



Climate Change in the Pacific Northwest:

Why a global scale problem matters at the local scale

Lara Whitely Binder

Climate Impacts Group
Center for Science in the Earth System
Joint Institute for the Study of the Atmosphere and Ocean
University of Washington



November 15, 2006

UW-Bothell

Climate science in the public interest

Presentation Overview



The Climate Impacts Group



Overview of global and regional climate change



Summary of climate change impacts on the Pacific Northwest



Planning for climate change

November 15, 2006
www.cses.washington.edu/cig

The Climate Impacts Group

1st of 8 U.S. Regional Integrated Sciences and Assessment (RISA) teams

Areas of study:

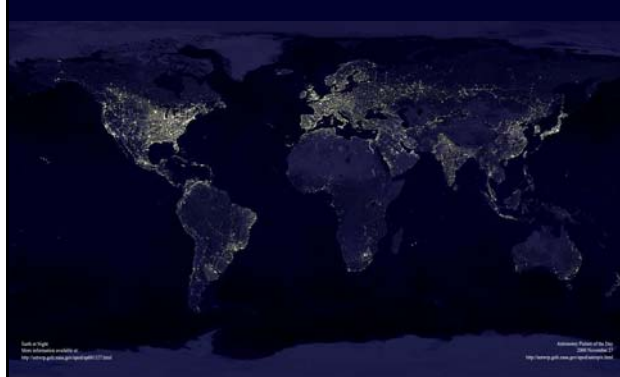
- Water resources
- Salmon
- Forests
- Coasts
- [Agriculture, Human Health]



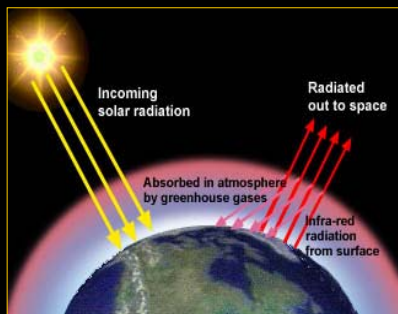
Objectives

- Increase regional resilience to climate variability and change
- Produce science useful to (and used by!) the decision making community

An Overview of Global Climate Change



Greenhouse gases (water vapor, CO₂, CH₄, N₂O) play a critical role in determining global temperature



Rapid increases in greenhouse gases are changing this natural balance

Temperature and GHG co-vary

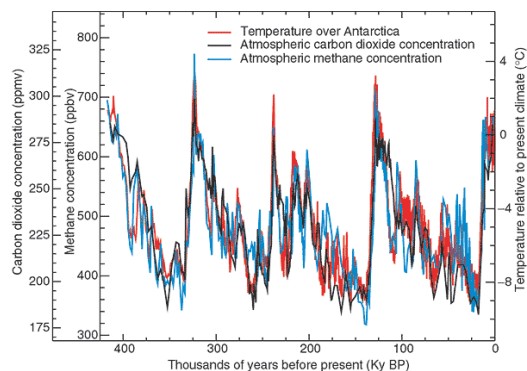


Figure source IPCC 2001, The Scientific Basis, Ch. 2

A Perspective on Climate Change...

Climate change is not new on a geologic time scale...

ex: *Glaciers in the Puget Sound region*

...and systems have adjusted

ex: *Species migration and extinction*



November 15, 2006
www.cses.washington.edu/cig

Ginkgo Petrified State Forest

- Located in central Washington near Vantage
- Swamps, shallow lakes approximately 15 million years ago (Miocene Period)
- Swamp cypress, ginkgo, maple, walnut, oak, sycamore in lower areas; Doug fir, spruce, pine above the lakes
- Drier climate evolved during second uplift of the Cascades (6 MYA)



November 15, 2006
www.cses.washington.edu/cig

So what has driven past climate change?

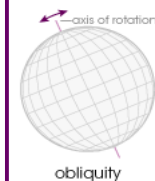
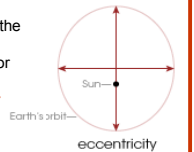


Causes of Past Climate Change: Earth's Orbit

Cyclical changes in the Earth's orbit affect the amount of sunlight reaching the Earth's surface.

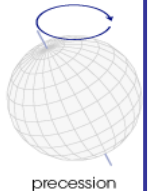
<http://www.epa.gov/climatechange/science/pastcc.html>
http://earthobservatory.nasa.gov/Study/Paleoclimatology_Evidence/

...changes in the shape of the Earth's orbit (or eccentricity)
[100,000 year cycles]



...changes in the Earth's tilt (or obliquity)
[41,000 year cycles]

...changes in the wobble of the Earth's orbit (or precession)
[19,000-23,000 year cycles]

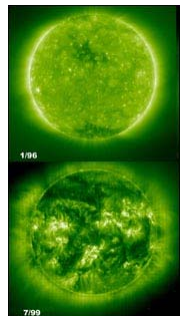


Ice Ages and Changes in the Earth's Orbit

- Theorized in the early 1900s by Serbian mathematician Milutin Milankovitch (published 1930)
- Theorized that the ice ages occurred when orbital variations caused the Northern Hemisphere around the latitude of the Hudson Bay and northern Europe to receive less sunshine in the summer.
- Milankovitch predicted that the ice ages would peak every 100,000 and 41,000 years, with additional "blips" every 19,000 to 23,000 years.
- The paleoclimate record shows peaks at exactly those intervals.

Additional Causes: Solar Intensity

- **Changes in the sun's intensity** (sun spots)
 - stronger solar intensity = more warming
 - weaker solar intensity = more cooling
- Changes in solar activity affect the amount of UV radiation reaching the Earth's upper atmosphere. These changes have a ripple effect in the overall climate system, including the jet stream.



Minimum (1/96; above) and maximum (7/99; below) sun spot activity

Additional Causes: Volcanic Eruptions

- Emit aerosols, CO₂ into the atmosphere.
 - Volcanic aerosols tend to block sunlight and contribute to short term cooling.
 - Volcanic carbon dioxide emissions have a warming effect.
- Volcanic eruptions from rapid sea floor spreading are thought to be the cause of higher (than today's) CO₂ concentrations and temperatures in the last 400 million years. Evidence is not conclusive, however. [Note: human activities now emit 150 times as much CO₂ as volcanoes according to USGS].



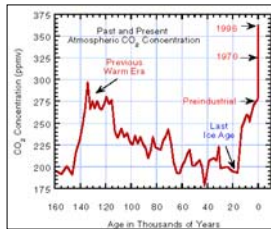
So Why is Present Day Climate Change Different?

- CO₂ concentration levels**
 - Appear to be higher than any time in past ~23 million yrs (*but not the highest ever...*)
- The human footprint**
 - Increasing evidence human activities altering Earth's climate (esp. last 50 years)
 - Human systems based on expectation of certain climate conditions
 - Population growth, political boundaries, resource dependency/depletion, habitat fragmentation **limit ability of natural and human systems to tolerate rapid change**



Carbon Dioxide (CO₂)

- Atmos. concentration has increased 31% since 1750.
 - 2006 WMO update: current (2005) level 379 ppm (+35.4% more than "late 18th century"... a "greenhouse gas record")
- Appears to be higher than any time in past ~23 million yrs
- ~70% of CO₂ emissions come from fossil fuel burning
- Accounts for ~60% of warming caused by greenhouse gases



Methane (CH₄)

- Atmos concentration has increased ~150% since 1750.
 - Current research indicates that methane levels are stabilizing (source: WMO, 2006)
- Current concentration has not been exceeded in at least 420,000 years
- Slightly more than 50% of CH₄ emissions originate from human activities
- Accounts for ~20% of warming caused by greenhouse gases

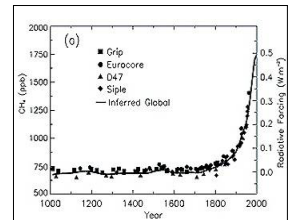


Figure source: IPCC 2001

Methane has 21 times the global warming potential than CO₂ on a molecule-for-molecule basis.

Nitrous Oxide (N₂O)

- Atmospheric concentration has increased 16% since 1750.
 - 2006 WMO update: current (2005) level 319 ppb
- Current concentration has not been exceeded in at least 1,000 years
- About 33% of current N₂O emissions originate from human activities
- Accounts for ~6% of warming caused by greenhouse gases

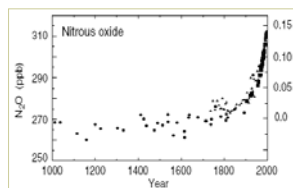


Figure source: IPCC 2001

Nitrous oxide has 300 times the global warming potential than CO₂ on a molecule-for-molecule basis.

Where do these increases come from?

- Human sources:**
 - Fossil fuel burning (oil, coal, natural gas) (CO₂, CH₄, N₂O)
 - Deforestation and land use change (CO₂)
 - Agricultural practices (CO₂, CH₄, N₂O)
 - Energy extraction (CO₂, CH₄)
 - Ruminant (e.g., cows) (CH₄)
 - Cement production (CO₂)
 - Landfills (CH₄)
- Natural sources**
 - Wetlands (CH₄)
 - Oceans, soils (CO₂, N₂O)
 - Decomposition of organic matter (CO₂, CH₄)

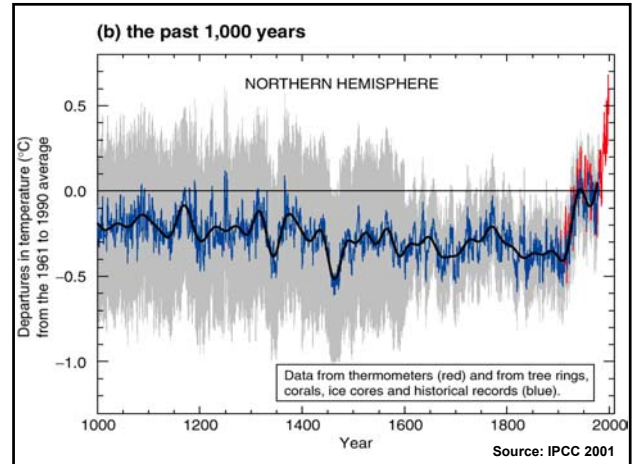




Changes in Global Average Temp

- With these changes in greenhouse gases, the Earth's average global temperature has been increasing
- Since 1900, the planet has warmed $0.6 \pm 0.2^\circ\text{C}$ ($1.1 \pm 0.4^\circ\text{F}$)
- The significance of this temperature increase is more evident when you look over the longer term.

November 15, 2006
www.cses.washington.edu/cig



How do we get perspective on these changes?

- Instrumental data
- “Proxy” data
 - Ice cores
 - Pollen
 - Tree rings
 - Corals
 - Landscape



November 15, 2006
www.cses.washington.edu/cig



Getting perspective (cont'd)

- Observed changes in natural systems (20th century)
 - The extent and thickness of Arctic sea-ice is in decline (extent is down 10-15%; thickness is down 40%)
 - Permafrost is thawing (with major implications for the region and the globe)
 - The growing season has lengthened 1-4 days per decade during the last 40 years in the Northern Hemisphere, especially at northern latitudes
 - Plant and animal ranges are shifting northward and to higher elevations

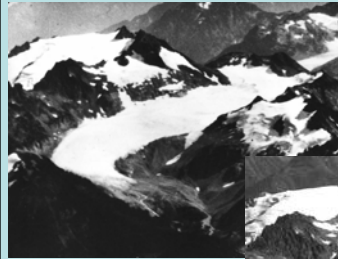


Getting perspective (cont'd)

- 20th century observed changes, cont'd
 - In the Northern Hemisphere, plants are flowering earlier, birds are arriving earlier, insects are emerging earlier
 - Increased frequency of coral bleaching, particularly during El Nino events
 - Weather-related economic losses are increasing (partly due to choices about where we live and work)
 - Mid-elevation mountain snowpack is in decline and melting earlier
 - Glaciers are in widespread retreat

November 15, 2006
www.cses.washington.edu/cig



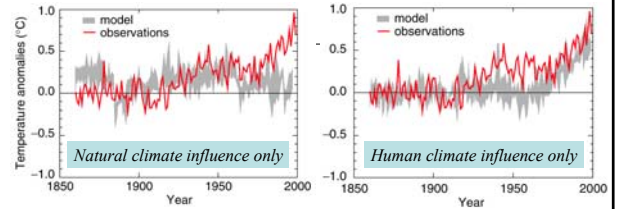


Nearly every glacier in the Cascades and Olympics has retreated during the past 50-150 years

South Cascade Glacier, 1928 (top) and 2000 (right)

Photos courtesy of Dr. Ed Josberger, USGS Glacier Group, Tacoma, WA

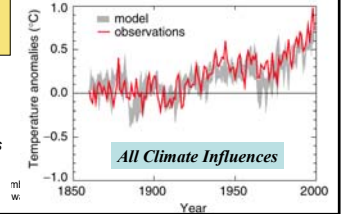
USGS



Gaining perspective through climate modeling

Observational record best matched when natural climate influences (solar variation and volcanic activity) and increases in CO₂ concentrations are both included.

Source: IPCC, 2001



ml

wi

"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities"

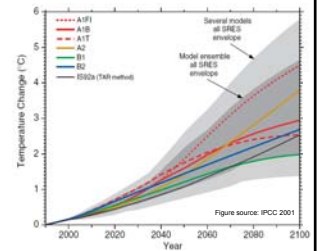
- Intergovernmental Panel on Climate Change, 2001

Figure 1.1
Temperature anomalies
http://www.grid.unh.edu/ipcc/ipcc2001/fig1.1.html

Attribution: Public in the City
© 2001, November 21
http://www.grid.unh.edu/ipcc/ipcc2001/fig1.1.html

21st Century Changes in Global Climate

- Projected range of global scale warming by 2100: **2.5-10.5°F (1.4-5.8°C)**
- Warming expected through 21st century even if CO₂ emissions end today due to persistence of greenhouse gases.



Estimated atmospheric lifetime of major greenhouse gas (per molecule)

Carbon Dioxide	~60% of warming from GHG	5 to 200 years
Methane	~20% of warming from GHG	8 to 12 years
Nitrous Oxide	~6% of warming from GHG	~120 years
CF ₄ (Perfluoromethane)		>50,000 years

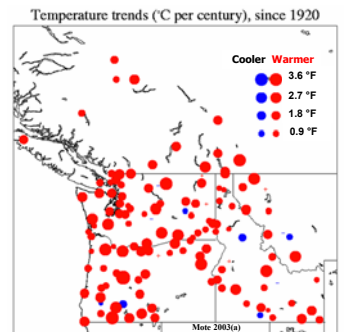


20th century PNW climate trends

PNW Temperature Trends by Station

- Average annual temperature **increased +1.5°F** in the PNW during the 20th century (**+2.3°F in the Puget Sound**)

- Almost every station shows warming
- Extreme cold conditions have become rarer
- Low temperatures rose faster than high temperatures



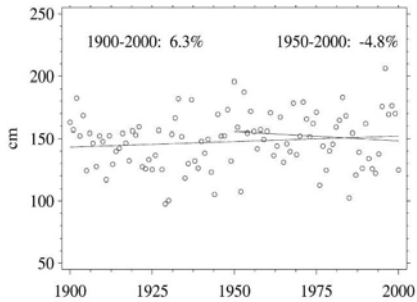
November 15, 2006
www.cses.washington.edu/cig

November 15, 2006
www.cses.washington.edu/cig

PNW Precipitation Trends

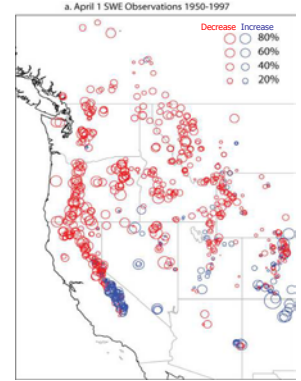
(Western WA, OR, BC)

No clear trend in precipitation over the 20th century due to interannual and interdecadal variability



Snow Water Equivalent Trends

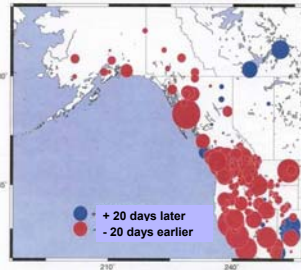
- Most PNW stations showing a decline in snow water equivalent
- Numerous sites in the Cascades with 30% to 60% declines
- Similar trends seen throughout the western United States - 73% of stations show a decline in April 1 snow water equivalent



Trends in the Timing of Spring Runoff

Peak of spring runoff is moving earlier into the spring throughout western US and Canada

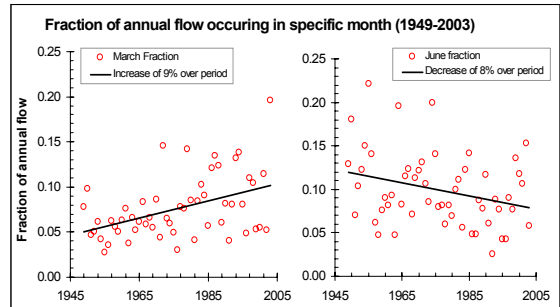
- Advances of 10-30 days between 1948-2000
- Greatest trends in PNW, Canada, and AK
- >30% of trends are statistically significant at the 90% level, especially in the PNW



Stewart, I., Cayan, D.R., and Dettinger, M.D., 2004. Changes in snowmelt runoff timing in western North America under a "Business as Usual" climate change scenario. *Climatic Change* 62, 217-232.

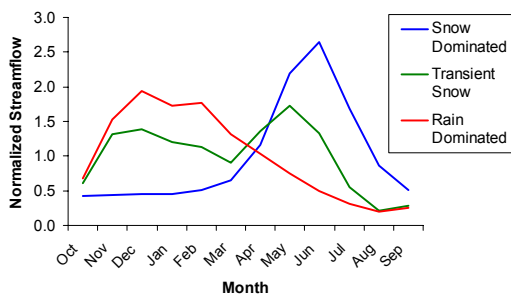
November 15, 2006
www.cses.washington.edu/cig

Changes in Annual Spring Flow on the Cedar River above Chester Morse Reservoir, 1949-2003



Fractions of annual flow occurring in March and June on the Cedar River above Chester Morse reservoir. Station Elevation 1560 ft.

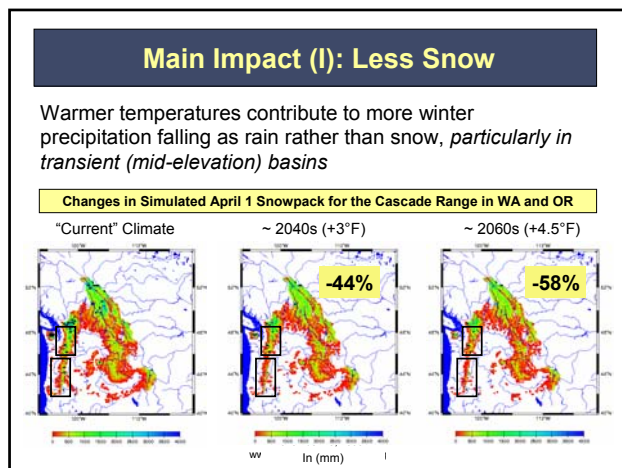
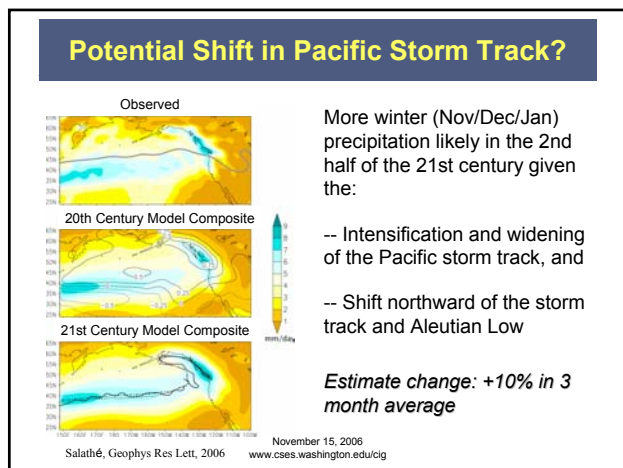
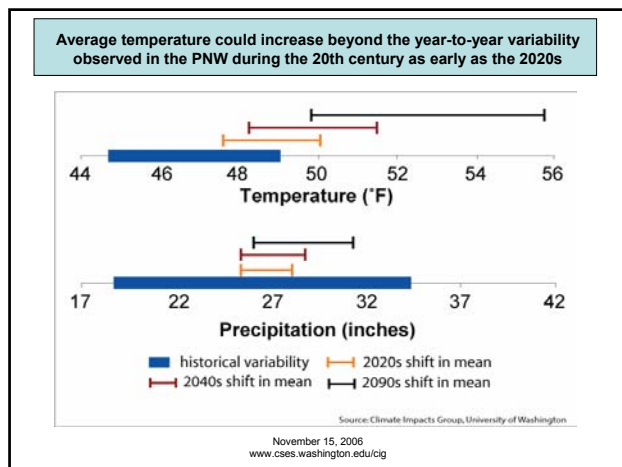
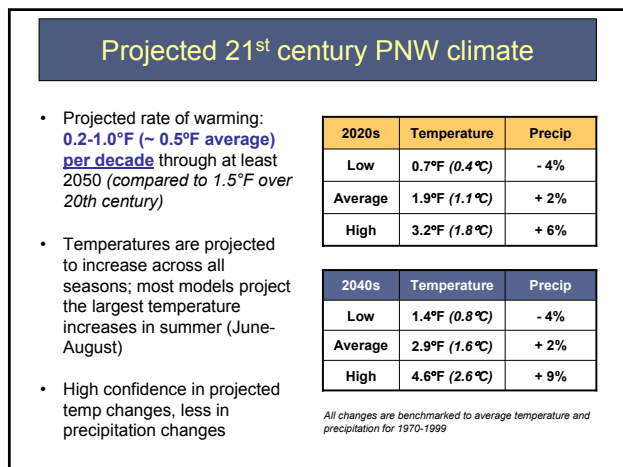
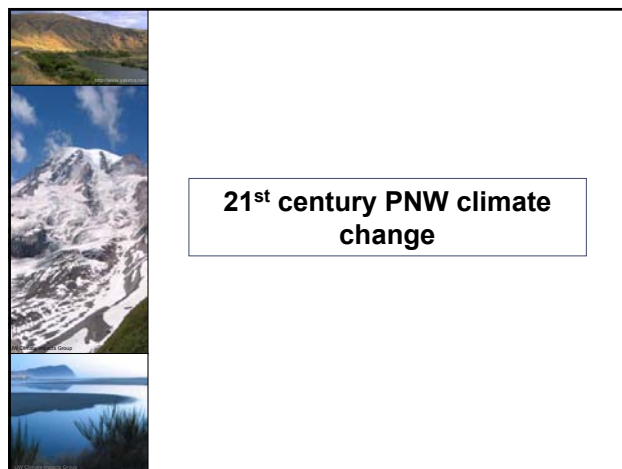
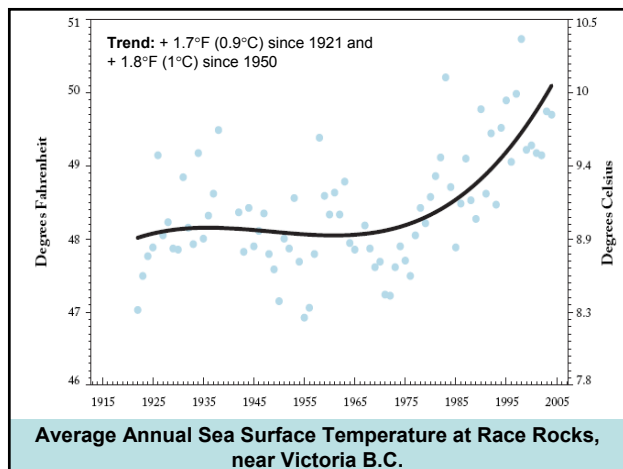
Hydrologic characteristics of PNW rivers



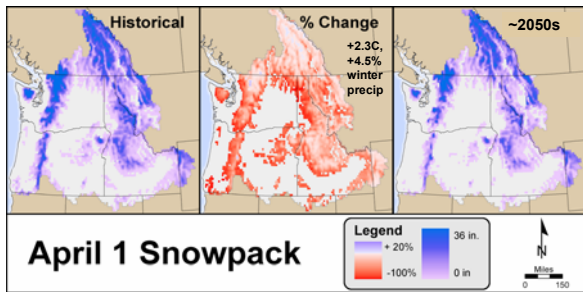
November 15, 2006
www.cses.washington.edu/cig

Flooding and 20th century warming

- Large-scale 20th century warming over the western U.S. has resulted in changes in winter/spring flood risks in many parts of the west depending on basin type
 - Rain-dominant basins show little systematic change in risk for 20-year and 100-year interval floods
 - Transient basins show a wide range of effects depending on competing factors (e.g., snow conditions and contributing basin area)
 - In most snow dominant basins, flood risk has been reduced due to reductions in snowpack. In some basins, the risk has increased (re: increased spring soil moisture, contributing basin area)

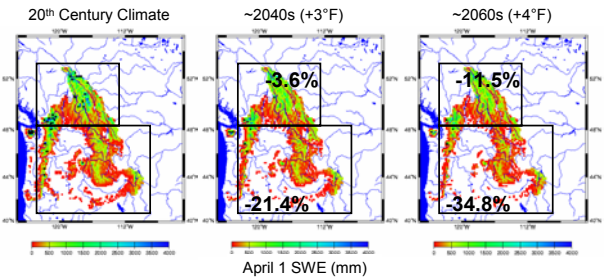


For areas that accumulate snowpack, areas close to freezing in mid-winter are most sensitive to warming



November 15, 2006
www.cses.washington.edu/cig

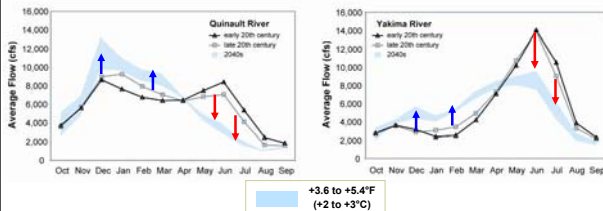
Changes in Simulated April 1 Snowpack for the Canadian and U.S. portions of the Columbia River basin (% change relative to current climate)



Main Impact (II): Altered Streamflows

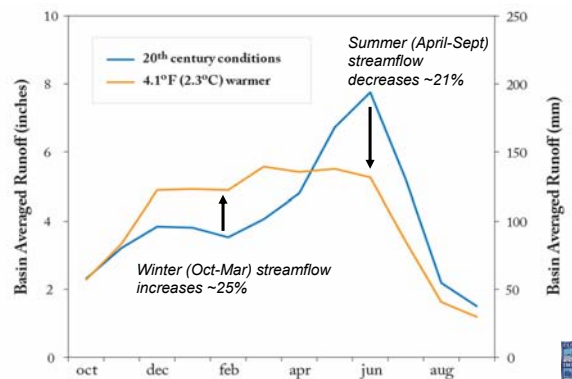
- If more winter rain → **higher winter streamflows**
- Warmer temperatures → **earlier snowmelt** and a **shift in the timing of peak runoff**
- Lower winter snowpack → **lower spring and summer flows**

Projected streamflow changes in the Quinault and Yakima Rivers



(note: under new scenarios, light blue bands are more likely to be seen mid-century (2050s) rather than 2040s)

Simulated average runoff for the Puget Sound Basin for 20th century climate (blue) and +4.1°F warming (approximately mid-21st century)



Water Resource Impacts



Water Supplies



- Increased demand for water for M&I uses, habitat management, water quality management due to warmer temps and lower summer streamflow
- Increased evapotranspiration (evaporation and plant respiration) likely due to warmer temps
- Population growth a major factor in changing demand
- Bottom line: Increased competition for water and increased vulnerability to drought*

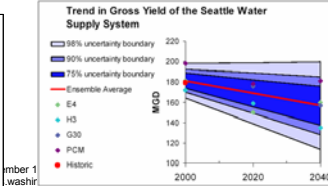
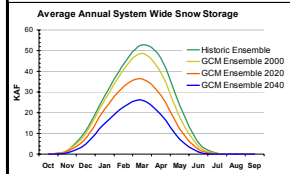
Seattle Water Supply Climate Change Study



2040s Climate Impacts SEATTLE (WA):

Decreasing Snowpack: -50%
Loss of Gross Yield: ≈ 20 mgd

**Seattle's water demand has decreased;
total regional demand is increasing and
all water supply sources will be impacted.**



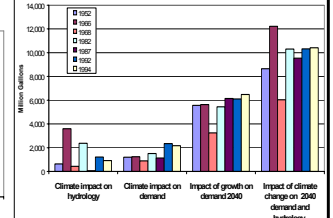
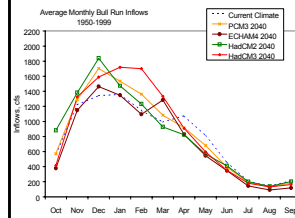
Portland Water Supply Climate Change Study



2040s WATER NEEDS IN PORTLAND (OR):

Regional growth: +40 mgd
Climate change: +20 mgd

**Climate change impacts =
50% of growth impacts**



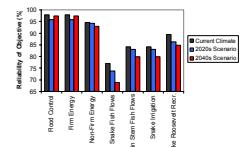
Flooding and Stormwater Management

- Increased risk of winter flooding and combined sewer overflows in low- and mid-elevation basins due to
 - Projected shift in precipitation type
 - Projected increase in precipitation
- Changes in urban flooding less clear, re: importance of freq. and intensity of storm events rather than changes in avg. conditions
- Increased groundwater levels can aggravate lowland flooding



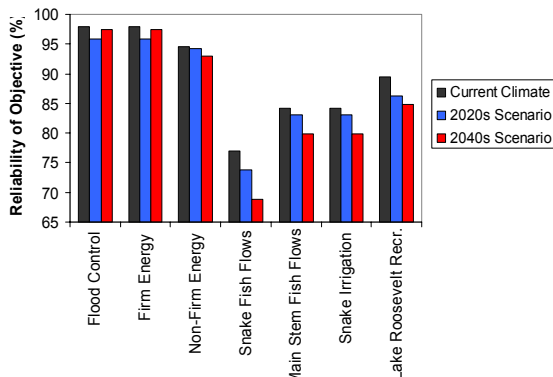
Hydropower

- Increased winter generation due to higher streamflows (but lower demand, re: warmer temps)
- Reduced summer generation due to lower streamflows (but increased demand, re: warmer temps)
- Ability to meet various management objectives will require greater tradeoffs



November 15, 2006
www.cses.washington.edu/cig

Simulated reliability of water resources objectives for "middle-of-the-road" scenarios



Impacts on Demand

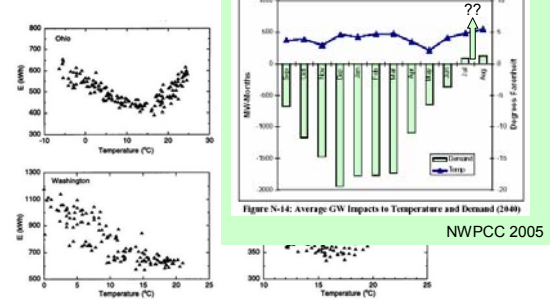
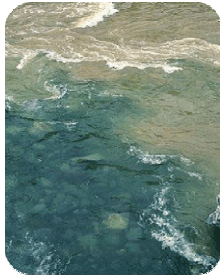


Fig. 2. Scatter plots indicating the sensitivity of per capita electricity consumption (kWh) to monthly air temperatures for four representative states in the study.

November 15, 2006
www.cses.washington.edu/cig

Climate Change Impacts on Key Water Quality Parameters



- **Water temperature.** Climate change almost certain to lead to additional warming due to projected increases in regional air temperature and decreases in summer stream flow
- **Salinity.** Observed increases (decreases) in salinity content with decreased (increased) streamflows. These changes are likely to be enhanced by projected changes in freshwater runoff.
- **Stratification.** Projected increases in winter streamflows would increase stratification in Puget Sound. Changes in summer months less clear.



Impacts on Key Water Quality Parameters cont'd

- **Dissolved Oxygen.** Probable that DO levels at depth could decrease given the likely impacts of climate change on factors controlling DO (e.g., water temp, stratification, organic production)
- **Nutrients (phosphorus and nitrogen).** Overall impacts of climate change will depend on balance of impacts among competing influences (e.g., changes in runoff which may increase or decrease nutrient contamination)
- **Fecal Coliform.** Climate change could contribute to increased fecal coliform contamination with higher winter rains (more stormwater runoff and combined sewer overflows + leaking septic systems from climate change)

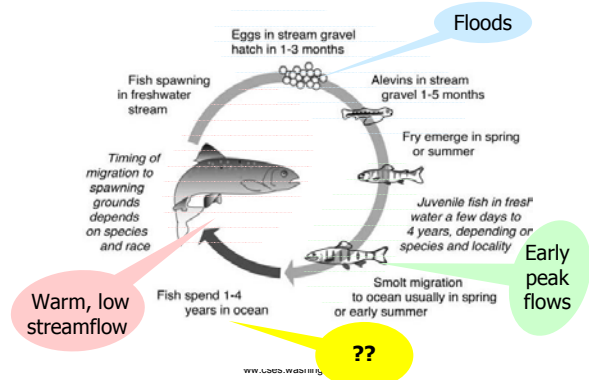
UNIVERSITY OF WASHINGTON
www.cses.washington.edu/cig



Salmon

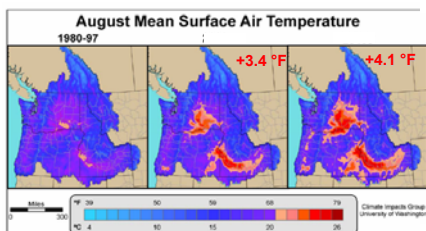


Climate impacts on salmon must be added to existing stresses across their full life-cycle



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 68°F (20°C) 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.



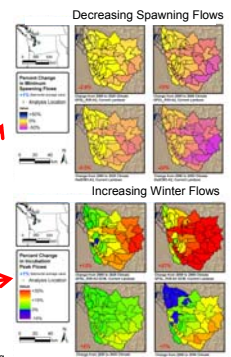
Impacts of Climate Change on Salmon Recovery in the Snohomish River



Climate Change will make salmon restoration **more difficult**:

- Decreasing Summer Low Flows
- Increasing Winter Peak Flows
- Increasing water temperatures in critical periods

November 15, 2006
www.cses.washington.edu/cig





Climate controls on forest ecosystem processes

- Regeneration (e.g., seedling establishment)
- Species distribution
- Forest productivity / tree growth
- Disturbance
 - Fire
 - Insect outbreaks
 - Direct mortality



November 15, 2006
www.cses.washington.edu/cig

Climatic change and regeneration

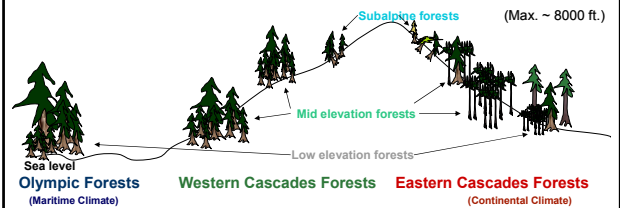
- How will tree regeneration change in a warmer climate?
- Effects of a warmer climate will probably be very site specific ~ precipitation patterns critical:
 - In high-snow forests, regeneration will increase
 - In high-rain forests, regeneration *may* increase
 - In dry forests, regeneration will decrease



November 15, 2006
www.cses.washington.edu/cig

Climatic change and tree growth responses

- 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



November 15, 2006
www.cses.washington.edu/cig

Climate drivers of fire area burned

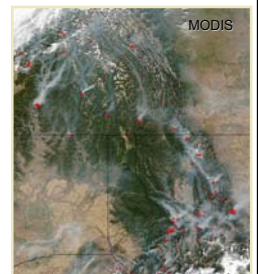
- Increasing temperature (winter and summer) appears related to increasing area burned trend.
- Interannual wet/dry "cycles" also appear related to small / big fire years.
- Combination of long-term soil → fuel moisture ("climatic set-up") and short term extreme weather implicated



November 15, 2006
www.cses.washington.edu/cig

Regional fire episodes and climatic change

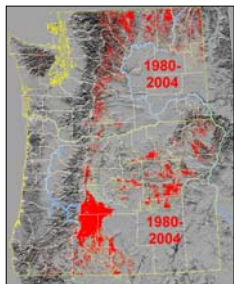
- As temperature increases, the atmosphere evaporates more water from the landscape and plant tissues
- This produces larger than normal areas of depleted fuel moisture during the fire season
- Regional synchronization of fires occurs



Northern Rockies, July 2003

November 15, 2006
www.cses.washington.edu/cig

Climate Change and Forest Insects



Mountain Pine Beetle Mortality
Pacific Northwest Region, Natural Resource
Forest Health Protection

WW

- Four "categories" of insects:
 - Native ubiquitous (ex: Spruce beetle)
 - Native innocuous (ex: Pinyon ips)
 - Native invasive (ex: Mountain pine beetle)
 - Exotic invasive (ex: Gypsy Moth)
- Climate change effects:
 - Host life cycle and rate of reproduction
 - Host vulnerability (ex: drought, tree vigor)
 - Insect life cycle and rate of reproduction
 - Insect outbreak frequency and duration
 - Insect range expansion
- Interactions with other disturbances:
 - Direct climate mortality
 - Increasing fire frequency

Forest Insects: The Usual Suspects

- Native insects likely to produce "normative" outbreaks in the PNW:
 - Mountain pine beetle
 - Western pine beetle
 - Spruce beetle
 - Douglas-fir bark beetle
 - Western hemlock looper
 - Ponderosa pine budworm
 - Western spruce budworm
 - Fir engraver
 - Douglas-fir tussock moth
- Exotics: Gypsy Moth



Hemlock stand prior to looper attack



Hemlock looper stand mortality

November 15, 2006
www.ces.washington.edu/cig

Why temperature increase releases mountain pine beetle populations

- Population synchronized by temperature (onset of spring)
- Rate of generation turnover increases with temperature increase
- Mountains were a barrier until recently; limitation is now forest extent and continuity



November 15, 2006
www.ces.washington.edu/cig

Forest Impacts: What Can We Expect?

- 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, especially after disturbance from harvest, fire and/or insects
 - Visible changes in forest ecosystem productivity



NIFC



Agricultural Impacts

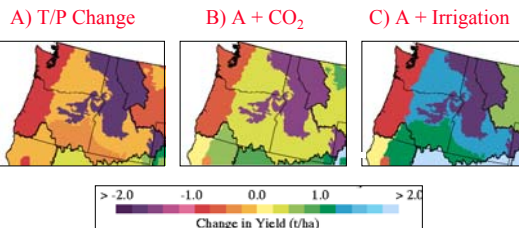
- Overall impacts vary with crops and availability of water
- Increased crop yields where there is sufficient soil moisture or irrigation water
- Increased weed growth and risk of pest outbreaks



November 15, 2006
www.ces.washington.edu/cig

Winter Wheat (PNNL Research)

- The Palouse is a major winter wheat production region
- 80% is dryland winter wheat
- A slight increase in winter wheat yield for a mild warming



Author: Ruby Leung, Pacific Northwest National Laboratory
November 15, 2006
www.ces.washington.edu/cig

Climate Change and its Effects on Viticulture/Wine

Observed/Potential Effects include:

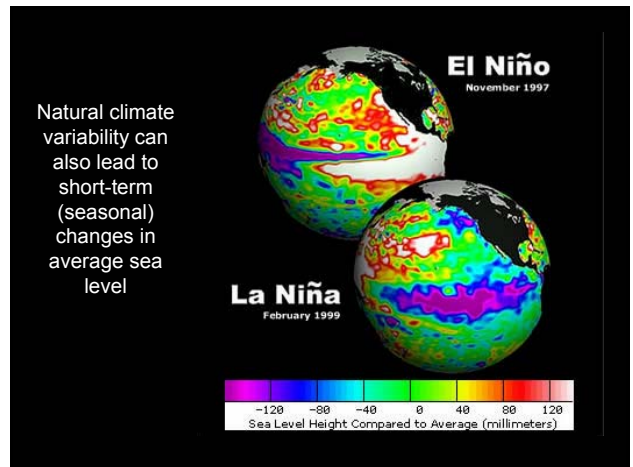
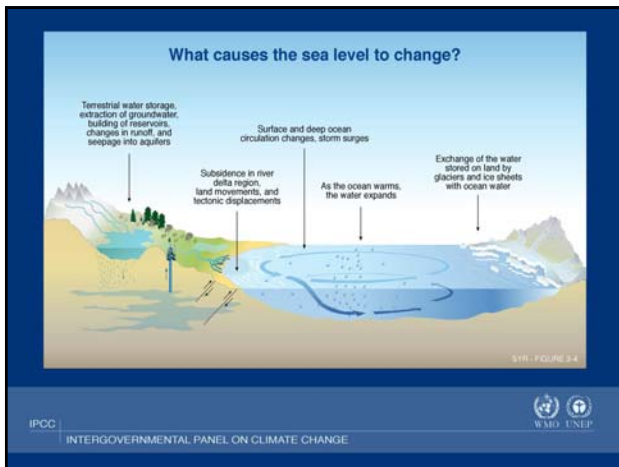
- Warmer & longer growing seasons
- Altered phenological timing
- Altered ripening profiles
- Climatic thresholds
- Altered disease timing/severity
- Altered pest timing/severity
- Altered water needs
- CO₂ issues (growth and quality)
- Need for management adaptations



Slide courtesy of Gregg Jones, OSU



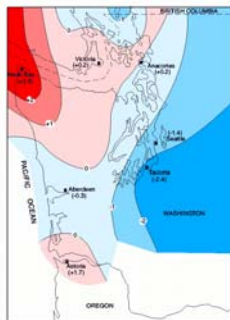
PNW Sea Level Rise



Vertical Land Movement...

... alters sea level rise rates

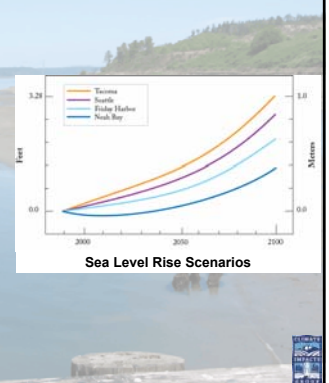
- Subduction zone tectonic forces 'wrinkle' the land surface:
- Uplift occurs on most of the Ocean coast
- Subsidence occurs in most of Puget Sound



November 15, 201
www.cses.washington.edu/cig

Combining it all for Washington...

- Sea level rise in Puget Sound likely to proceed as rapidly as, or faster than, global sea level rise due to plate tectonics
- Relative sea level rise will be greatest in South Puget Sound (~3.3ft by 2100) and least near Neah Bay (~1.3ft by 2100)
- Likely to increase pace and extent of erosion and nearshore habitat loss, especially in south Sound



PNW Sea Level Rise

Various impacts to be considered:

- Coastal erosion
- Inundation
- Salt water intrusion
- Impeded coastal drainage

Add in increased winter precip:

- Bluff landsliding
- Flooding



November 15, 2006
www.cses.washington.edu/cig

Choices & Change Preparing for climate impacts



November 15, 2006
www.cses.washington.edu/cig



Responding to Climate Change: Mitigation and Adaptation

- **Mitigation activities** focus on reducing emissions of greenhouse gases
 - Ex: Kyoto Protocol, West Coast Governors' Climate Change Initiative
- **Adaptation activities** focus on developing the capacity to manage the change that occurs as mitigation strategies are debated and enacted. *Focus of the CIG.*
 - Ex: Developing more robust water supply systems, migration corridors for wildlife, relocation of coastal communities in NW Alaska
- “Mitigate we might, adapt we must”

Climate change will force resource managers and planners to deal with increasingly complex trade-offs between different management objectives. **Planning for climate change is needed if the region is to adapt to climate change.**



November 15, 2006
www.cses.washington.edu/cig

Preparation for change should begin now

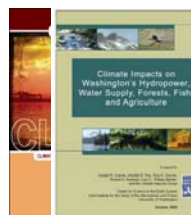
- Decisions with long-term impacts are being made every day
- Significant impacts of climate change projected within decades, i.e., the timescale of adaptation planning
- Significant time is required for motivating and developing adaptive capacity and for implementing changes
- Increasing evidence that it will cost more to retrofit for climate resilience than to build it in the first place

November 15, 2006
www.cses.washington.edu/cig

Guiding Principles for Planning

Familiarize yourself with climate impacts. Information on regional impacts is available through:

CIG publications...



CIG website...



CIG meetings and workshops...



November 15, 2006
www.cses.washington.edu/cig

Guiding Principles for Planning cont'd

Recognize that the past may no longer be a reliable guide to the future

- Important to plan explicitly for a warmer future rather than basing management decisions solely on historical climate.



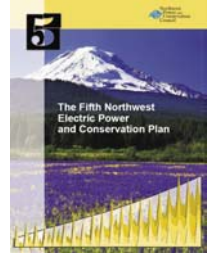
The NYSE: Because past performance does not guarantee future performance

November 15, 2006
www.cses.washington.edu/cig

Guiding Principles for Planning cont'd

Integrate climate change projections into planning processes

- Integrating information on climate impacts into planning helps ensure that management objectives will be met as conditions change
- Many communities are taking this step, including....



November 15, 2006
www.cses.washington.edu/cig

Who's Preparing for Change in the PNW?

- Snohomish Basin Salmon Recovery Forum
- Northwest Power and Conservation Council
- Seattle (City Auditor, SPU)
- King County
- Washington (DOE, CTED)
- USFS (Okanogan, Wenatchee & Colville long-term forest management plans)
- City of Portland

Gov. Gregoire's Energy Policy Brief:



"Goal #4: Address Global Warming

Washington State is facing climate issues, such as lower snow packs and summer droughts, which will only become worse as global warming advances. ...

The Governor will convene a forum of the state's top economists to analyze the economic impacts of climate change based on the latest scientific information and a state inventory of greenhouse gas emissions. This process will provide the foundation to make effective decisions about critical, long-term infrastructure investments, and to further reduce greenhouse gases."

Guiding Principles for Planning cont'd

Take actions to increase the resilience of regional systems

- It will be very difficult, if not impossible, to project exactly how climate change will affect complex systems
- It may be more effective to maintain a system's capacity to adapt to future climate change rather than trying to engineer a solution



Log weirs placed in a small coastal Washington stream to create pools and habitat for coho salmon. NWFSC.

November 15, 2006
www.cses.washington.edu/cig

Guiding Principles for Planning cont'd

Monitor regional climate and resources for ongoing change

- The effects of climate change may initially be subtle and difficult to distinguish from other impacts (e.g., human impacts, natural variability)
- Monitoring helps ensure that these changes can be detected and assessed



November 15, 2006
www.cses.washington.edu/cig

Guiding Principles for Planning cont'd

Design for surprises

- Think of preparing for climate change as an exercise in risk management.
- Policies & management practices should be **flexible** to deal with uncertainties



Picasso - The Acrobat (1930)

November 15, 2006
www.cses.washington.edu/cig

Planning Opportunities....

- Watershed Planning Program (EHSB 2514)
- Salmon recovery (ESHB 2496)
- Water supply planning
- Local land use planning
- Flood control planning
- Forest management plans
- Nearshore and coastal planning
- Water quality management (state, federal reqs)
- Others....

November 15, 2006
www.cses.washington.edu/cig

Summary

- **Continued warming expected.** The PNW is expected to continue warming through the 21st century even if greenhouse gas emissions stopped today. Even the lowest projected warming would change PNW climate significantly.
- **Human choices matter.** Human activities have a significant impact on PNW ecosystems and ultimately affect the resiliency of these systems (negatively or positively).
- **Knowledge and tools for planning exist now.** Take steps to increase capacity to adapt to changes, monitor for ongoing change, design for flexibility.

For More Information

- *Climate Change and Its Effects on Puget Sound: Overview report and Foundation report*
- Climate Impacts Group (www.cses.washington.edu/cig)
- Puget Sound Action Team (<http://www.psat.wa.gov/>)



November 15, 2006
www.cses.washington.edu/cig