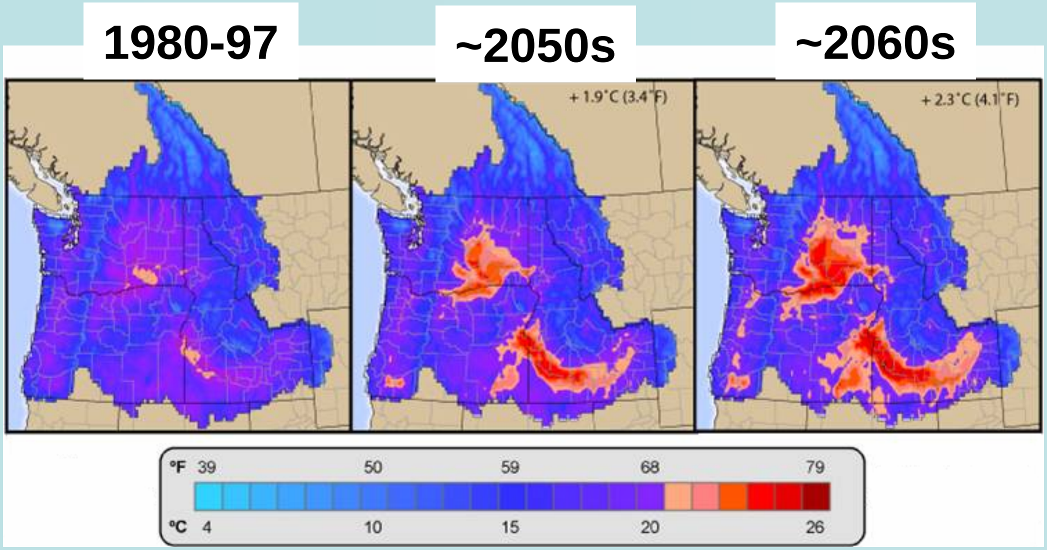
ISAB Climate Change Review

<u>Background</u>

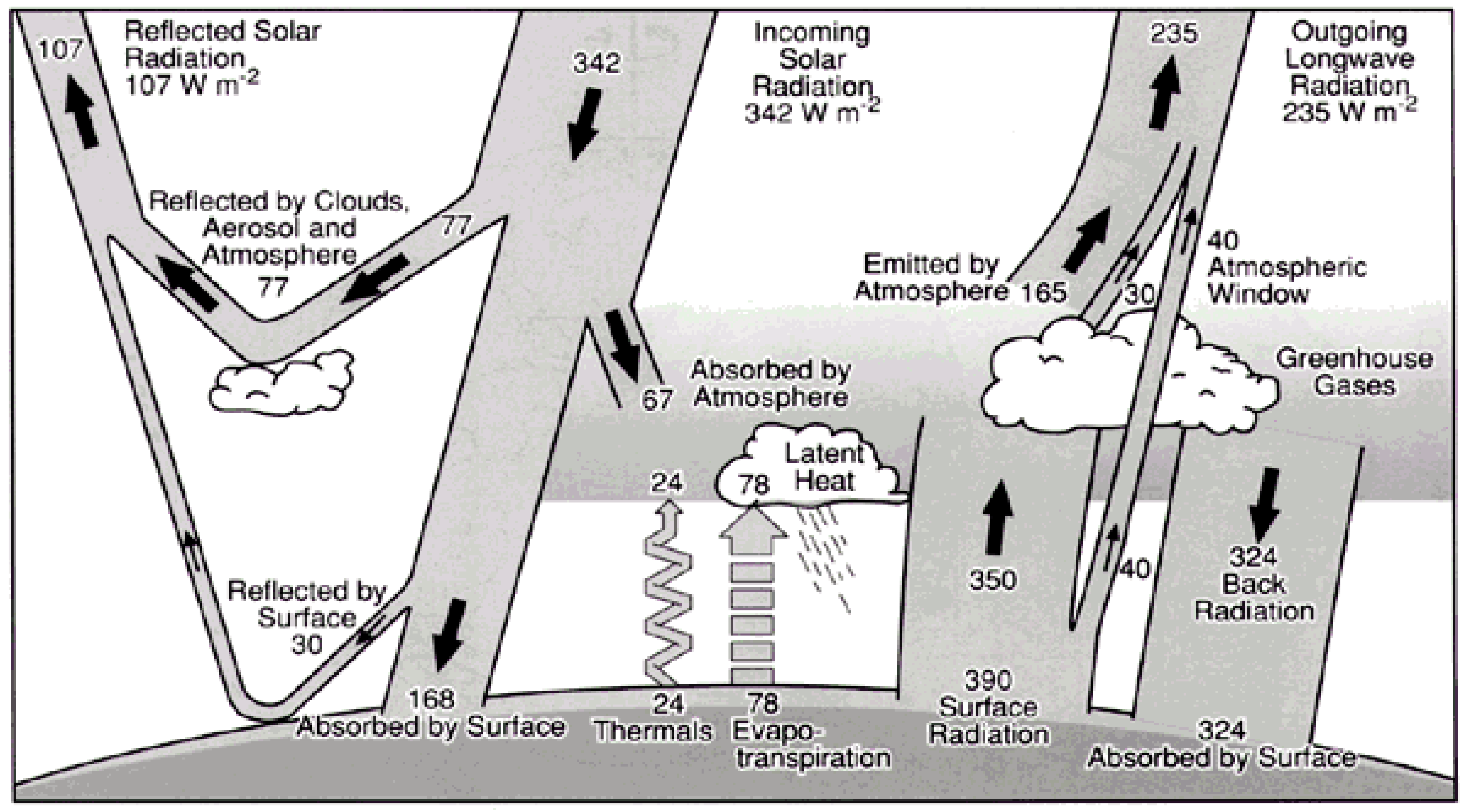
- Initial request for this review was in 2002
- Objectives: "*1) review projections of climate change and synthesize the current scientific understanding of climate trends in the Pacific Northwest and how these affect biologically important parameters such as marine conditions, stream flow, temperatures, and species ranges, and 2) focus on how these trends could impact the success of restoration efforts and suggest how consideration of these trends might impact the direction of the Council's program and how the region should incorporate knowledge of climate trends in fish and wildlife planning and management.*"
- Review initiated in 2006 – delayed due to several time-sensitive ISAB projects
- Delay somewhat fortuitous – new information available including release of latest IPCC report in Feb. 2007
- Dr. Nate Mantua from UW participated in the review as an ad hoc ISAB member

Impacts of Climate Change on Fish and Wildlife Resources of the Columbia River Basin

- Climate change processes and indicators of change
- Regional impacts of climate change
- Effects on terrestrial habitats
- Effects on tributary habitats
- Effects on the mainstem
- Effects in on the estuary
- Effects on the ocean
- Recommendations



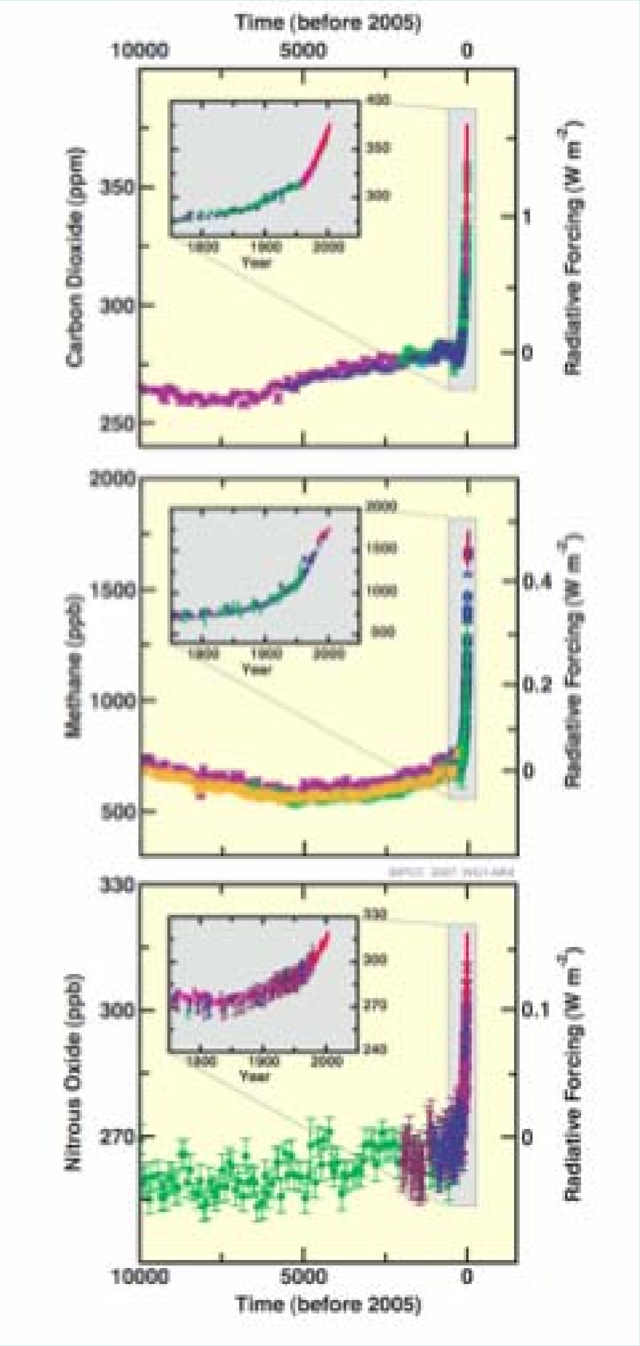
Earth's radiation budget and the natural greenhouse effect



From Kiehl and Trenberth, 1996: Bull. Of the American Met. Soc.

Changes in greenhouse gas concentrations from ice-cores and direct measurements

- Concentrations of key greenhouse gases have increased rapidly and substantially due to human-caused emissions, mostly since the mid-20th century

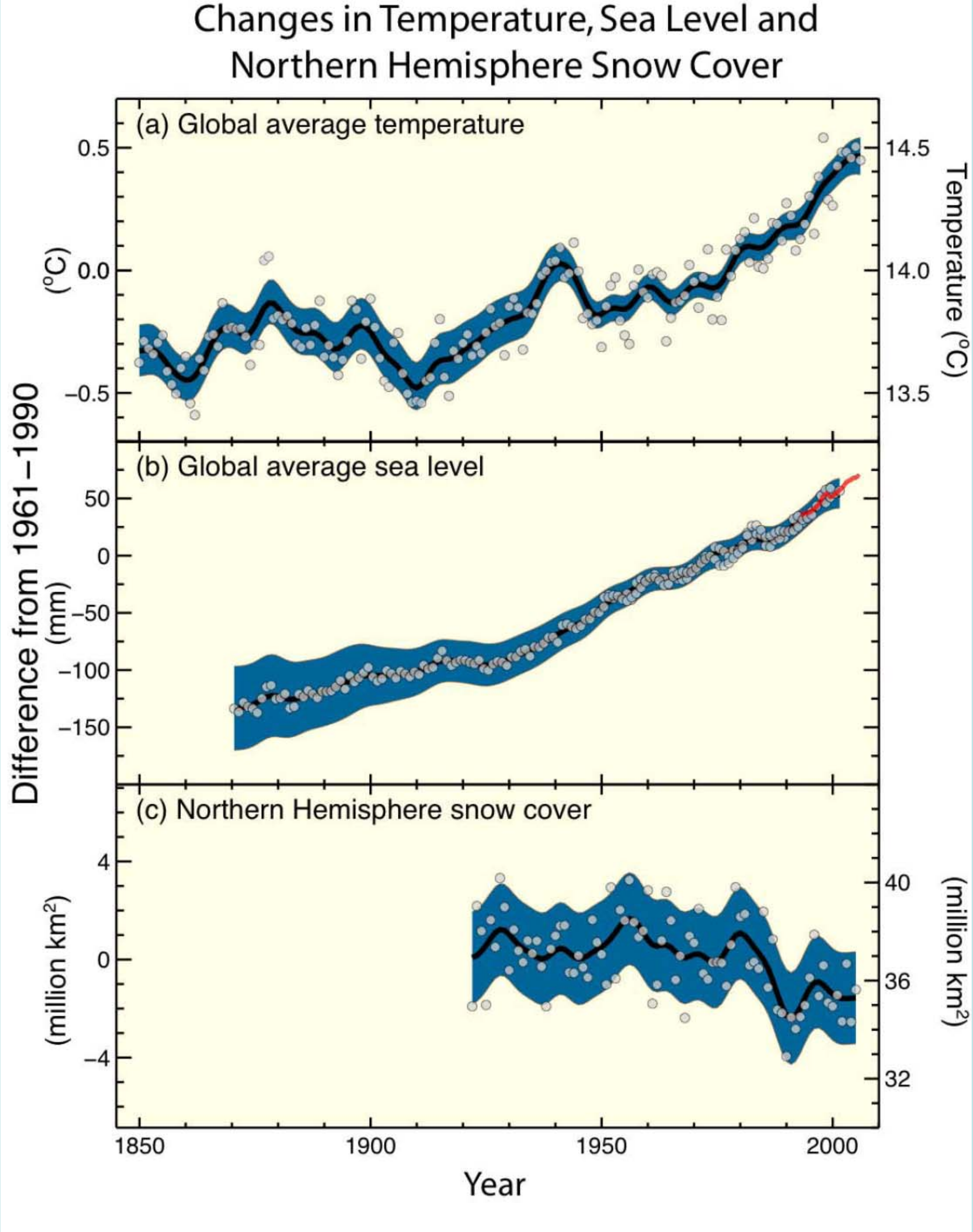


greenhouse gases are long-lived once put into the atmosphere

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

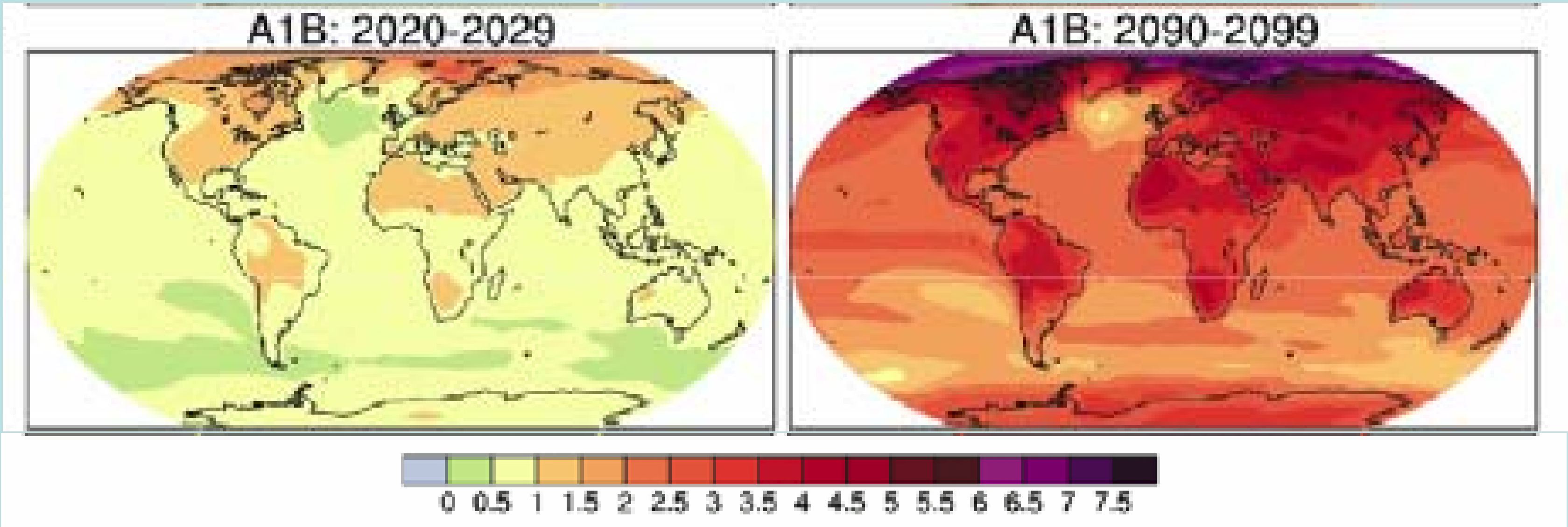
Source: IPCC. 1990. *Climate Change: The Scientific Assessment*, Working Group 1.

A wealth of observational evidence paints a consistent picture of a globally averaged warming climate in the period of modern climate observations



IPCC.AR4.2007

Scenarios for future temperature change

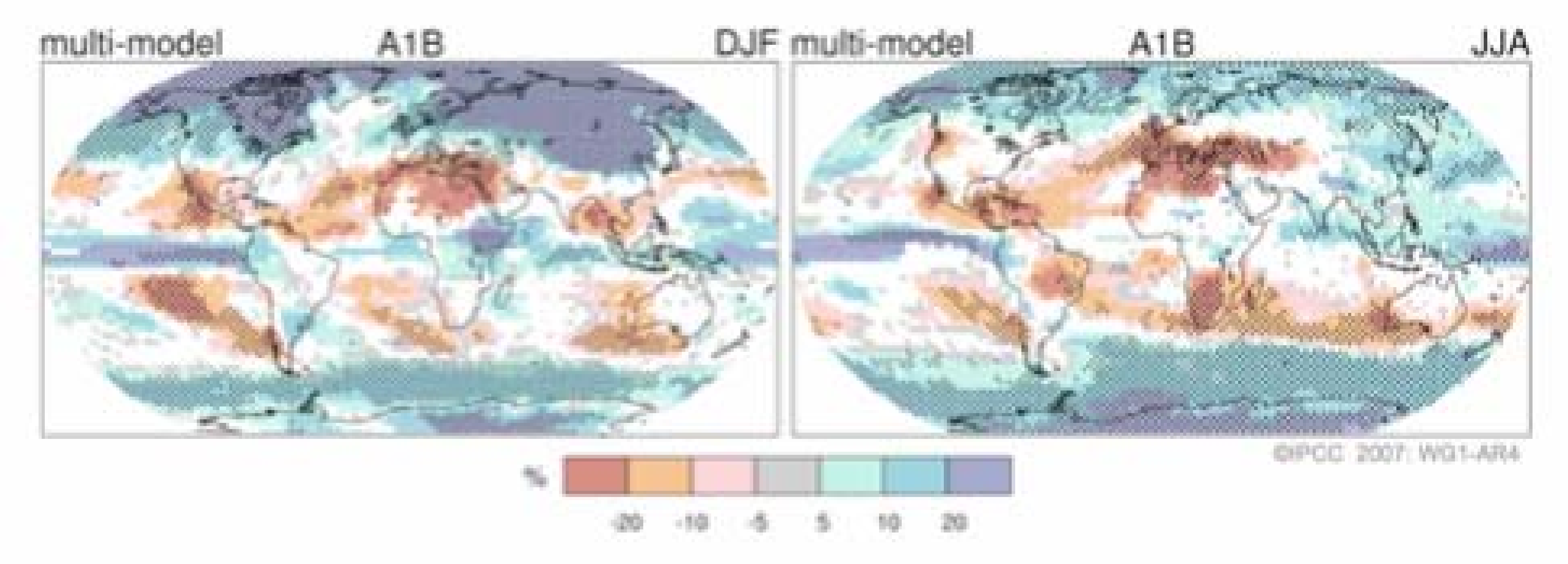


IPCC multimodel projected temperature changes for a range of greenhouse gas emissions scenarios point to a rapidly warming future, with the greatest warming over the Arctic

Source: IPCC 4th Assessment Summary for Policymakers

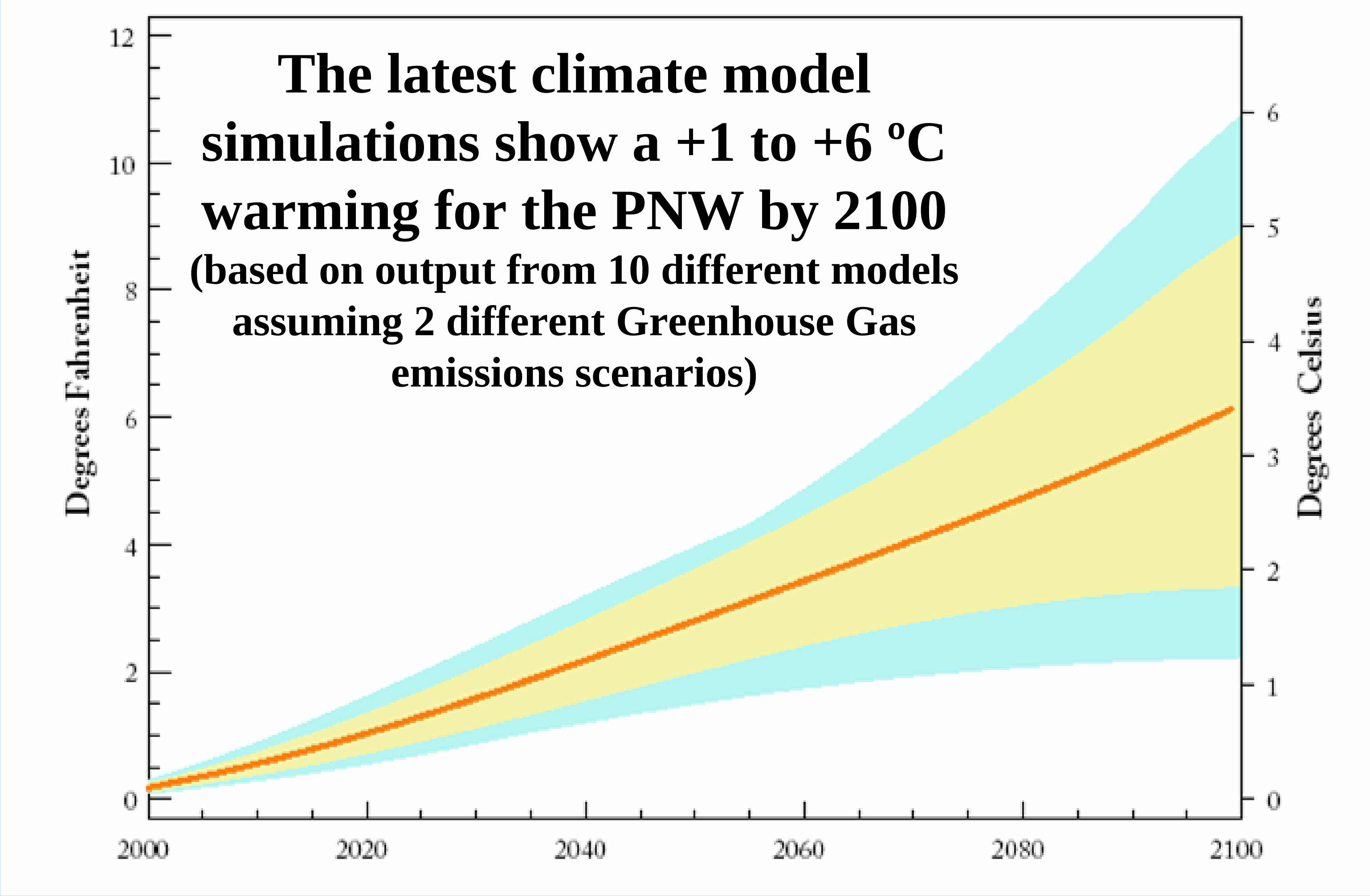
http://www.ipcc.ch

Projected patterns of precipitation changes
(IPCC 2007)

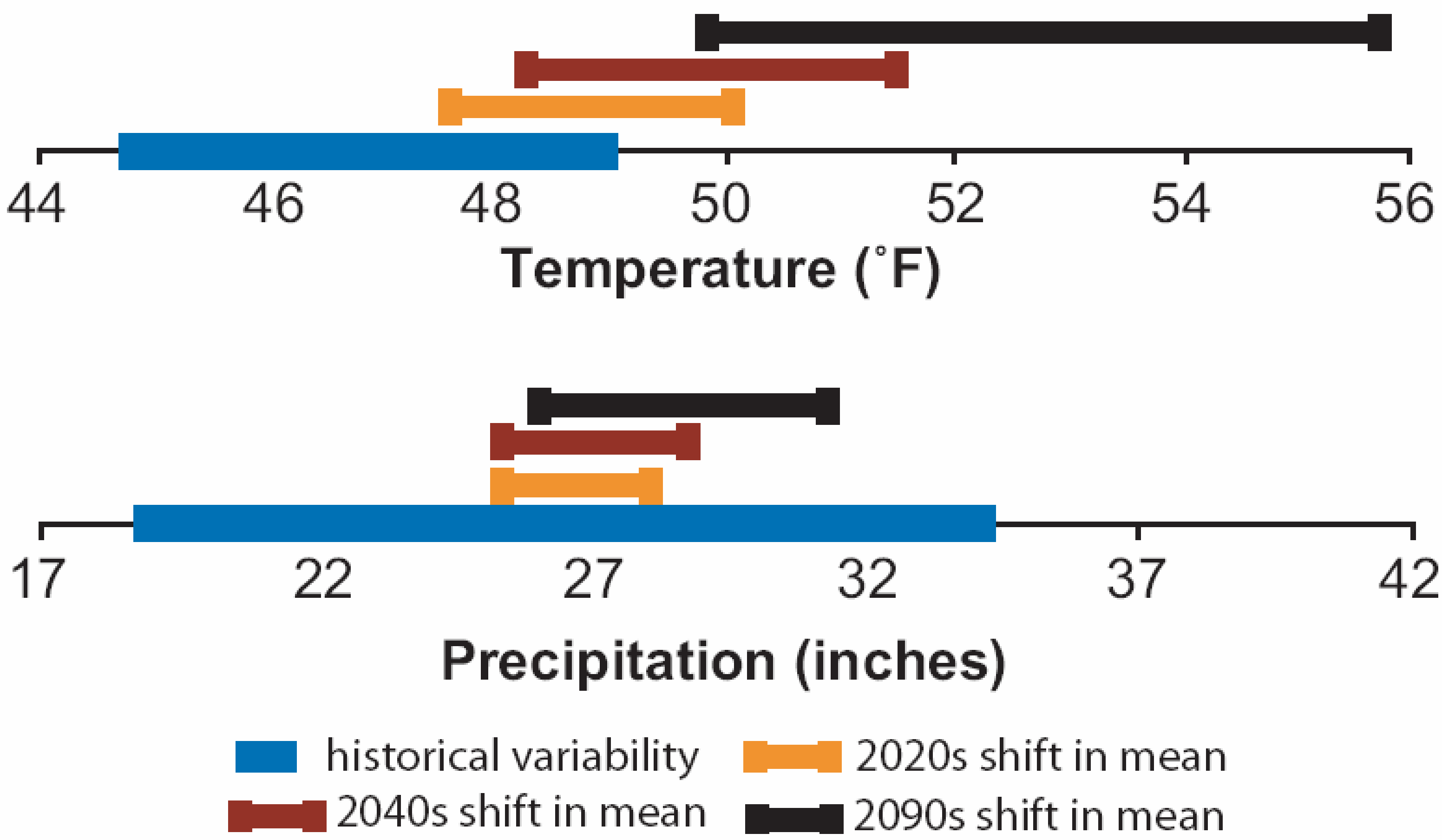


- Climate models consistently show ~10 to 30% increases in high latitude summer and winter precipitation; for mid-latitudes, winter precipitation increases ~10% while summer precipitation changes are more regional (and less consistent between models)

21st Century PNW Temperature Change Scenarios

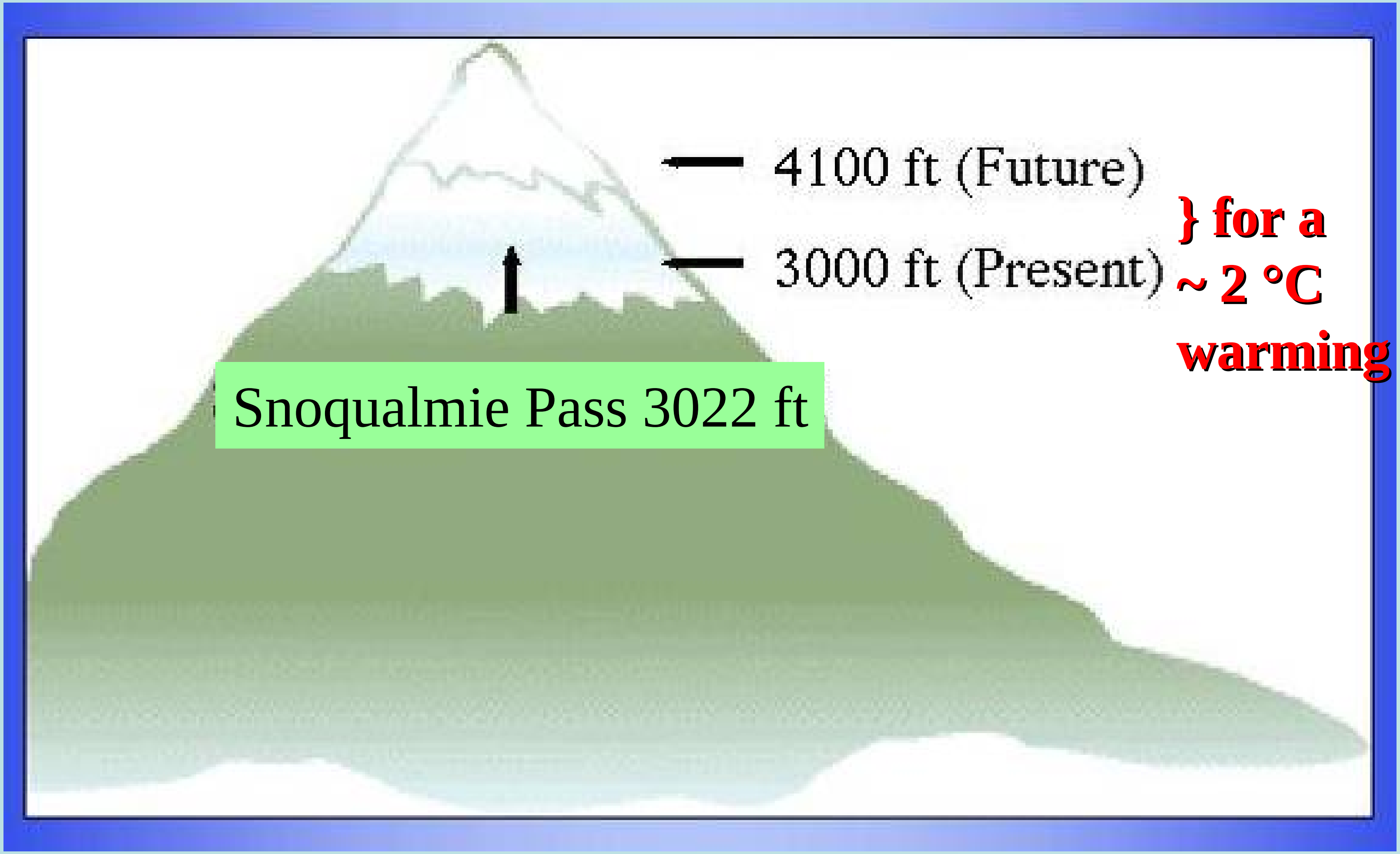


Source: UW Climate Impacts Group, also see Salathé et al. 2007: Int'l J. of Clim.



Comparison of observed year-to-year variability and projected shifts in temperature and precipitation from climate models

The main impact: less snow



springtime snowpack will decline in the warmest locations

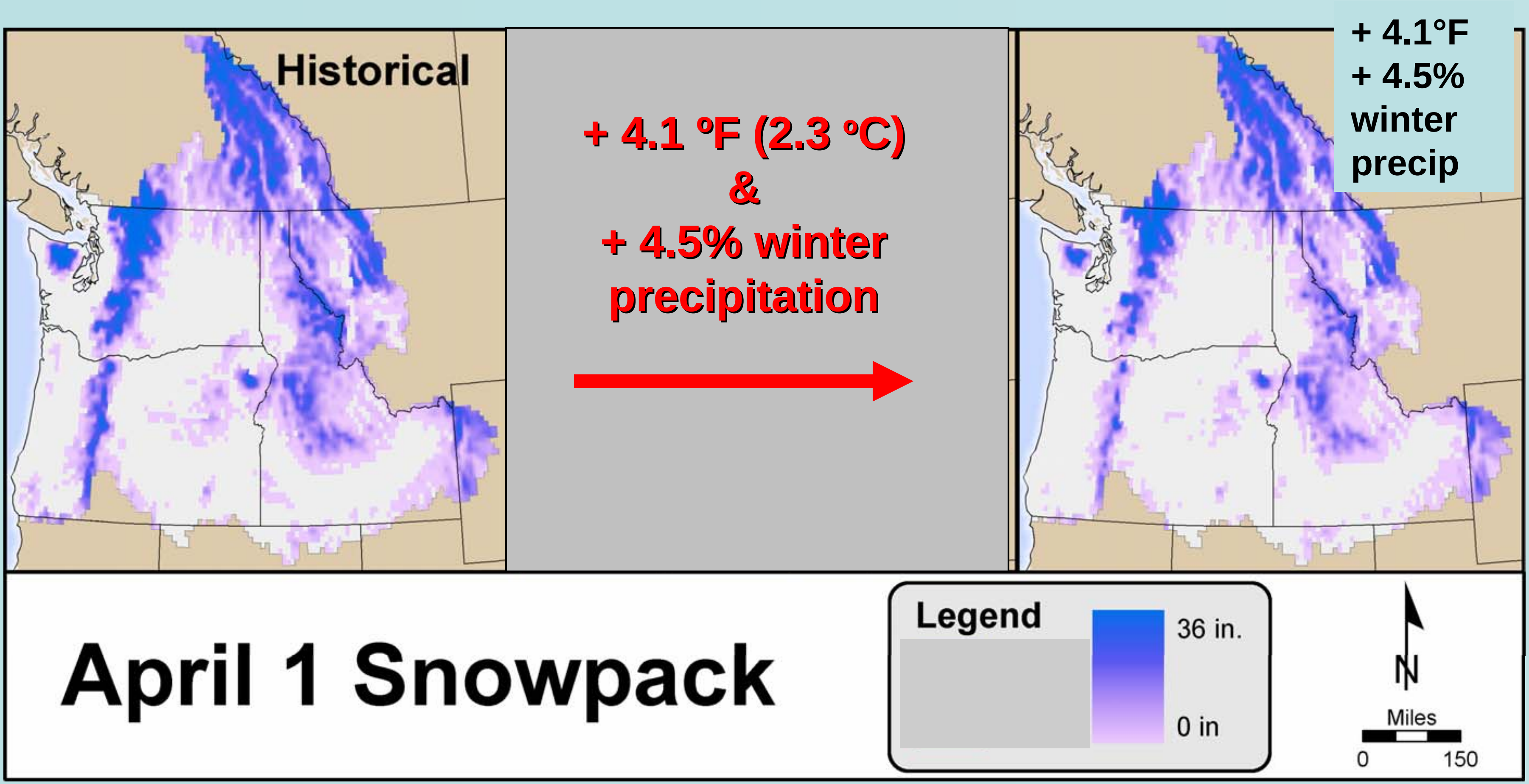


Figure courtesy of Alan Hamlet, UW Climate Impacts Group

The coldest locations are less sensitive to warming

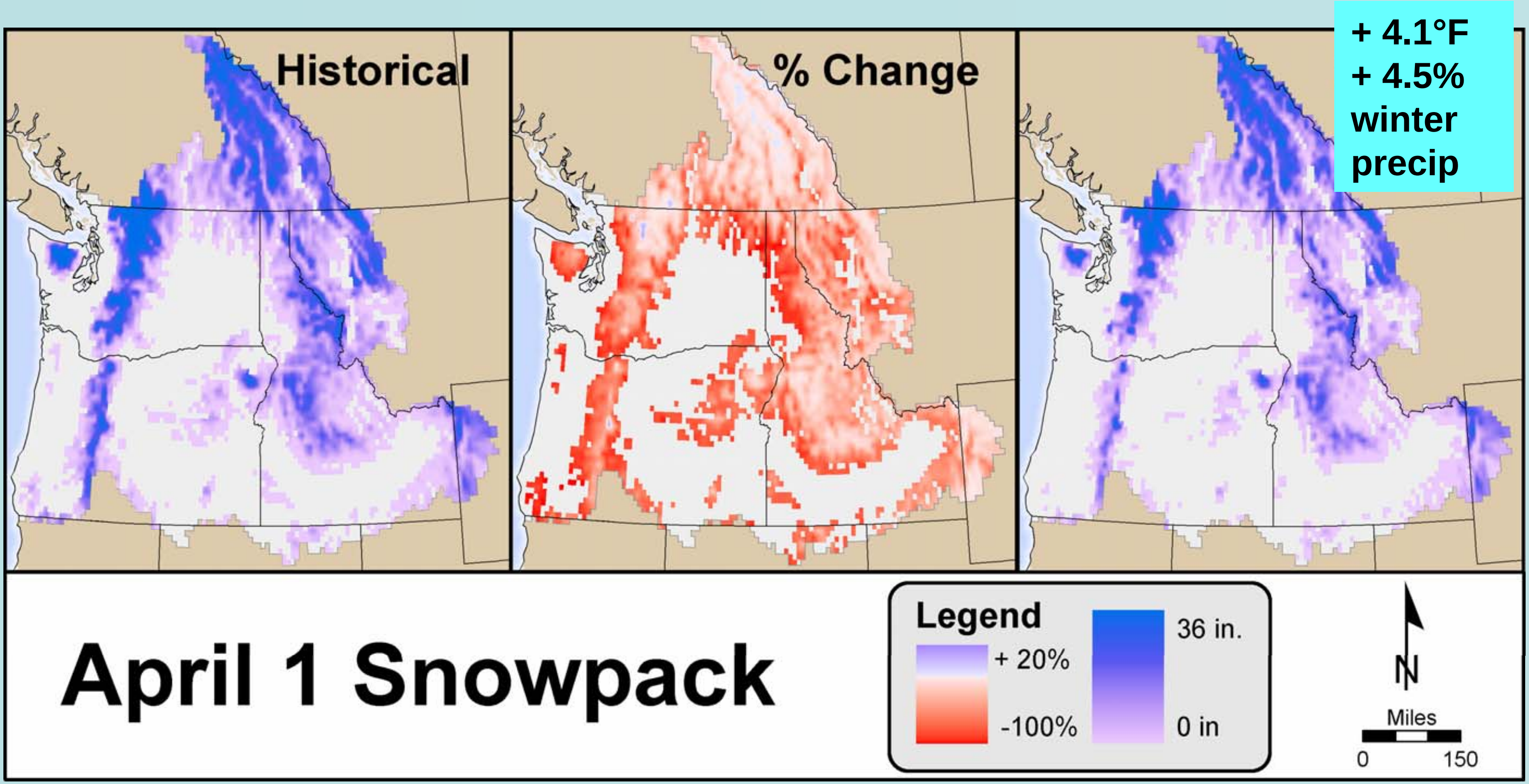
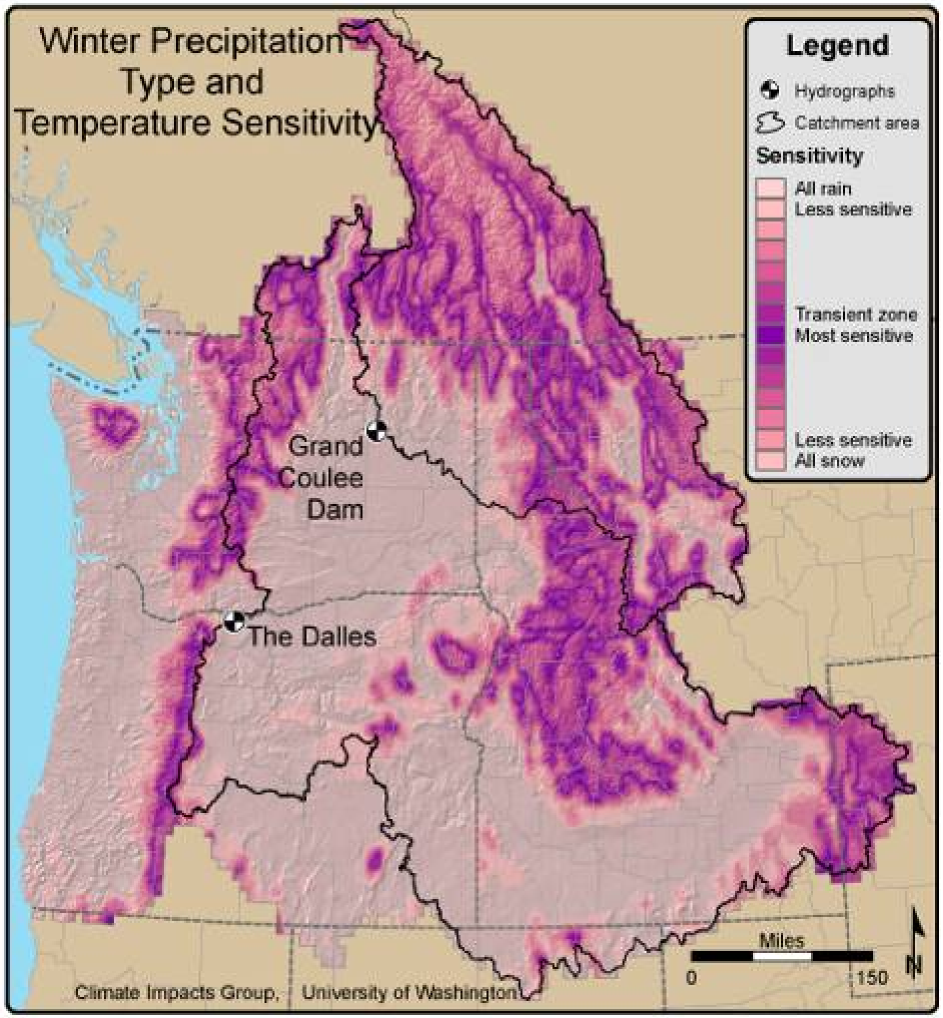
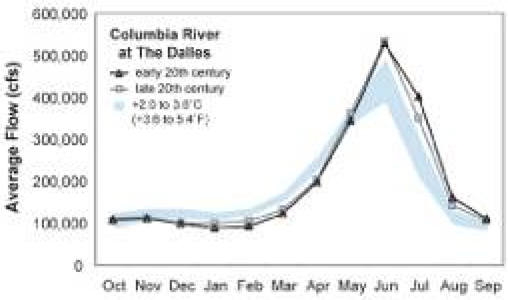


Figure courtesy of Alan Hamlet, UW Climate Impacts Group

The hydrologic sensitivity to warming varies

- The warmest sub-basins, where recent winter temperatures are near freezing, have the largest hydrologic sensitivities to projected temperature changes





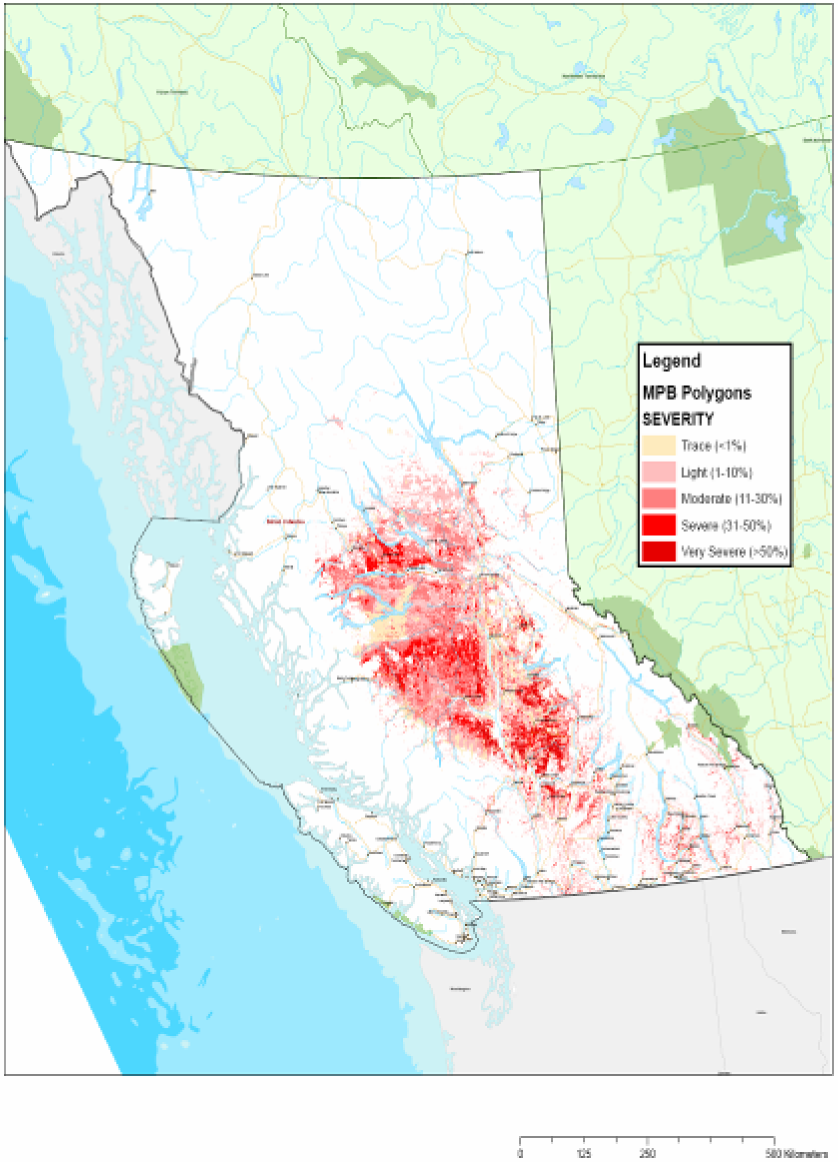
Impacts on Terrestrial Habitats

Increase in temperature
Altered snow level
Decrease in summer moisture availability

Potential Impacts on Vegetation

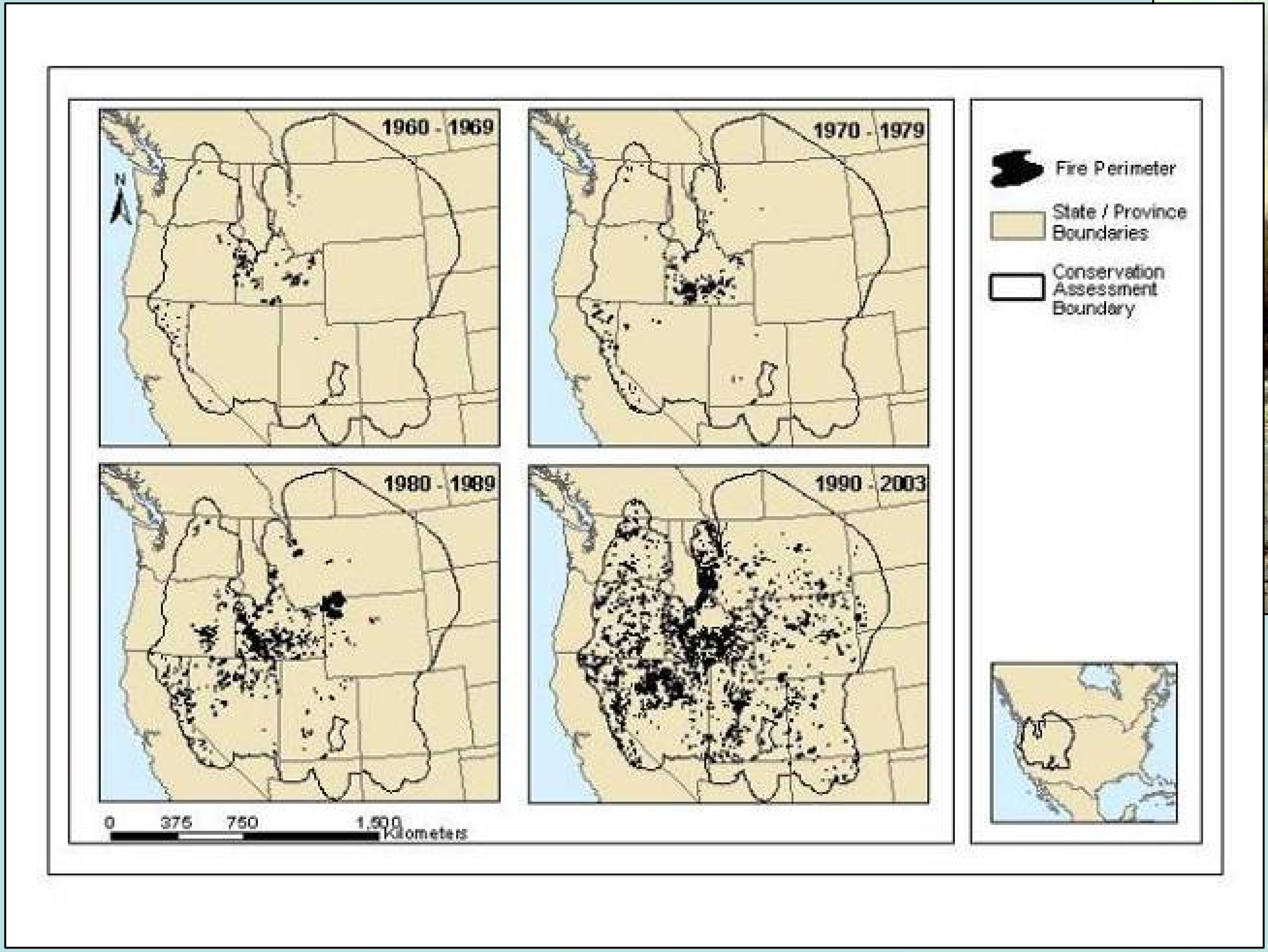
- Subalpine forests: longer, warmer growing seasons, shorter snowpack duration = growth increase
- Mid elevation forests: warmer summers, lower snow pack = growth depends on precipitation change
- Low elevation forests: warmer summers, potentially less summer precipitation = large growth decrease
- Potential for restructuring of plant communities
  - Species ranges generally shift northward and to higher elevation
  - Expansion of west-side Cascade species to the east-side (e.g., w. hemlock, red alder)
  - Expansion of woodlands into current sagebrush/steppe habitat
- Changes in age and species composition of forests due to elevated mortality from insects and fire
- Reduction in shrub/steppe habitat
- Distribution of sagebrush pushed to the north, may be absent in much of the Columbia Basin

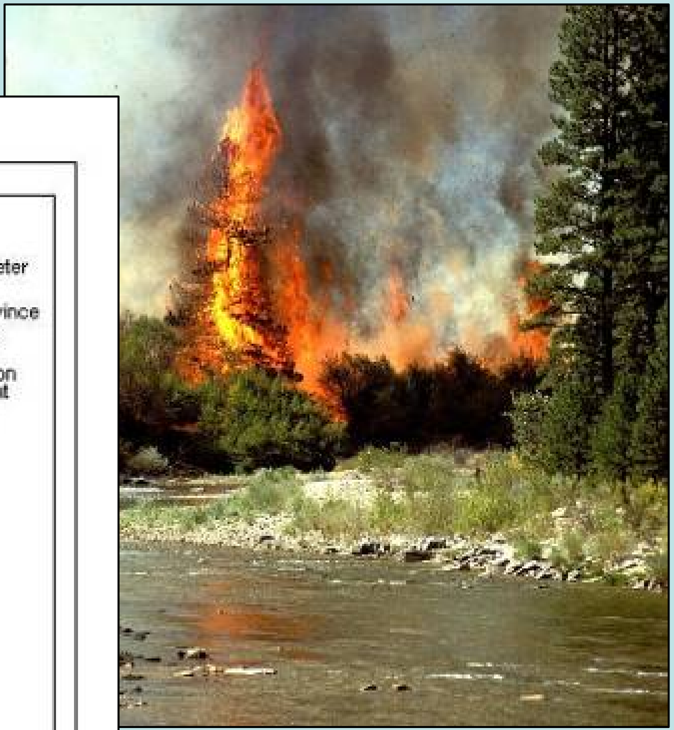
2006 Provincial Aerial Overview Survey
Mountain Pine Beetle



BC Ministry of Forests and Range

Changes in Fire Frequency in the Western U.S. 1960-2003





What Can We Expect?

NIFC

- **Short term (1-2 decades):**
  - Increasing drought mortality
  - Increasing area burned and fire severity
  - Increases in area of insect mortality
- **Mid term (2-5 decades):**
  - Increases in fire frequency
  - Forest adaptation to native insect disturbance, but exotics….?
  - Disturbance (insects, fire, or both) becomes the main factor determining which forest management actions are *possible.*
- **Long term (3-?? decades):**
  - Changes in forest communities
  - Changes in forest ecosystem productivity

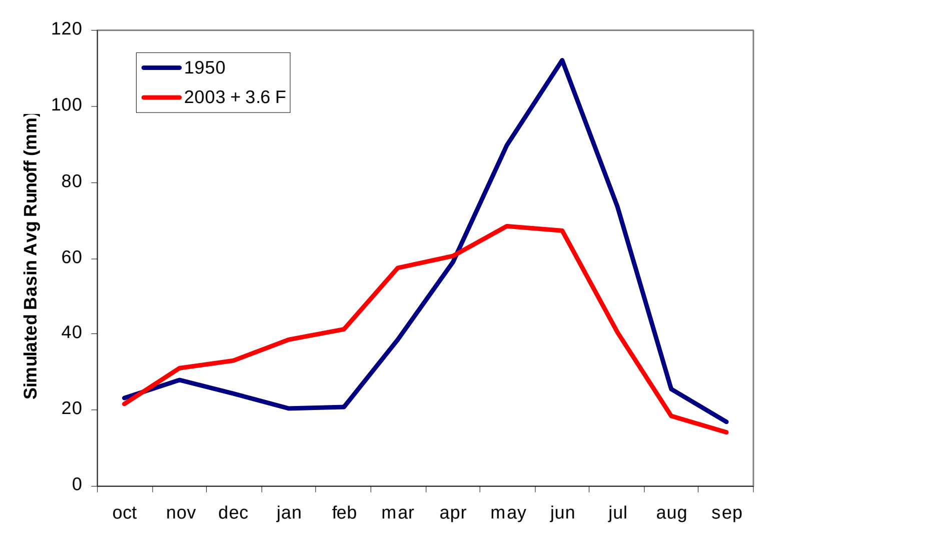
From Littell and McKenzie, UW CFR 2006

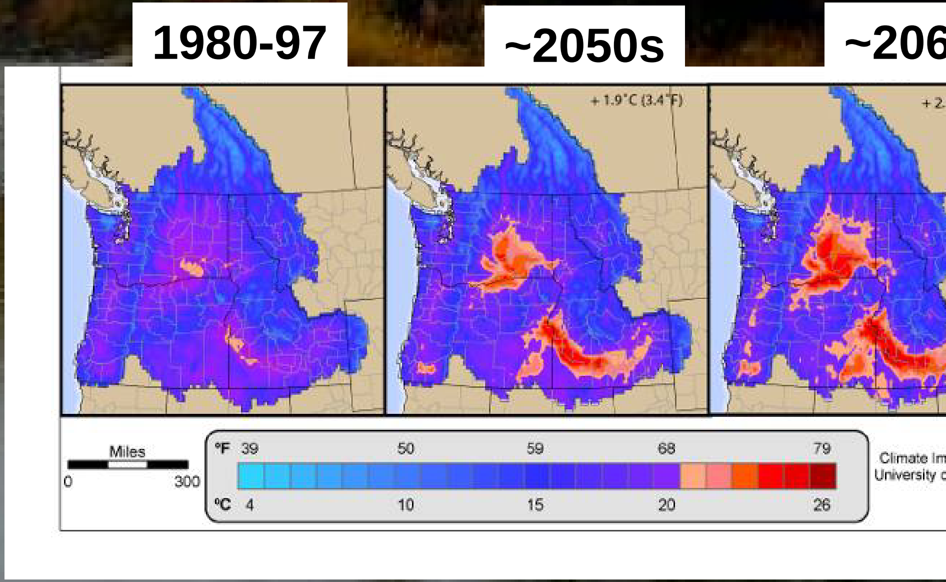
Potential Impacts on Wildlife

- Responses hard to predict – affected by various factors that will be impacted in different ways by changing climate
  - Direct effects of altered temperature and moisture
  - Vegetation changes will alter habitat
  - New species associations may alter competitive and predator-prey relationships
- Invasive species further complicate predictions of wildlife response
  - Invasives may enjoy a competitive advantage over native spp. with altered climate
  - Presence of invasives may make range adjustments more difficult
- Strong interaction with human land use
  - Leads to fragmentation of habitat - may preclude range adjustment as a compensatory mechanism
  - Promotes invasives

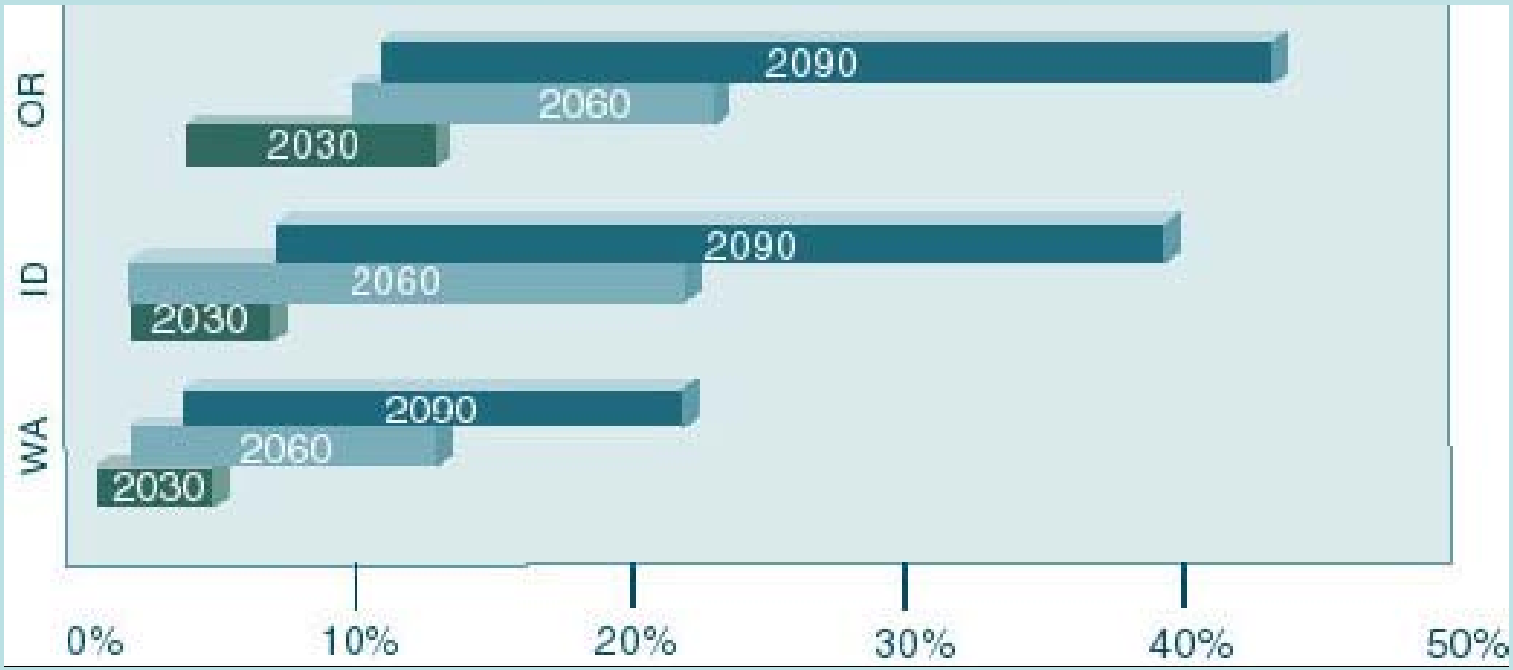
Effects on Tributary Habitat

Altered hydrology
Increased water temperature





Projected Loss of PNW Salmon Habitat over the Next Century

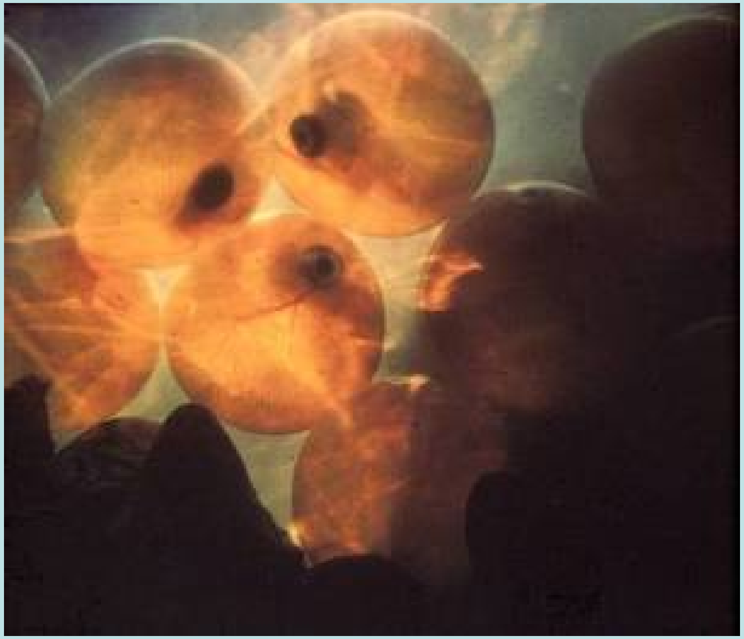


CGCM2 model; A2 GHG Scenario; 5^{o}C increase by 2090

O'Neal 2002

Egg Incubation – Fry Emergence

- Increased maintenance metabolism will produce to smaller fry.
- Lower disease resistance may lead to lower survival.
- Faster embryonic development will lead to earlier hatching.
- Increased mortality due to more frequent flood flows



Spring/Summer Rearing

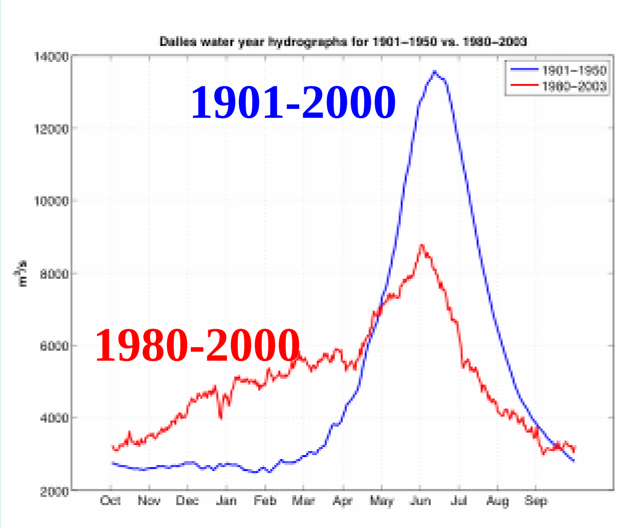
- Lower summer/early autumn flow will reduce habitat area
- Cold-water species may be excluded from areas currently occupied
- Lower growth due to increased metabolic rate (if food limiting)
- Competitive advantage for non-native and warm-water species
- Increased predation mortality
- Fish in streams with very cold water may benefit (high elevations)
  - Earlier spawning and fry emergence
  - Higher summer growth
  - Higher overwinter survival

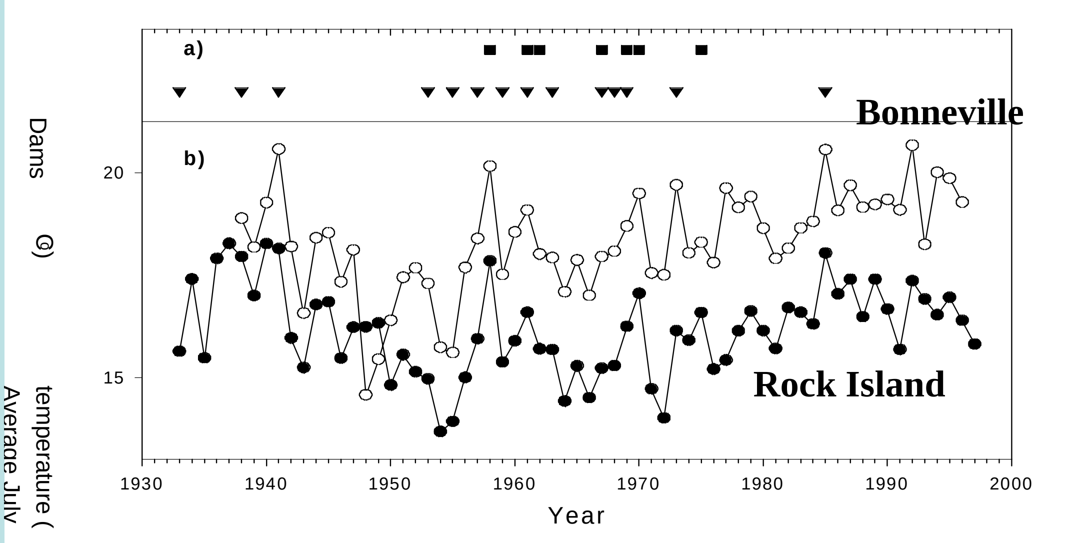
Overwinter Survival

- Potential for positive and negative effects
- Higher water temperature increases metabolic rate and activity
  - Higher growth rate with sufficient food
  - Lower growth rate if food is limiting
- Higher predation rates
- Increased frequency and severity of winter high flow will have detrimental effects: Fish displaced downstream if sufficient off-channel, refuge habitat not available

Observed streamflow at the Dalles

- hydrosystem operations have already caused substantial reductions in peak summer flows, increases in winter flows, and rising summertime water temperatures





Shifts in natural runoff timing will pose challenges to meeting hydrosystem objectives

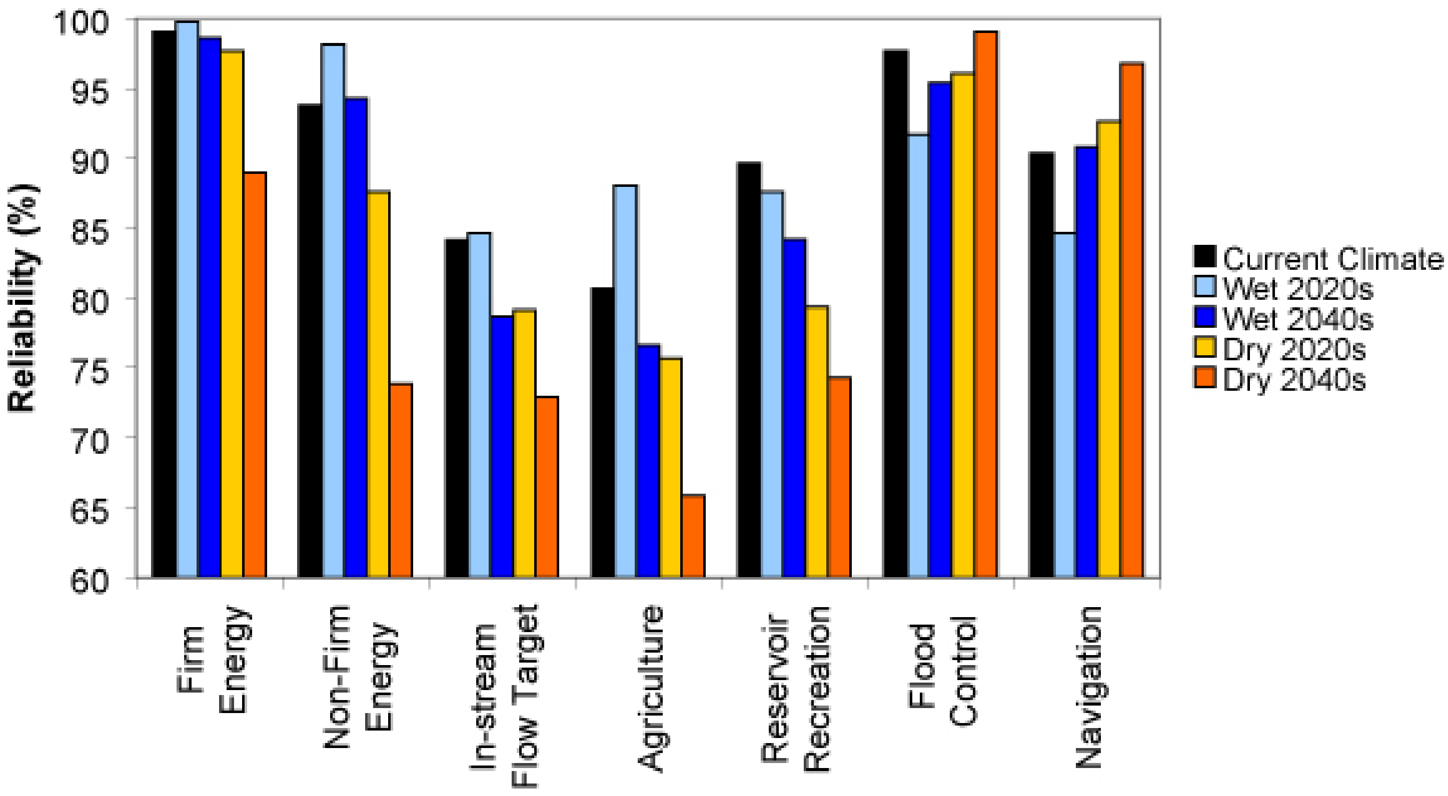
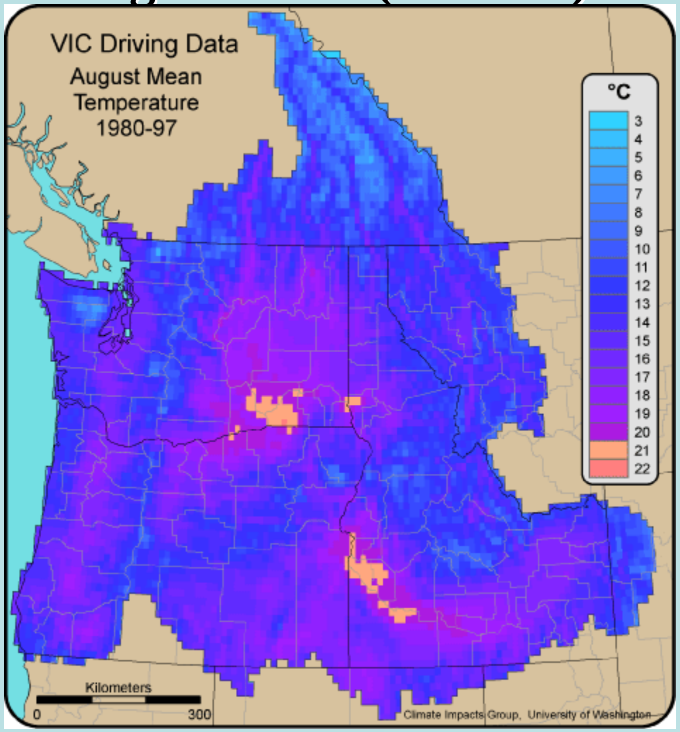


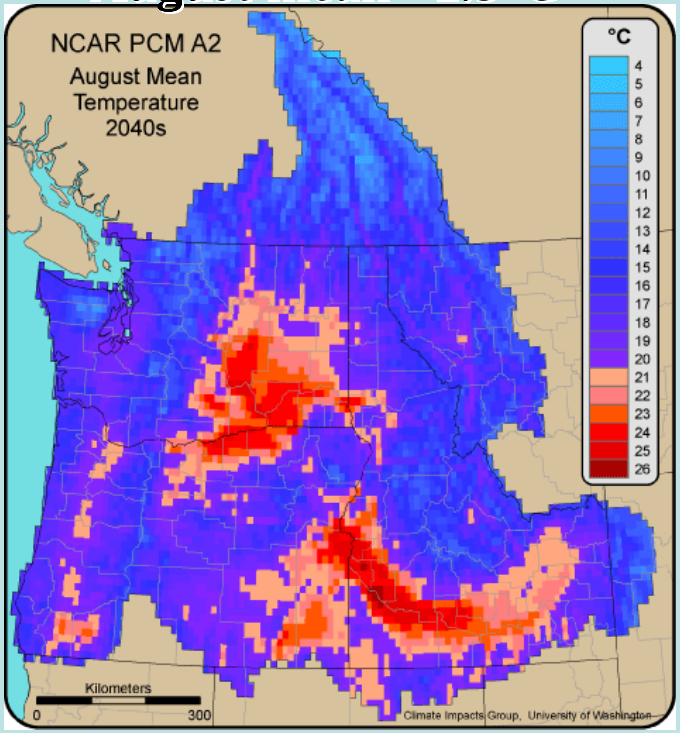
Figure based on data from Miles et al. (2000)
Figure source: Climate Impacts Group, University of Washington

A *Plausible Warming* and the 21°C threshold

August mean (1980-97)



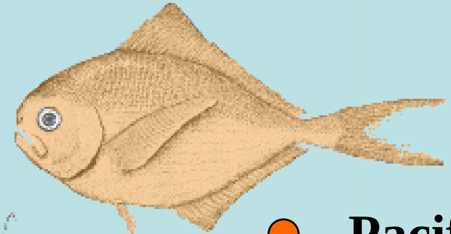
August mean +2.3°C



- 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)

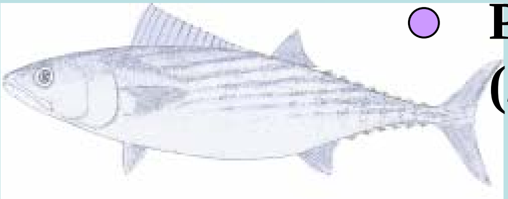
Exotic Species Sightings off the BC Coast During 1983, an extreme El Niño year (J. Fulton, P.B.S.)



Pacific Pomfret (*Brama japonica*)

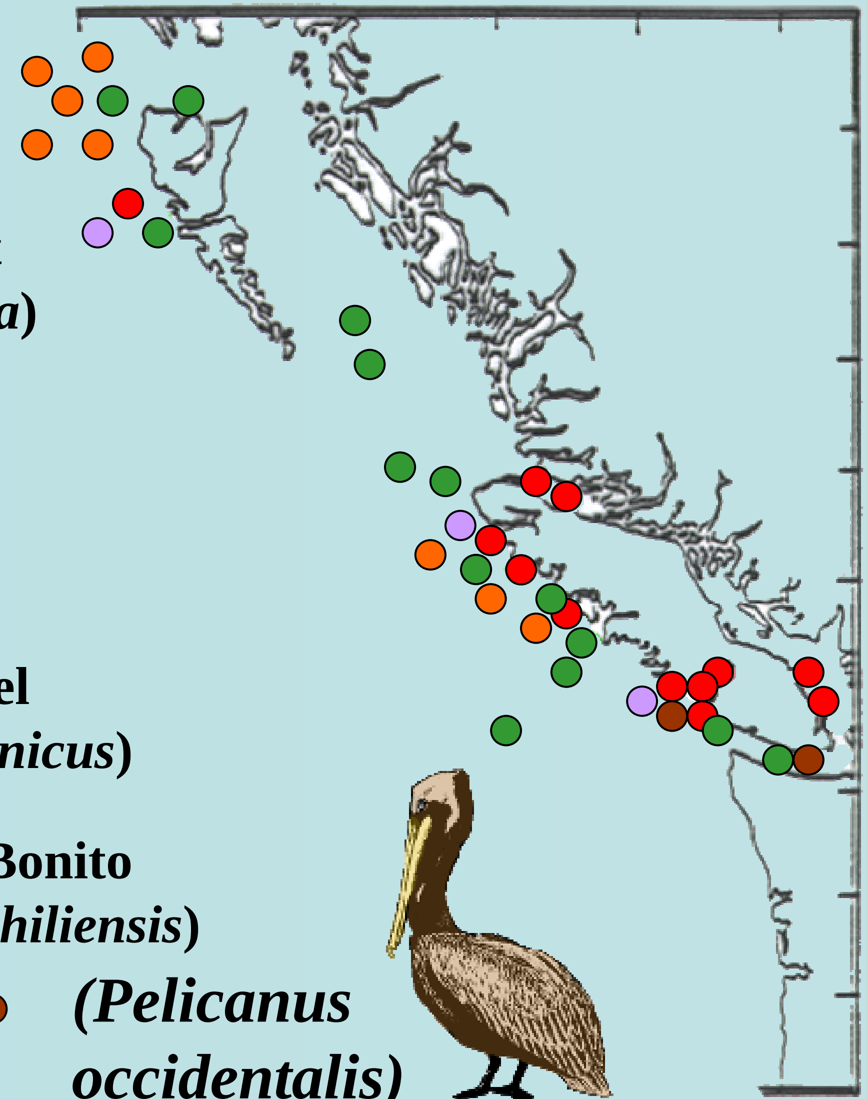
Ocean Sunfish (*Mola mola*)

Chub mackerel (*Scomber japonicus*)



Pacific Bonito (*Sarda chiliensis*)

(Pelicanus occidentalis)

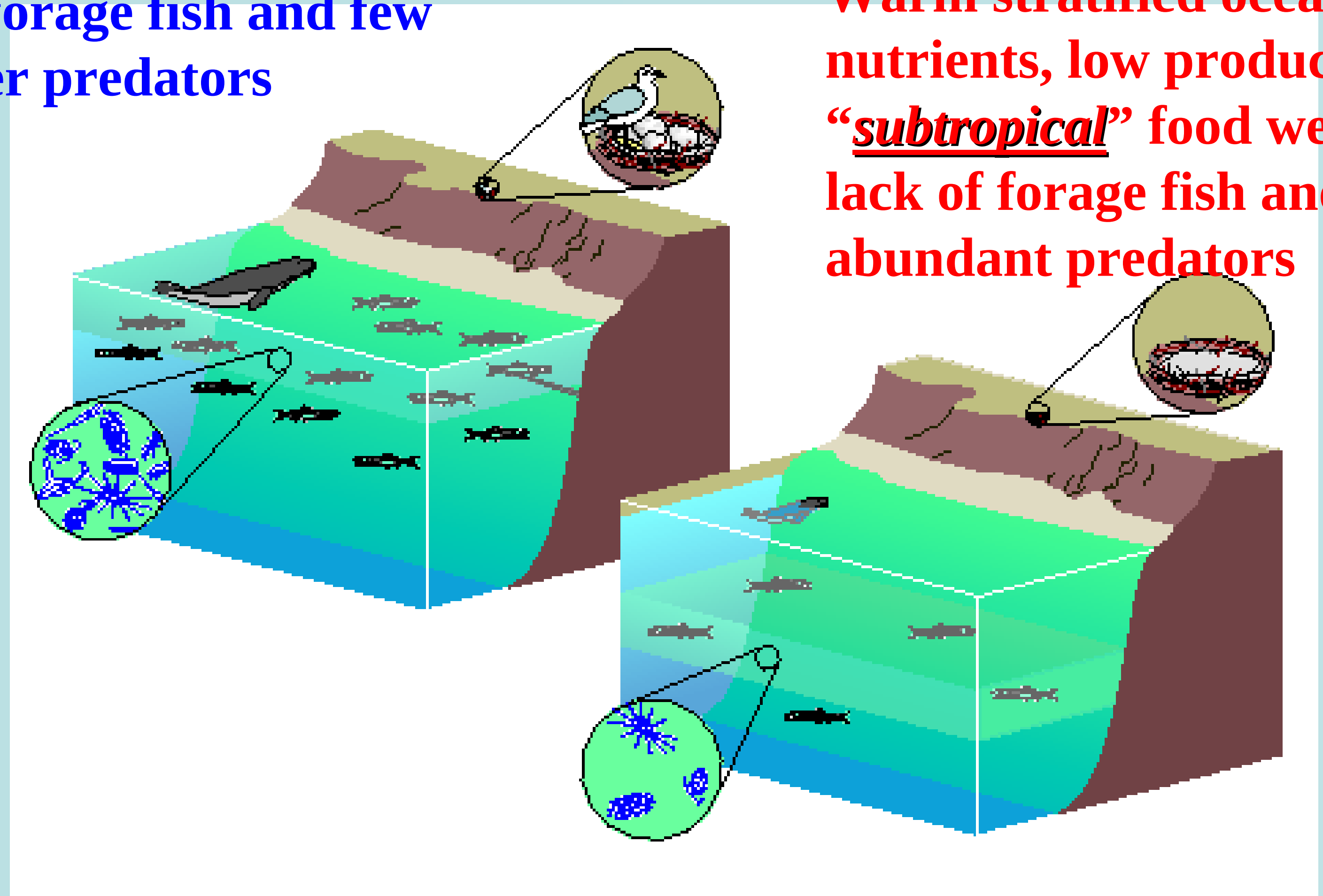


Slide provided by Kim Hyatt, DFO

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



Upwelling in a warmer future?
(Snyder et al. 2004, GRL)

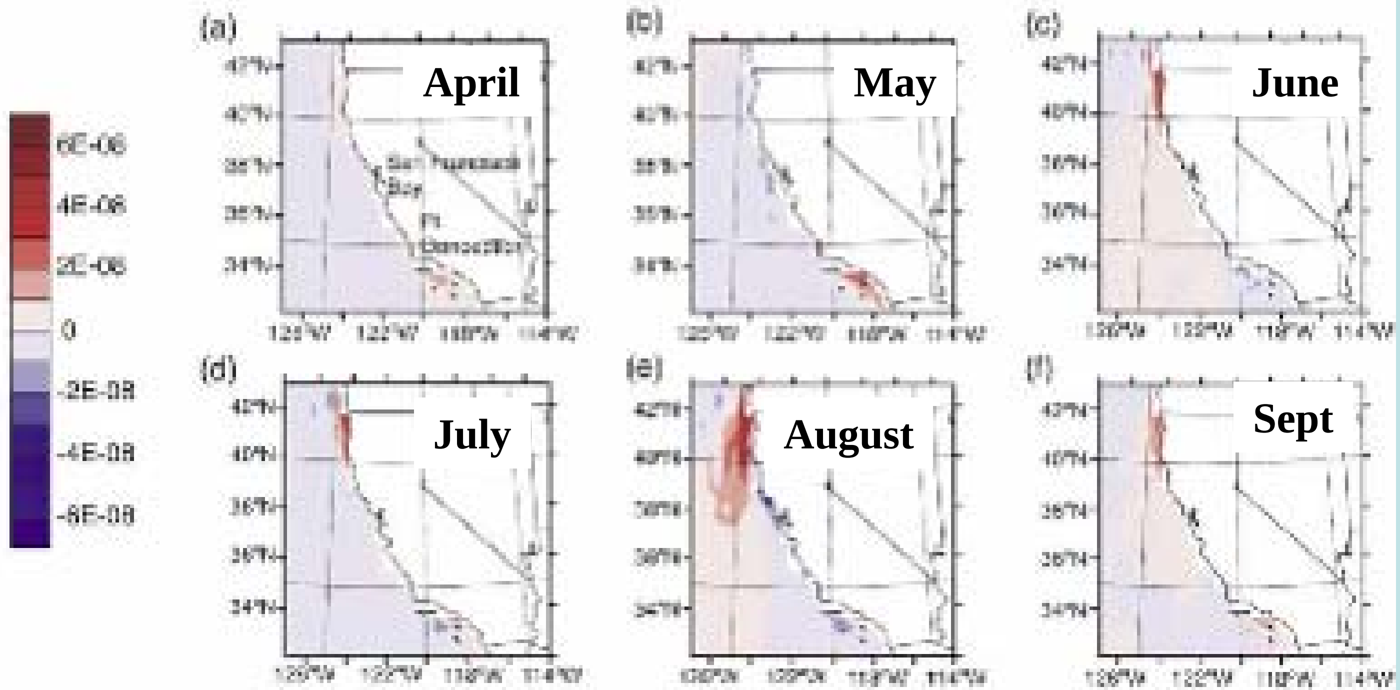
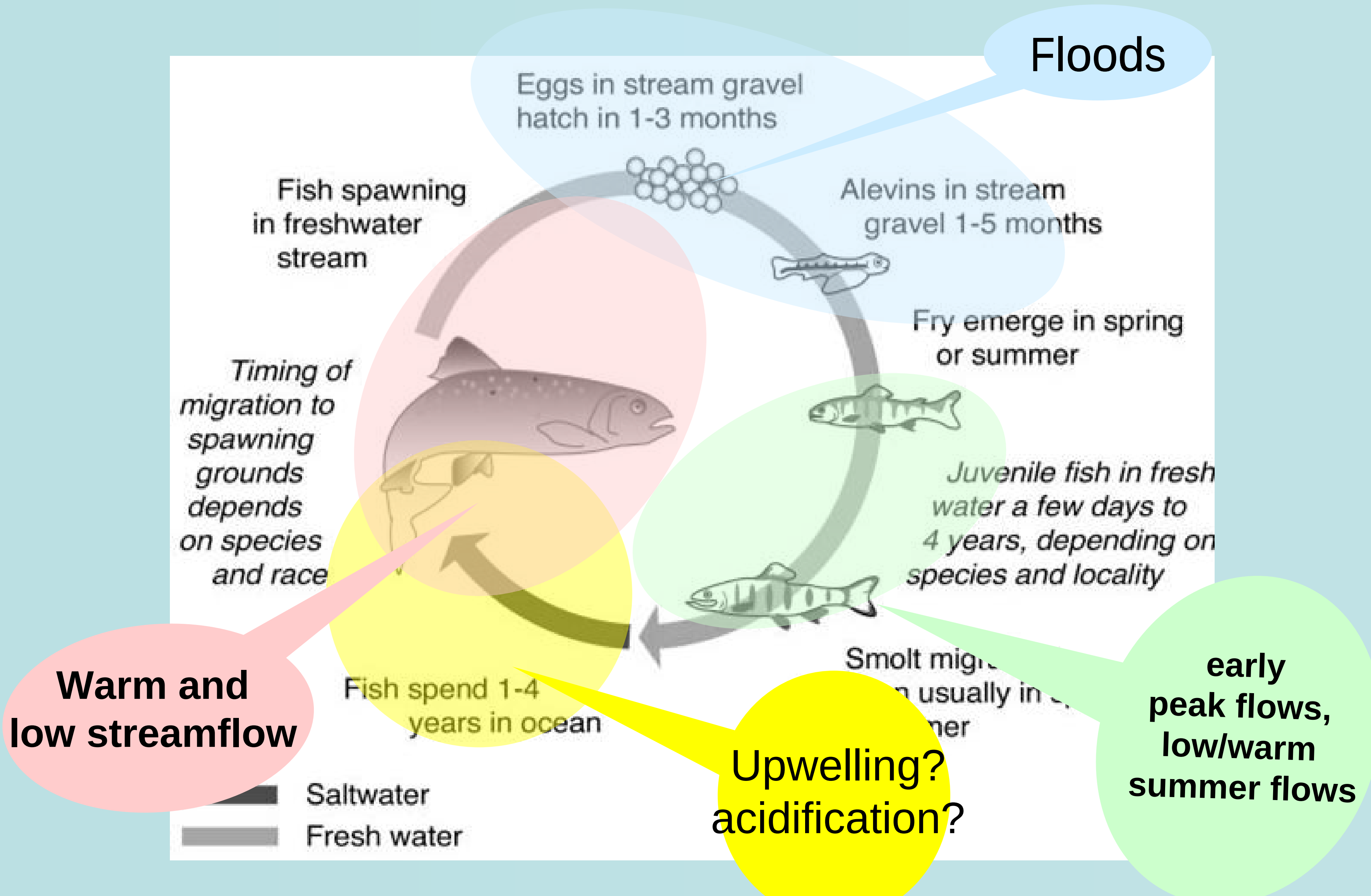


Figure 2. Difference of the monthly average wind-stress curl (N/m^2), calculated as FUTURE-MODERN, for (a) Apr, (b) May, (c) June, (d) July, (e) August, (f) September.

- In one climate modeling study, springtime upwelling is delayed, while summertime upwelling intensifies (comparing the monthly averages from the 2080-2099 and 1980-1999 simulation periods)

Climate change impacts summary



ISAB Recommendations

Climate change should be considered in prioritizing restoration projects

- Subbasin plans generally did not consider climate change impacts
- Many mentioned climate change in the assessment but it was not used as a factor in identifying priority actions
- Planners may require some technical assistance in addressing climate change in Subbasin Plan updates
  - Climate change information at spatial scales relevant to subbasin planning is becoming more available
  - Tools for conducting a climate change assessment (e.g., hydrologic models) also are becoming more available

ISAB Recommendations

Some climate change impacts can be partially mitigated

- Effective application of mitigation measures will require identification of those locations where these actions will have the greatest benefit
- Locations especially sensitive to climate change and with high ecological value are prime locations to consider land purchase or conservation easements
- Measures that help maintain or enhance water temperature and late summer flow may be effective in addressing some tributary habitat impacts
  - Identify and protect areas with cool water (thermal refugia)
  - Protection/restoration of riparian vegetation
  - Minimize land use activities in riparian areas that would reduce canopy cover
  - Buy or lease water rights in sensitive locations
  - Increase efficiency of diversions and irrigation systems
  - Restore wetlands, floodplains of other landscape features that store water

ISAB Recommendations

- Mitigation of climate-change impacts in the mainstem, estuary and plume is possible with alteration in hydrosystem operations
- Mainstem and estuary impacts may be addressed through:
  - Flow augmentation in summer to reduce water temperature (sufficient storage capacity?)
  - Use of RSW to reduce time spent by juvenile salmon in dam forebays
  - Reduce water temperature in fish ladders during adult salmon migration
  - Establish thermal criteria for initiation of full transportation for juvenile fall Chinook (adults?)
  - Reduce predation by liberalizing harvest of introduced predatory fishes (walleye, bass, etc.)
  - Restore connections to floodplains along the mainstem and estuary to provide off-channel habitats
- Mitigating impacts of climate change in the ocean can only be accomplished by modifying fish management
  - Reduce release of hatchery fish during poor ocean conditions to enhance wild fish survival
  - Develop mechanisms to incorporate climate change, PDO, ENSO cycles, etc. into run size predictions and harvest management
  - Modify ocean salmon fisheries to better target hatchery stocks and robust wild stocks