Local Impacts of Global Change

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Symposium on Climate Change Adaptation & the Law
Center for Progressive Reform
Seattle University
January 21, 2010

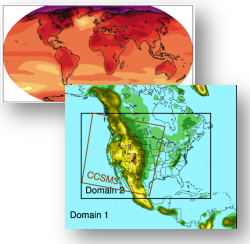
CLIMATE IMPACTS GROUP

Climate Science in the Public Interest

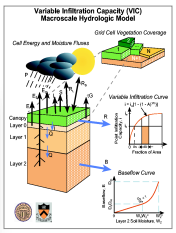
The Climate Impacts Group

An integrated research team studying the impacts of climate variability and climate change in the PNW and western US

Downscaling global climate model projections

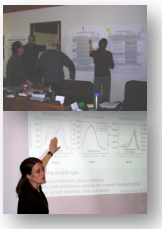


Macro and fine-scale hydrologic modeling



Impacts assessments for water resources, terrestrial and aquatic ecosystems

Adaptation planning and outreach



Working since 1995 to:

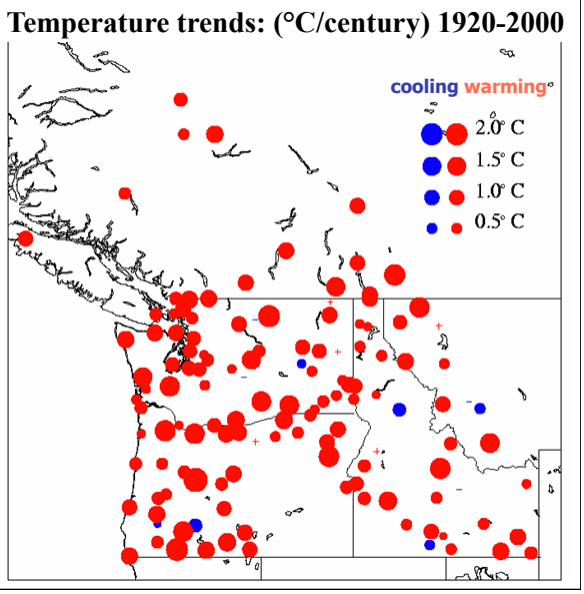
- Perform climate science in the public interest
- Increase regional resilience to climate variability and change
- Produce science useful to (*and used by!*) the decision making community

Setting the Stage for Pacific Northwest Climate Change

GLOBAL CLIMATE CHANGE

20th Century PNW Climate: Temperature

- 154 stations with long records
- Almost every station showed **warming**
- Urbanization not a major source of warming
- Regional average = +1.5 F/century

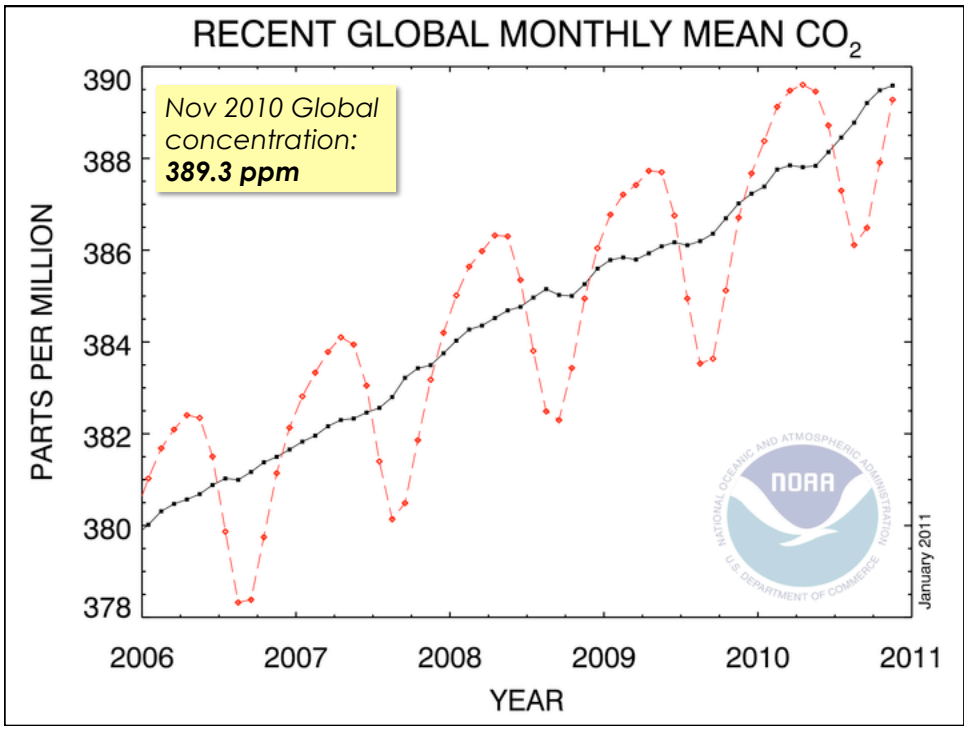


Evidence of change in the Pacific Northwest

Observed 20th century change

- **Northern hemisphere spring snow cover has declined** (~8%, 1922-2005) (Lemke et al., 2007)
- **Spring snowpack has declined** (decreases in 73% *(n=824)* of western U.S. stations, 1950-1997) (Mote et al. 2005)

- **Spring snowmelt and peak runoff have shifted earlier** (1 to 4 weeks in much of the western U.S., 1948-2002) (Stewart et al. 2005)
- **Northern hemisphere glaciers are losing mass and/or length.**



Projecting Future Climate:

Greenhouse Gas Emissions Scenarios

40 emissions scenarios are used to "drive" global climate models.

Different scenarios result in different climate change projections.

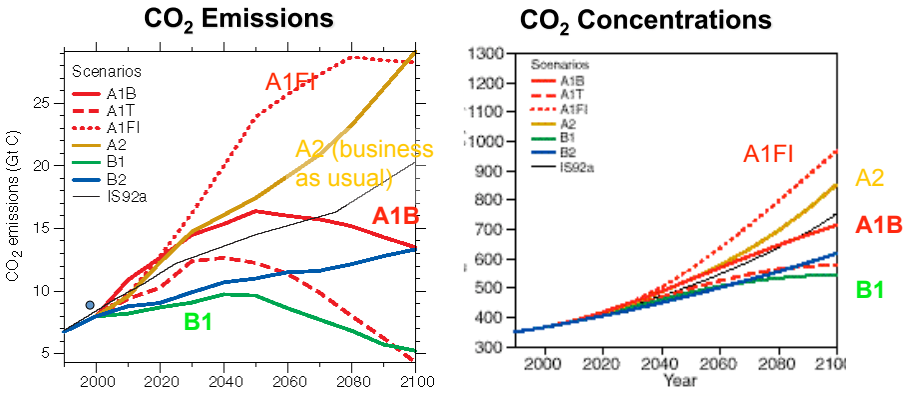
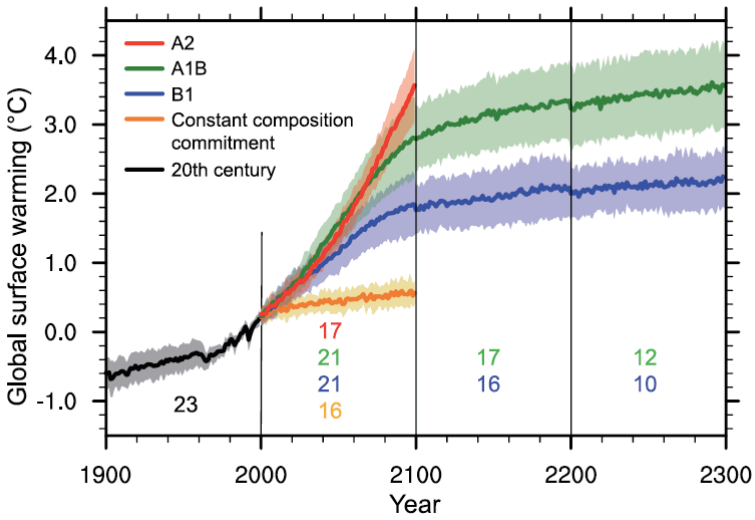


Figure source: IPCC 2001, Summary for Policy Makers

Without drastic changes in current emissions trends, GHG concentrations will increase dramatically over the 21st century and with that, global temperature.

Multi-model Averages and Assessed Ranges for Surface Warming



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mary for Policy Makers

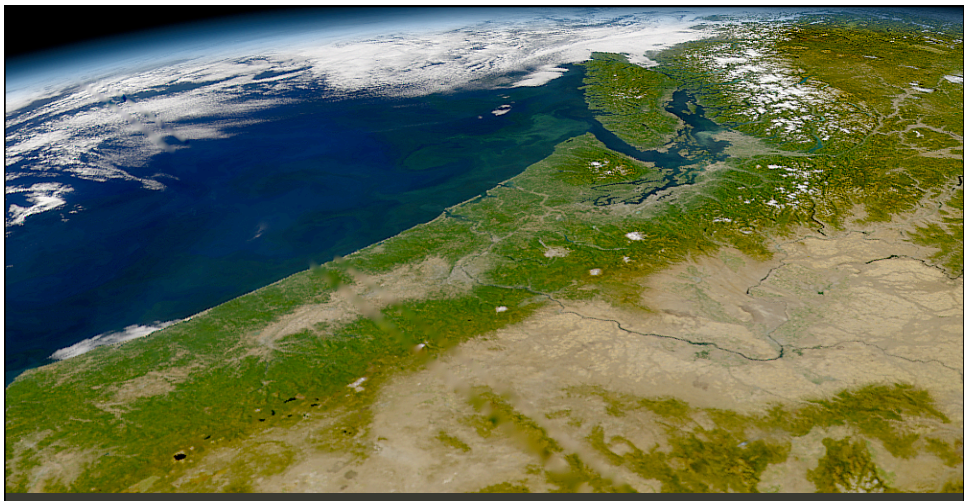
Sea Level is Expected to Increase

Major determinants of global sea level rise:

- **Thermal expansion** of the ocean
- **Melting** of land-based ice sheets (Greenland, Antarctica)

Global Projections for 2100:
+7 to +23 inches *(IPCC 2007)*
and more recently
+2.6 ft to +6.6 ft *(Pfeffer et al. 2008)*

Sea level will not stabilize until several centuries after global temperatures stabilize.



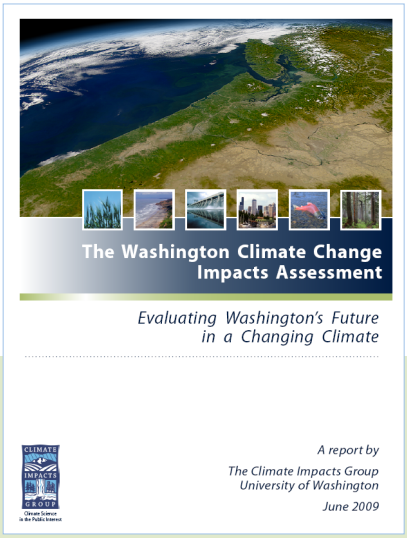
Regional Impacts

CHANGES IN PACIFIC NORTHWEST CLIMATE

Washington Climate Change Impacts Assessment

- Funded by the WA State Legislature under HB 1303, §404
- First comprehensive assessment of climate change impacts on WA
- Products include final report as well as comprehensive data sets

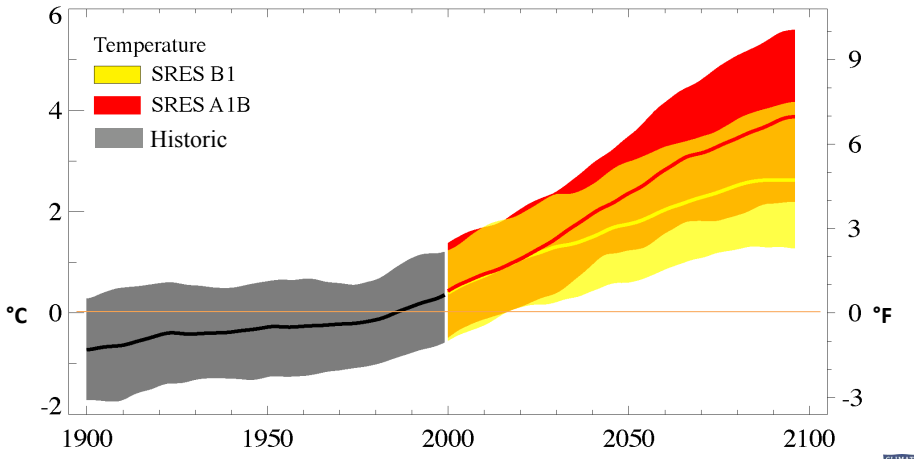
Sectors studied: hydrology & water management, urban stormwater infrastructure, energy, agriculture & economics, salmon & ecosystems, forests, human health, coasts, preliminary adaptation options



Projected Increases in Annual PNW Temperature

** Relative to 1970-1999 average*

2020s	+2.0°F *(1.1-3.4°F)*
2040s	+3.2°F *(1.6-5.2°F)*
2080s	+5.3°F *(2.8-9.7°F)*

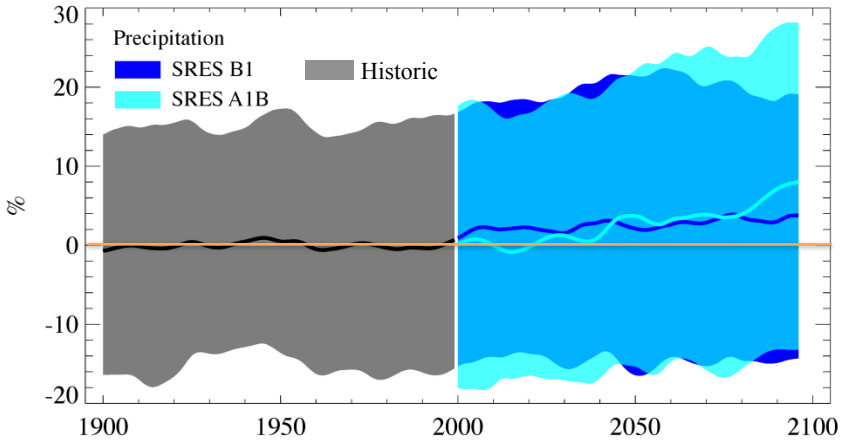


Mote and Salathé, 2009

Projected Increases in Annual PNW Precipitation

** Relative to 1970-1999 average*

2020s	+1% *(-9 to 12%)*
2040s	+2% *(-11 to +12%)*
2080s	+4% *(-10 to +20%)*



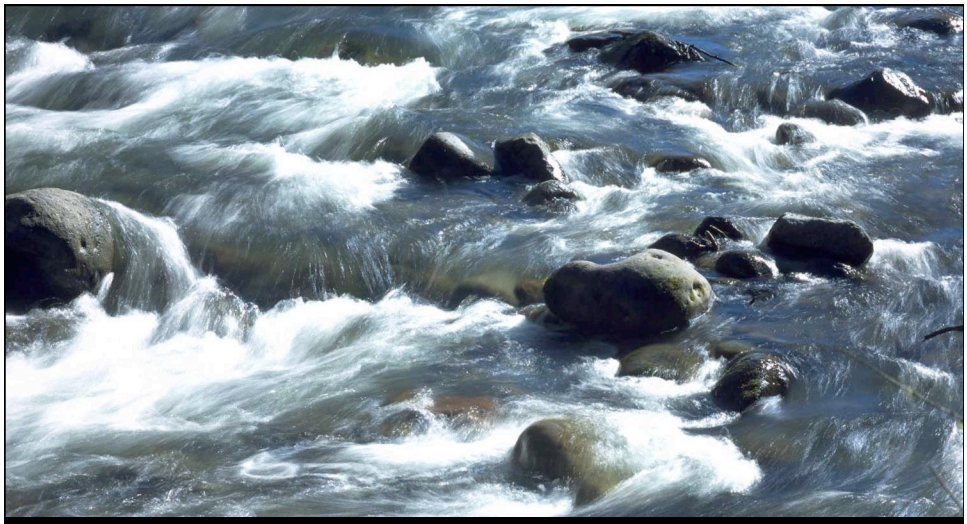
Mote and Salathé, 2009

What About Changes in Extreme Precipitation?

Simulations generally indicate increases in extreme precipitation over the next 50 years, however:

- The projections vary by model and region, and
- Actual changes may be difficult to distinguish from natural variability.

Salathé et al. 2009, Rosenberg et al. 2009)

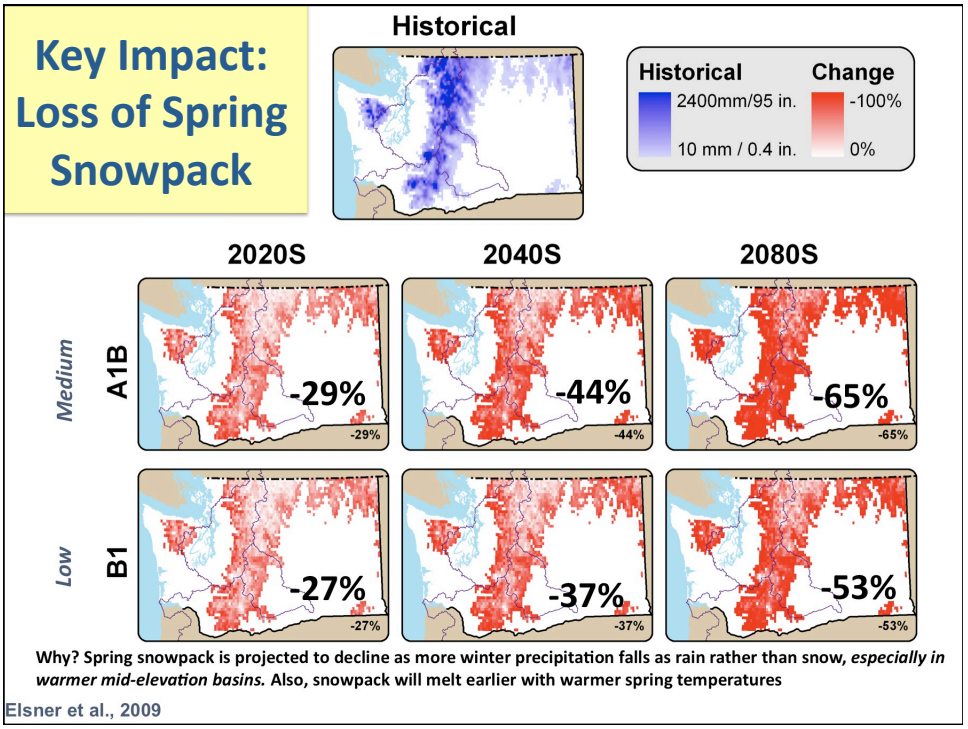


Hydrologic Impacts

PROJECTED CHANGES IN PACIFIC NORTHWEST HYDROLOGY

Expected 21st century changes in temperature and precipitation will *transform* the hydrologic behavior of many mountain watersheds in the West.

Key Impact: Loss of Spring Snowpack



Why? Spring snowpack is projected to decline as more winter precipitation falls as rain rather than snow, *especially in warmer mid-elevation basins.* Also, snowpack will melt earlier with warmer spring temperatures

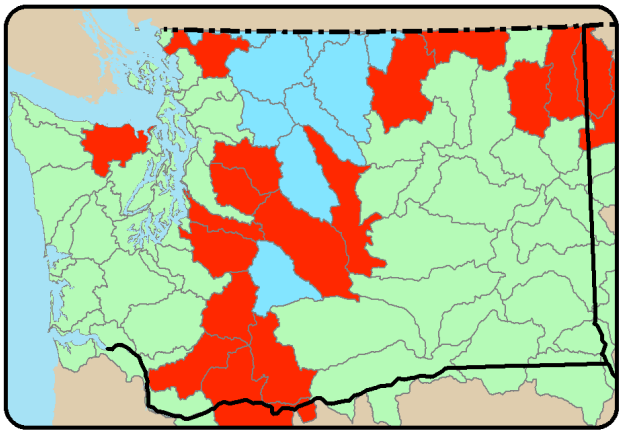
Elsner et al., 2009

Watershed Classifications: Historical

Washington currently has a mix of:

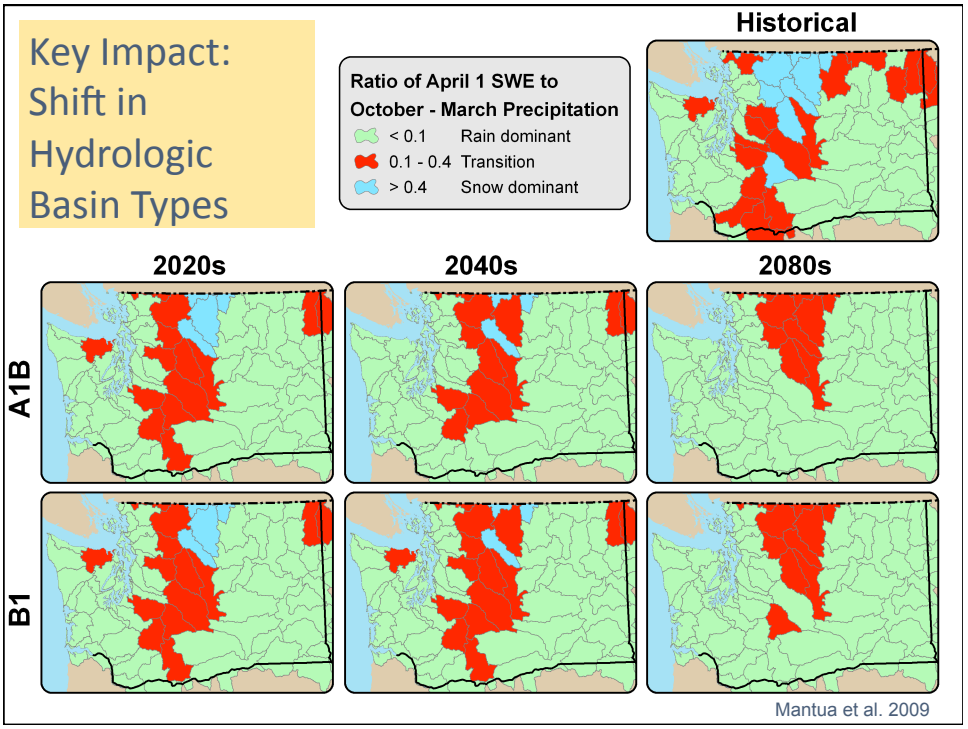
- rain dominant,
- transient (rain/ snow mix), and
- snow dominant

hydrologic basin types



Mantua et al. 2009

Key Impact: Shift in Hydrologic Basin Types



Mantua et al. 2009

Changes in Streamflow Timing

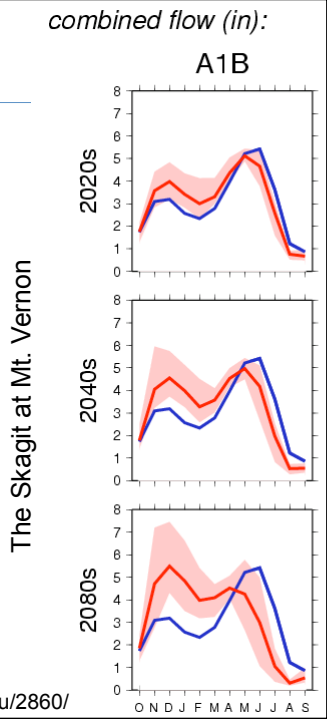
Mixed Rain/Snow (Transient) Basin

Overall:

- Increased flow in fall/winter
- Decreased flow in spring/summer

Implications:

- Increased competition for water
- Increased vulnerability to drought
- Increased summer water temperature
- Changes in sediment transport
- Increased risk of winter flooding in many basins west of the Cascades; decreased risk of spring flooding in many interior basins.



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

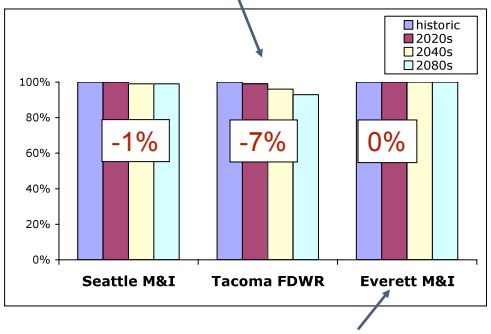
Municipal Water Supply in Key Puget Sound Basins

- Reliability measures differ across systems
- With current demands, climate change has little impact on system reliability

Note:

– *simulations do not include adaptation*

Tacoma, water allocations closer to current system capacity



Everett, largest system capacity

Vano et al. 2009a

* Projections compared to water year 1917-2006 average

Urban Stormwater Infrastructure

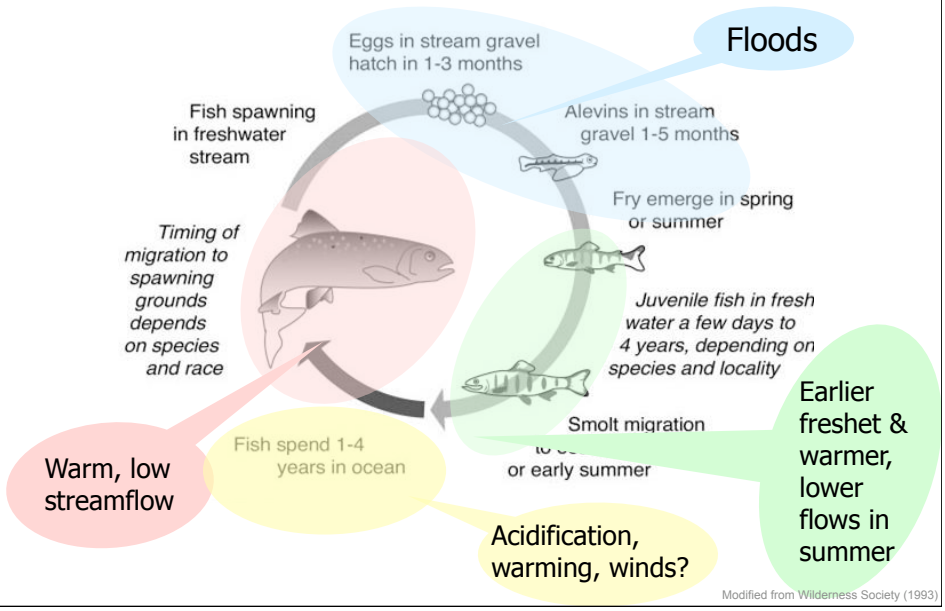
- Precipitation intensity and the magnitude of extreme precipitation events are projected to increase in western Washington, according to two regional climate model simulations.
- Drainage infrastructure designed using historical rainfall records may not meet future required capacity as precipitation intensity and extremes become more severe.

Rosenberg et al. 2009

Aquatic and Terrestrial Environments

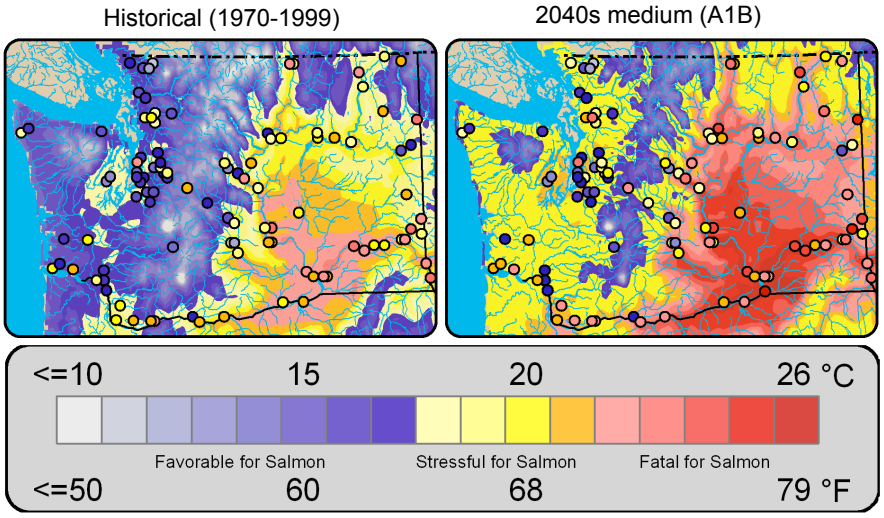
PROJECTED CHANGES IN AQUATIC AND TERRESTRIAL ECOSYSTEMS

Salmon Affected Across Their Life-Cycle



Salmon and Aquatic Ecosystems

August Mean Surface Air Temperature and Maximum Stream Temperature



* Projections are compared with 1970-1999 average

Mantua et al. 2009

Impacts Will Vary Depending On Life History And Watershed Types

In Washington State, for example:

- **Low flows + warmer water = increased pre-spawn mortality for summer run salmon and steelhead.** Increased stress on:
  - Columbia Basin sockeye
  - Summer steelhead
  - Summer chinook
  - Lake Washington sockeye
  - Lake Washington chinook

- **Increased winter flooding in Puget Sound streams**
  - Increased stressor on egg-to-fry survival rates for fall spawners and overwinter survival rates for yearling parr (steelhead, coho, and stream-type chinook)

Mantua et al. 2009

Impacts on PNW Forests

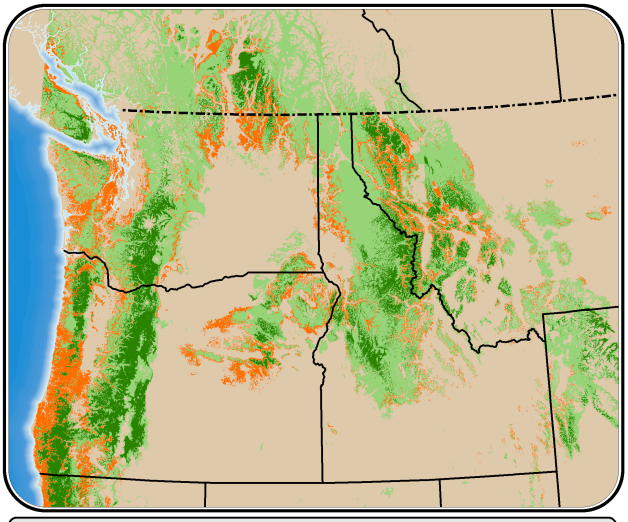
- Changes in species distributions
- Changes in productivity
- Increased disturbance from insects
- Changes in forest fire risk
- "Stress complexes" (e.g., drought, fire, insects) will be strong agents of landscape change by midcentury.

Mountain pine beetle

Littell et al. 2009

Changes in Species Distribution

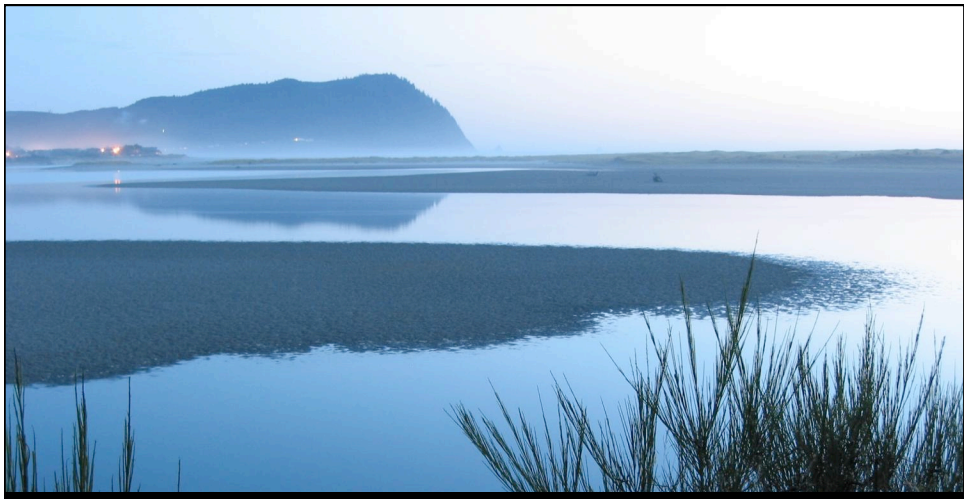
Projected suitability changes: Douglas-fir (2060s)



Data: Rehfeldt et al. 2006; map: Rob Norheim, UW CIG

Douglas-fir at risk (<50% models)
Douglas-fir (50-75% models)
Douglas-fir (>75% models)
Douglas-fir unlikely current *
**Modeled* current distribution

Littell et al. 2009

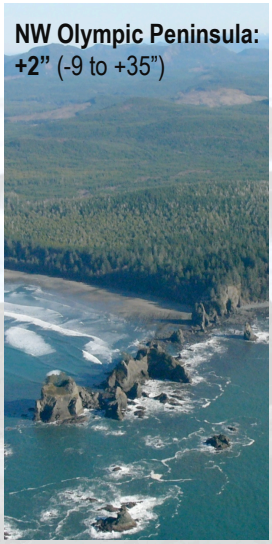


Coastal and Marine Environments

PROJECTED IMPACTS ON PNW COASTAL AND MARINE ENVIRONMENTS

Washington State Sea Level Rise

Medium (w/range) estimates of sea level rise in Washington for **2100:**



Mote et al. 2008

Near-term Challenges of SLR

Sea level rise increases storm surge and the risk of:

- flooding
- erosion
- habitat loss

These impacts will affect coastal areas *long before permanent inundation.*

Changing Coastal Flood Risk

Increased storm surge and related episodic flooding will present a greater near-term challenge.

For much of Puget Sound…

- A one foot sea level rise turns a 100 year flood event into a 10 year event.
- A two foot sea level rise turns a 100 year flood event into an annual event.

Numbers and photos courtesy of Hugh Shipman, Washington Dept. of Ecology

Anacortes (4 February 2006)

Whidbey Island (4 February 2006)

Impacts on Puget Sound

Impacts on Puget Sound:
A Convergence of Change

Changes in the coastal landscape and ecosystems will result from

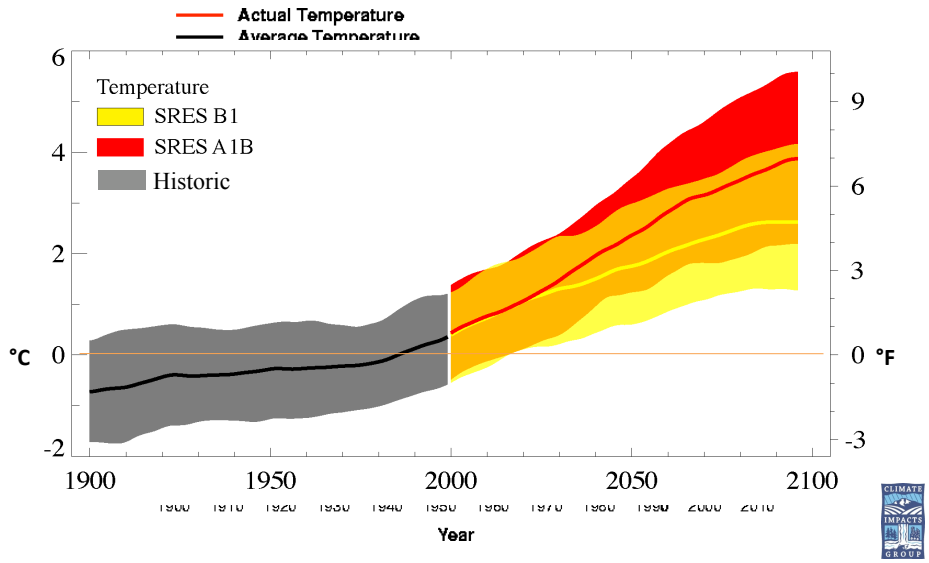
- Changes in hydrology
  - *Streamflow amount, timing, temperature, sediment transport*
- Changes in coastal/delta dynamics
  - *Sea level rise vs. altered sediment supply, erosion, landslides*
- Changes in ocean conditions
  - *Temperature, acidity*

Human Health

- In Washington, climate change will lead to larger numbers of heat-related deaths due mainly to hotter summers. For example in greater Seattle, a medium climate change scenario projects 101 additional deaths for people over 45 by 2025 and another 50% increase by 2045
- Although better control of air pollution has led to improvements in air quality, warmer temperatures threaten some of the sizeable gains that have been made in recent years.

Jackson et al. 2009

Prepare for a bumpy ride



Planning for Climate Change

Anticipate changes. Accept that the future climate will be substantially different than the past.

Use scenario based planning over long time scales to evaluate options rather than the historical record.

Expect surprises and plan for flexibility and robustness in the face of uncertain changes rather than counting on one approach.

Plan for the long haul. Where possible, make adaptive responses and agreements "self tending" to avoid repetitive costs of intervention as impacts increase over time.

Our Challenge:

To develop tools for dealing with not only *projected change*, but the irreducible *uncertainty and variability* of a non-stationary climate.

Picasso – The Acrobat (1930)

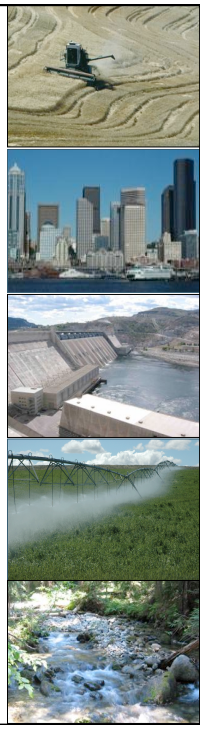
www.georgetown.edu

JISAO CSES Climate Impacts Group

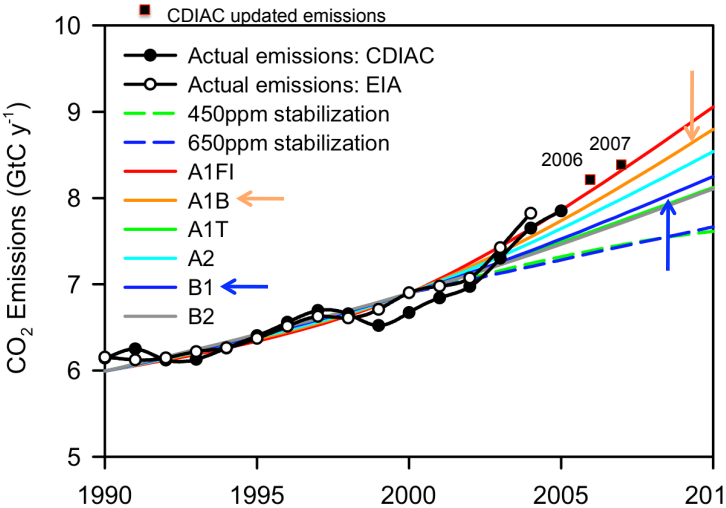
The Climate Impacts Group

www.cses.washington.edu/cig

Climate science in the public interest



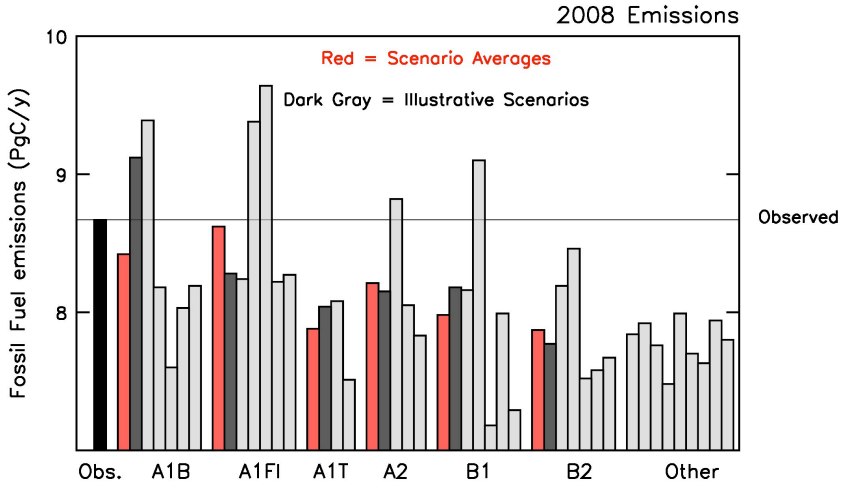
CO_2 Annual Emissions



Raupach et al. 2007, PNAS

CDIAC = Carbon Dioxide Information Analysis Center, Oak Ridge National Lab (DOE)

Recent emissions have been near the upper end of the most intense (A1FI) fossil fuel scenario established by the IPCC's 2000 special report on emissions scenarios



From realclimate.org

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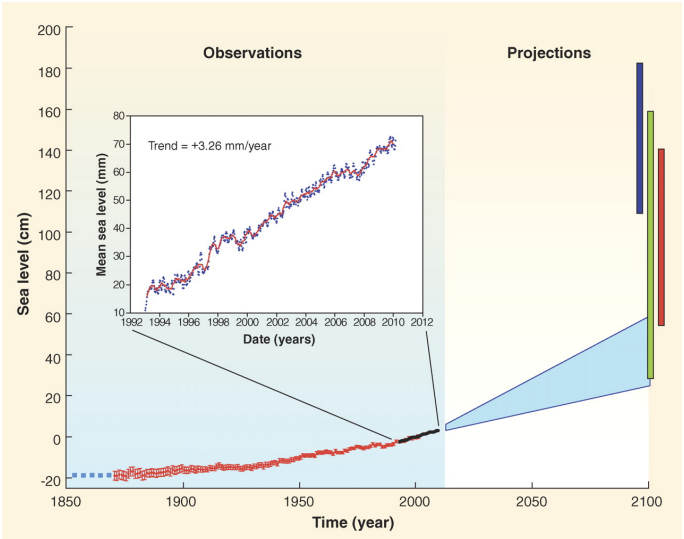
Sea Level Rise



Nicholls, R. J. and Cazenave, A. (2010) Sea-Level Rise and Its Impact on Coastal Zones. *Science* 328, 1517-1520