Climate Change in the Skagit River Basin

Dr. Alan F. Hamlet

Department of Civil and Environmental Engineering
Climate Impacts Group, University of Washington
Skagit Climate Science Consortium (SC^2)

June 21st, 2012
County Commissioner's Hearing Room, Mt. Vernon

SC^2 Vision Statement

Reduce vulnerability of human communities and ecosystems in the Skagit River basin to the impacts of a changing climate.

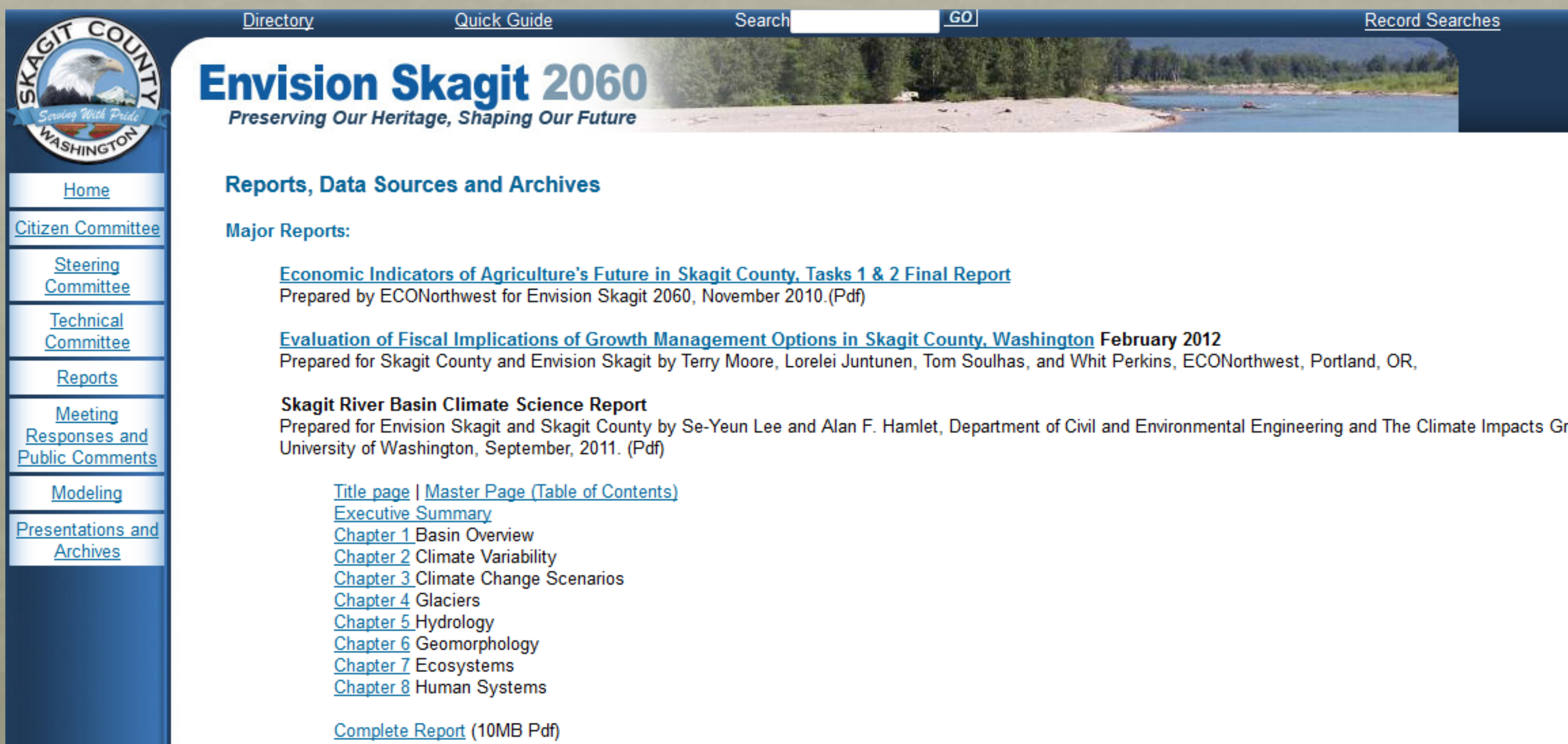
SC^2 MISSION

To support Skagit communities as they adapt to climate change, SC^2:

- *Fosters collaborative scientific research* to understand the diverse and interrelated impacts of climate change from the Skagit's headwaters to Puget Sound.
- *Produces relevant climate-related products* closely integrated with the Skagit community's needs and concerns.
- *Connects Skagit communities and SC^2 scientists* to assist in the development of adaptation strategies.

ENVISION SKAGIT REPORT

http://www.skagitcounty.net/Common/asp/default.asp?d=EnvisionSkagit&c=General&P=reports.htm



Directory | Quick Guide | Search GO | Record Searches

SKAGIT COUNTY WASHINGTON Serving With Pride

Envision Skagit 2060

Preserving Our Heritage, Shaping Our Future

Home

Citizen Committee

Steering Committee

Technical Committee

Reports

Meeting Responses and Public Comments

Modeling

Presentations and Archives

Reports, Data Sources and Archives

Major Reports:

Economic Indicators of Agriculture's Future in Skagit County, Tasks 1 & 2 Final Report
Prepared by ECONorthwest for Envision Skagit 2060, November 2010.(Pdf)

Evaluation of Fiscal Implications of Growth Management Options in Skagit County, Washington **February 2012**
Prepared for Skagit County and Envision Skagit by Terry Moore, Lorelei Juntunen, Tom Soulhas, and Whit Perkins, ECONorthwest, Portland, OR,

Skagit River Basin Climate Science Report
Prepared for Envision Skagit and Skagit County by Se-Yeun Lee and Alan F. Hamlet, Department of Civil and Environmental Engineering and The Climate Impacts Gro
University of Washington, September, 2011. (Pdf)

Title page | Master Page (Table of Contents)
Executive Summary
Chapter 1 Basin Overview
Chapter 2 Climate Variability
Chapter 3 Climate Change Scenarios
Chapter 4 Glaciers
Chapter 5 Hydrology
Chapter 6 Geomorphology
Chapter 7 Ecosystems
Chapter 8 Human Systems

Complete Report (10MB Pdf)

Weather vs. Climate

WEATHER:

Current state of the atmosphere (timescale: hours, days, weeks)

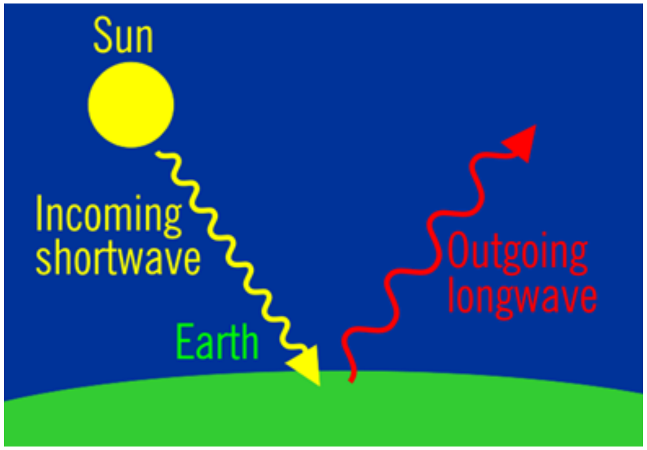
CLIMATE:

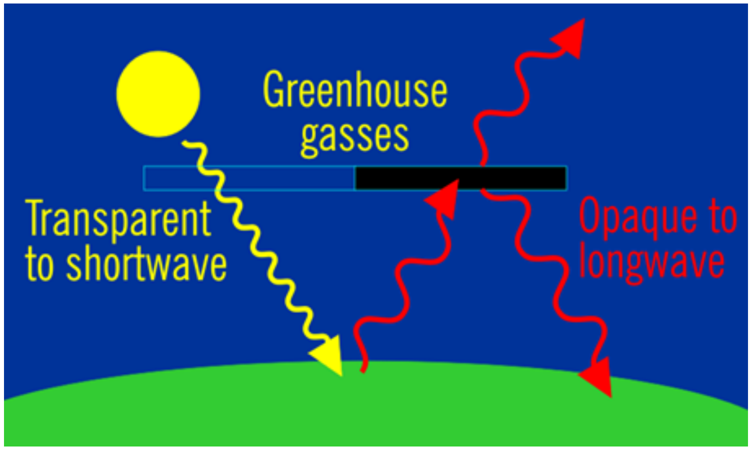
Statistics of weather over time (timescale: usually 30 or more years)

- Climate is what you *expect* today (norms)
- Weather is what you *get* today (rainy, sunny, cold, hot, windy)

The Greenhouse Effect

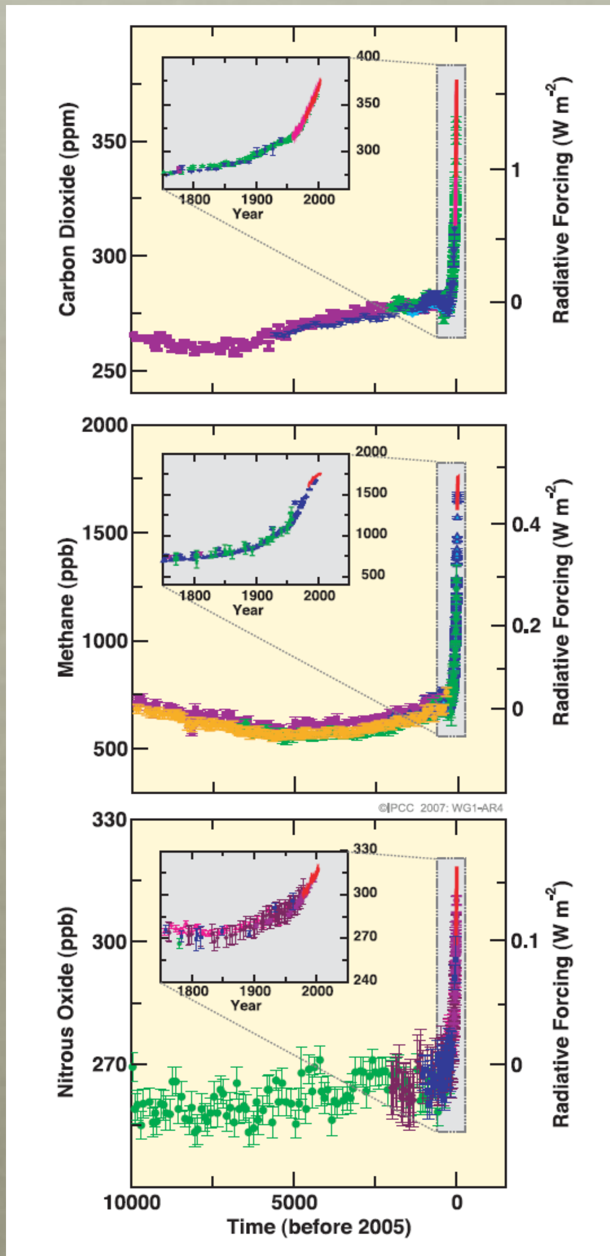
There is a natural greenhouse effect that warms the earth's average surface temperature by ~33 C (about 60 deg. F)

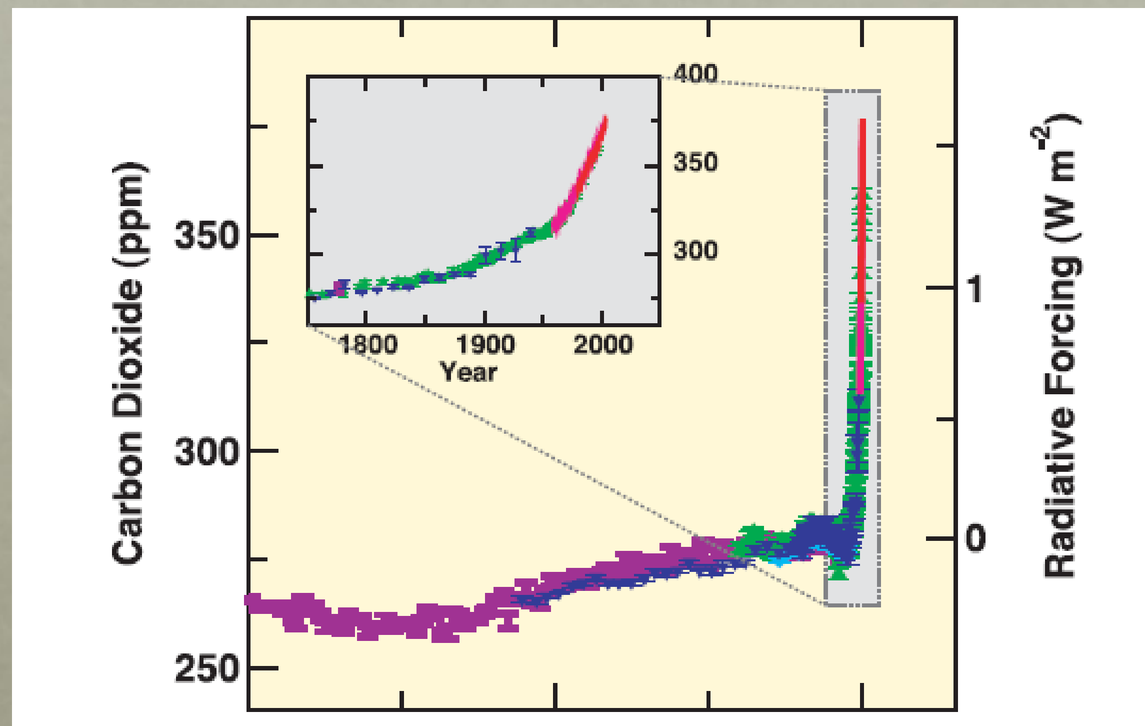




http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/models

Sources of Global Climate Change:

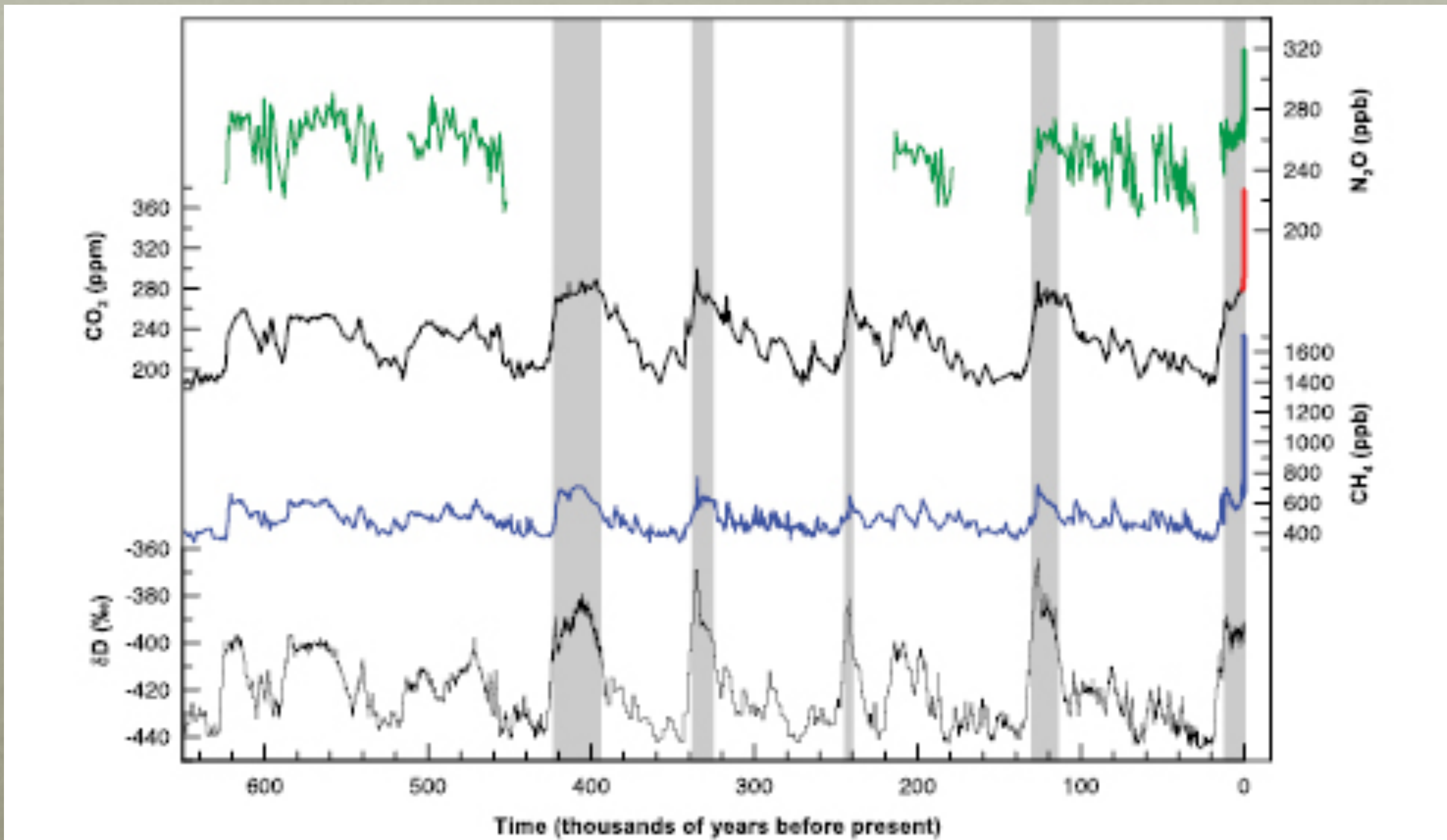




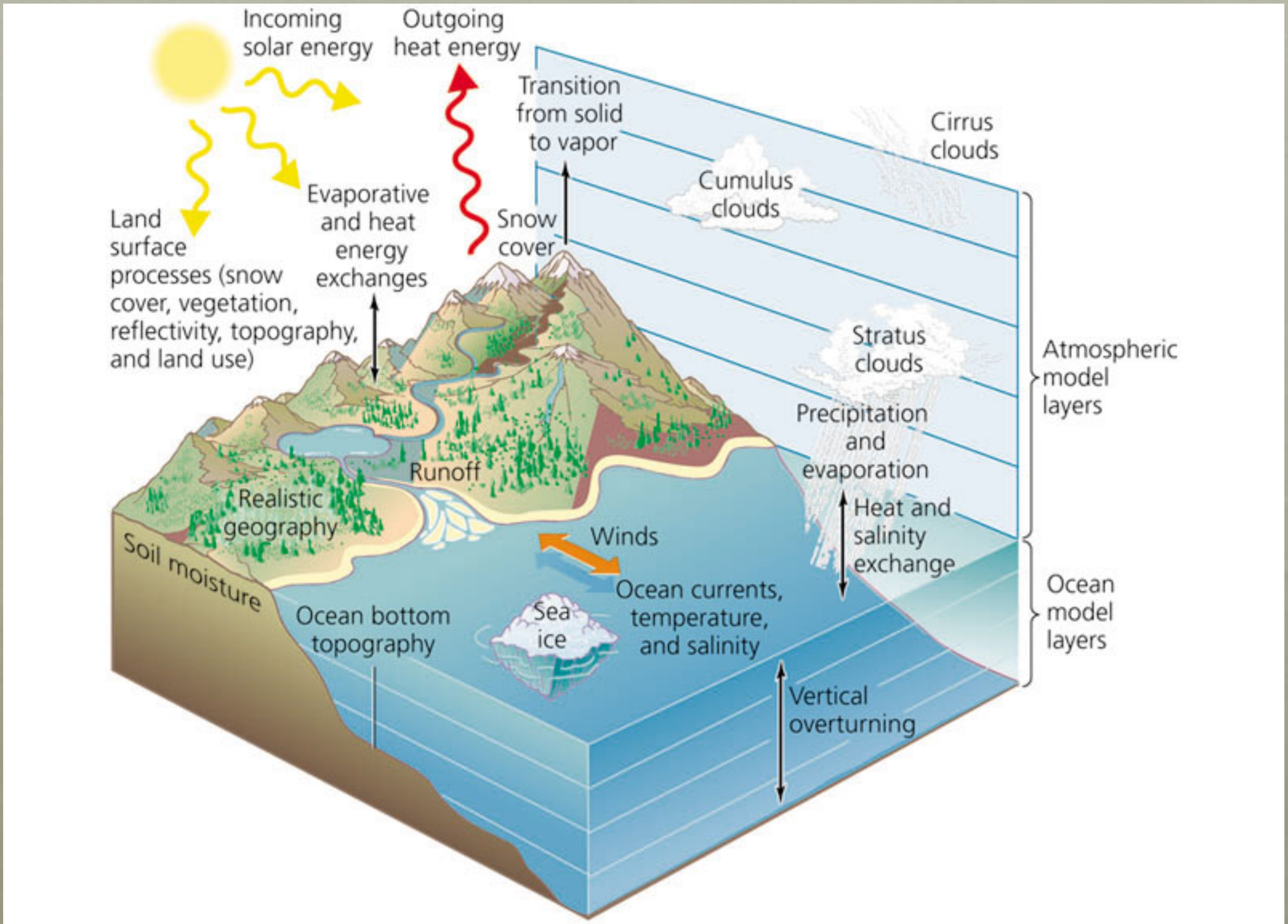
10000 5000 0

Years Before the Present

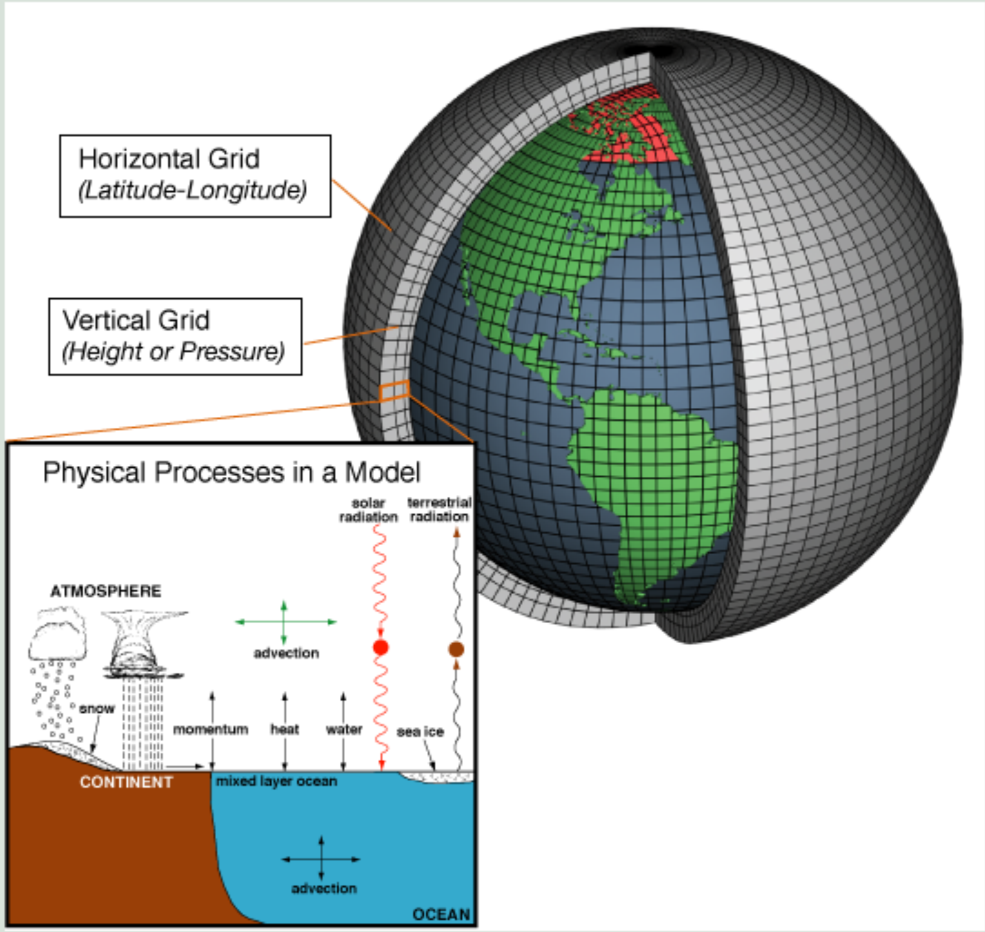
Paleoclimatic Reconstructions:



Global Climate System



Global Climate Models

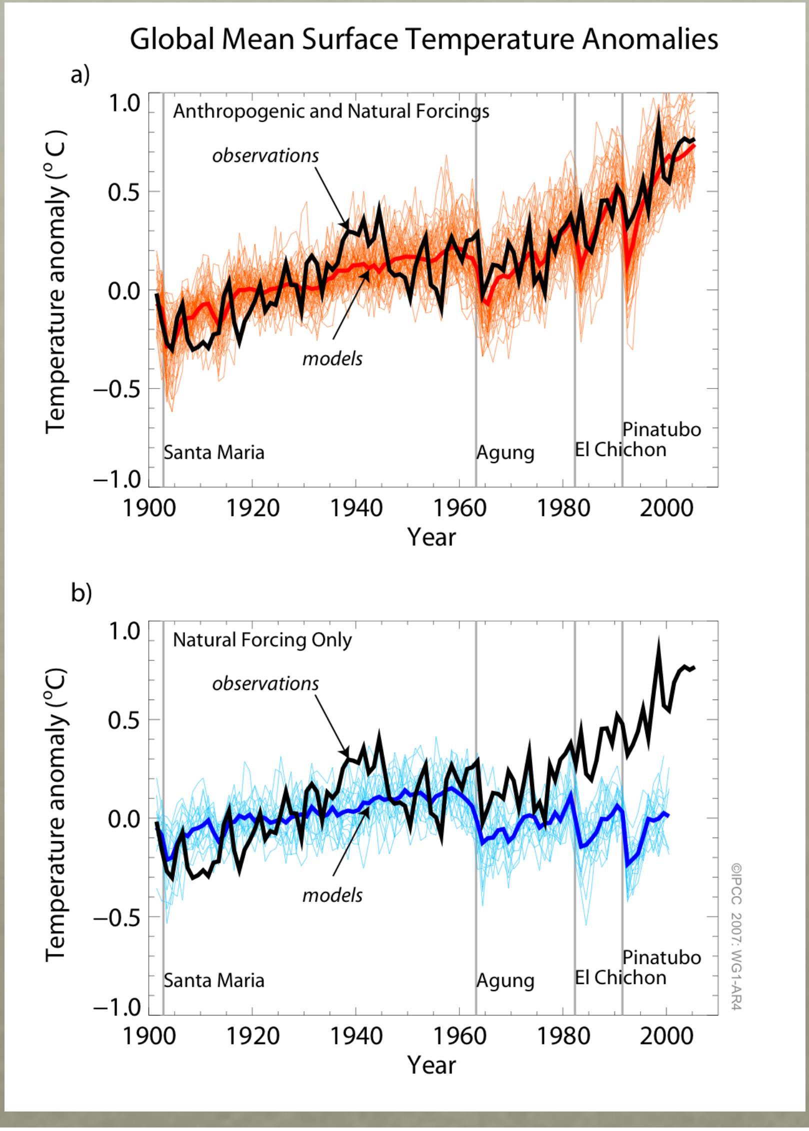


Climate models are systems of differential equations based on the basic laws of physics, fluid motion, and chemistry. To "run" a model, scientists divide the planet into a 3-dimensional grid, apply the basic equations, and evaluate the results. Atmospheric models calculate winds, heat transfer, radiation, relative humidity, and surface hydrology within each grid and evaluate interactions with neighboring points.

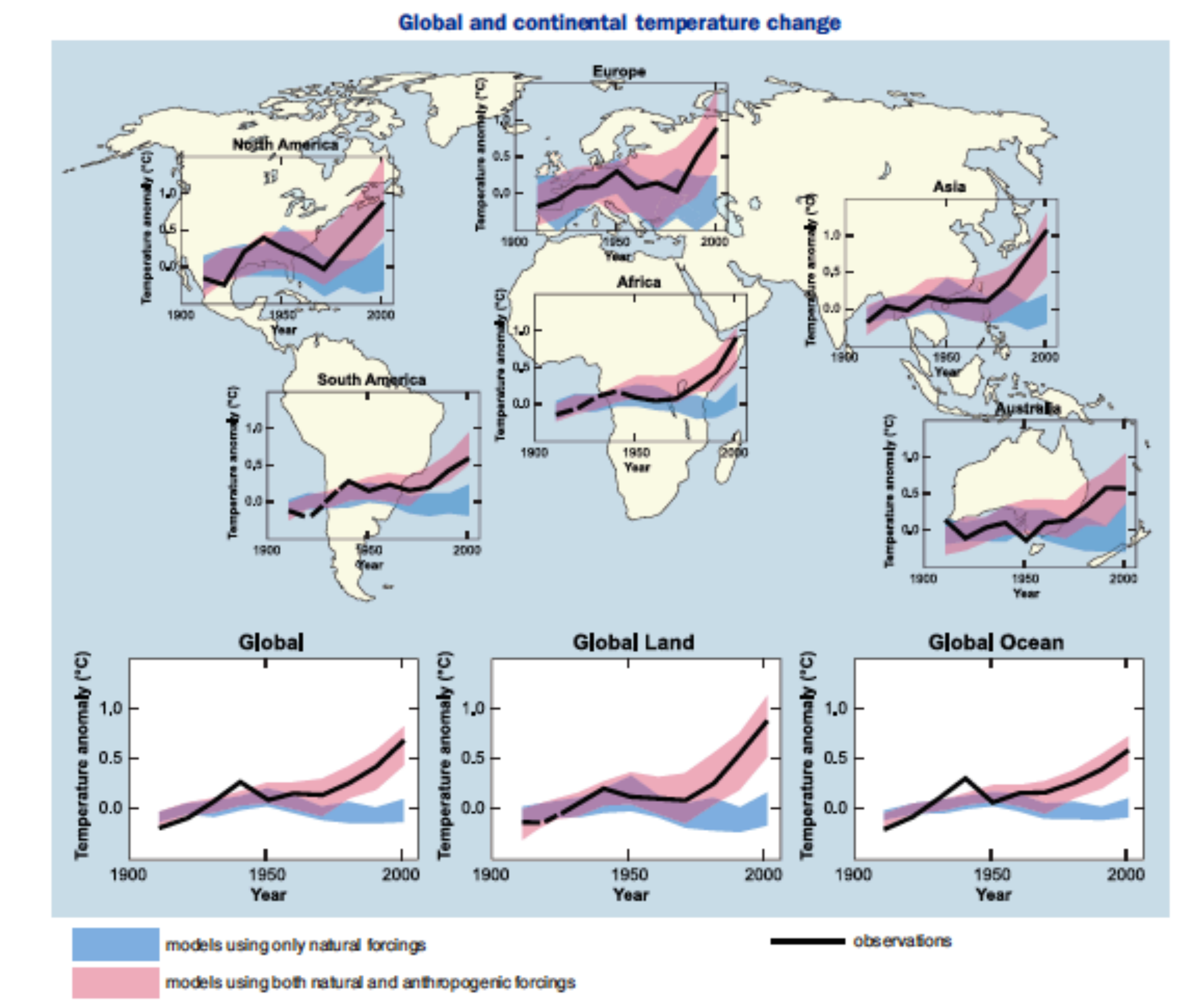
Quantifying the Human Role in Climate

Global climate modeling experiments reproduce the history of global temperatures remarkably well when both human and natural factors are included.

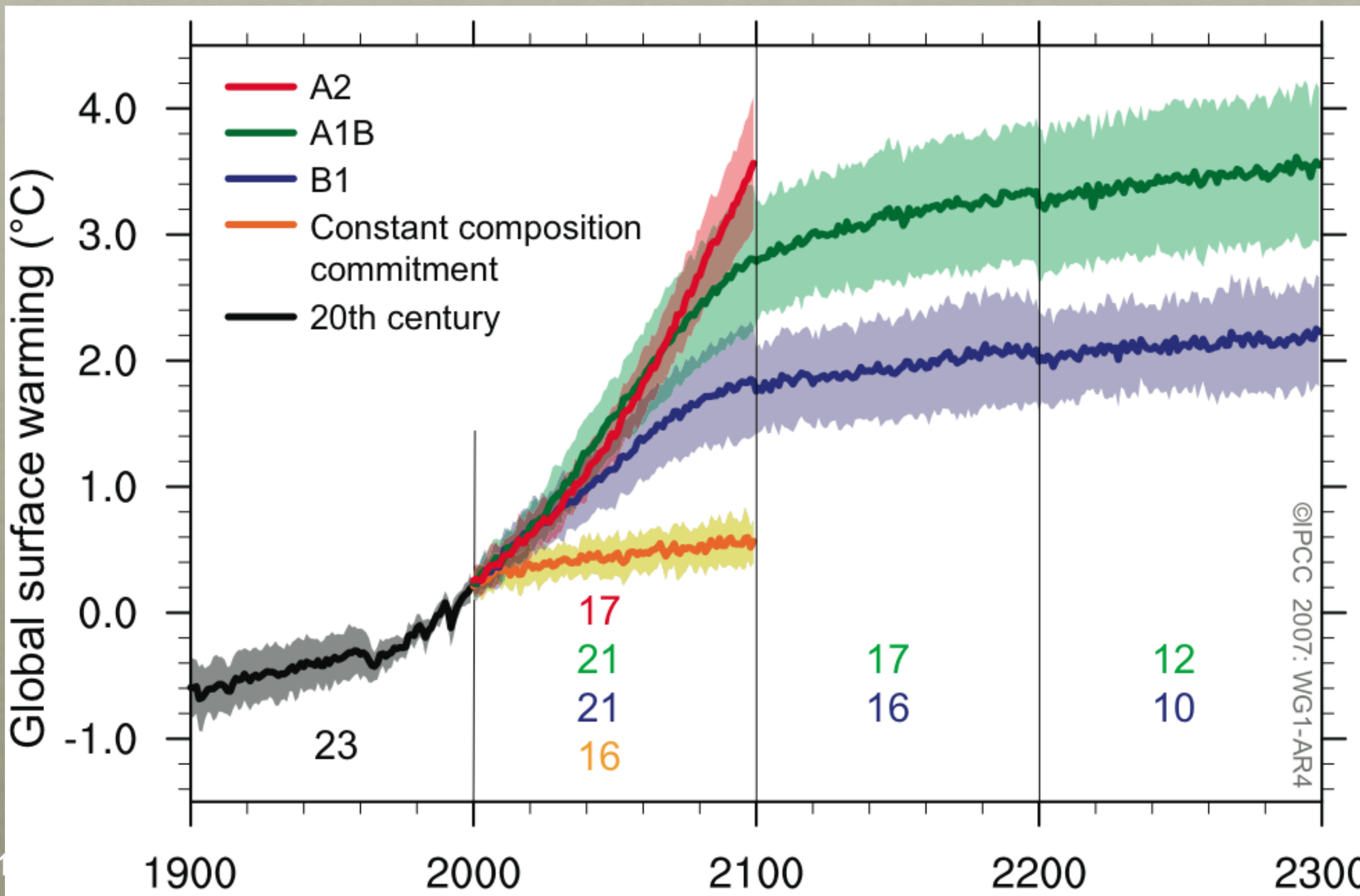
Volcanic eruptions, variations in solar radiation, etc. cannot alone explain rapid rise in temperature at the end of the 20th century.



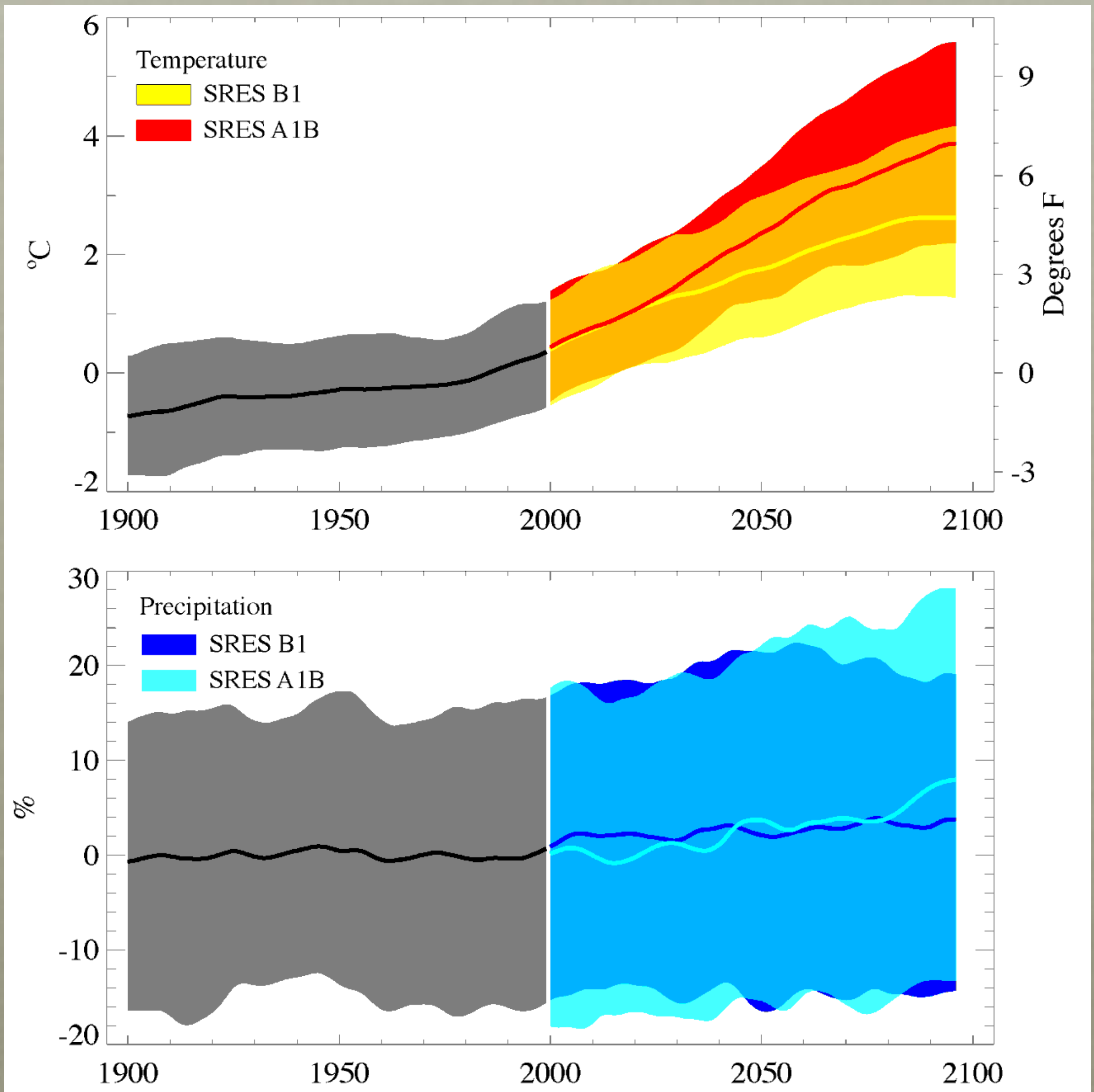
Regional Trends



FUTURE EMISSIONS SCENARIOS



PNW Temperature and Precipitation Scenarios

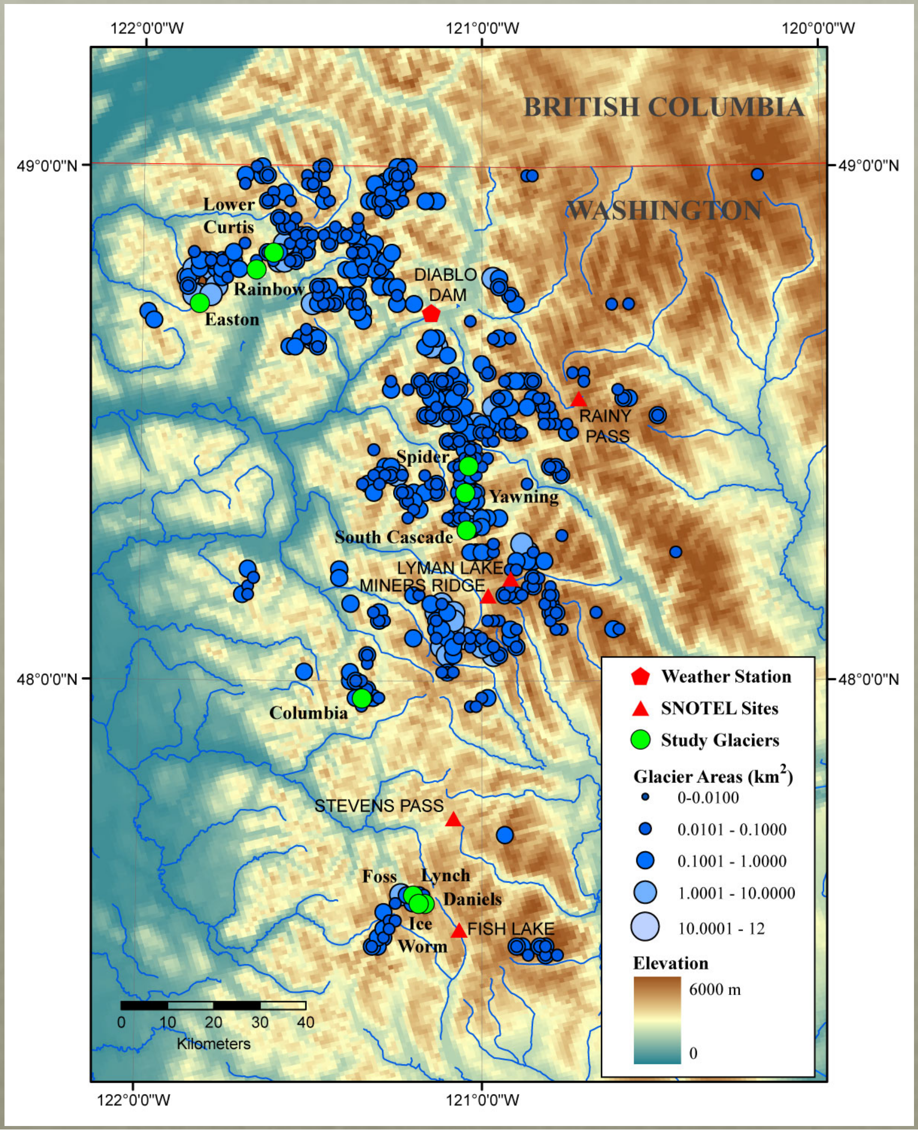


Model Consensus:

- Strong Warming in All Seasons, and Especially Summer
- Relatively Small Changes in Annual Precipitation
- Wetter Falls, Winters, and Springs
- Drier Summers

How will the Skagit Basin respond to a changing climate?

Changing Glaciers



There are approximately 394 glaciers in the Skagit Watershed (Post et. Al 1971)

Between 1900-1998 the North Cascades lost ~ 50% of its glacial area (Granshaw, 2002)

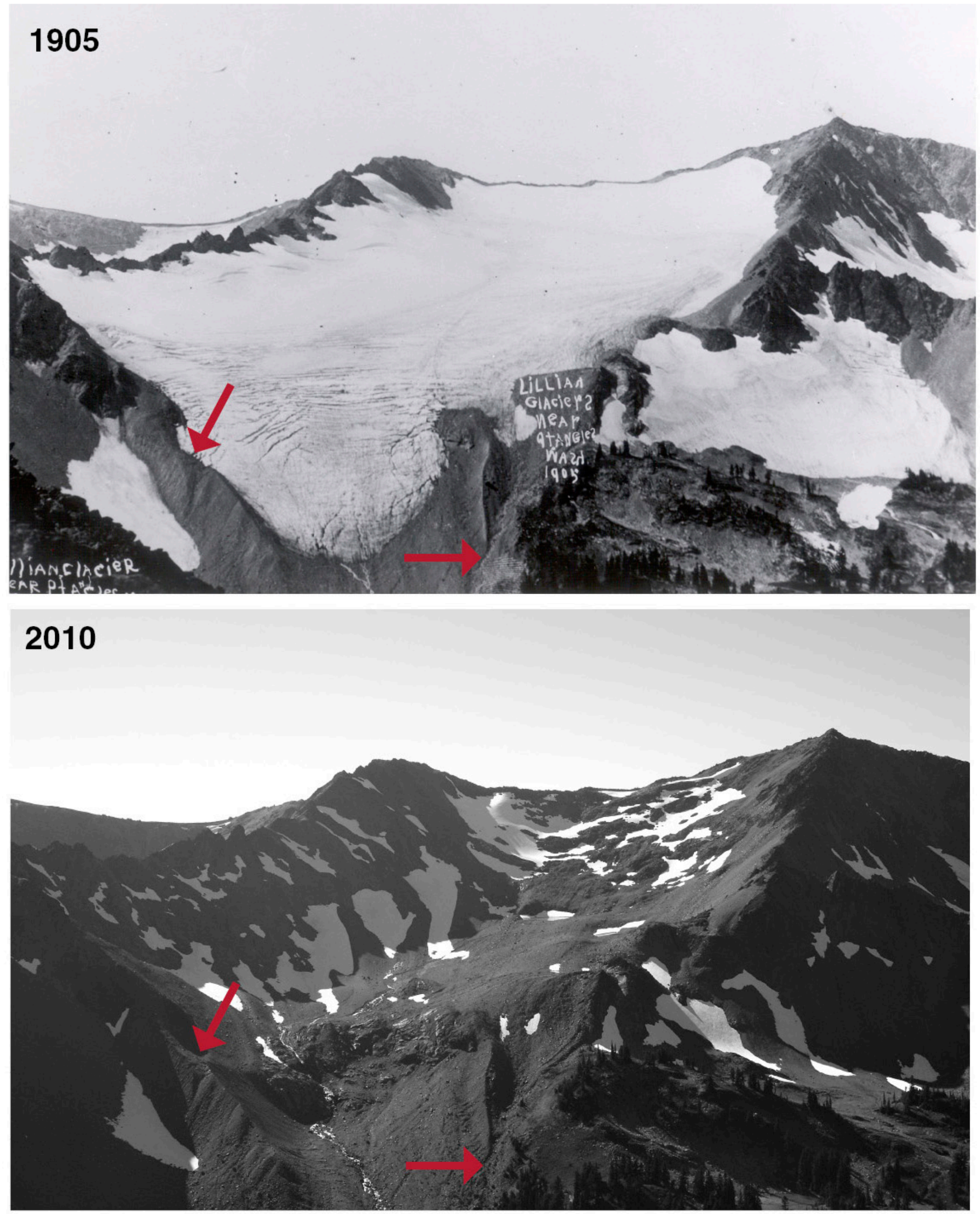
SILVER GLACIER

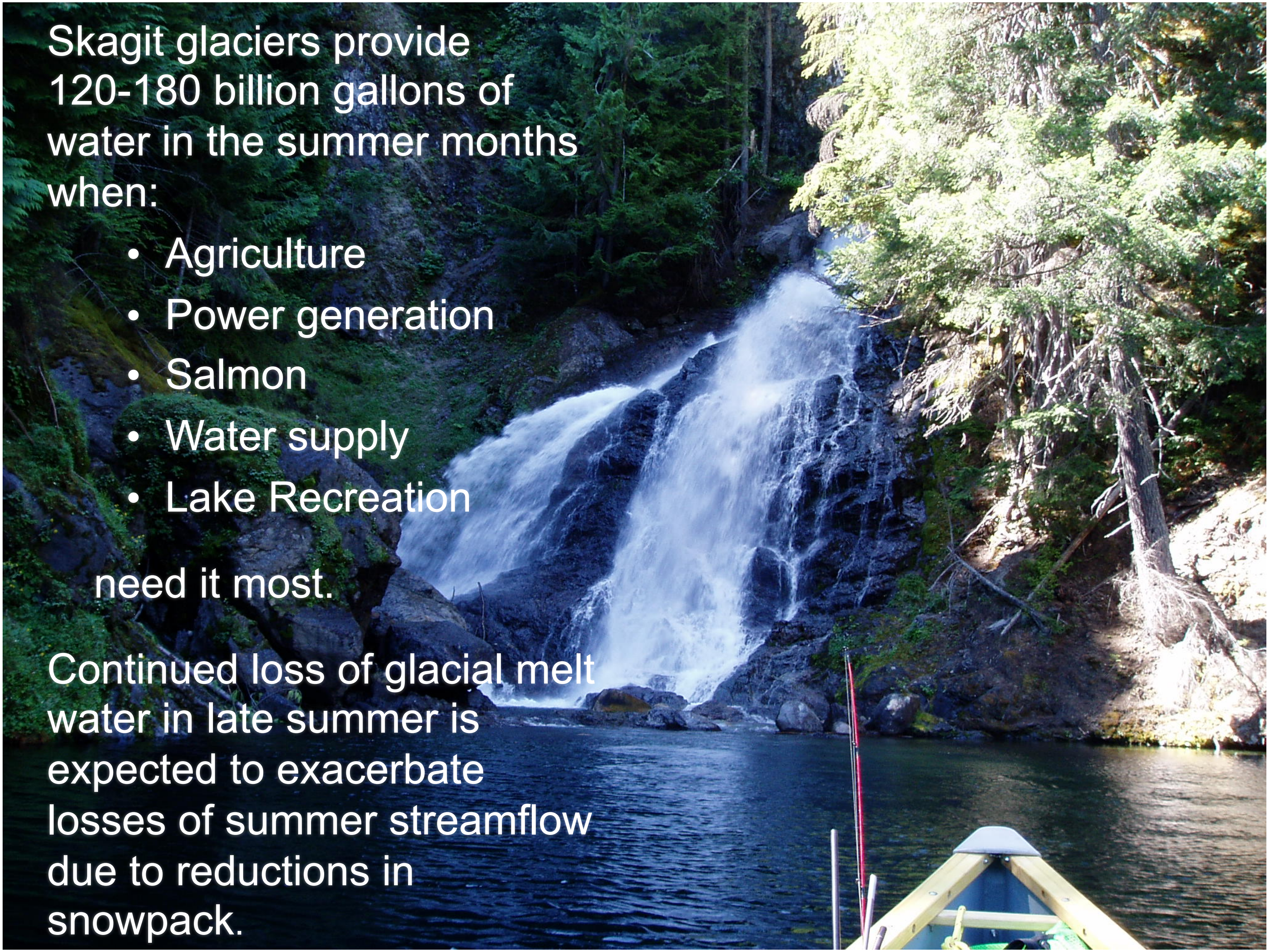
1958 2006

Other Pacific Northwest glaciers are also rapidly receding.

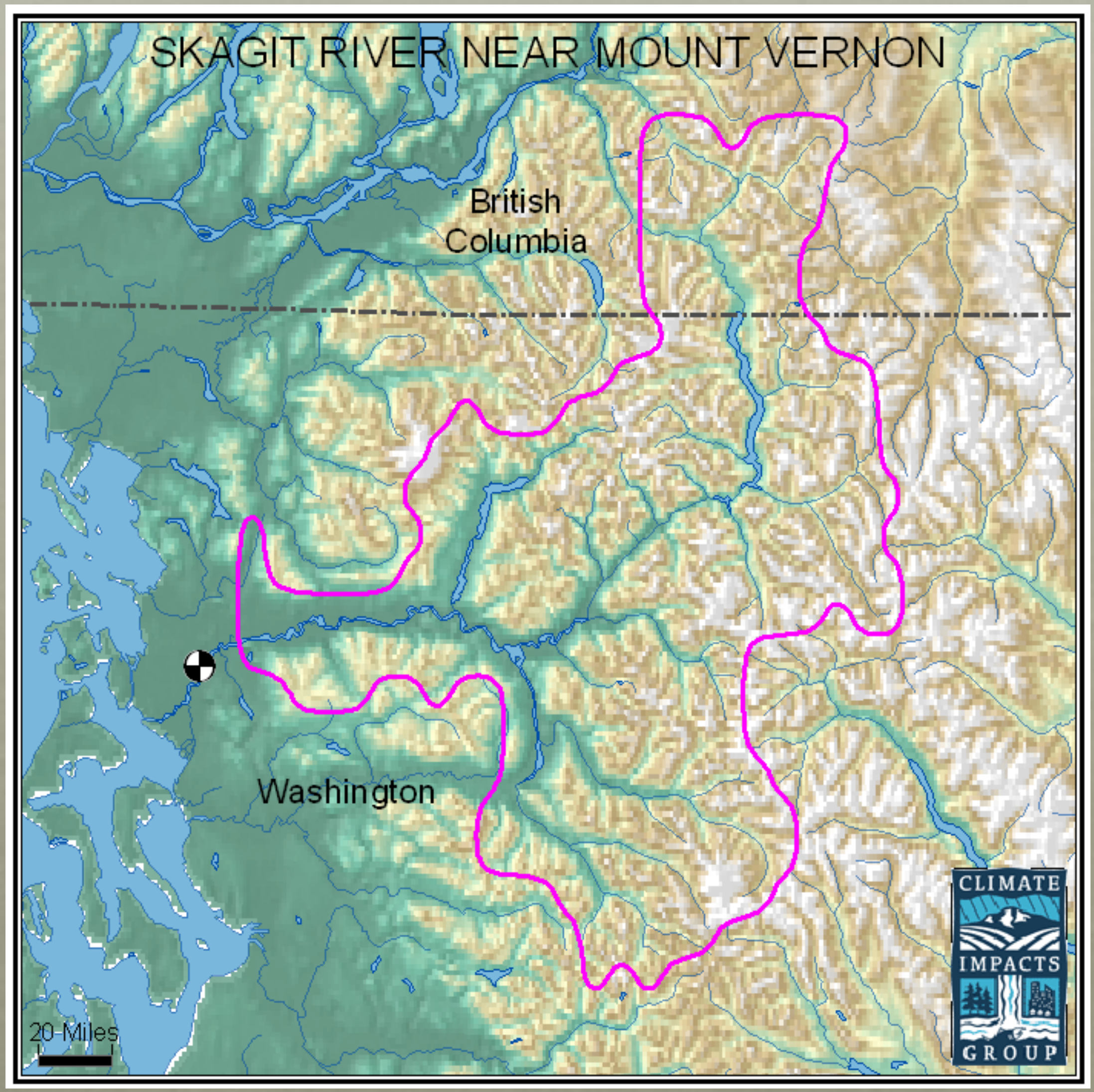
Some, like Lillian Glacier in the Olympic National Park, are already gone.

Olympic National Park - Lillian Glacier

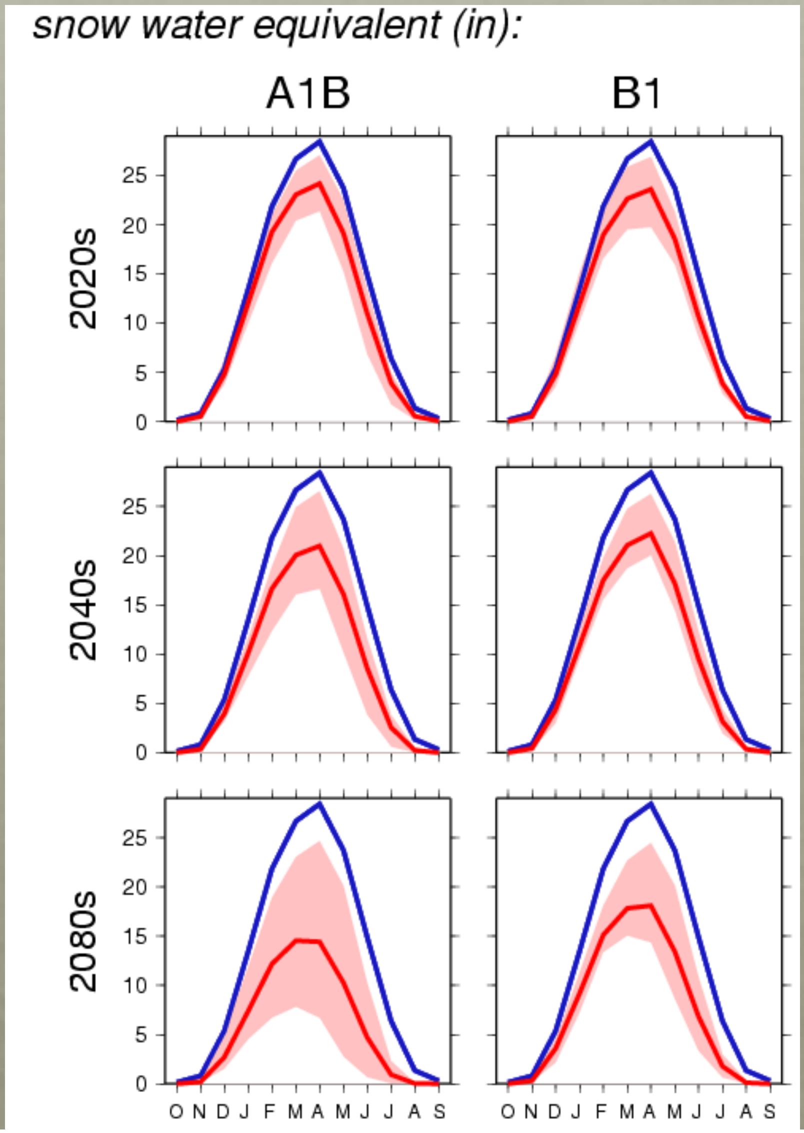



Skagit glaciers provide 120-180 billion gallons of water in the summer months when:
• Agriculture
• Power generation
• Salmon
• Water supply
• Lake Recreation
need it most.
Continued loss of glacial melt water in late summer is expected to exacerbate losses of summer streamflow due to reductions in snowpack.

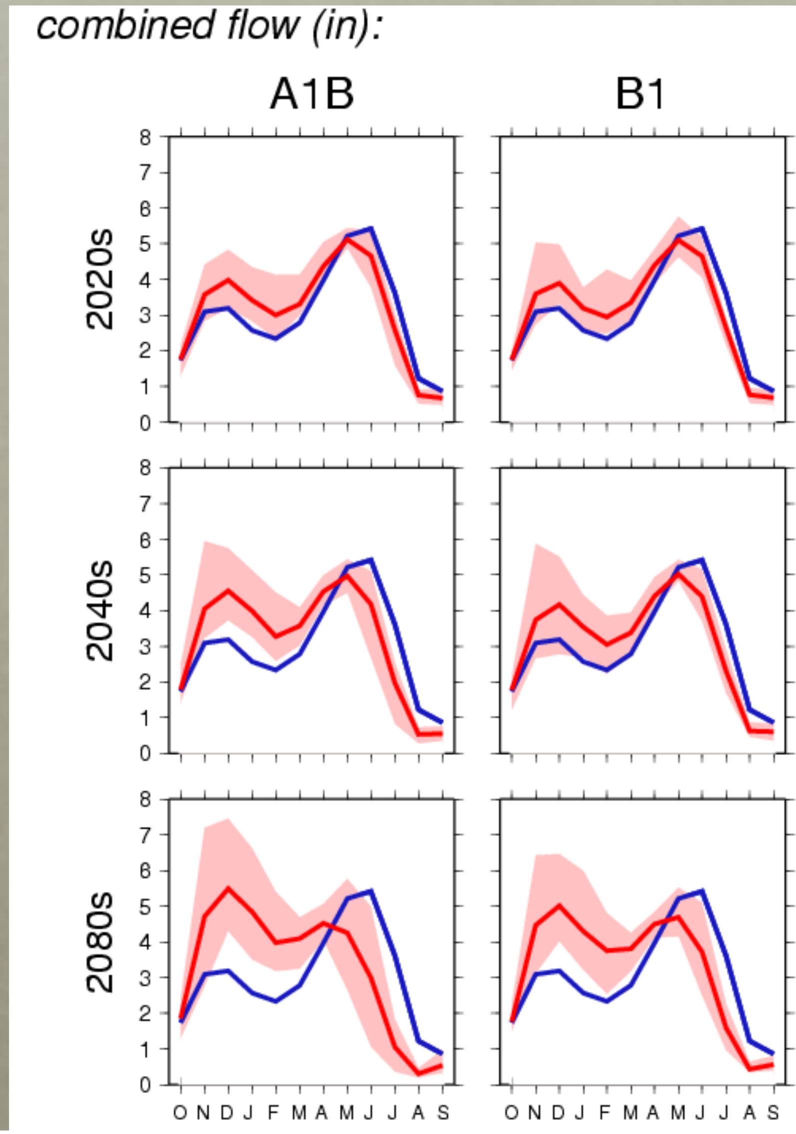
Changing Local Hydrology



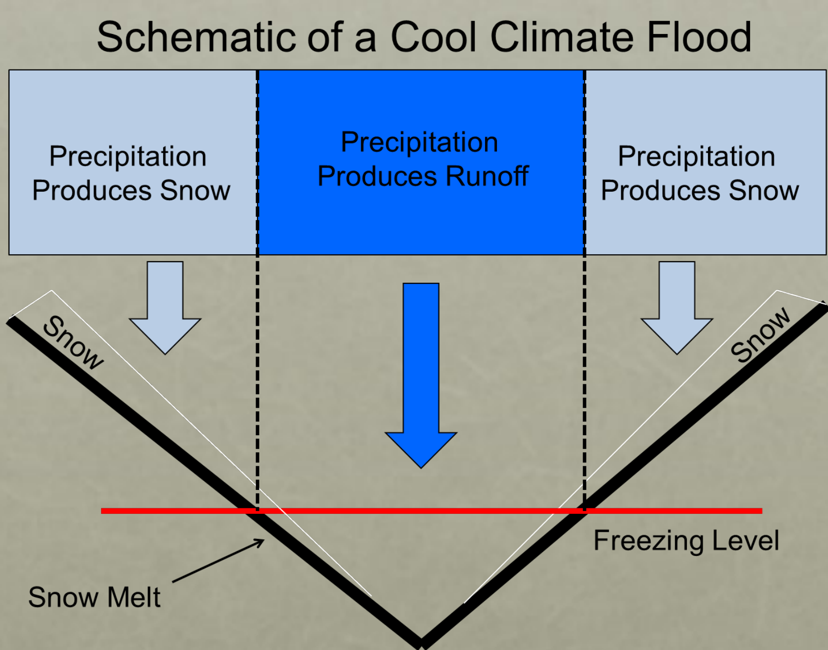
SNOWPACK

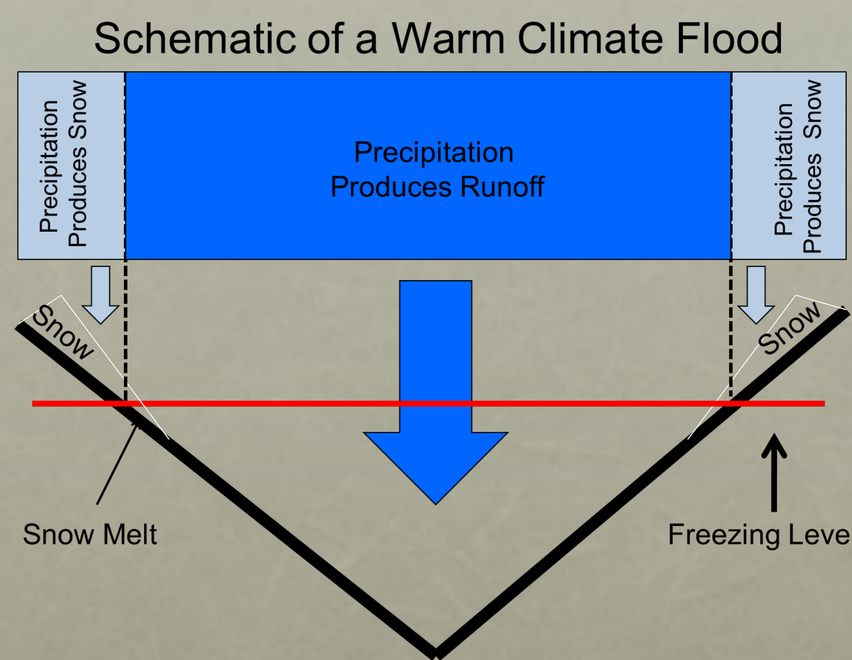

snow water equivalent (in):
A1B
B1
2020s
2040s
2080s
0
5
10
15
20
25
O N D J F M A M J J A S

Seasonal Runoff Timing



Changing Snow Line and Effective Basin Area





Since 1958 the average winter snow elevation is estimated to have risen about 650 feet. A higher snow elevation increases the effective basin area that produces runoff during winter storms.

Changes in the Regulated 100-year Flood

Skagit dams reduce flooding, but most of the runoff production during floods is downstream of headwater dams, which limits the role that reservoir operations can play in protecting the lower basin from projected larger future floods.

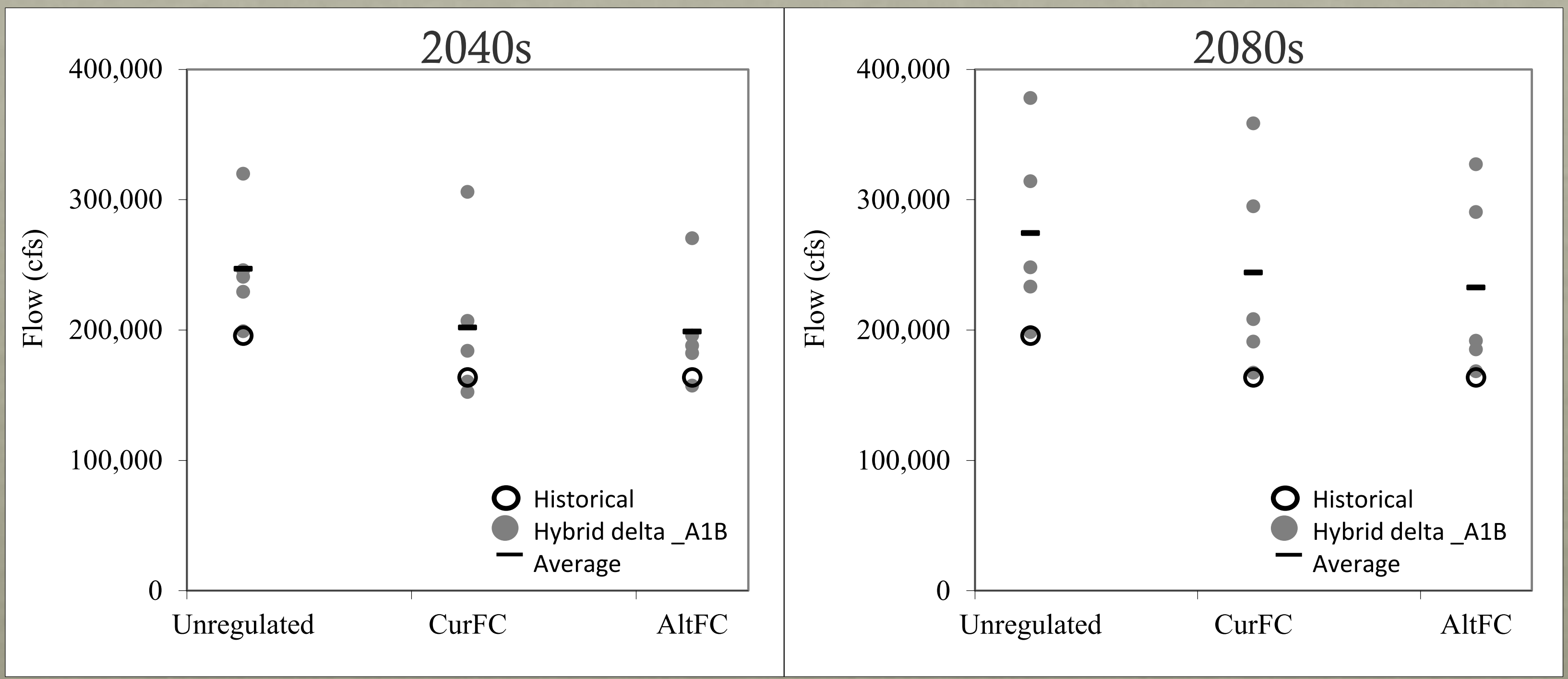


Figure 9. The magnitude of 100-year floods at the Skagit River near Mount Vernon for unregulated flows and for regulated flows under current flood control operations (CurFC) and alternative operations (AltFC). Historical run and echam5 A1B scenarios for the 2040s and the 2080s are considered.

CHANGES IN REGULATED LOW FLOWS (7Q10)

Low flows under natural conditions are less than under regulated conditions, but climate change reduces low flows in each case.

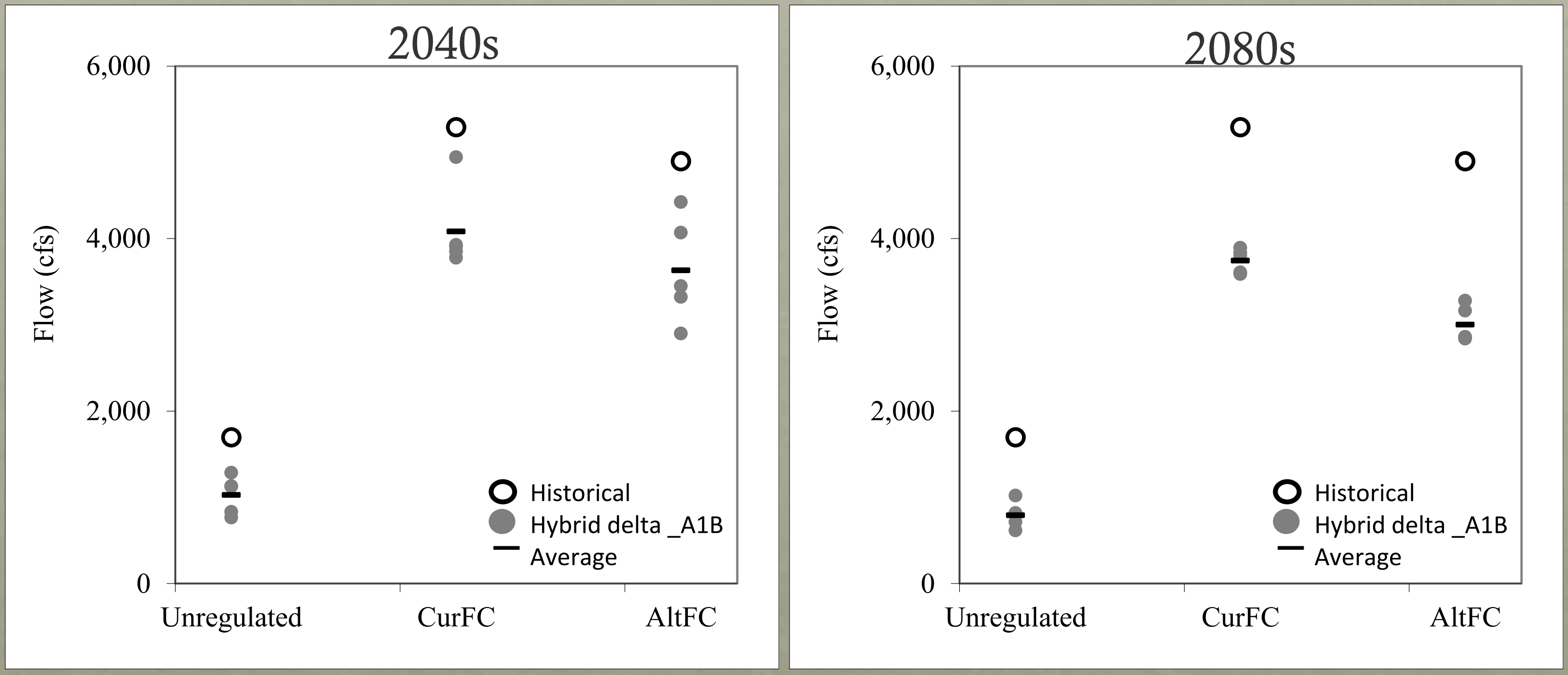
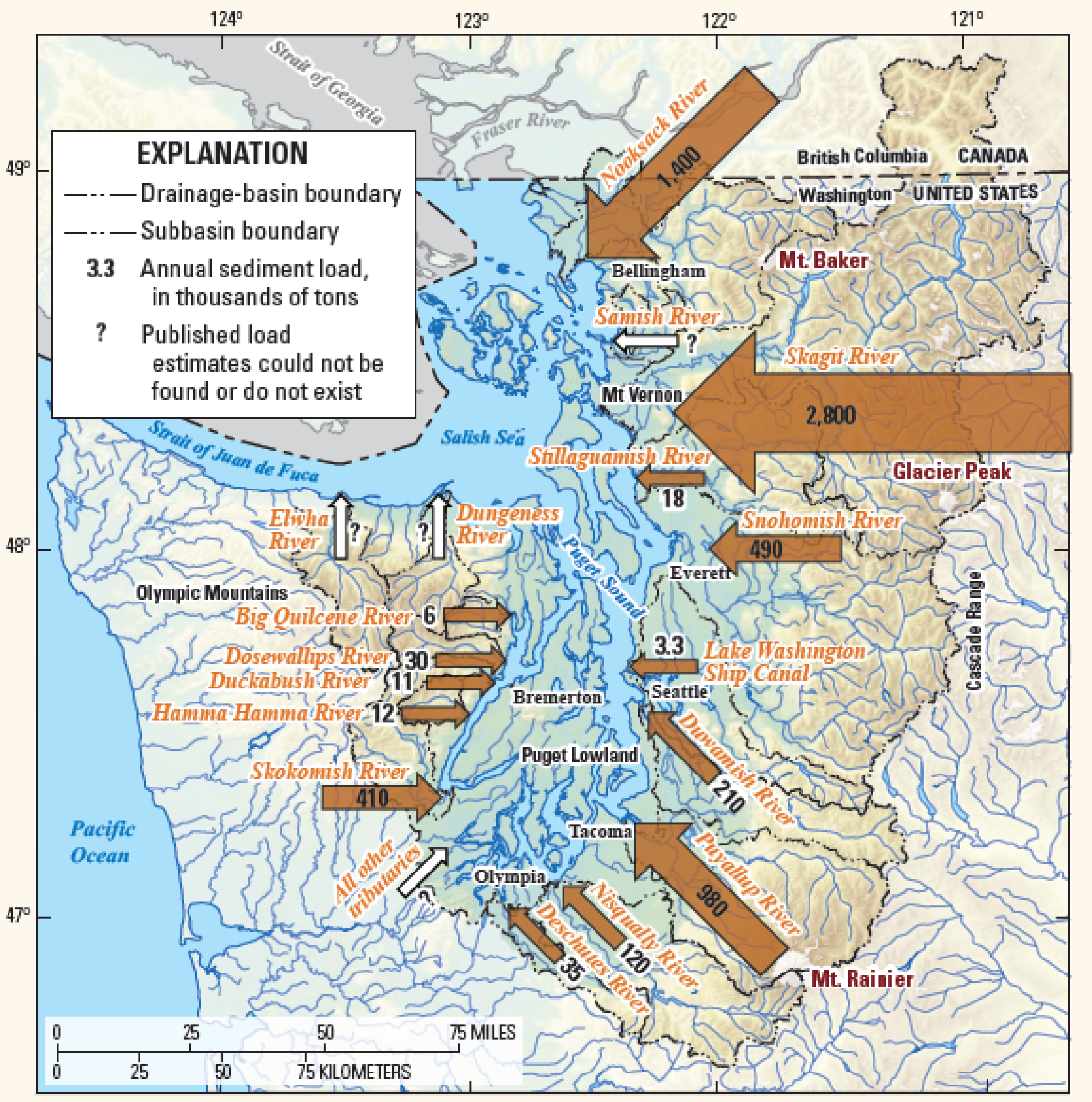


Figure 11. The magnitude of low flow statistic (7Q10) at the Skagit River near Mount Vernon for unregulated flows and for regulated flows under current flood control operations (CurFC) and alternative operations (AltFC). Historical run and echam5 A1B scenarios for the 2040s and the 2080s are considered.

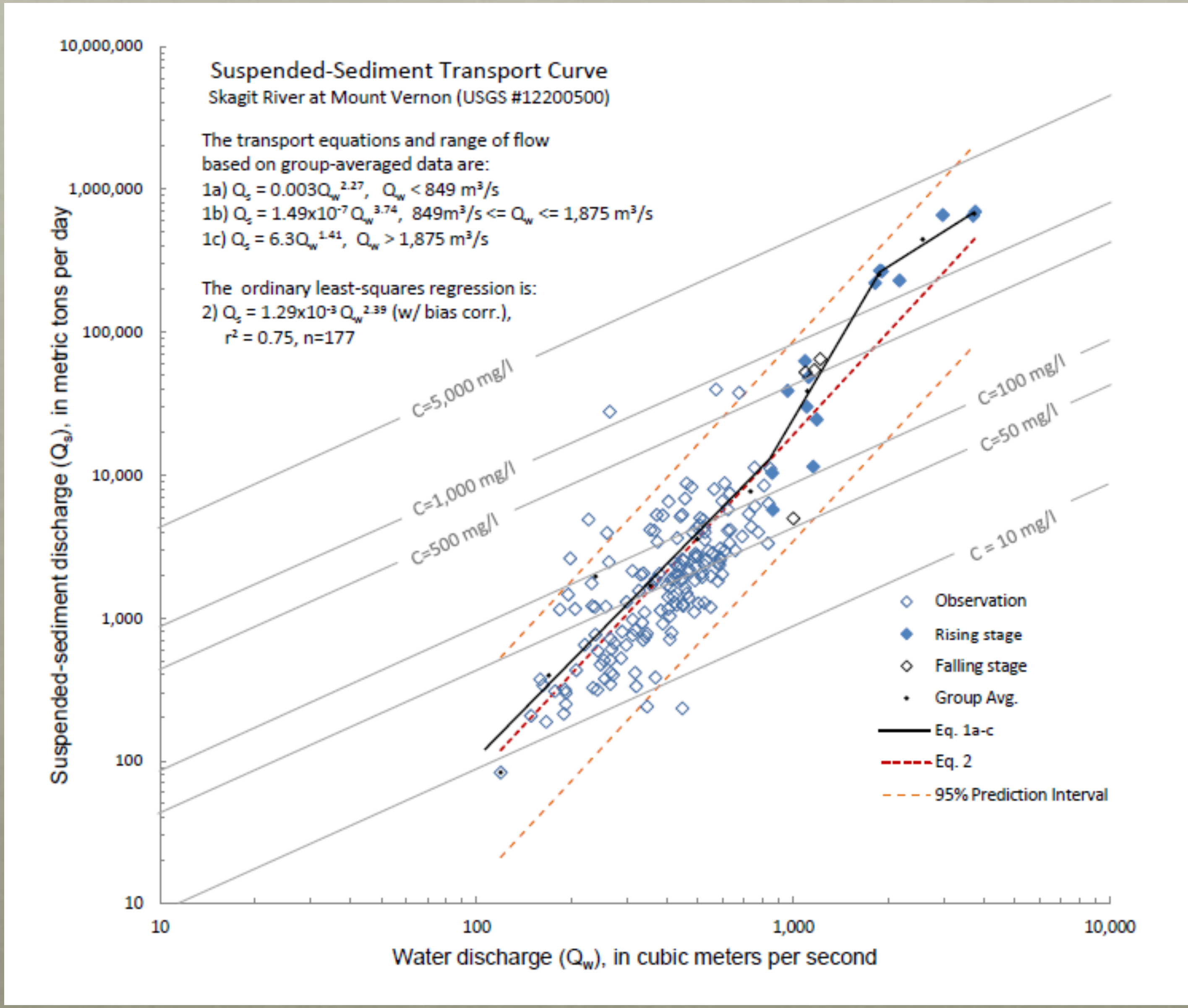
SEDIMENT TRANSPORT



The Skagit River already moves a tremendous amount of sediment (compounded by current human land uses).

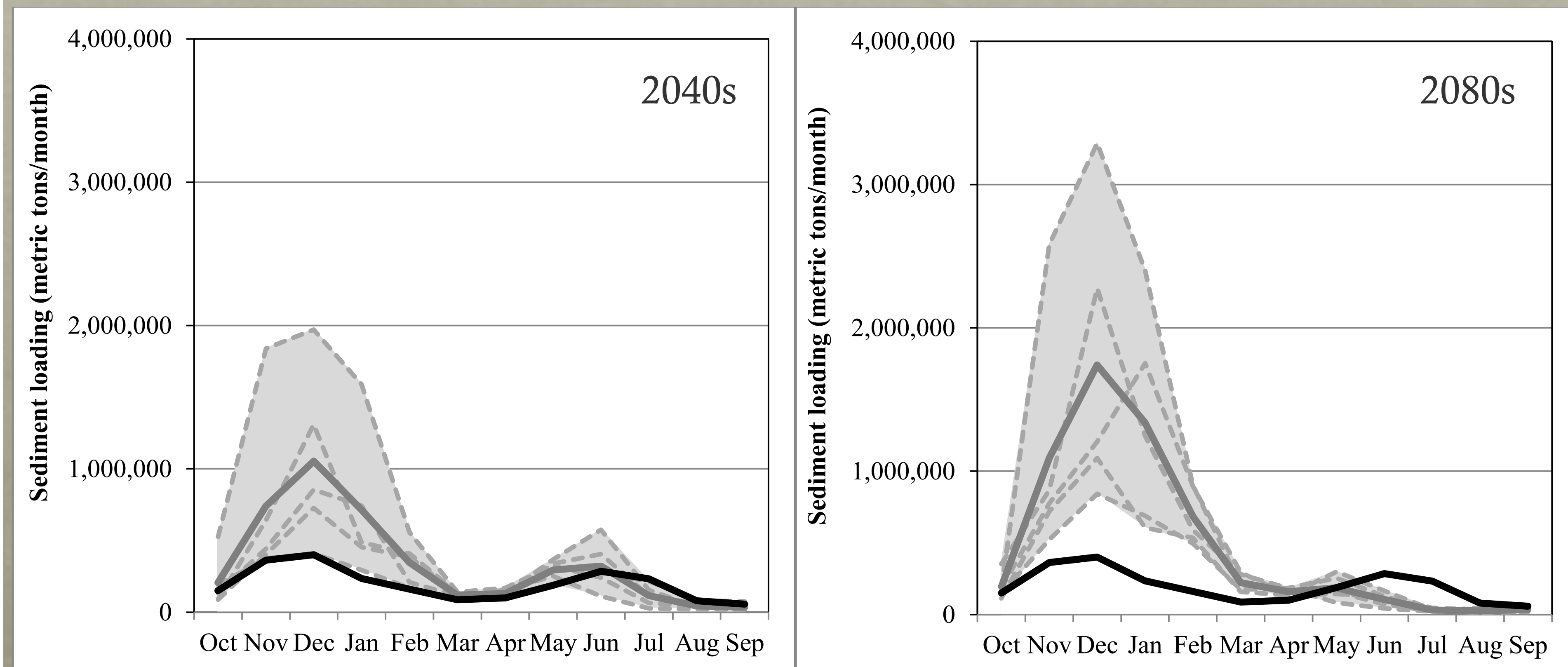
Retreating glaciers and declining snowpack are both hypothesized to increase sediment production in the future.

Current Sediment Transport Regime



(Source: Curran et al. 2011)

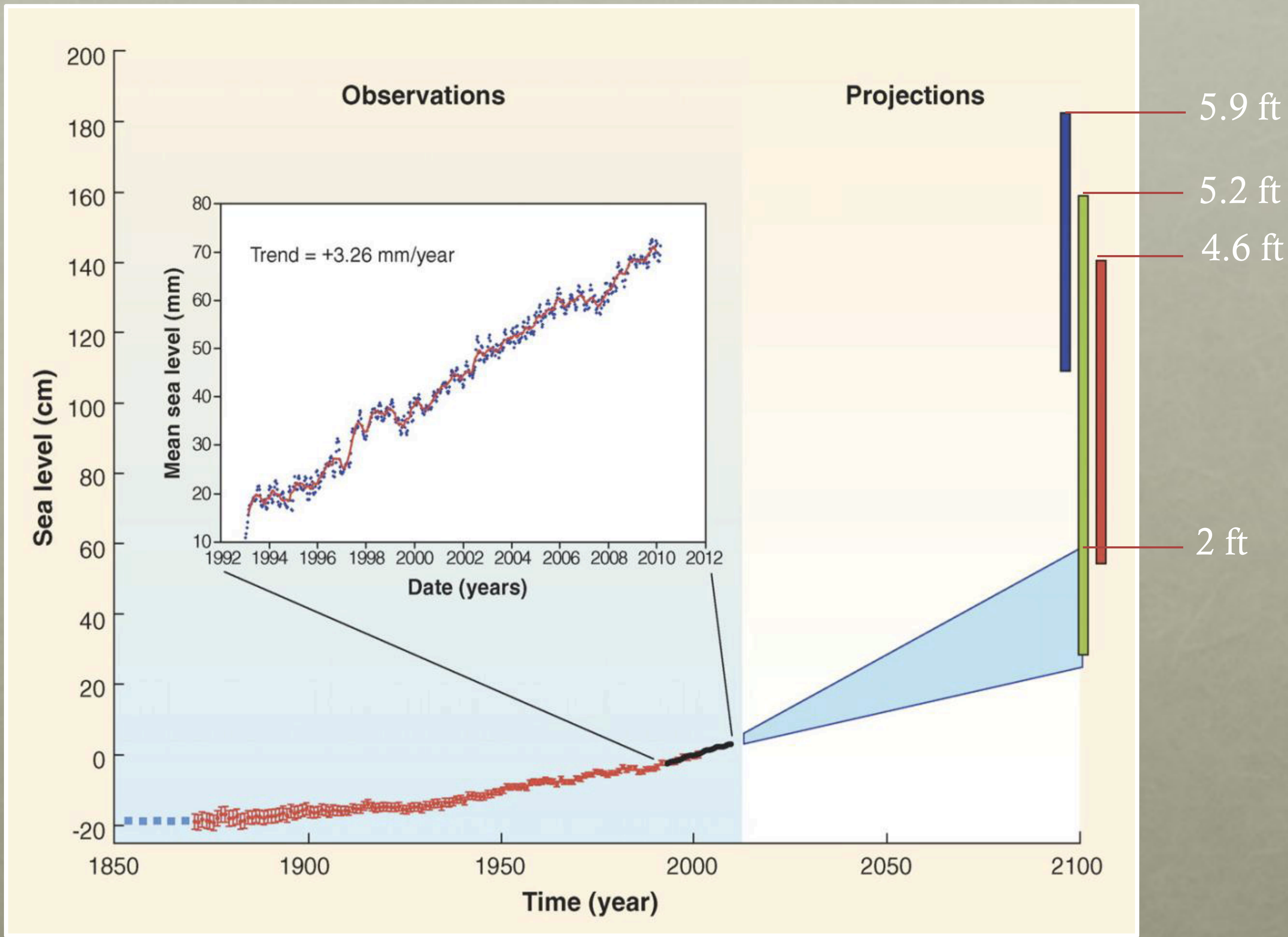
Daily Flow Regime Alone Changes Sediment Transport



Black lines show historical sediment transport
Grey shading and lines show the range and average of 5 climate change scenarios

Changing Sea Levels

Sea Level Rise Projections are Rapidly Evolving

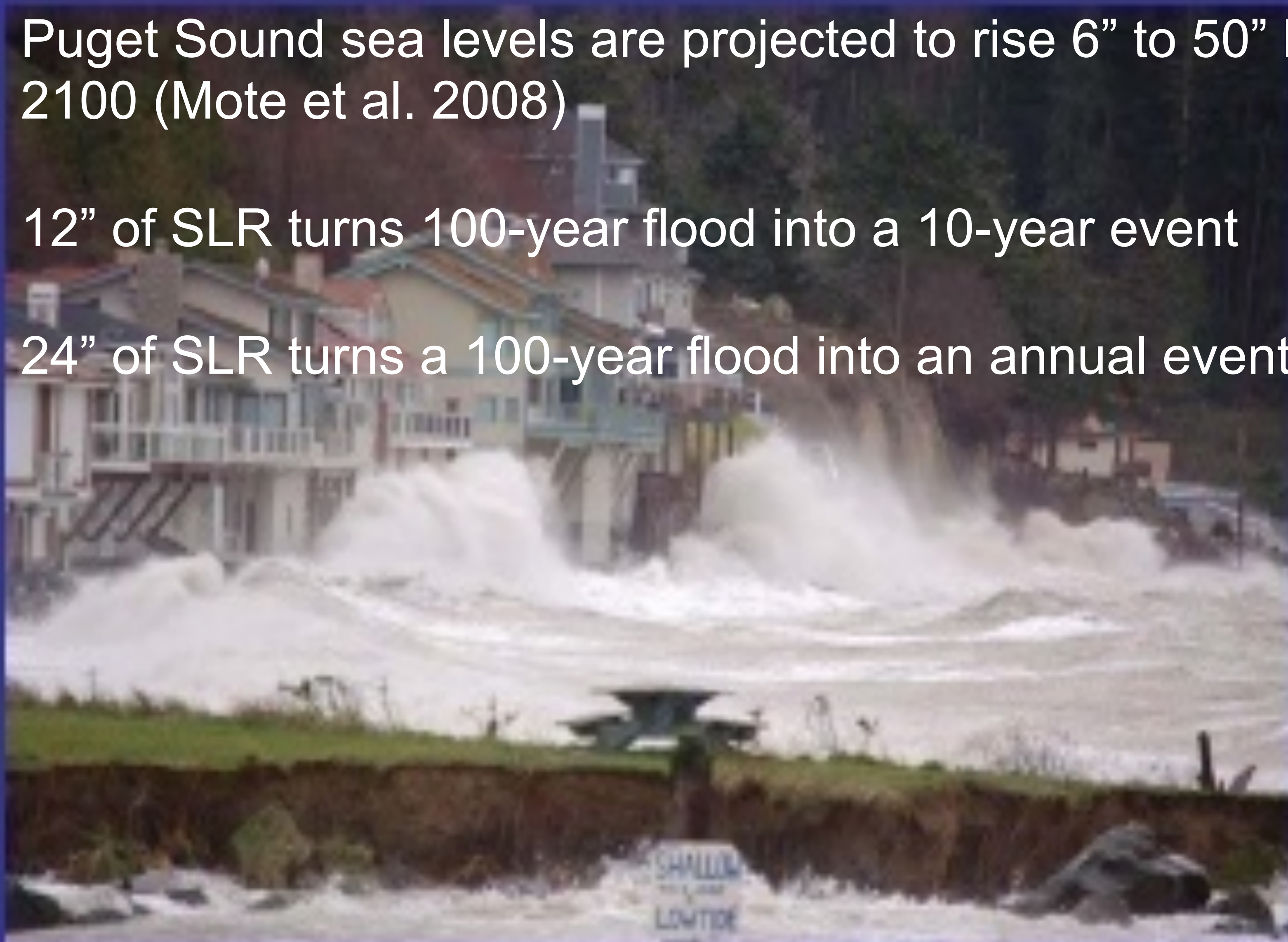


(Nicholls and Cazenave 2010)

Puget Sound sea levels are projected to rise 6” to 50” by 2100 (Mote et al. 2008)

12” of SLR turns 100-year flood into a 10-year event

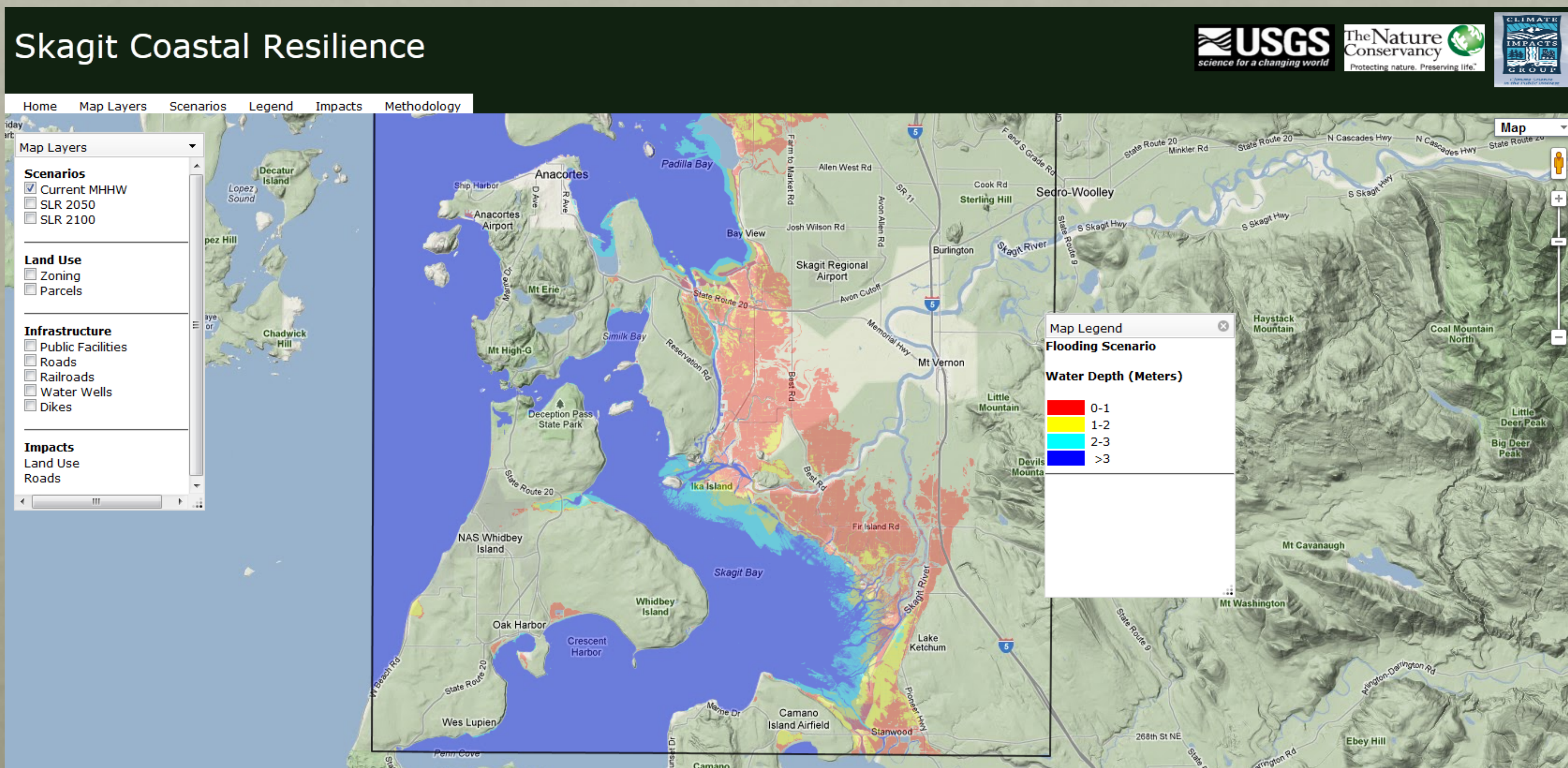
24” of SLR turns a 100-year flood into an annual event



Anacortes (4 February 2006)

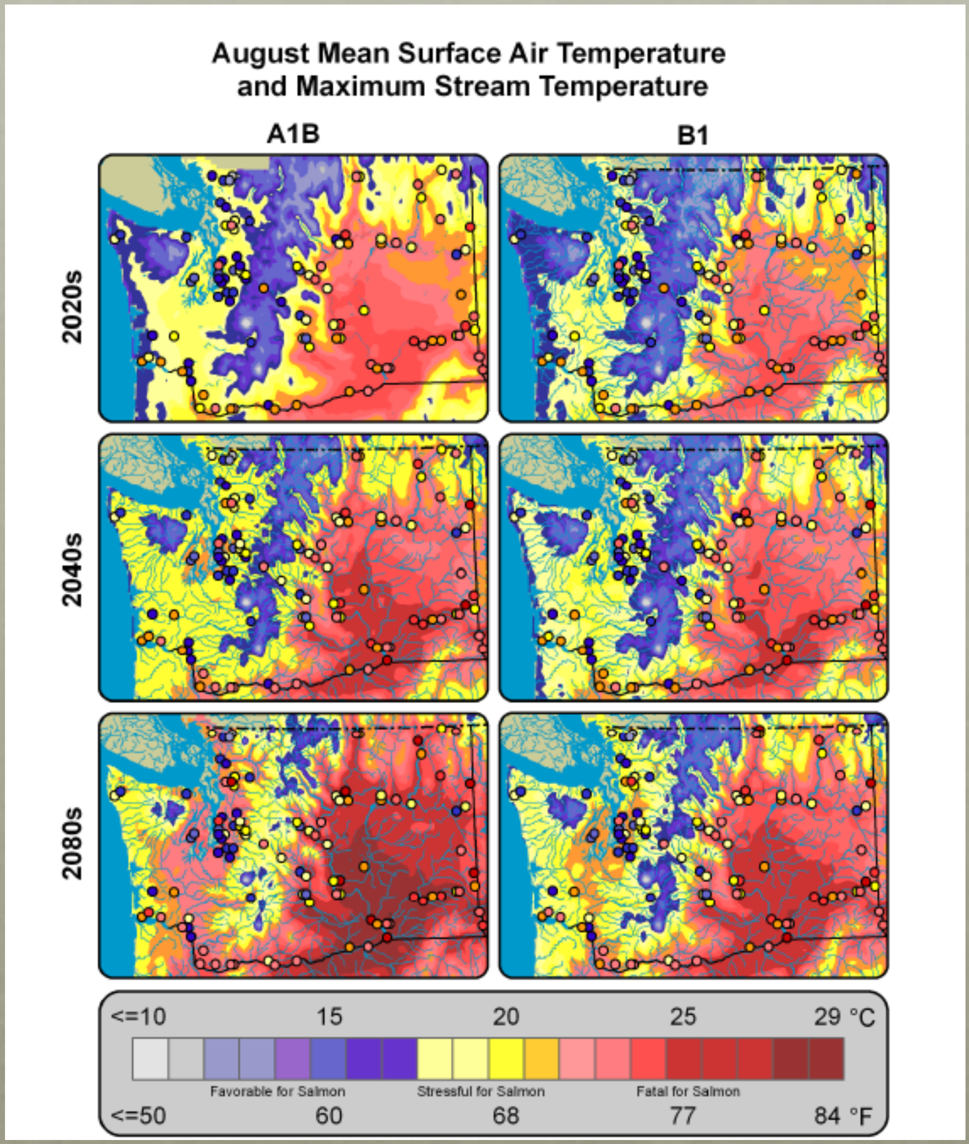
Coastal Flooding Scenarios (without dikes)

http://myweb.students.wwu.edu/hornep/SkagitCoastalResilience.html



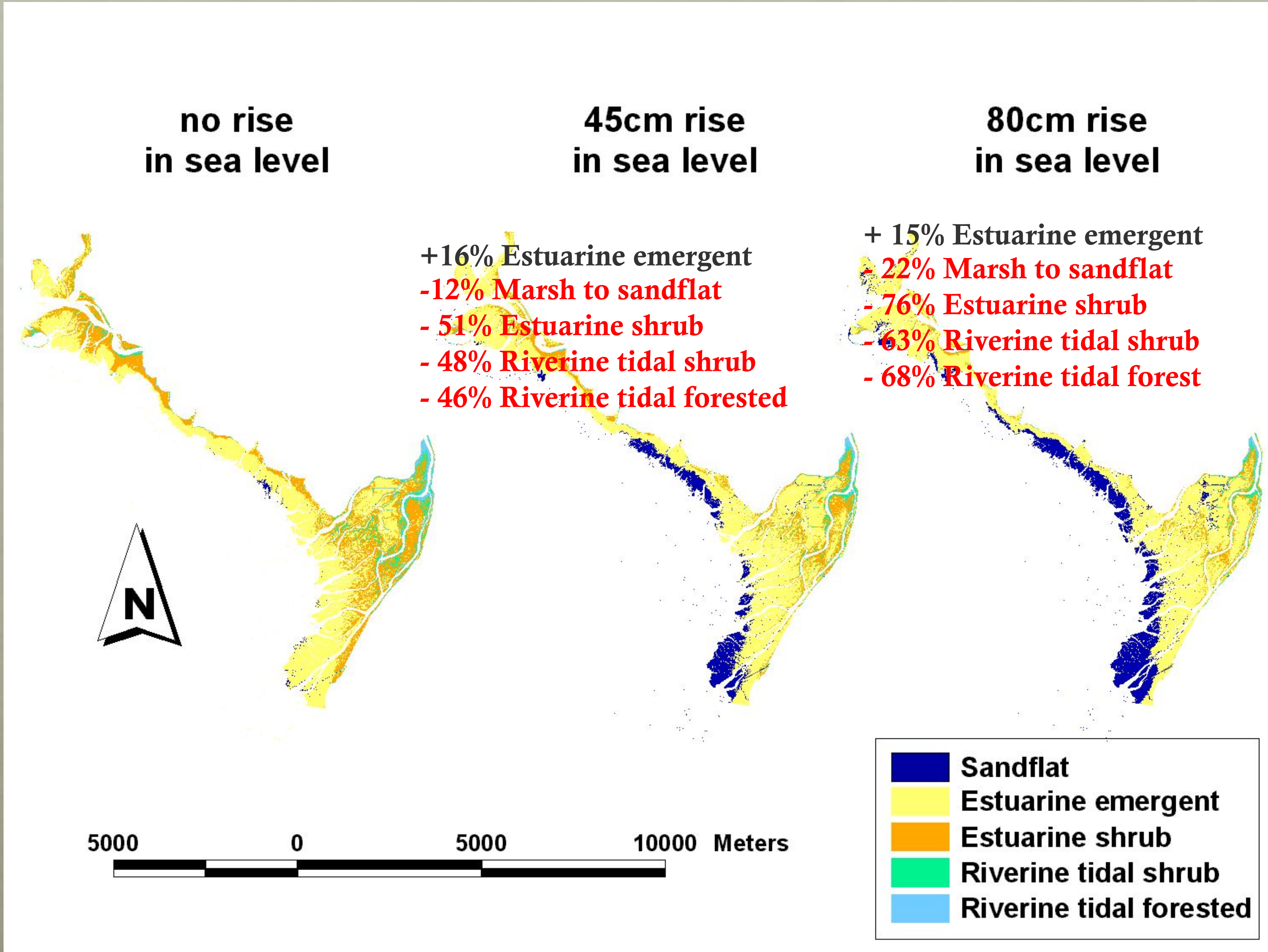
ECOSYSTEMS IMPACTS

Impacts to Cold Water Fish



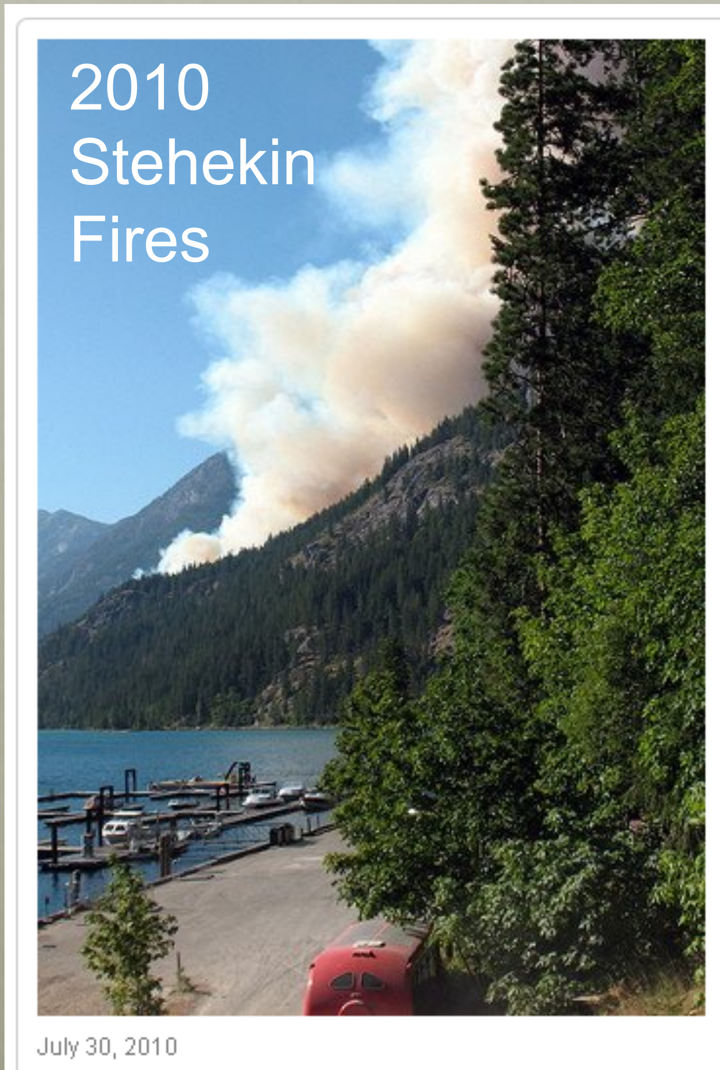
Mantua, N., I. Tohver, A.F. Hamlet, 2010: Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State, *Climatic Change*, online first, doi: 10.1007/s10584-010-9845-2

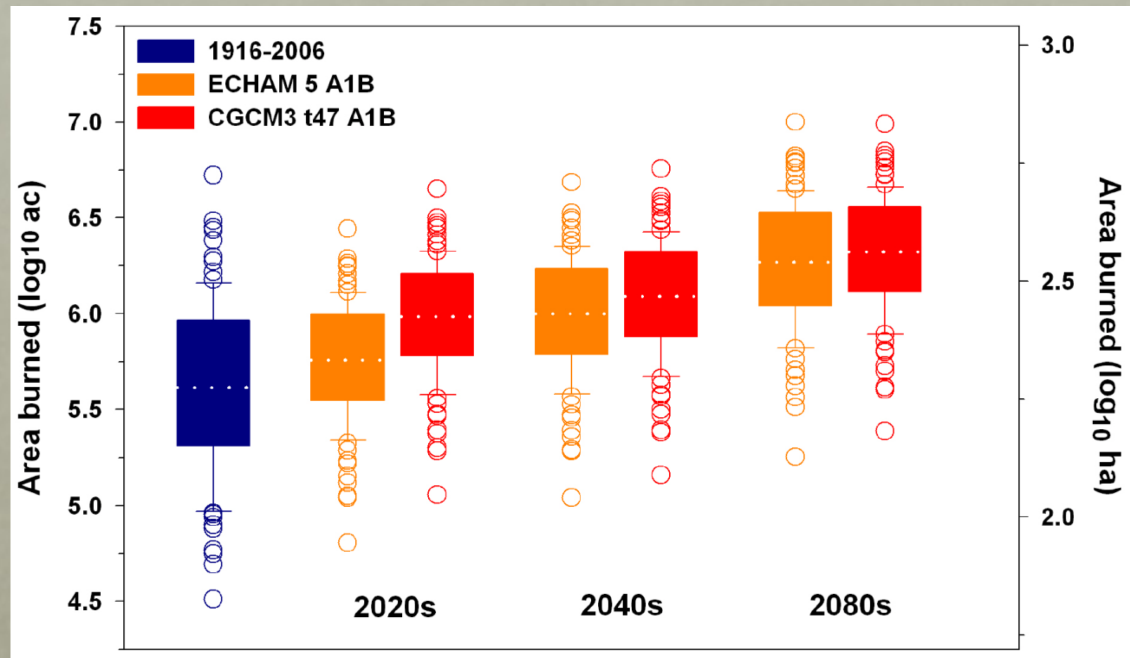
Projected Impacts to the Skagit Estuary



(Source: Beamer et al. 2005)

Forest Fire





Projected Area Burned in WA

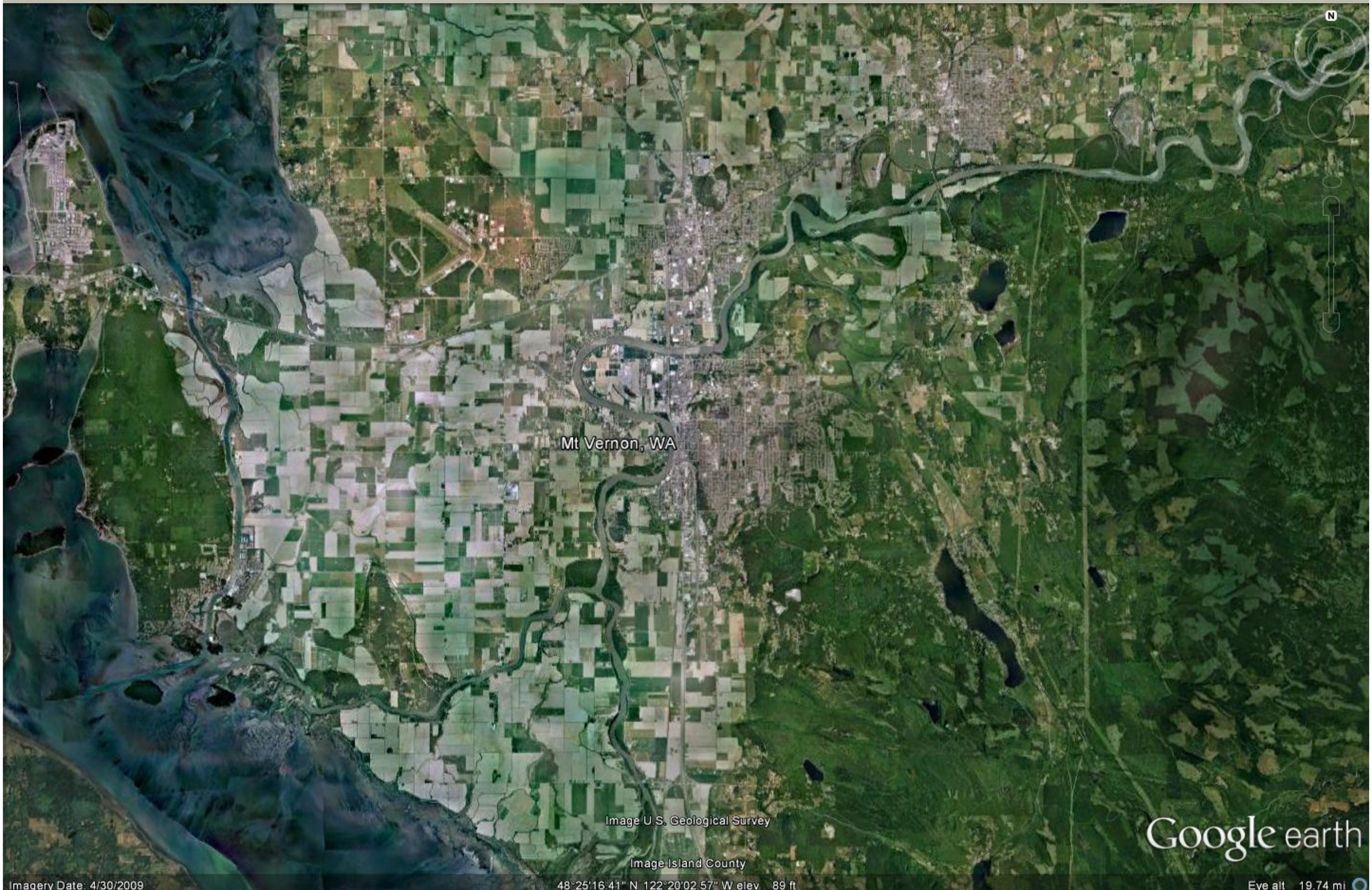
Littell, J.S., E.E. Oneil, D. McKenzie, J.A. Hicke, J.A. Lutz, R.A. Norheim, and M.M. Elsner. 2010. Forest ecosystems, disturbance, and climatic change in Washington State, USA. Climatic Change 102(1-2): 129-158, doi: 10.1007/s10584-010-9858-x

Insect Attack

Mountain Pine Beetle Damage in British Columbia

IMPACTS TO HUMAN COMMUNITIES

Floodplain Management



Coastal Inundation

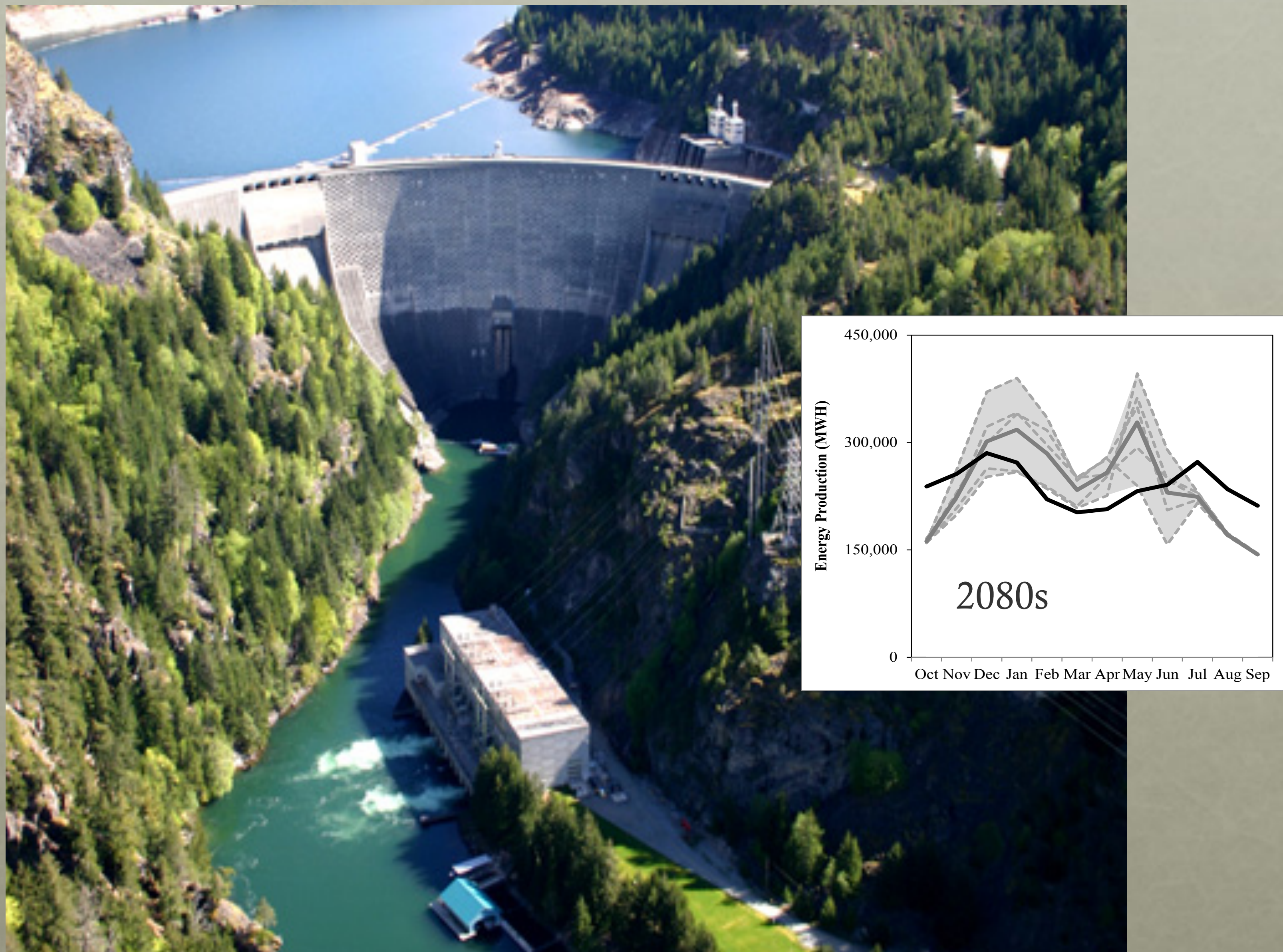
Effects of a “King Tide” at the Nisqually Wildlife Refuge in Sound Puget Sound on Feb 2, 2010 (photo by Russ McMillan).

Municipal Water Supply

Judy Reservoir, Skagit PUD
http://skagitpud.org/index.php/resources/water_system/watershed/

Agriculture

Hydropower Production



Ross Dam, Seattle City Light

Recreation

Please Visit SC2 at:

http://www.skagitclimatescience.org

Please Visit Climate Impacts Group at:

http://cses.washington.edu/cig/