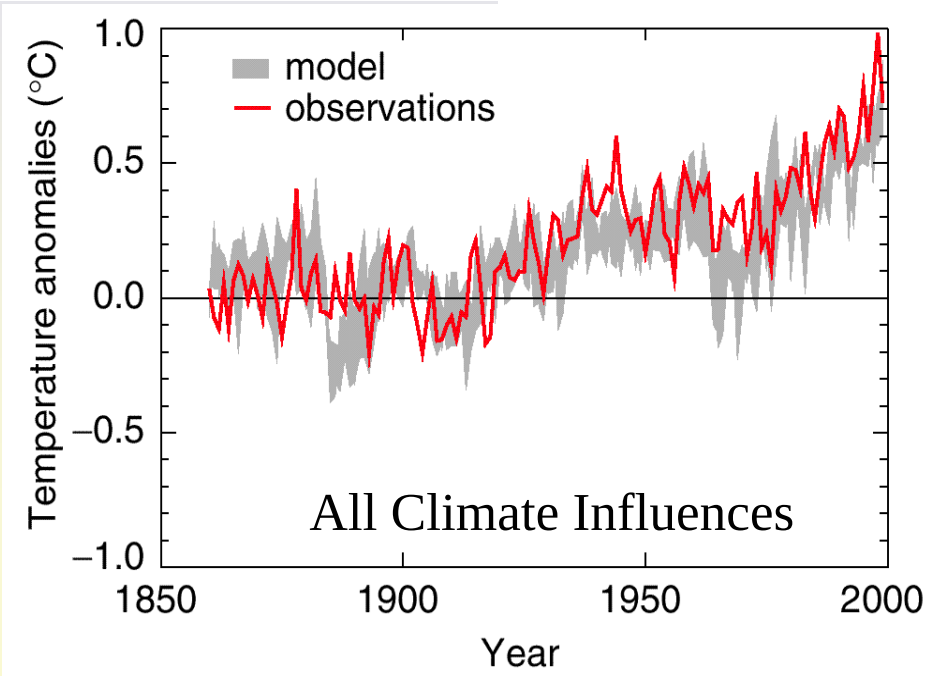


Snow water equiv. (% avg)

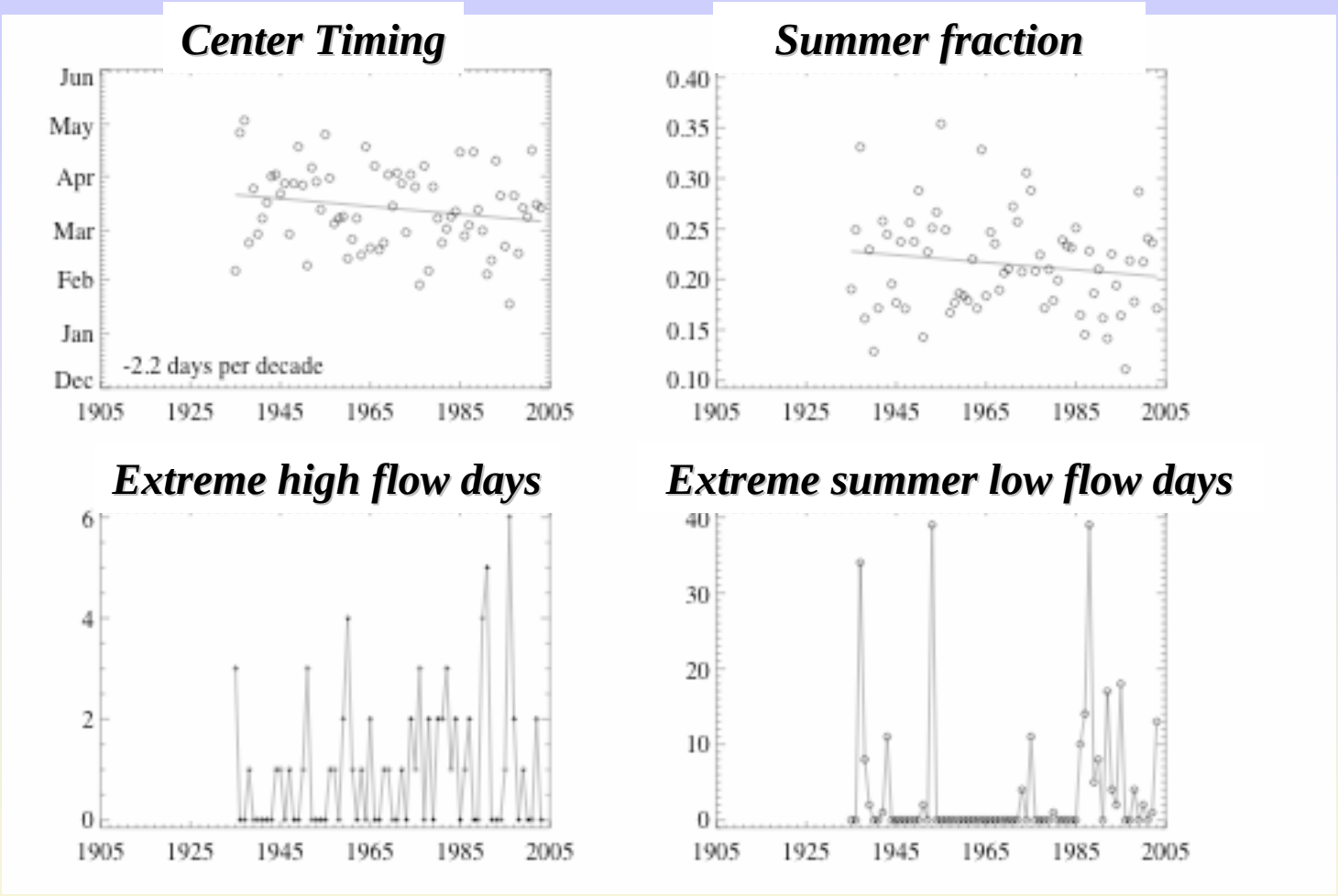



model
observations
Temperature anomalies (°C)
1.0
0.5
0.0
–0.5
–1.0
1850
1900
1950
2000
Year
Natural Climate Influence


model
observations
1.0
0.5
0.0
–0.5
–1.0
1850
1900
1950
2000
Year
Human Climate Influence


model
observations
Temperature anomalies (°C)
1.0
0.5
0.0
–0.5
–1.0
1850
1900
1950
2000
Year
All Climate Influences

Puget Sound streamflow data: 1935-2003



From combined gage flows from major unregulated Puget Sound rivers: the Skykomish, Snoqualmie, Puyallup, Nooksack, and Stillaguamish
(unpublished data, Mote and Mantua, UW Climate Impacts Group)

Science of climate change

- 2001 **White House request for advice** from the **US National Academy of Sciences**
  - *"… are there any substantive differences between the IPCC Reports and IPCC Summaries?"*
- **National Research Council** convened a panel of **11 leading US climate scientists** to write the report
- Conclusions:
  - *"Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures to rise and subsurface ocean temperatures to rise. Temperatures are, in fact, rising. The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability … The committee generally agrees with the assessment of human-caused climate change presented in the IPCC scientific report …"*