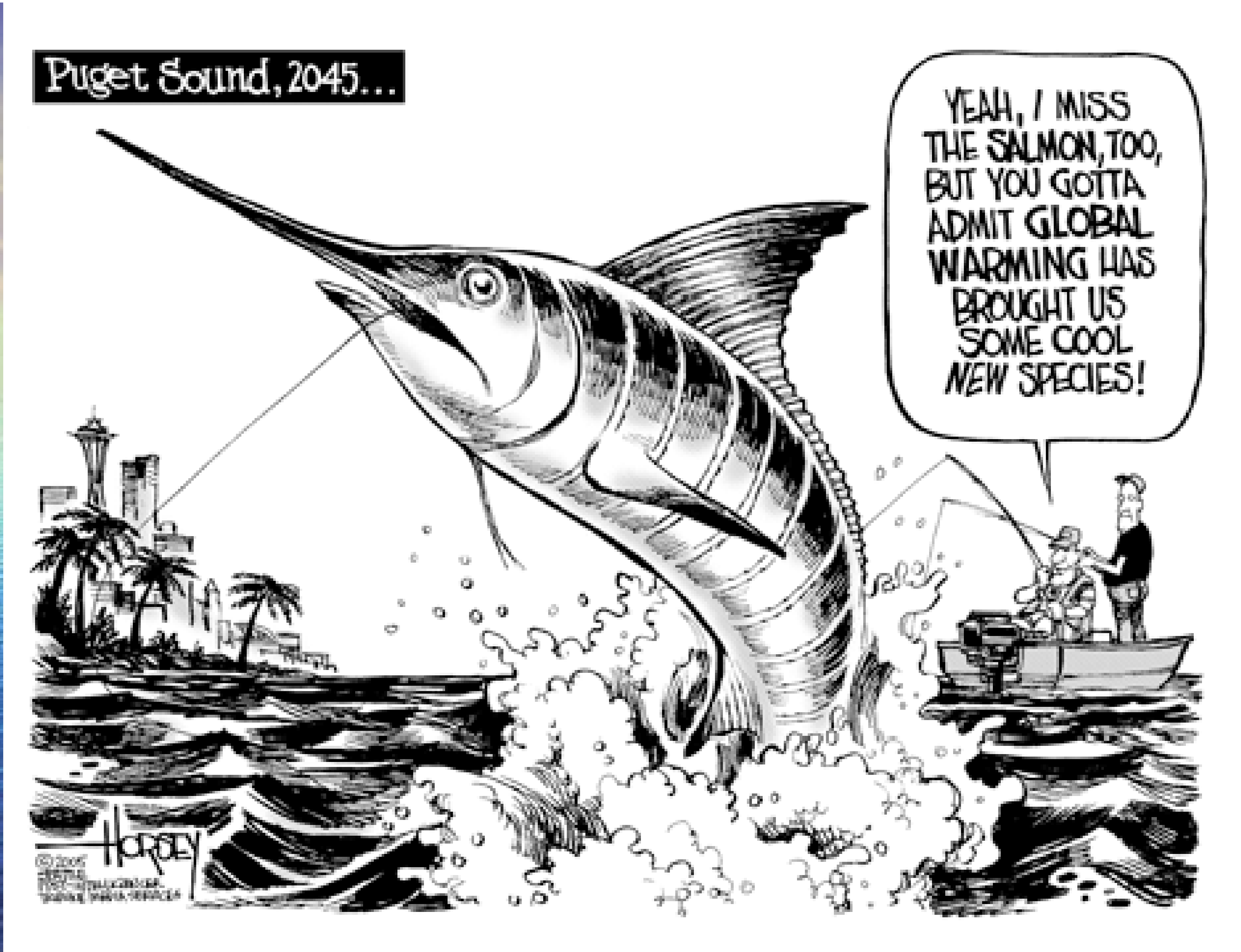


From the Seattle Post-Intelligencer, October 20, 2005

Overview of fish-related sensitivities to projected changes in climate and hydrology

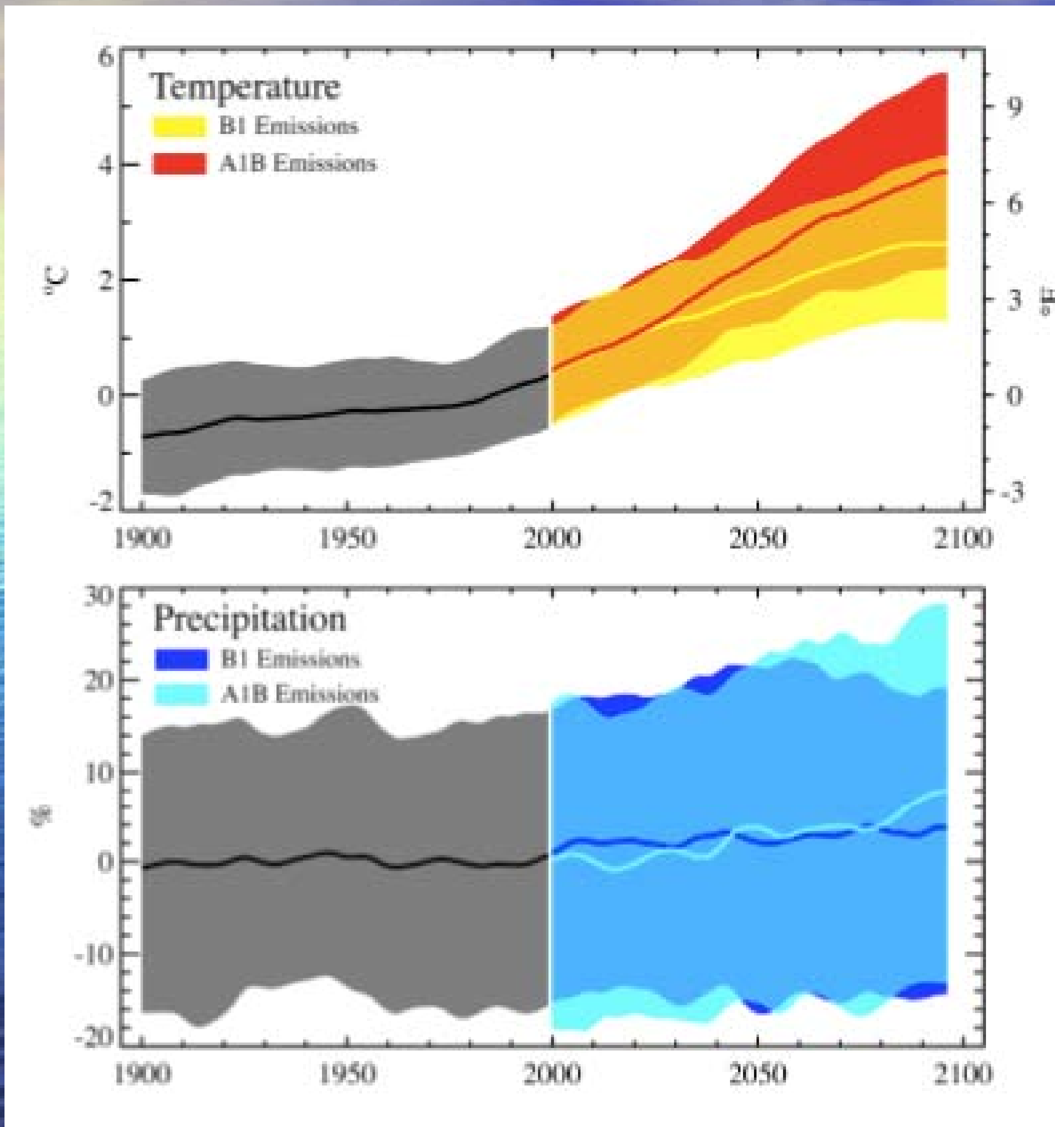
Nate Mantua, Ingrid Tohver, Alan Hamlet,

Climate Impacts Group, University of Washington

Workshop on climate change, fish and fish habitat in the North Cascadia Ecosystem

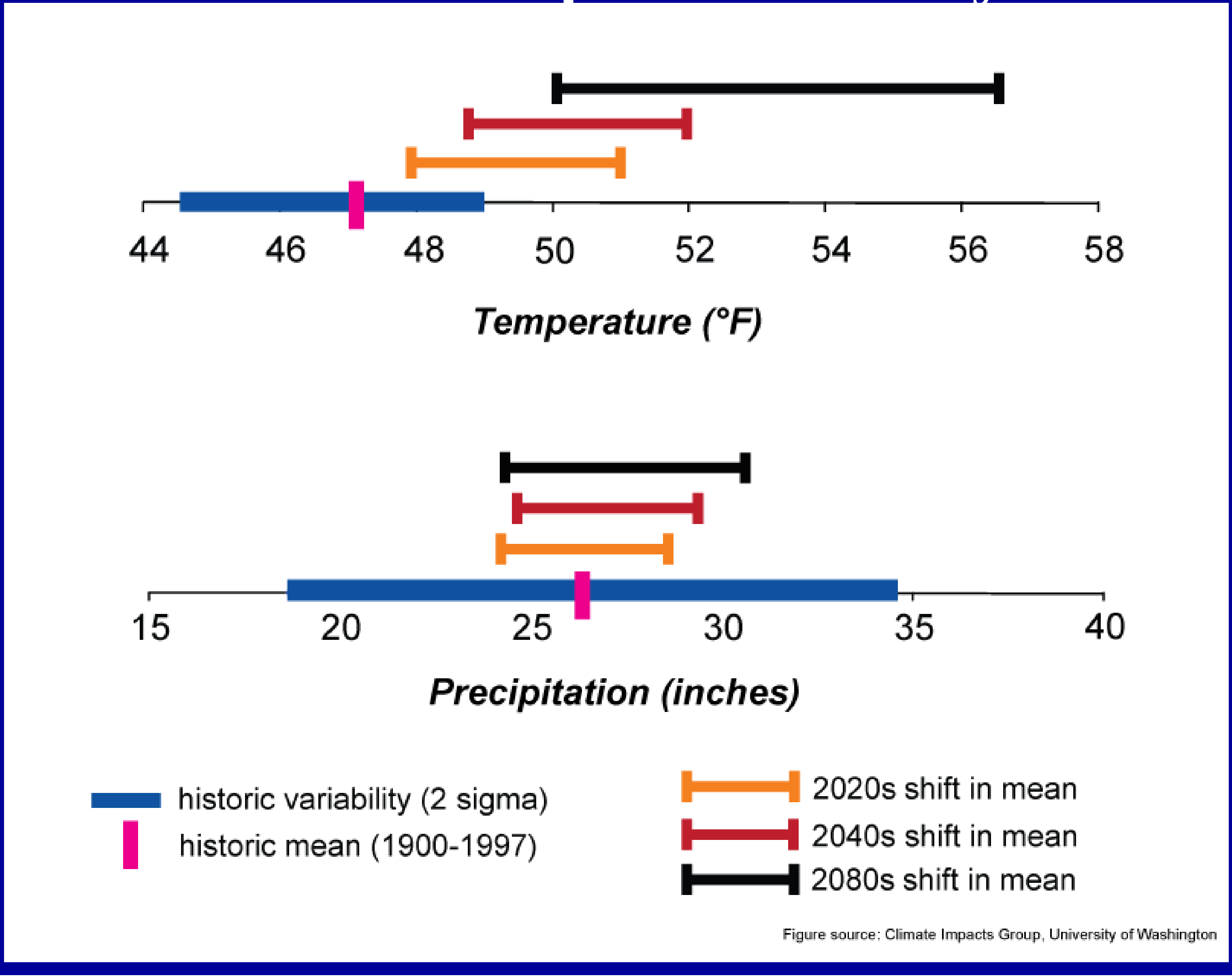
July 27-28, 2011

21st Century PNW Temperature and Precipitation Change Scenarios

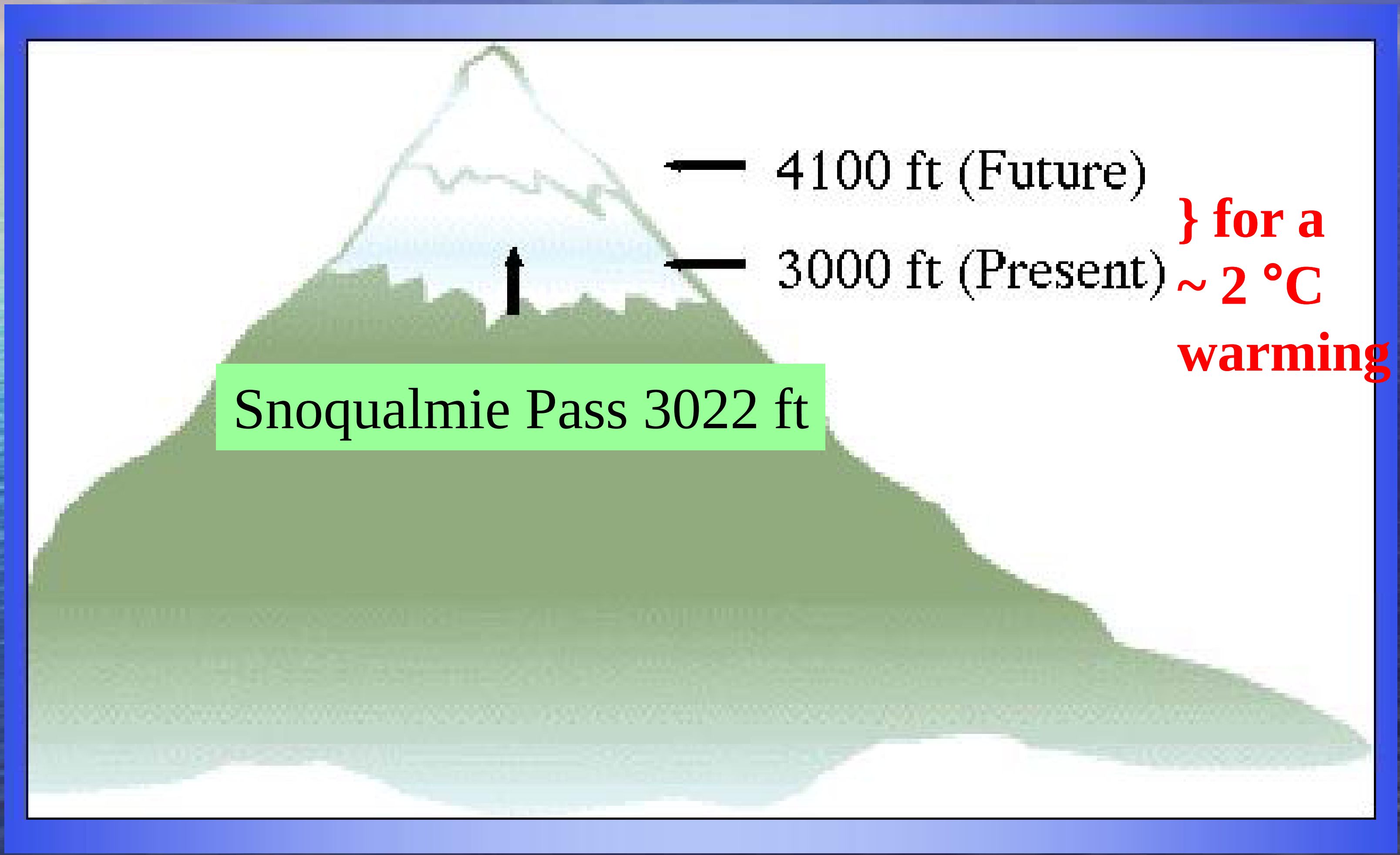


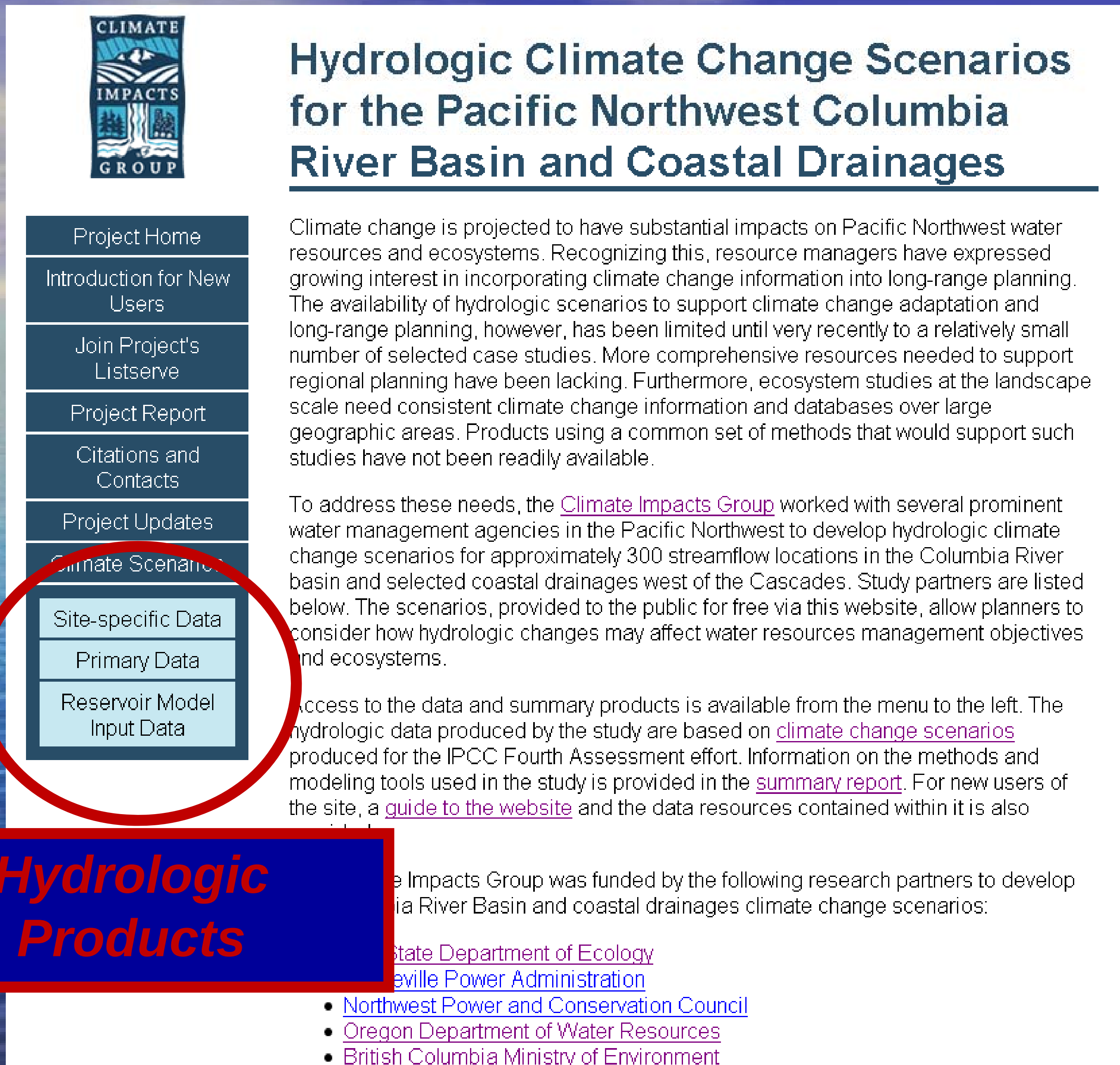
- Projected changes in temperature are large compared to historic variability
- Changes in annual precipitation are generally small compared to past variations, but some models show large seasonal changes (***wetter autumns and winters*** and ***drier summers***)

21st century PNW climate scenarios relative to past variability



A robust impact of climate warming: **less snow**





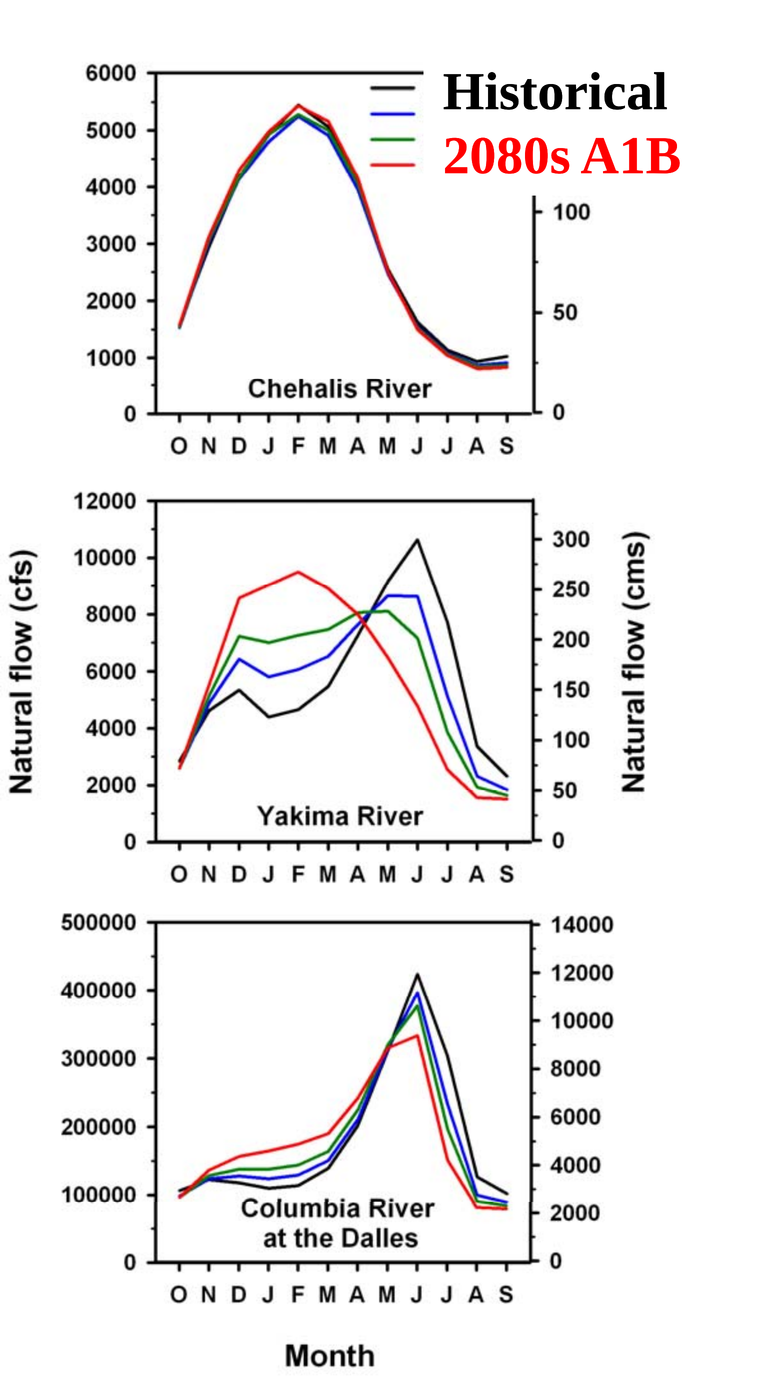
Hydrologic Products

http://www.hydro.washington.edu/2860/

Available PNW Scenarios (80!)

Downscaling Approach			A1B Emissions Scenario	B1 Emissions Scenario
Hybrid Delta	hadcm cnrm_cm ccsm3 echam5 echo_g cgcm3.1_t47 pcm1 miroc_3.2 ipsl_cm4 hadgem1	2020s	10	10
		2040s	10	10
		2080s	10	10
Transient BCSD	hadcm cnrm_cm ccsm3 echam5 echo_g cgcm3.1_t47 pcm1	1950-2098+	7	7
Delta Method	composite of 10	2020s	1	1
		2040s	1	1
		2080s	1	1

2020s – mean 2010-2039; 2040s – mean 2030-2059; 2080s – mean 2070-2099

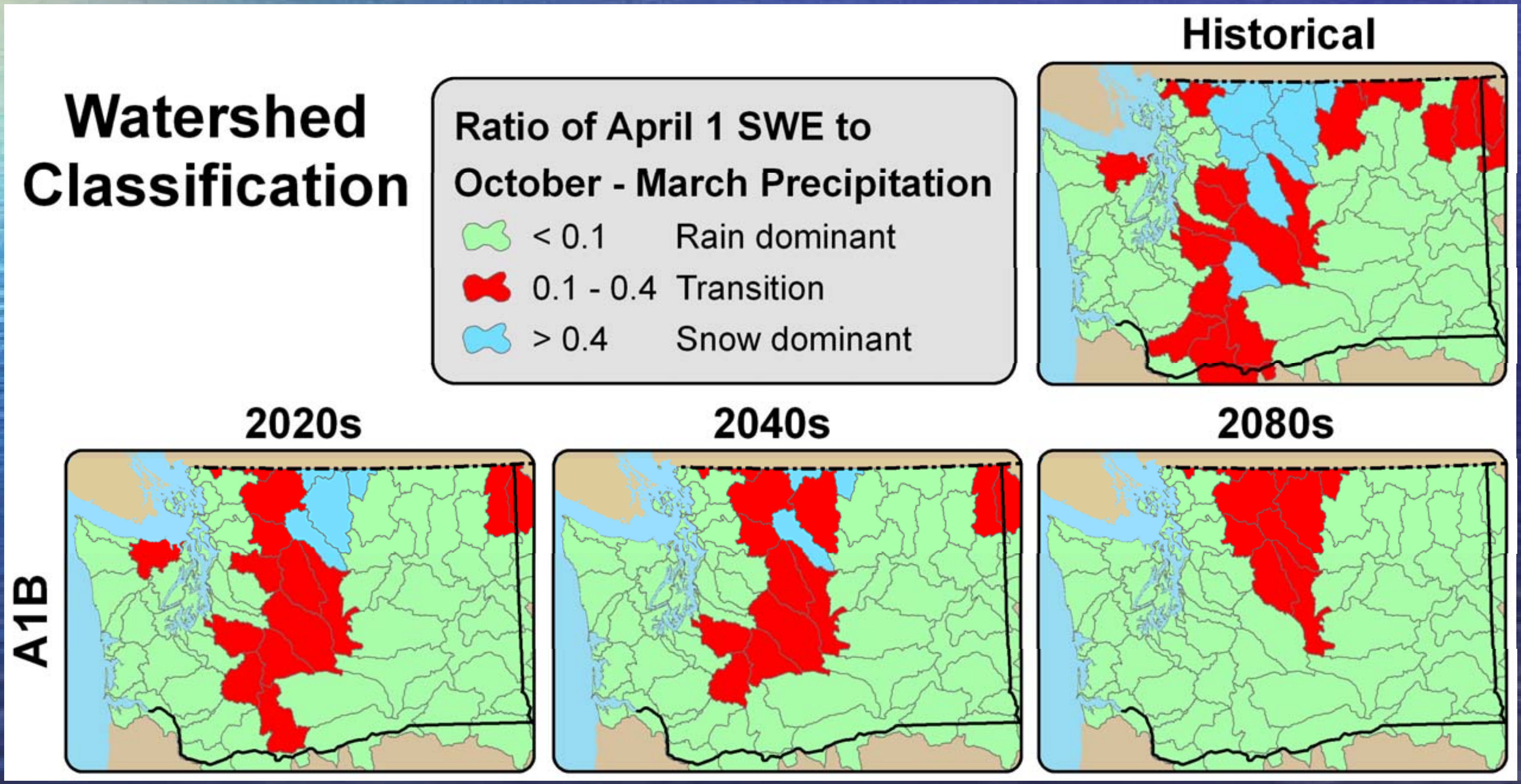


3 basic streamflow patterns

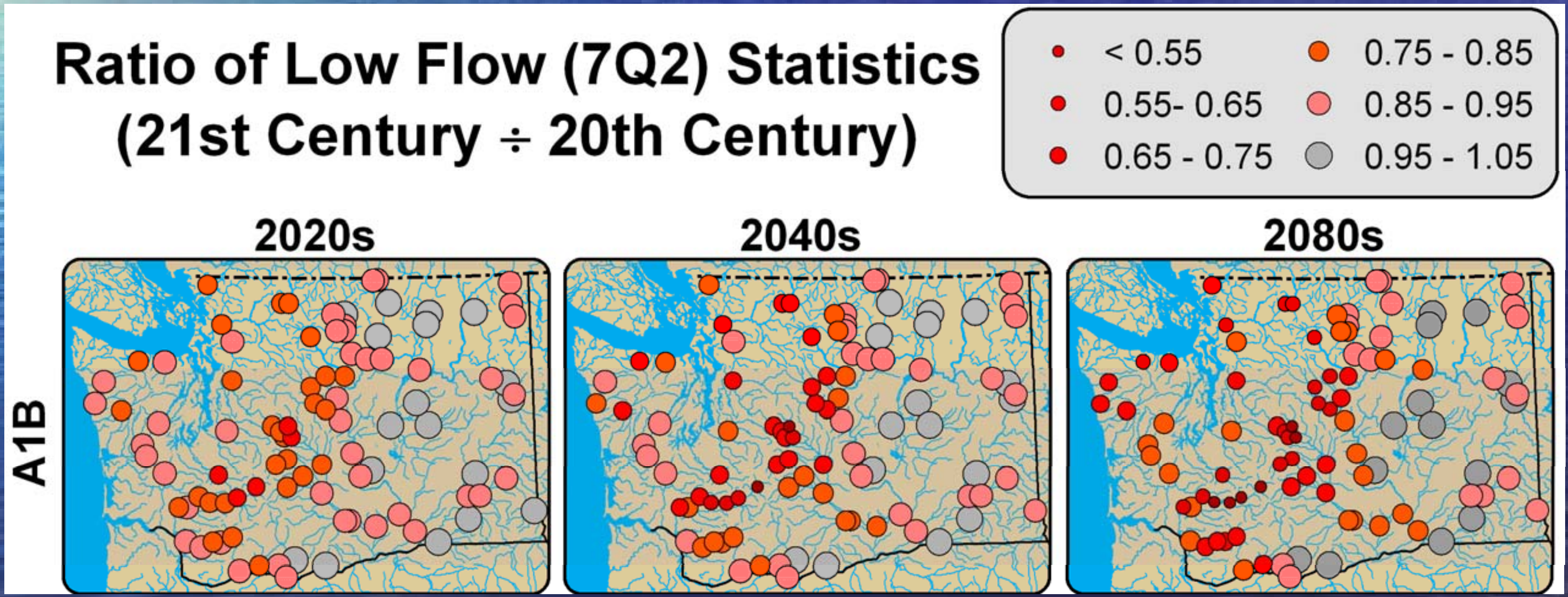
1. ***rain-dominated***
2. "***transient***" basins with an early winter peak from rainfall, and a spring peak from snowmelt
3. ***snowmelt-dominated*** basins, where streamflow peaks in late spring and early summer

Dramatic changes in snowmelt systems

- Snowmelt rivers become transient basins
- Transient basins become rainfall dominant



- **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

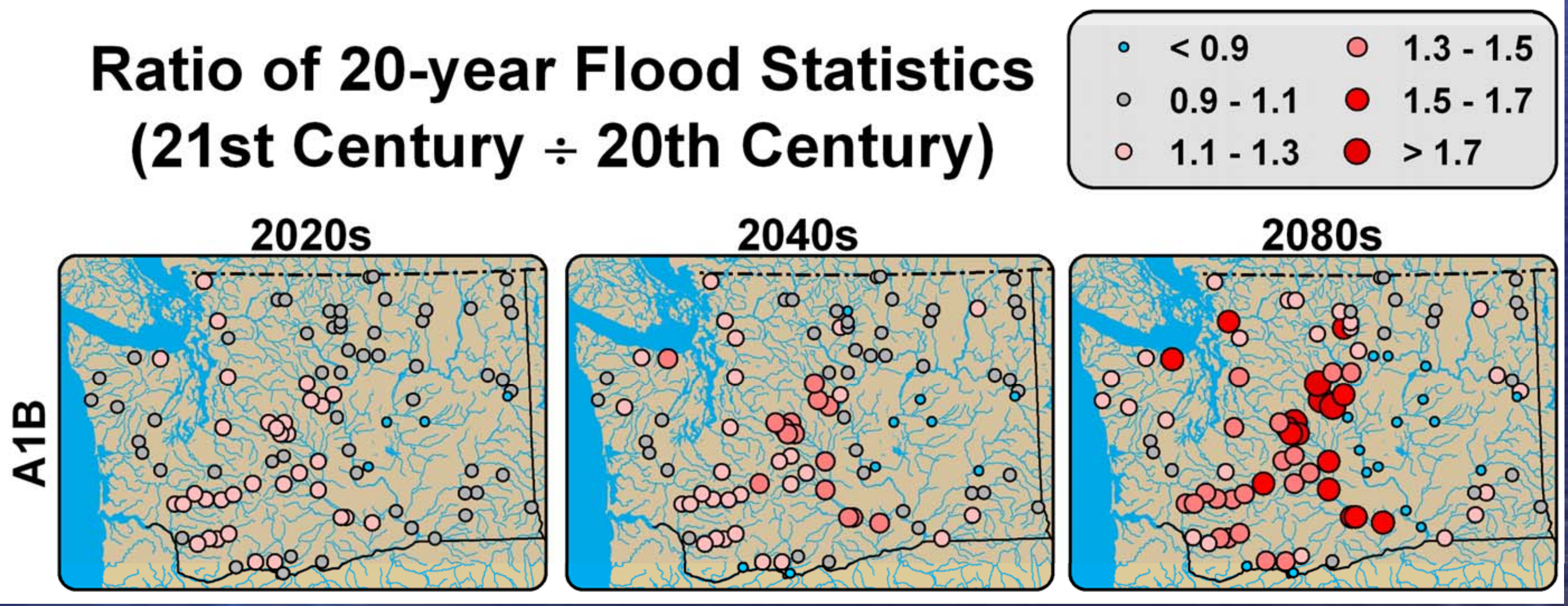


Mantua et al. 2009: Impacts of climate change on key aspects of freshwater salmon habitat for in Washington State (in review)

A warmer climate and flooding

- **At mid-elevations, more precipitation will fall as rain and less as snow**
- **a warmer atmosphere holds more moisture: theory and climate models suggest an increased intensity of precipitation, stronger storm (but maybe fewer)**
  - **This combination points to ar increased frequency of river flooding in fall and winter**

- 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



- Join Project's Listserve
- Project Home
- Introduction for New Users
- Project Report
- Citations and Contacts
- Project Updates
- Climate Scenarios
- Site-specific Data
- Primary Data
- Reservoir Model Input Data

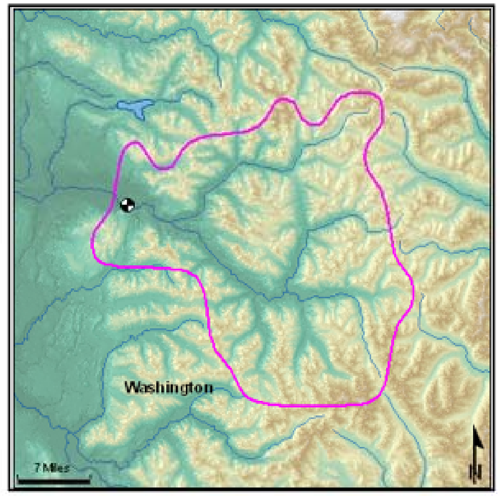
Research Site Data Spreadsheet

Site: SKYKOMISH RIVER NEAR GOLD BAR WA

SKYKOMISH RIVER NEAR GOLD BAR WA

Site Info: SKYGB (6015)

USGS Id: 12134500
Latitude (DMS): 47 50 15
Longitude (DMS): 121 39 56
Latitude (Decimal): 47.8375
Longitude (Decimal): -121.6656
Area: 535 $miles^2$
Nash Sutcliffe Efficiency = 0.69



General FTP directory

Raw Data

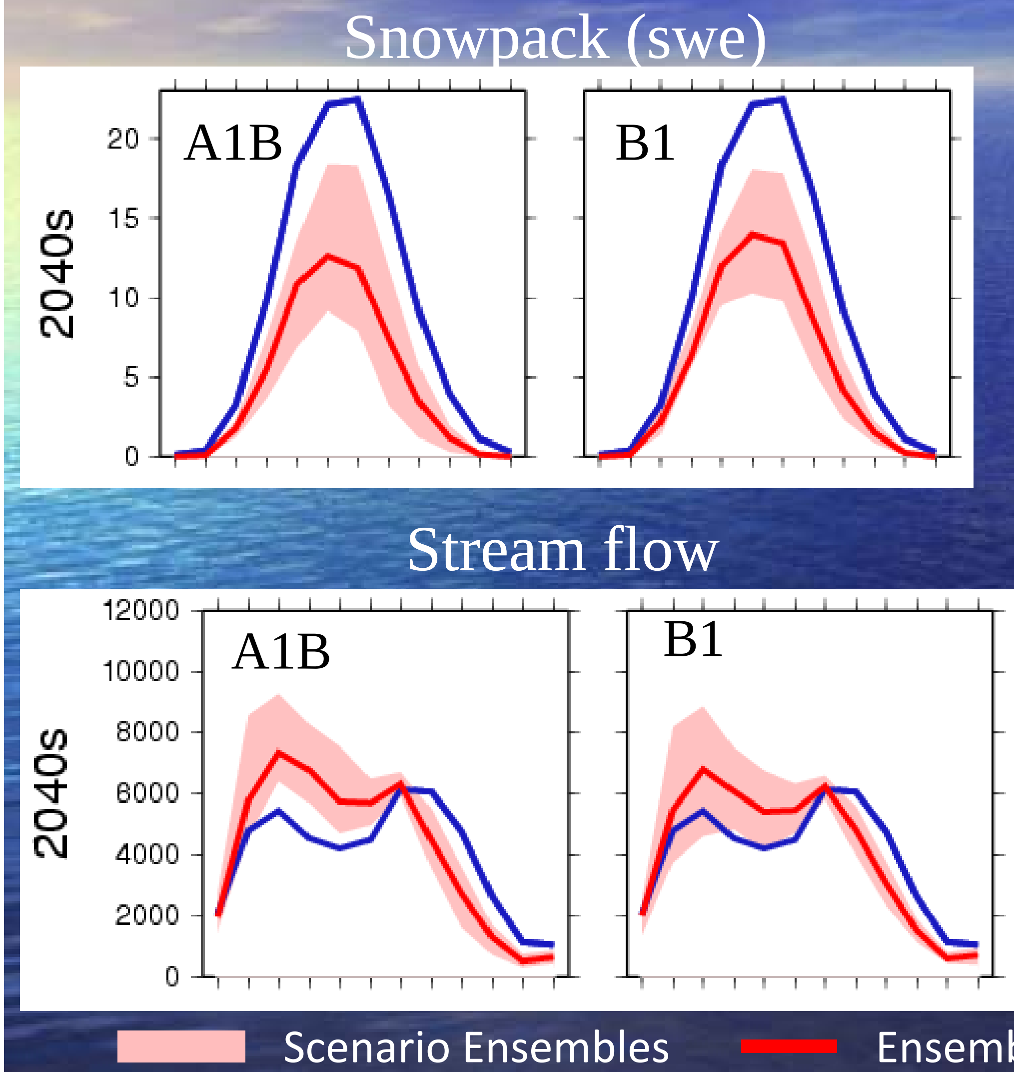
- vic_streamflow_daily_dt_2020.dat
- vic_streamflow_daily_dt_2040.dat
- vic_streamflow_daily_dt_2080.dat
- vic_streamflow_daily_hd_2020.dat
- vic_streamflow_daily_hd_2040.dat
- vic_streamflow_daily_hd_2080.dat
- vic_streamflow_daily_historical.dat
- vic_streamflow_daily_tr.dat
- vic_streamflow_monthly_dt_2020.dat
- vic_streamflow_monthly_dt_2040.dat
- vic_streamflow_monthly_dt_2080.dat
- vic_streamflow_monthly_hd_2020.dat
- vic_streamflow_monthly_hd_2040.dat
- vic_streamflow_monthly_hd_2080.dat
- vic_streamflow_monthly_historical.dat
- vic_streamflow_monthly_tr.dat

Bias-Adjusted Data

- nat_bias_adjusted_vic_streamflow_daily_dt_2020.dat
- nat_bias_adjusted_vic_streamflow_daily_dt_2040.dat
- nat_bias_adjusted_vic_streamflow_daily_dt_2080.dat
- nat_bias_adjusted_vic_streamflow_daily_hd_2020.dat
- nat_bias_adjusted_vic_streamflow_daily_hd_2040.dat
- nat_bias_adjusted_vic_streamflow_daily_hd_2080.dat
- nat_bias_adjusted_vic_streamflow_daily_historical.dat
- nat_bias_adjusted_vic_streamflow_daily_tr.dat
- nat_bias_adjusted_vic_streamflow_monthly_dt_2020.dat
- nat_bias_adjusted_vic_streamflow_monthly_dt_2040.dat
- nat_bias_adjusted_vic_streamflow_monthly_dt_2080.dat
- nat_bias_adjusted_vic_streamflow_monthly_hd_2020.dat
- nat_bias_adjusted_vic_streamflow_monthly_hd_2040.dat
- nat_bias_adjusted_vic_streamflow_monthly_hd_2080.dat
- nat_bias_adjusted_vic_streamflow_monthly_historical.dat
- nat_bias_adjusted_vic_streamflow_monthly_tr.dat

http://www.hydro.washington.edu/2860/products/sites/?site=6015

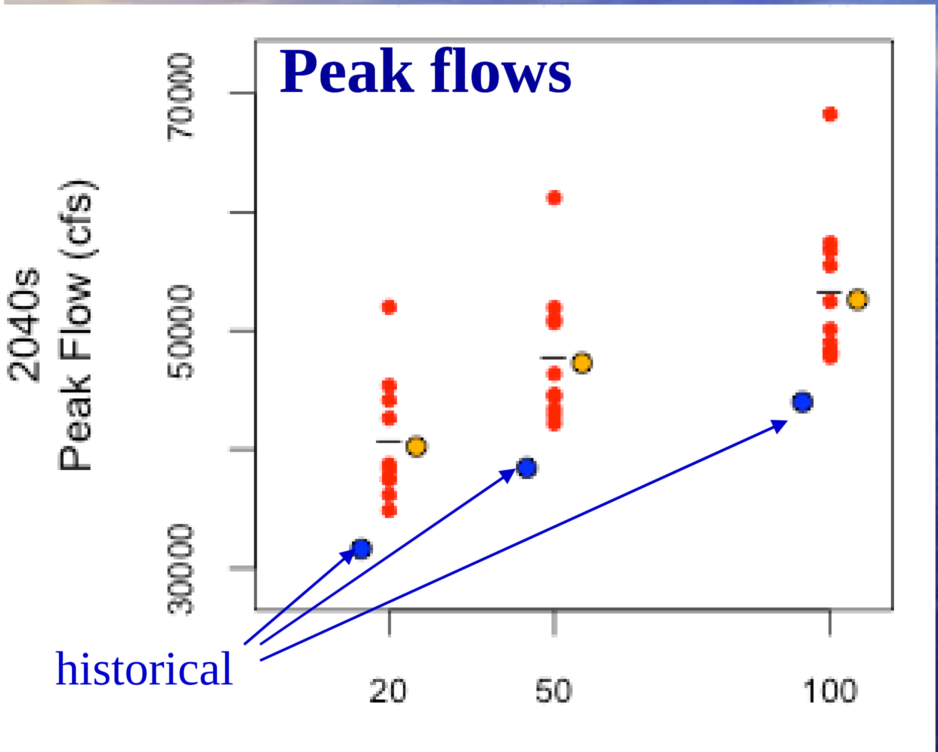
Snow and Runoff Scenarios (Skykomish R at Gold Bar)
A1B and B1 emissions, 10 GCMs, HD downscaling

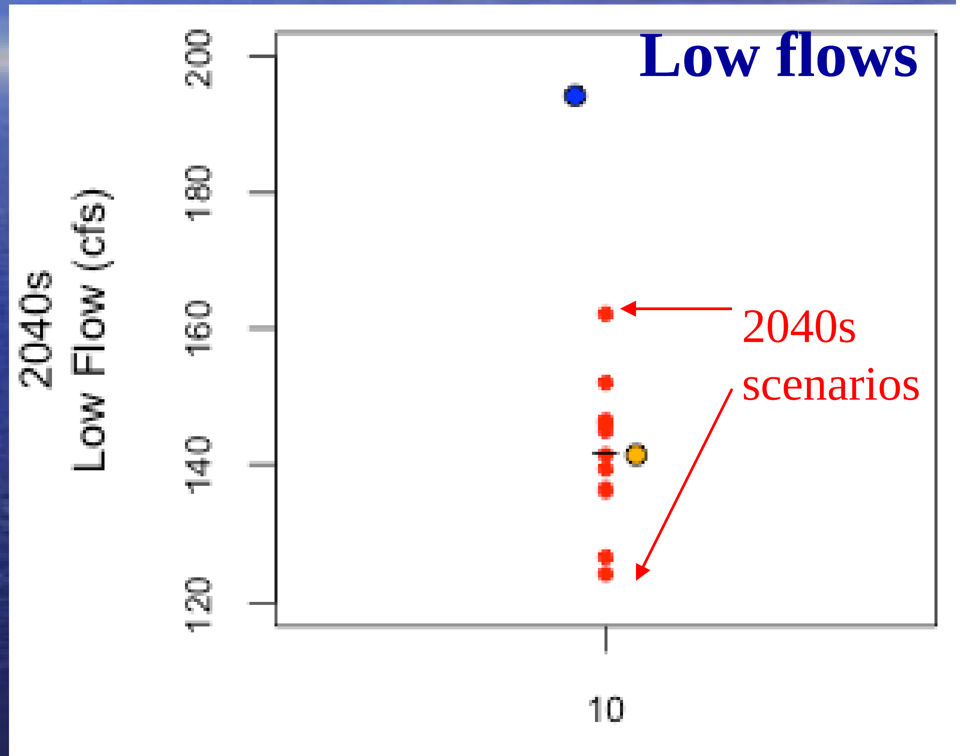


All these scenarios have less accumulated snowpack and a shorter snow season

They also show increased winter/spring flows, earlier snowmelt, and an earlier snowmelt recession

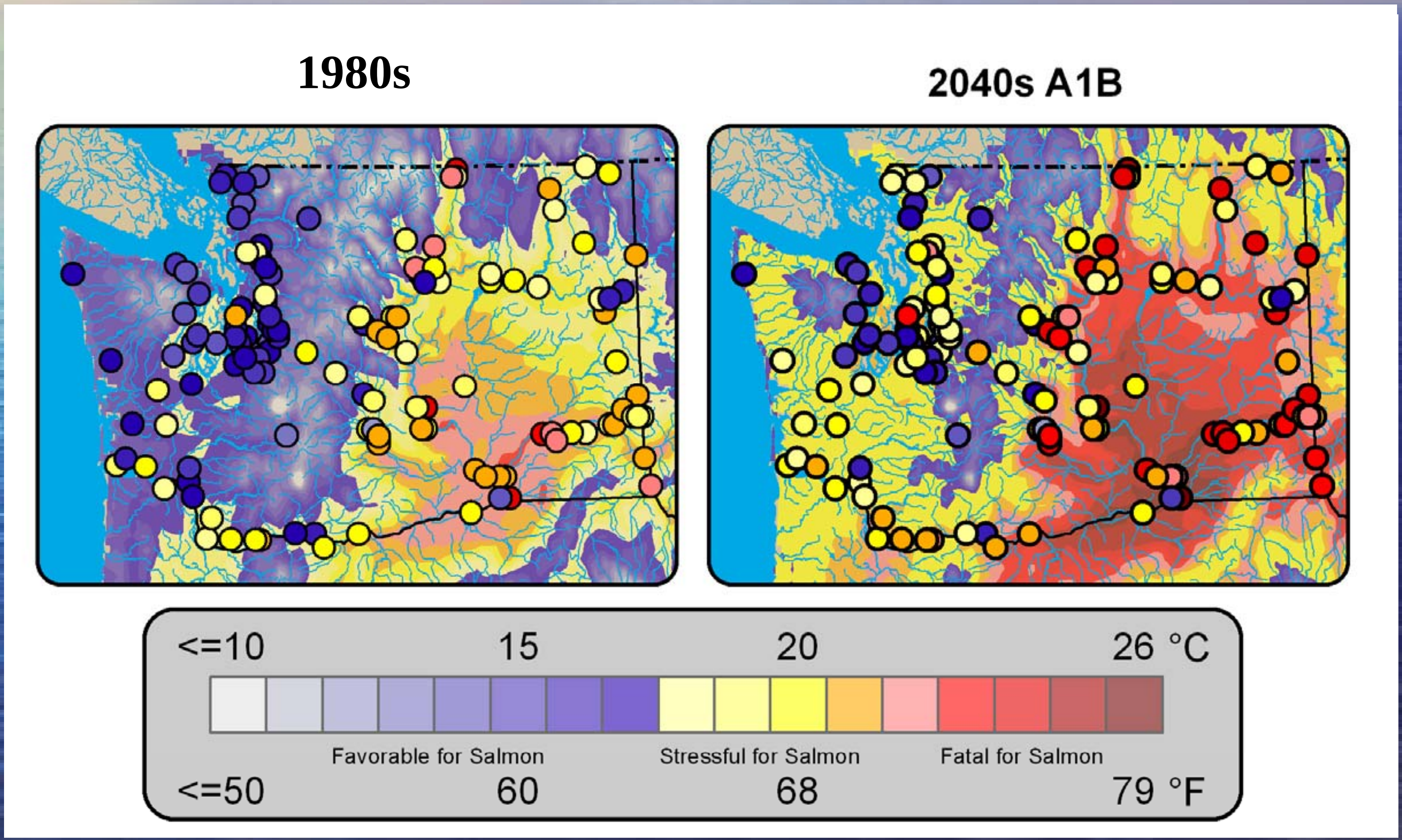
Flooding and low flows (Skykomish R at Gold Bar)
A1B emissions, 10 GCMs, HD downscaling





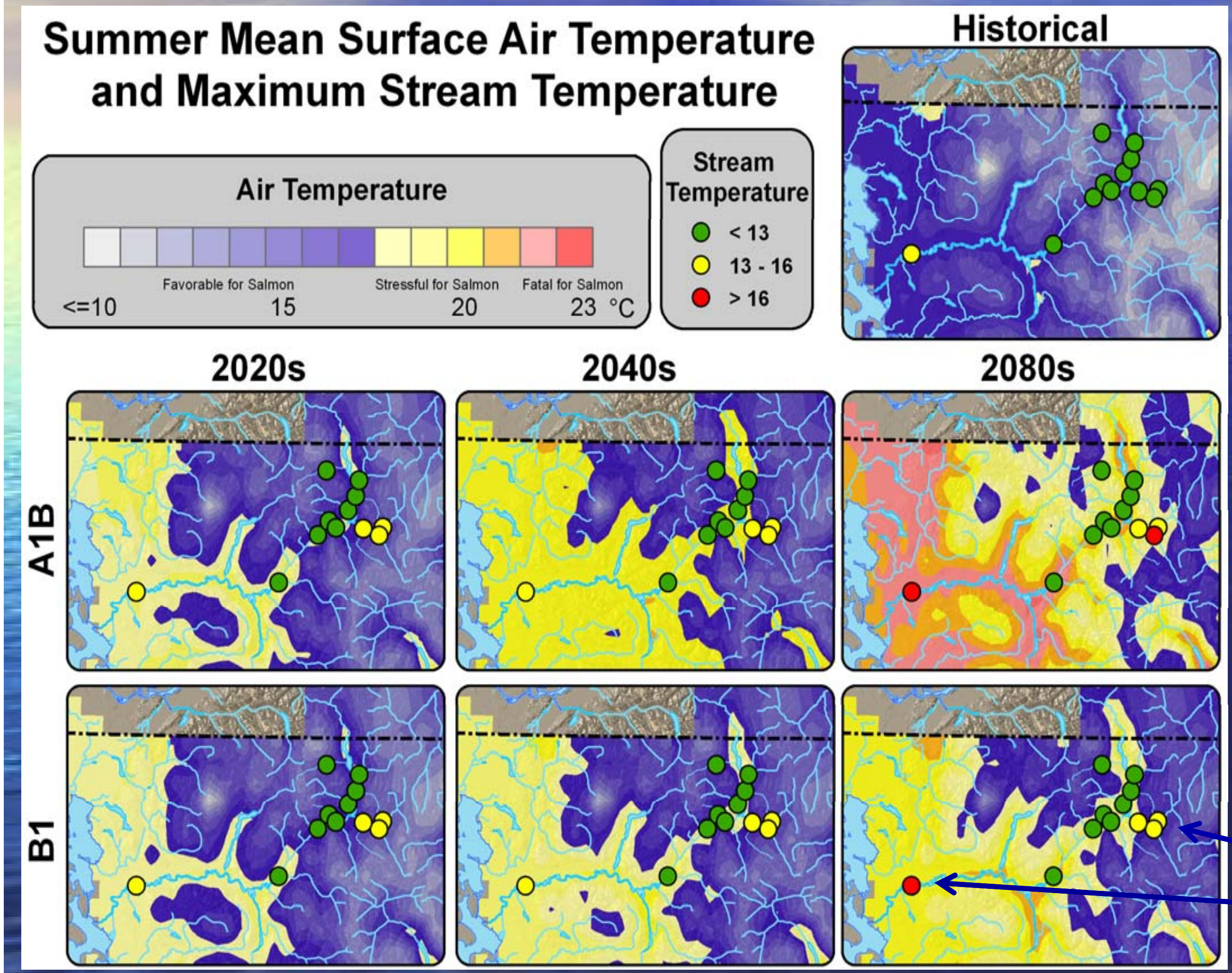
These scenarios show daily peak flow magnitudes increasing, while 7Q10 low flow magnitudes decline. Different climate model scenarios (in red and yellow) have different impacts, however.

Western Washington's "maritime" summer climate becomes as warm as today's interior Columbia Basin, temperatures in the interior Columbia Basin become as warm as today's Central Valley in California



Mantua, Tohver and Hamlet 2010: *Climatic Change*

Projected Summertime Temperatures
Skagit River Basin



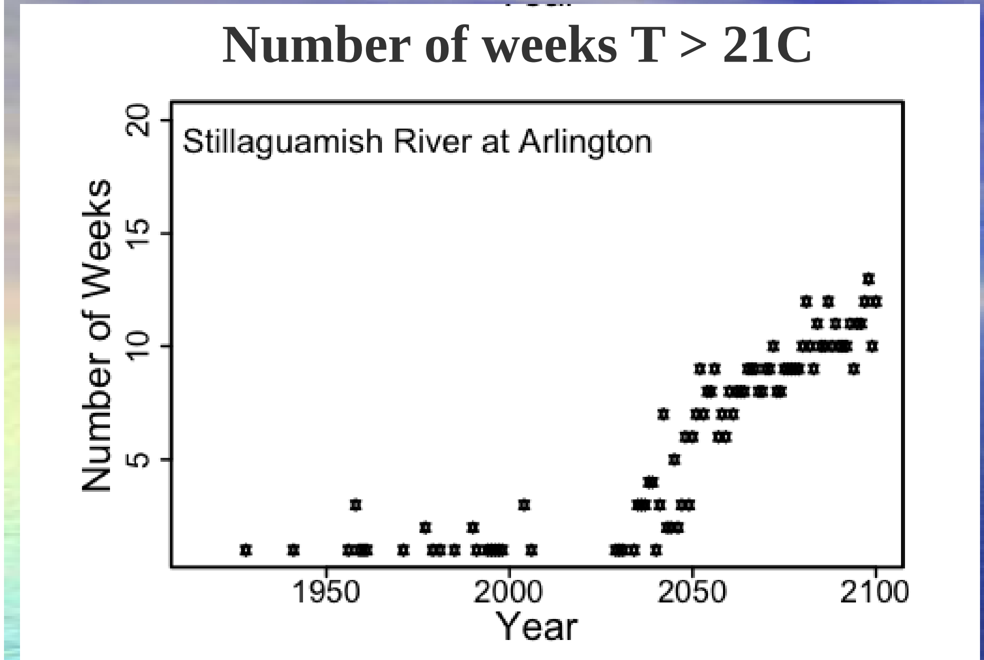
EPA and WA DOE criteria for thermal habitats for salmon:

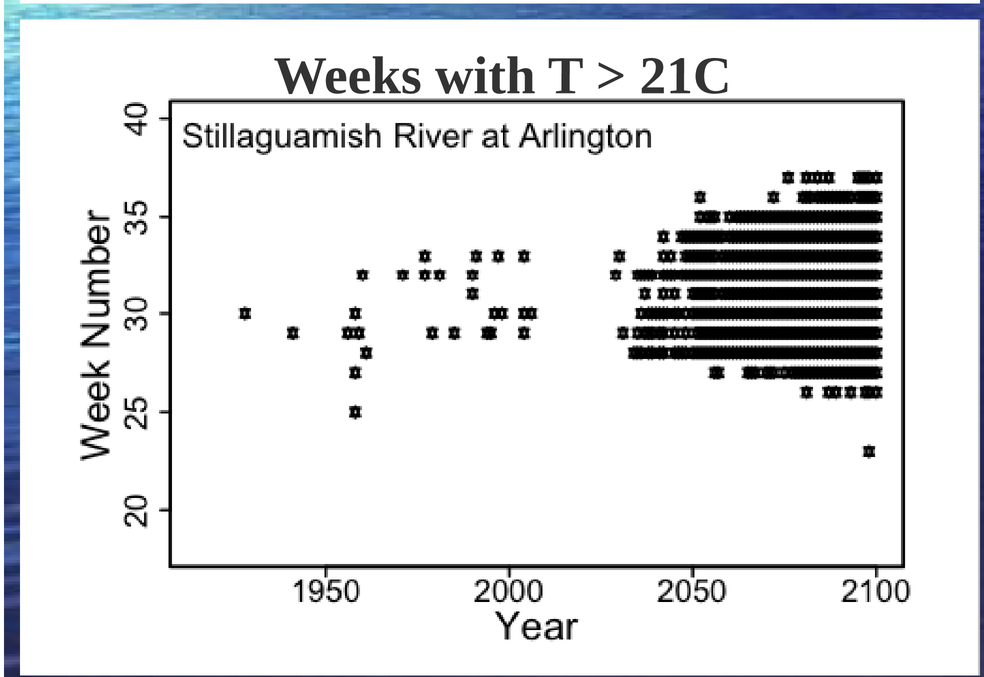
13°C – spawning, incubation and optimal growth temperature for salmon and trout

16°C – core summer salmon habitat temperature

Thermal exceedances projected for 2 areas:
- upper basin tributaries
- lower mainstem site

Thermal stress season





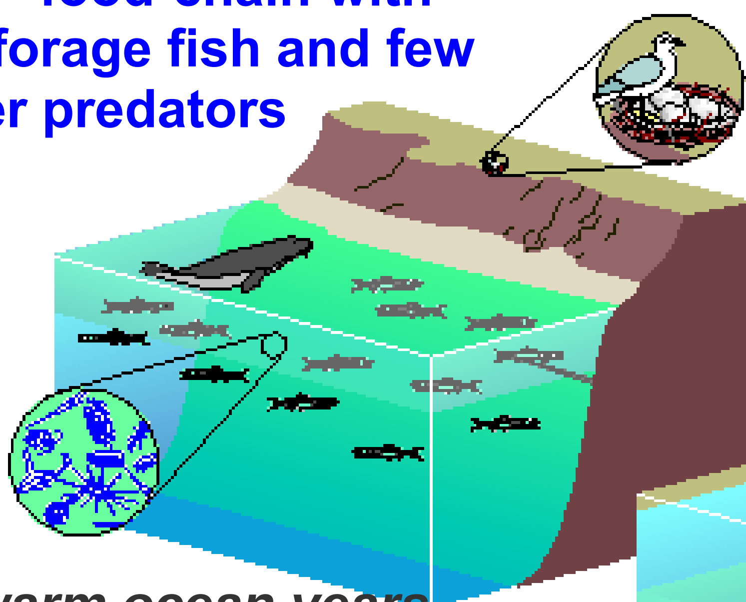
- Extended periods with weekly average water temperatures > 21C
  - the season of thermal migration barriers for migrating salmon predicted to last up to 11 weeks in the mainstem Stillaguamish River

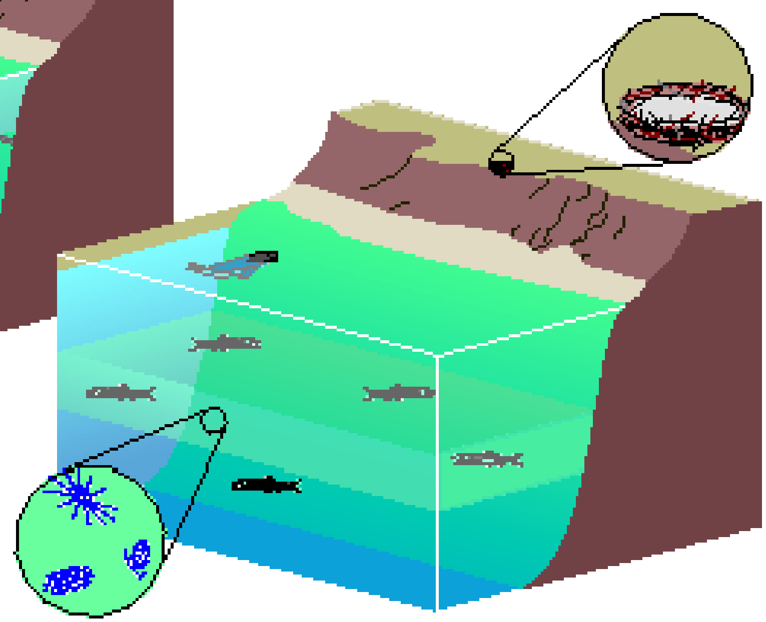
Mantua, Tohver and Hamlet 2010: Climatic Change

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

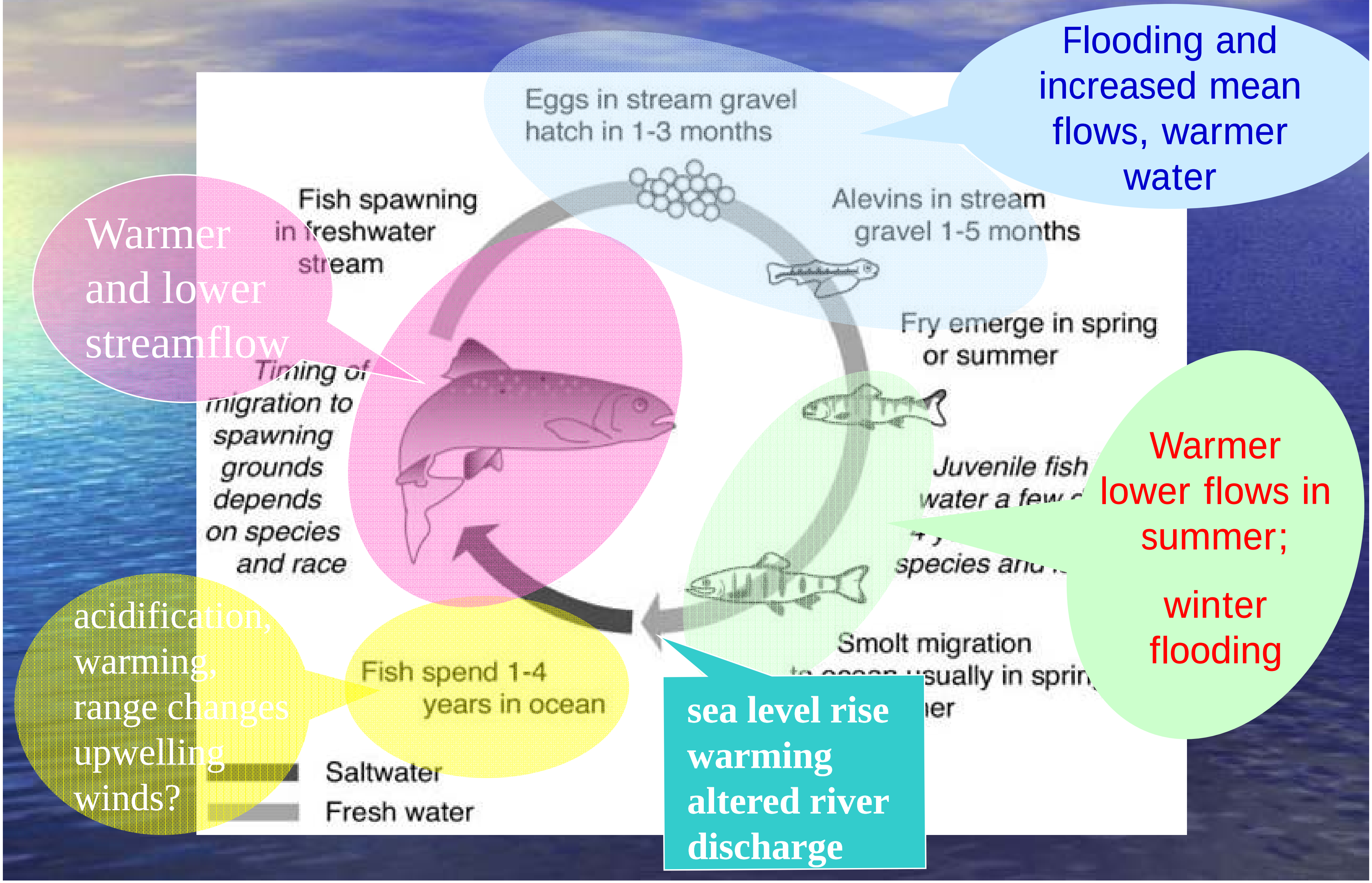
Warm stratified ocean, few nutrients, low productivity "*subtropical*" food web, a lack of forage fish and abundant predators





Recently, warm ocean years have generally been poor for NW chinook, coho and sockeye, but good for Puget Sound pink and chum salmon.

Impacts summary for PNW salmon



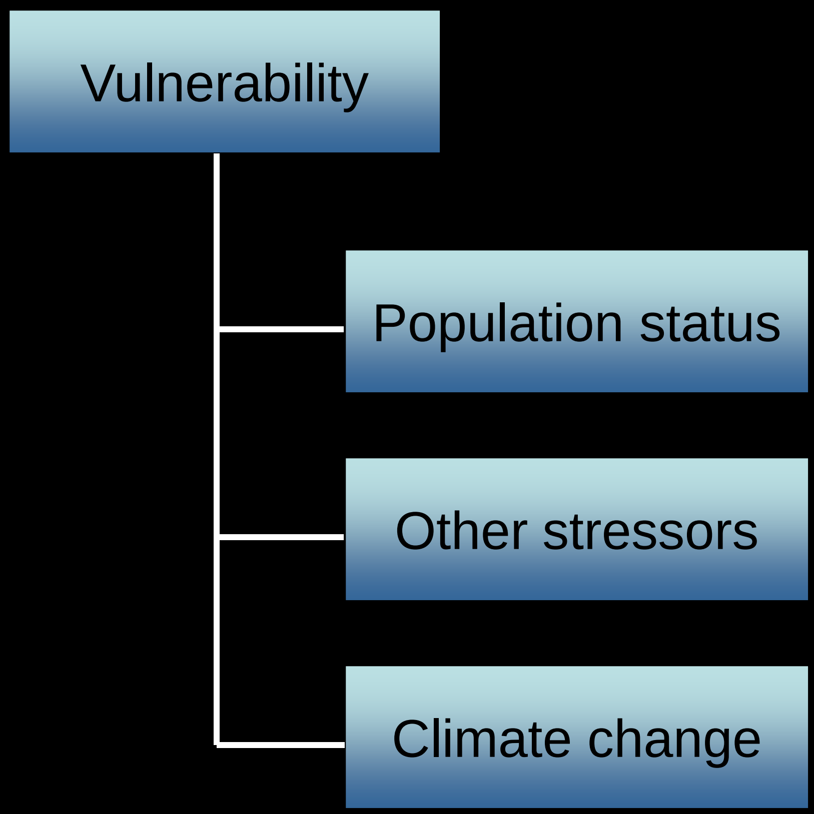
Impacts will vary depending on life history and watershed types

- **Low flows+warmer water = increased pre-spawn mortality for summer run and stream-type salmon and steelhead**
  - Clear indications for increased stress on Columbia Basin sockeye, summer steelhead, summer Chinook, and coho more generally

Harley Soltes/Seattle Times

- **Increased winter flooding in transient rain+snow watersheds**
  - a limiting factor for egg-fry survival for fall spawners + yearling parr overwinter survival in high-gradient reaches

Salmon vulnerability to climate change



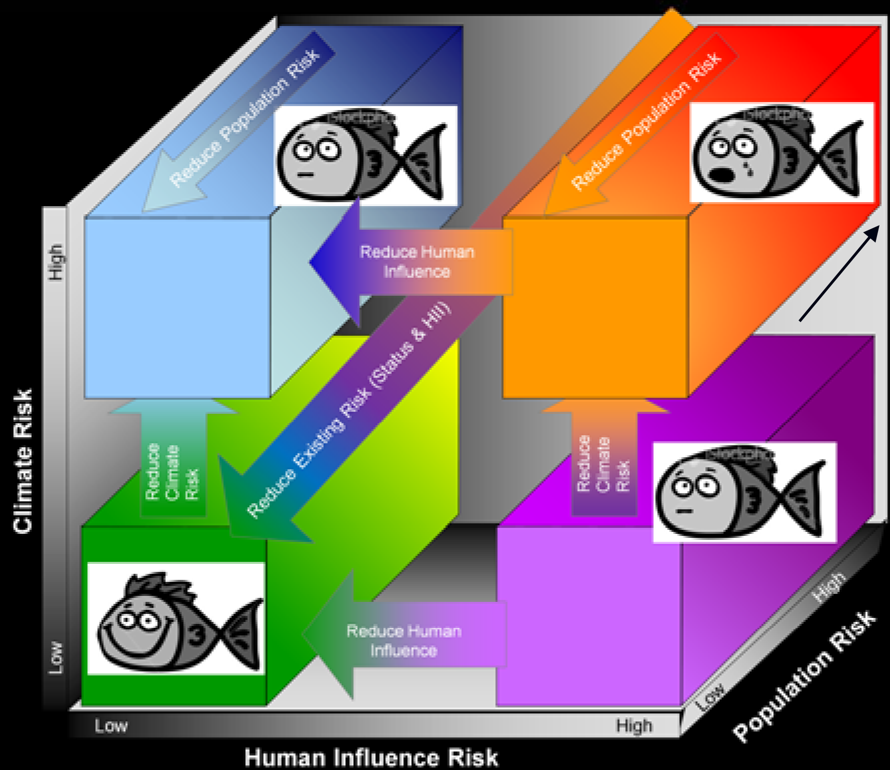
- Conceptual basis:

  Existing stresses reduce salmon’s ability to respond to climate change

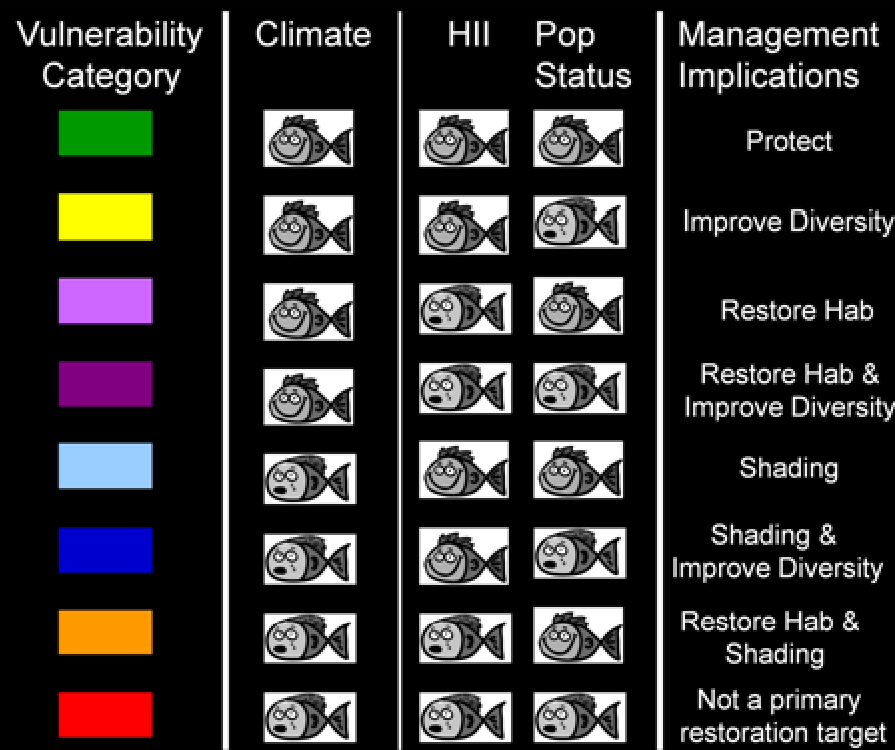
Slide from Tim Beechie, NOAA NWFSC

Prototype – vulnerability mapping

Schematic of Vulnerability Categories



Vulnerability Mapping Legend



Slide from Tim Beechie, NOAA NWFSC

North Cascades Datasets

- Regional Climate and Change Summaries (1/16th deg)
  - http://cses.washington.edu/picea/USFS_ORWA/pub/
    (follow link to summaries for omernik 77)
  - *source data:* http://www.hydro.washington.edu/2860/

- High-resolution meteorology (30 arc-sec)
  - http://cses.washington.edu/picea/mauger/met30s/pnw_30s/

- High-resolution snow simulations (30 arc-sec)
  - http://cses.washington.edu/picea/mauger/VIC_SNOW/pub/

Regional Climate and Change Summaries

Website:

[*http://cses.washington.edu/picea/USFS_ORWA/pub/*](http://cses.washington.edu/picea/USFS_ORWA/pub/)

Resolution:

1/16th degree (~5-7 km)

Source:

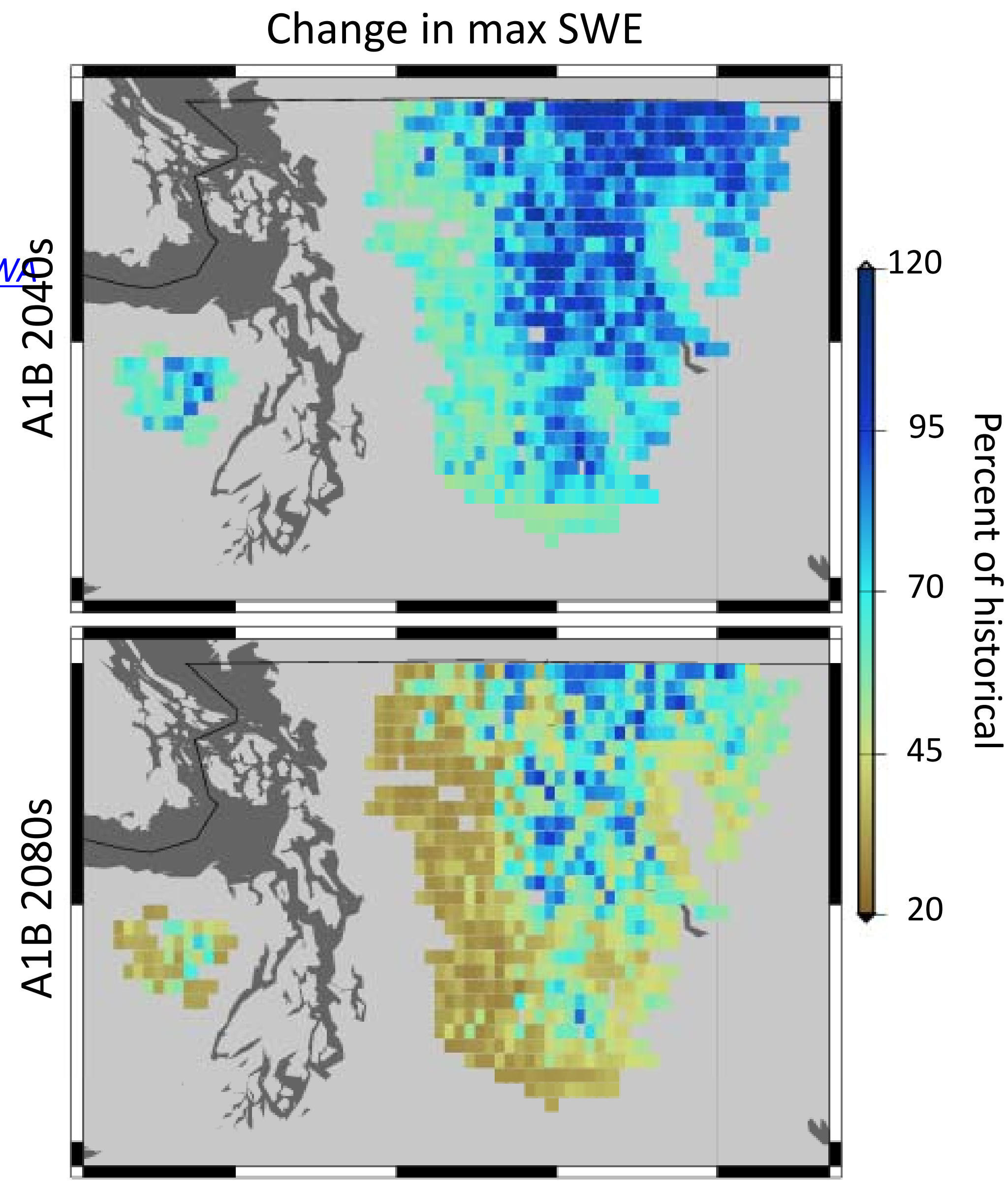
Columbia Basin Climate Change Scenarios Project (CBCCSP)

Hamlet et al., 2010

http://www.hydro.washington.edu/2860/

Variables (daily time step):

temperature: average, min, max
Precipitation
runoff, baseflow, combined flow (runoff + baseflow)
flow statistics: flood, low flow
snow amount: swe, snow depth, peak swe
Snow dates: peak swe, 10% accum, 90% accum
relative humidity, vapor pressure deficit
actual evapotranspiration, potential evapotranspiration
soil moisture



High-resolution Meteorology

Website:

http://cses.washington.edu/picea/mauger/met30s/pnw_30s/

Resolution:

30 arc-seconds (~700-900 m)

Sources:

CBCCSP (1/16th degree daily met data):
http://www.hydro.washington.edu/2860/

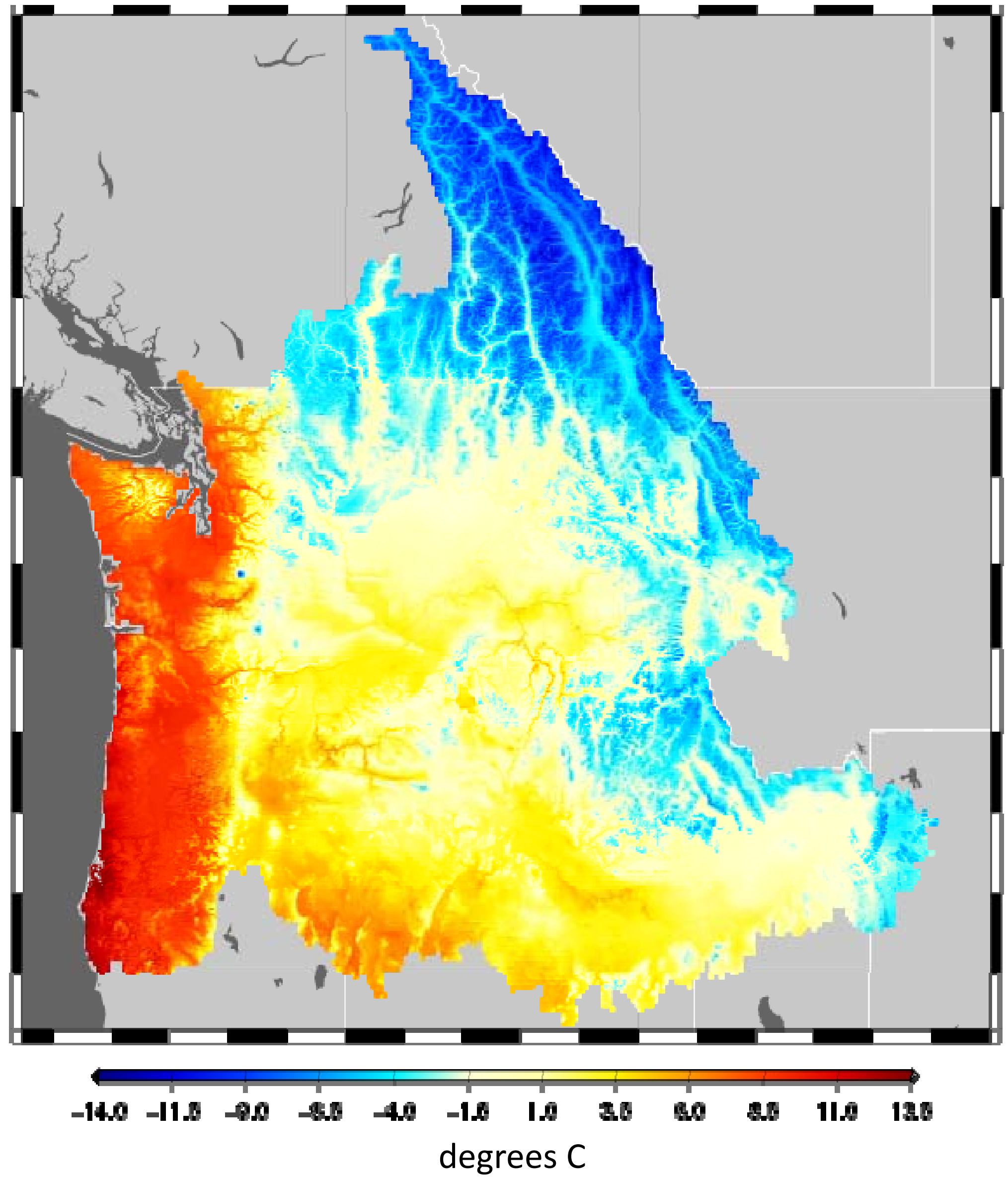
PRISM (30 arc-second climatologies):

http://www.prism.oregonstate.edu/

Variables (monthly time step):

- minimum temperature (monthly average)
- maximum temperature (monthly average)
- precipitation (monthly total)

Dec 2000: average maximum temperature



High-Resolution Snow Simulations

Website:

[*http://cses.washington.edu/picea/mauger/VIC_SNOW/pub/*](http://cses.washington.edu/picea/mauger/VIC_SNOW/pub/)

Resolution:

30 arc-seconds (~700-900 m)

Sources:

CBCCSP (1/16th degree daily met data): http://www.hydro.washington.edu/2860/

PRISM (30 arc-second climatologies):

http://www.prism.oregonstate.edu/

VIC macroscale hydrologic model

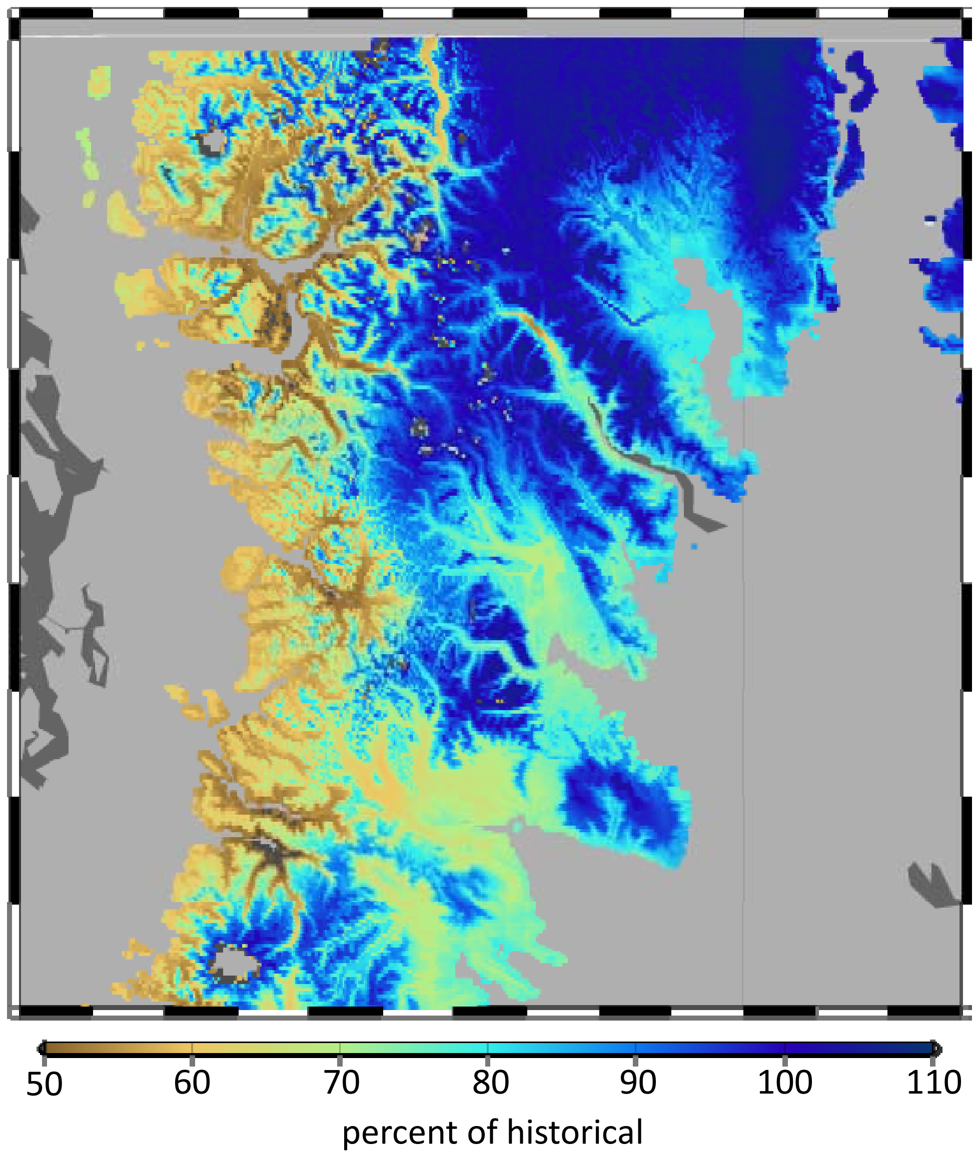
http://www.hydro.washington.edu/Lettenmaier/Models/VIC/

Variables (daily time step):

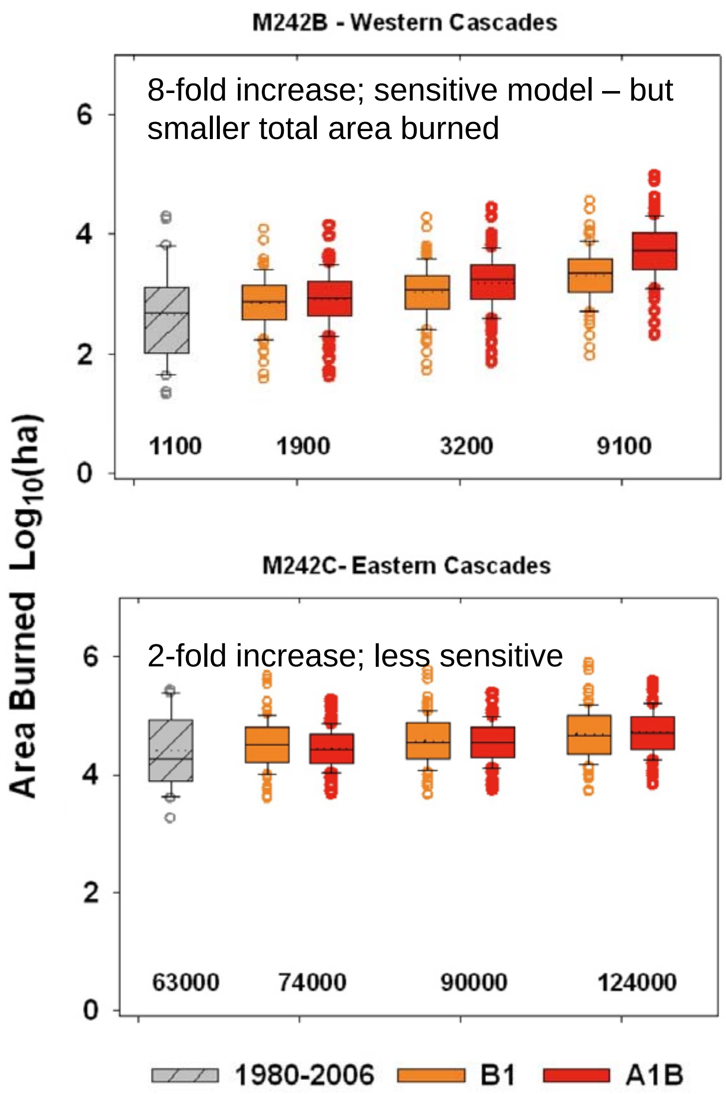
snow amount: swe, snow depth, peak swe

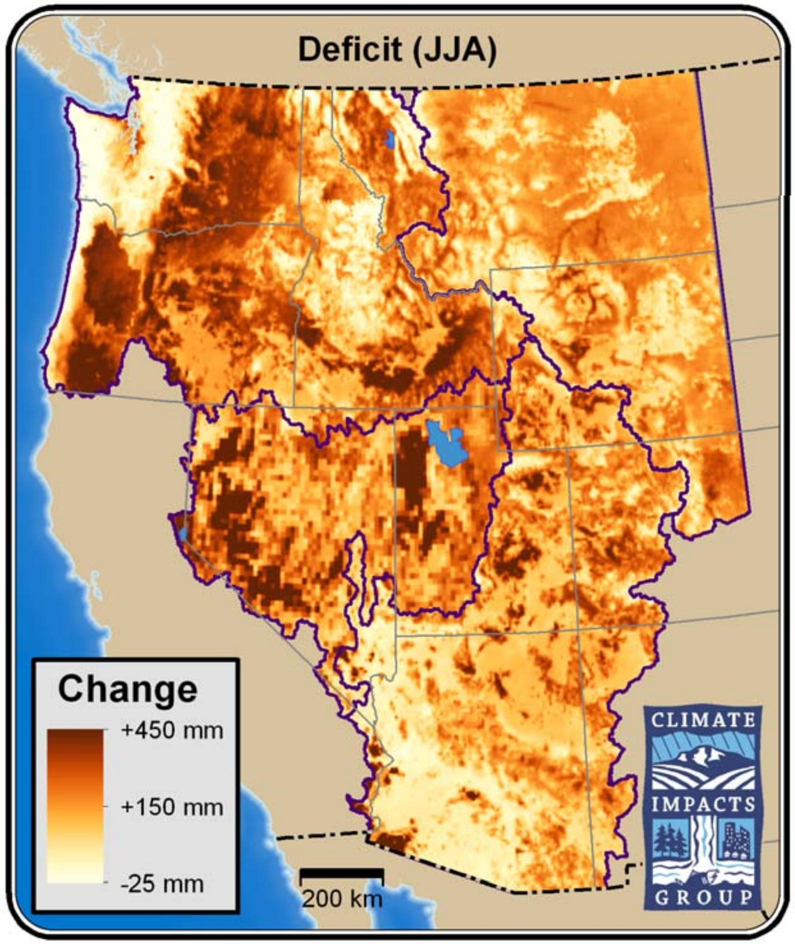
snow dates: peak swe, 10% accum, 90% accum

A1B 2040s: Change in Max SWE



Water balance deficit and future fire scenarios

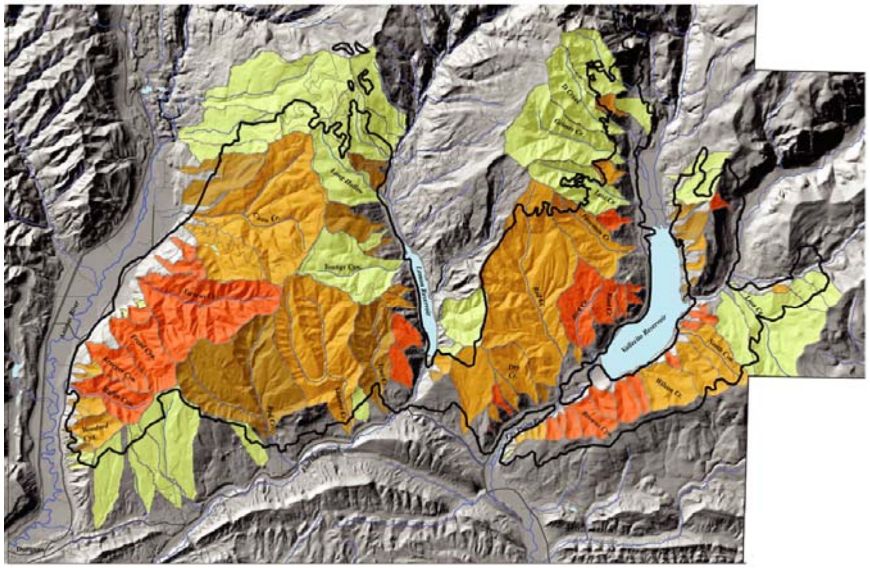




2040s change in summer water deficit, relative To 1970-1999 **Figure: R. Norheim**

Left: Based on statistical fire models and WACCIA ensemble future climate and VIC modeling, Littell et al. 2010.
Right: Littell et al. 2011. Ensemble of 10 GCMs, VIC hydrologic modeling, from R1/R6 analysis for USFS.

Water balance, increased disturbance, and hydrologic impacts



An example of a map showing the probability of debris-flow occurrence from basins burned by the 2002 Missionary Ridge Fire near Durango, CO. Map generated by incorporating the logistic regression statistical model into a GIS. USGS.

Post-fire (2008 Cascade fire near Red Lodge, MT. Blacktail Creek debris flow *(Photo by Drew Downs)*

Fire severity, proportion of watershed burned, and arrangement of burned patches contribute to fire effects on sediment transport

Image from http://www.getsomebass.com