SKAGIT CLIMATE SCIENCE CONSORTIUM

CLIMATE CHANGE 101
THE SKAGIT RIVER BASIN

Dr. Alan Hamlet

October 17th, 2012

WSU, Mt. Vernon

WEATHER VS. CLIMATE

WEATHER:

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

CLIMATE:

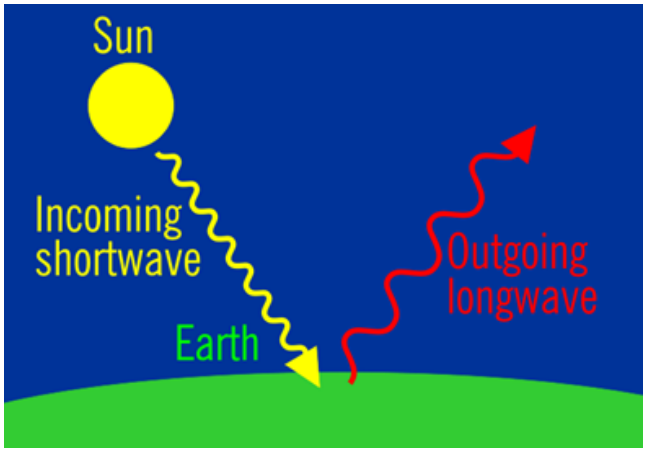
Long-term statistics of weather (timescale: usually 30+ years)

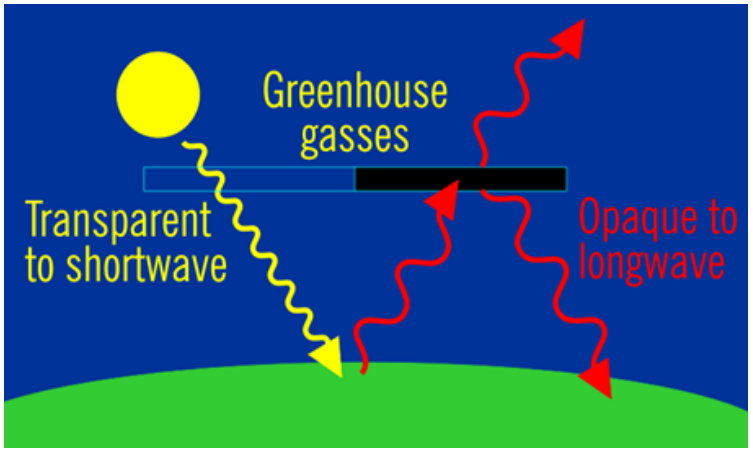
Climate is what you ***expect*** today (norms)

Weather is what you ***get*** today (rainy, sunny, cold, hot)

THE GREENHOUSE EFFECT

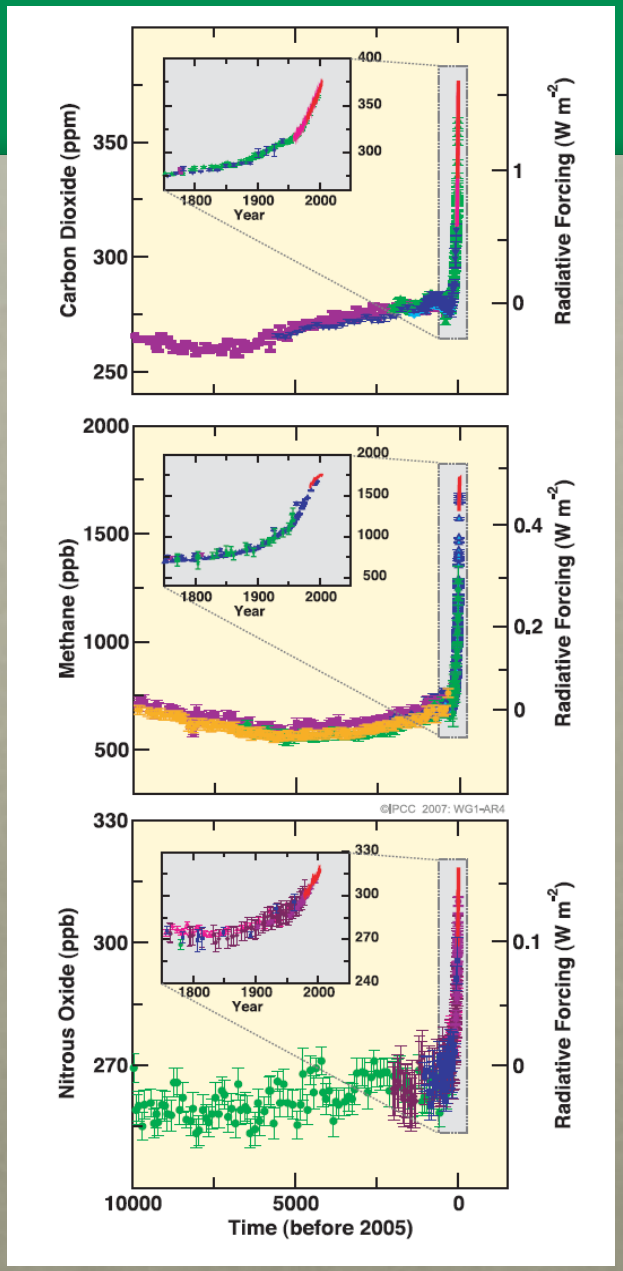
There is a natural greenhouse effect that warms the earth's average surface temperature by ~33 C (about 60 deg. F)

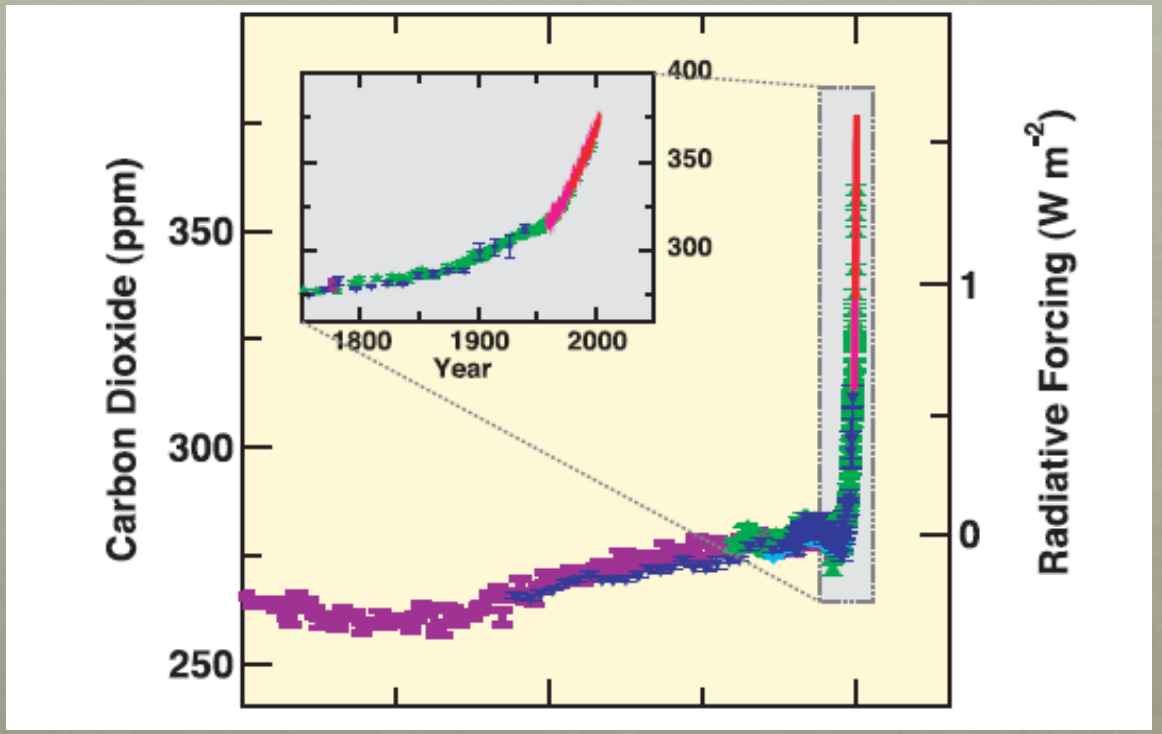




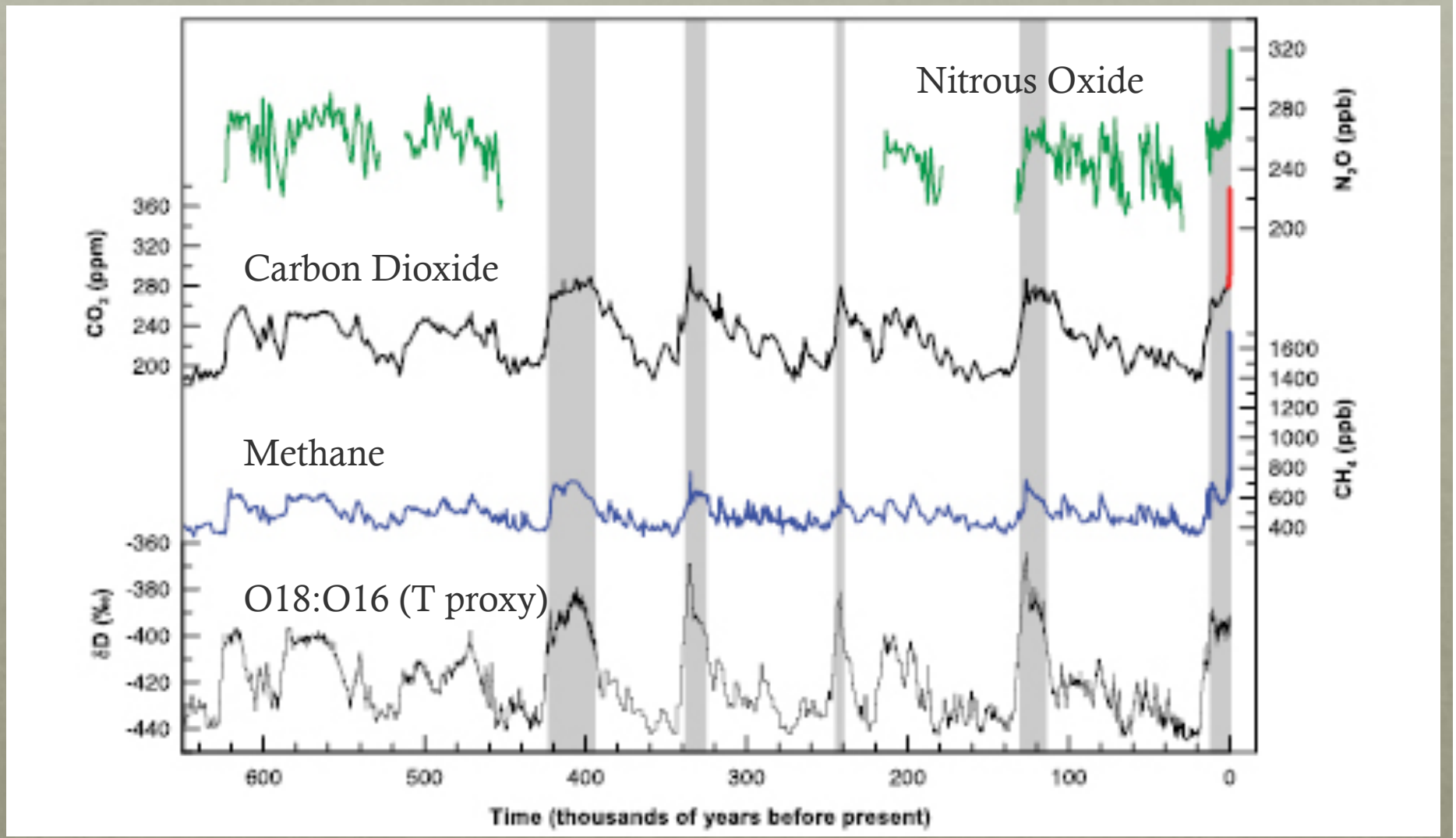
http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/models

SOURCES OF GLOBAL CLIMATE CHANGE

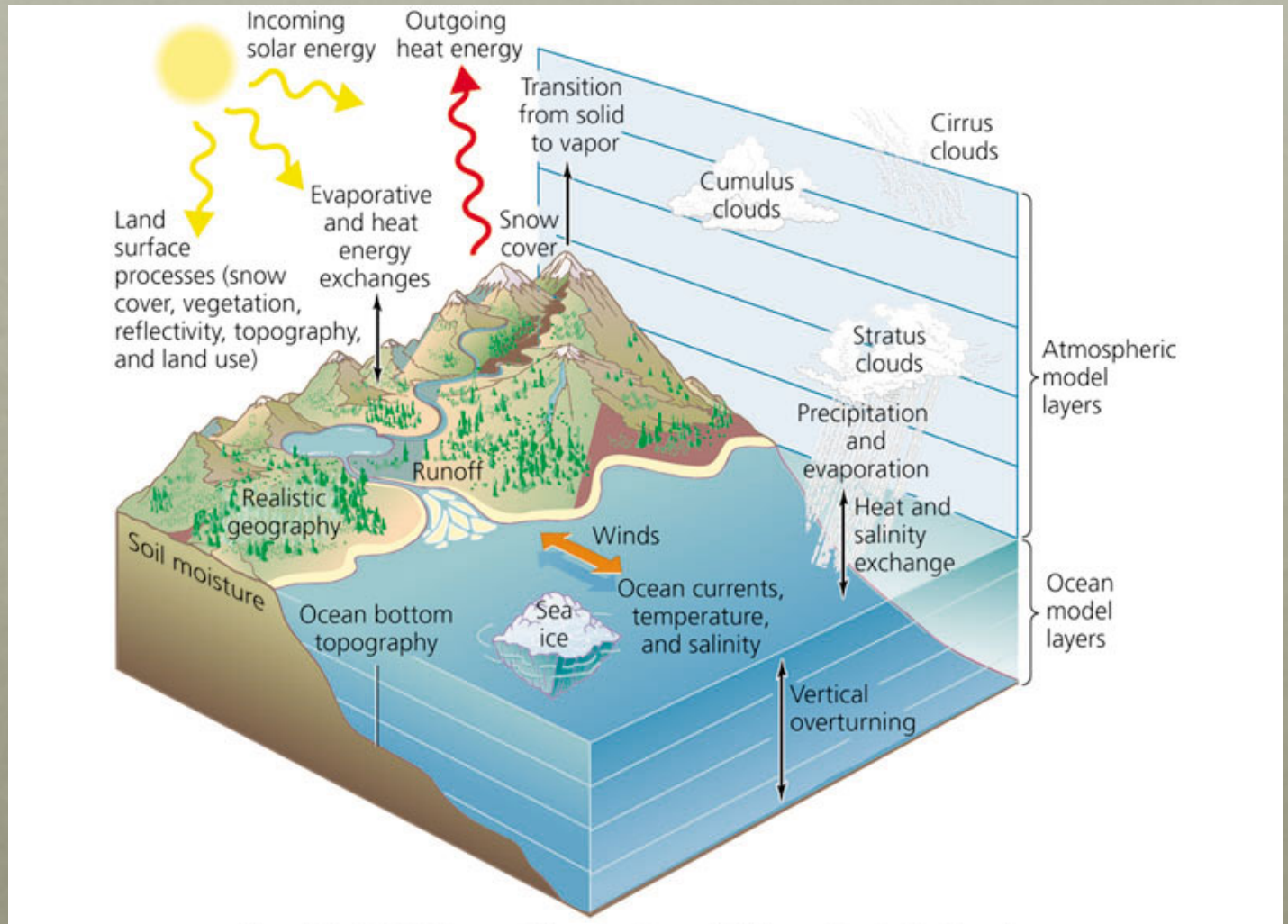




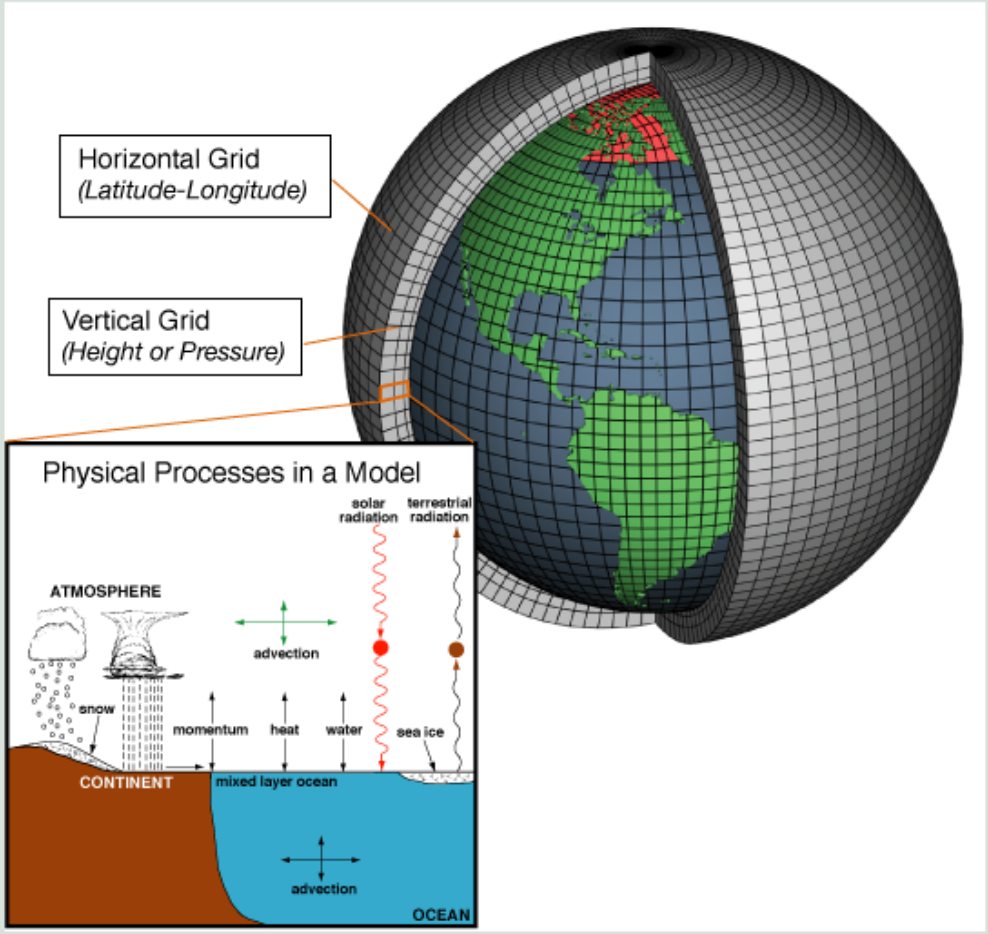
PALEOCLIMATIC RECONSTRUCTIONS



GLOBAL CLIMATE SYSTEM



GLOBAL CLIMATE MODELS

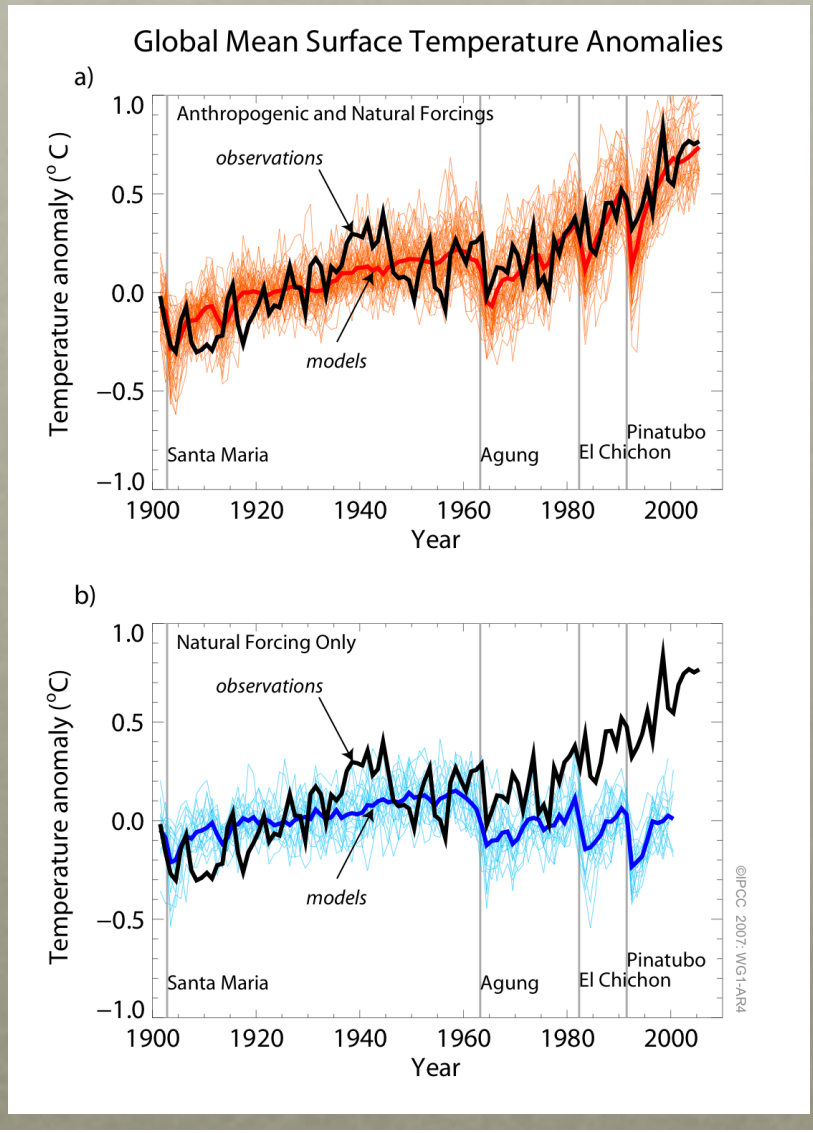


Climate models are systems of differential equations based on the basic laws of physics, fluid motion, and chemistry. To "run" a model, scientists divide the planet into a 3-dimensional grid, apply the basic equations, and evaluate the results. Atmospheric models calculate winds, heat transfer, radiation,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

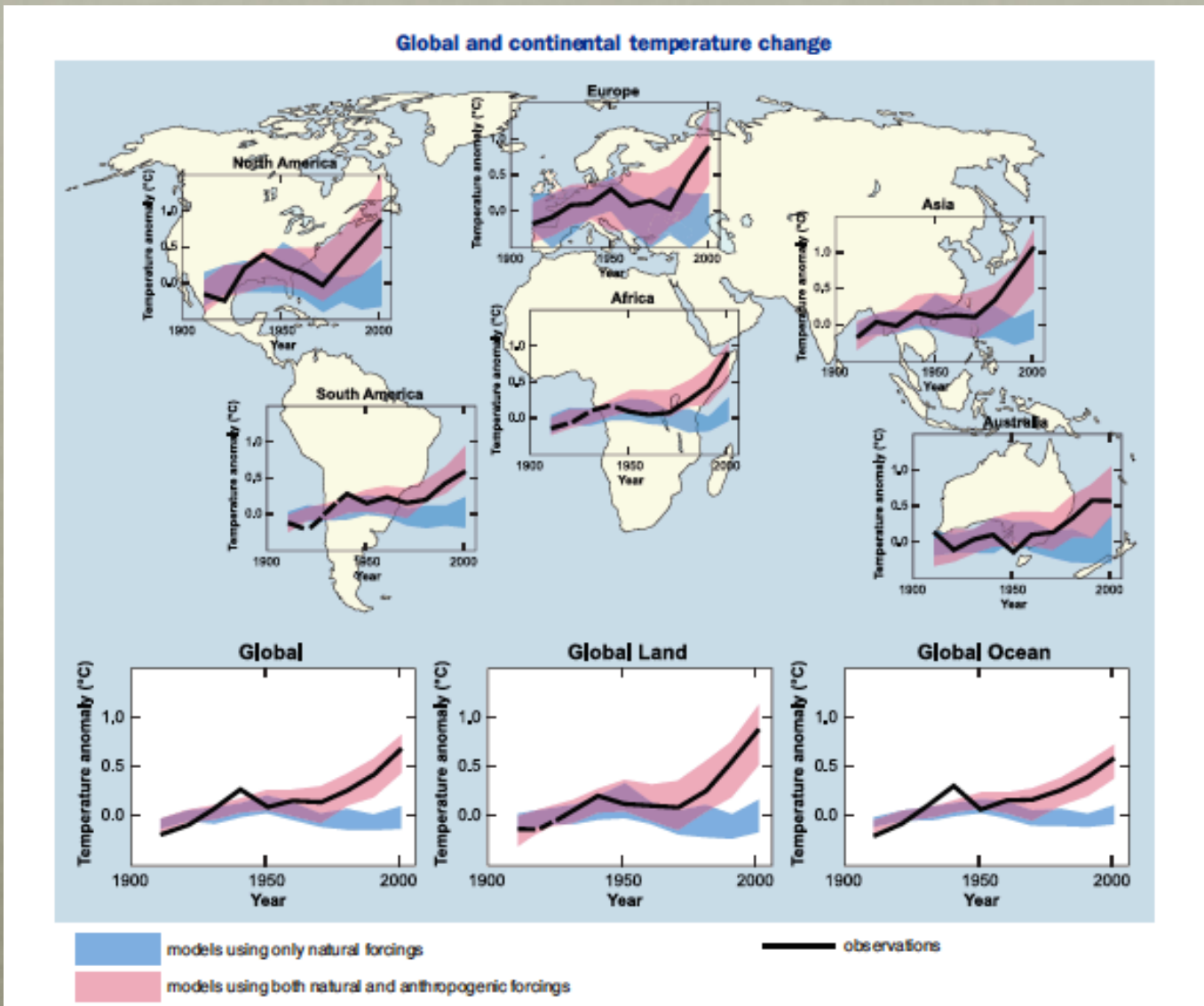
QUANTIFYING THE HUMAN ROLE IN OBSERVED CLIMATE CHANGE

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

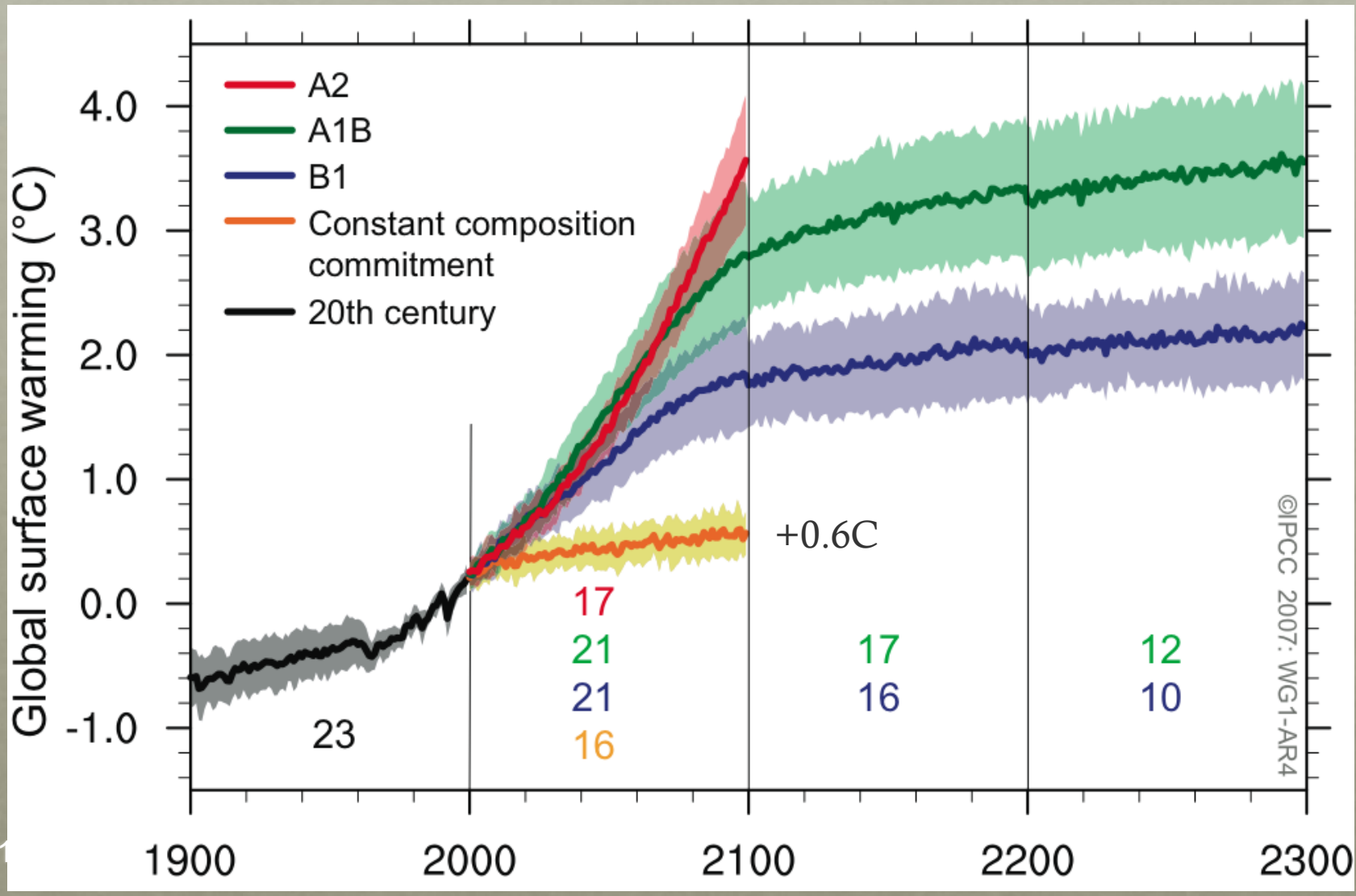
Volcanic eruptions, variations in solar radiation, etc. cannot alone explain rapid rise in temperature at the end of the 20th century.



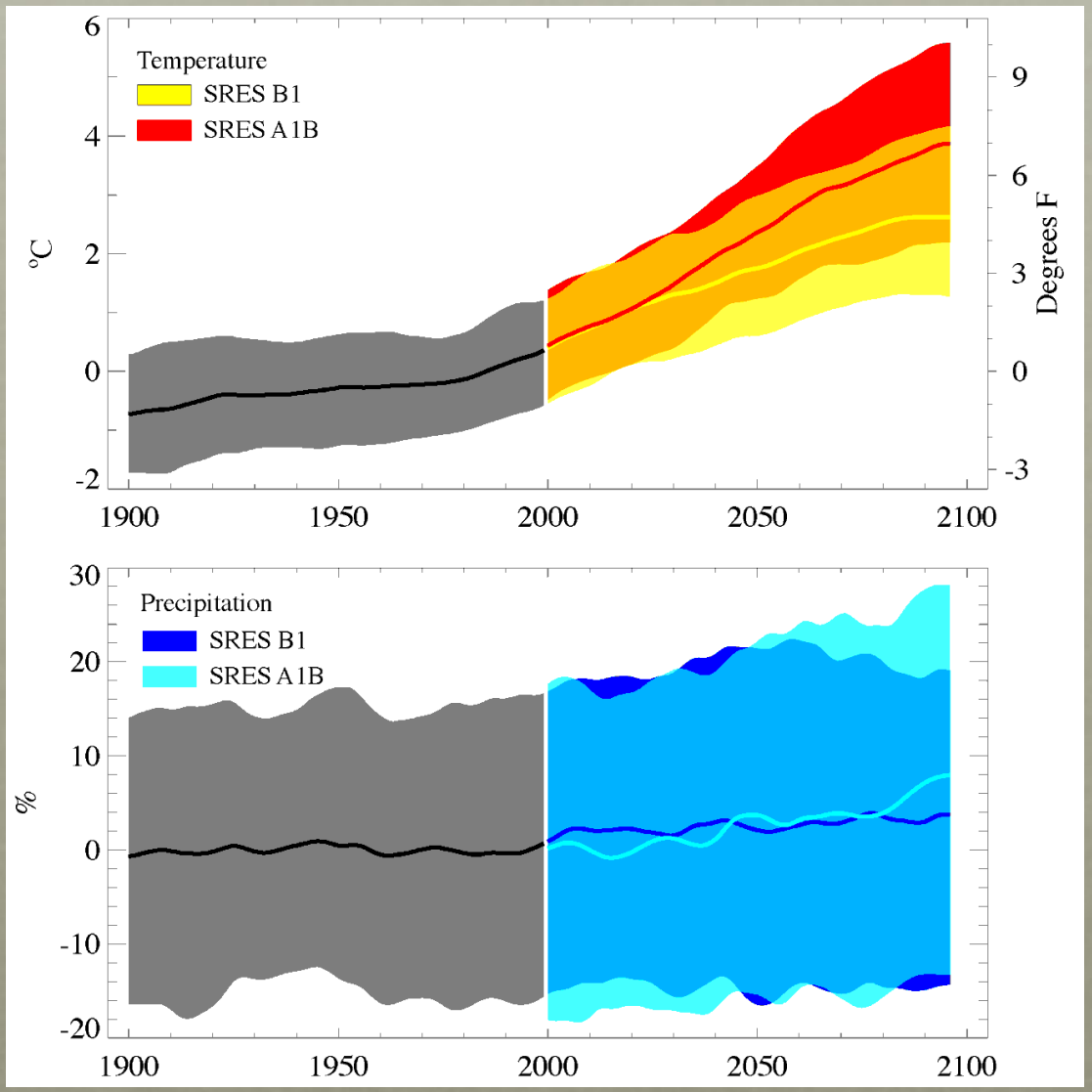
ATTRIBUTION OF REGIONAL TRENDS



FUTURE EMISSIONS SCENARIOS



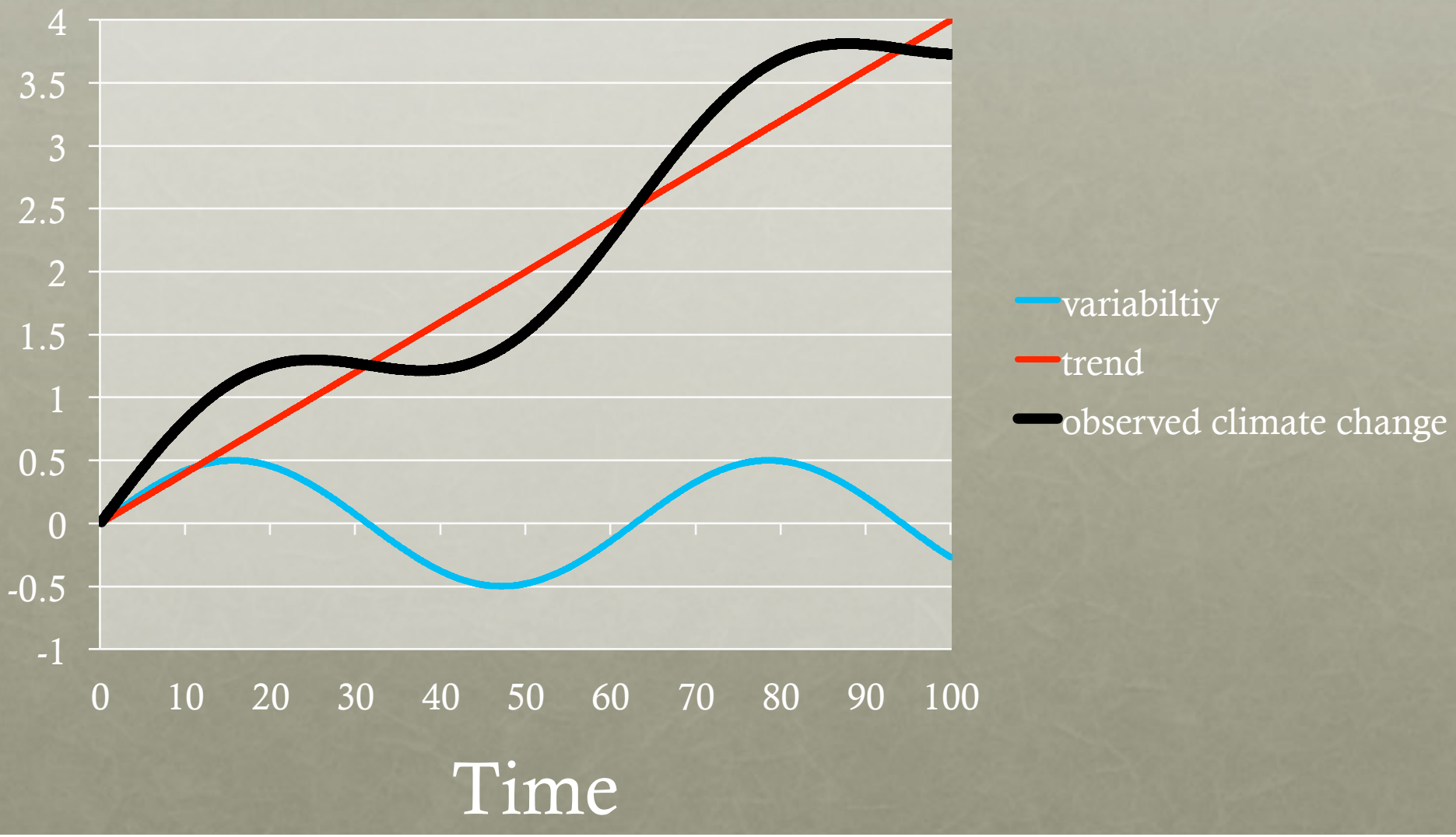
PNW TEMPERATURE AND PRECIPITATION SCENARIOS



Model Consensus:

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

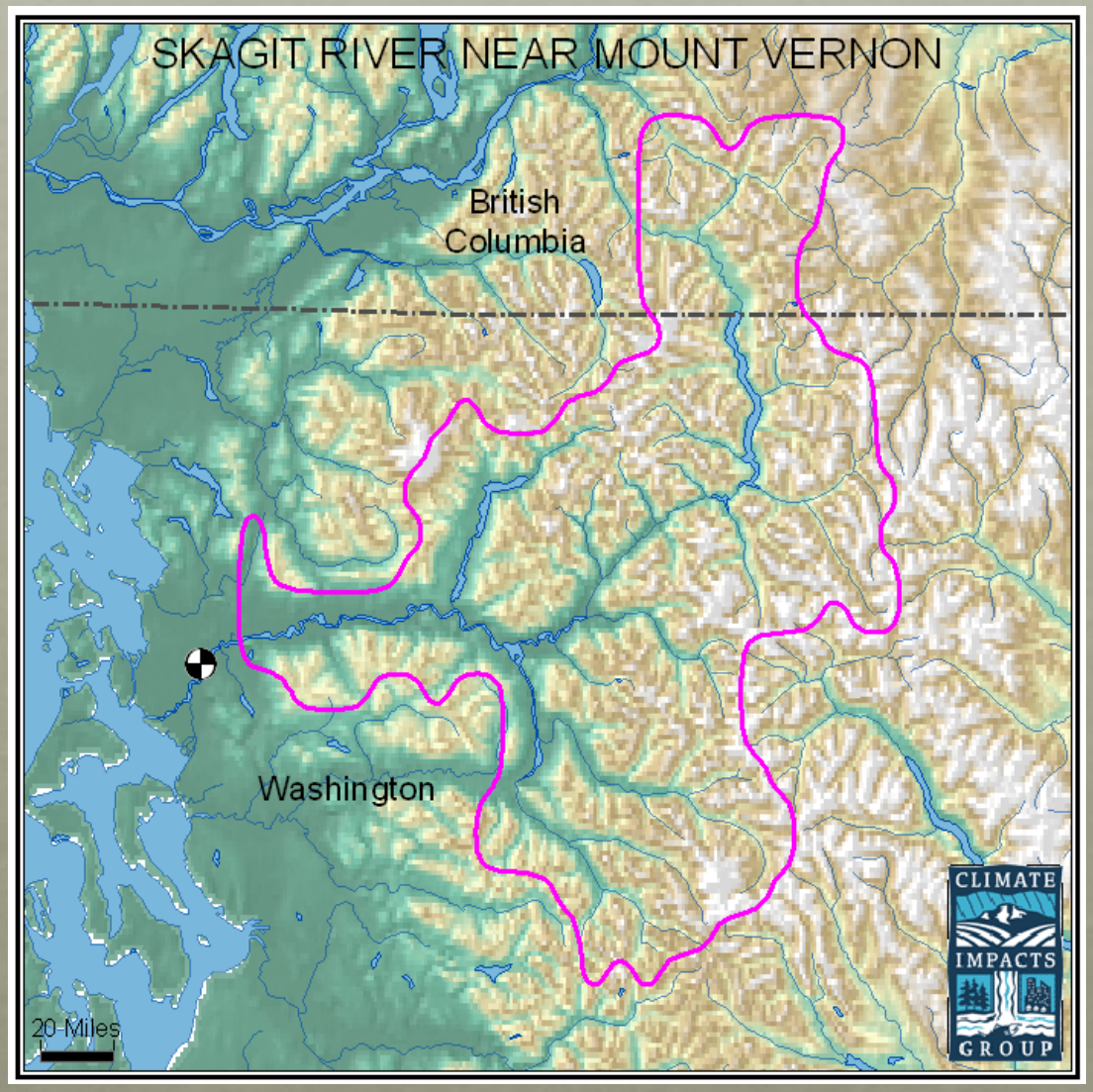
CLIMATE CHANGE WILL EXPRESS ITSELF AS A COMPLEX COMBINATION OF VARIABILITY PLUS TREND



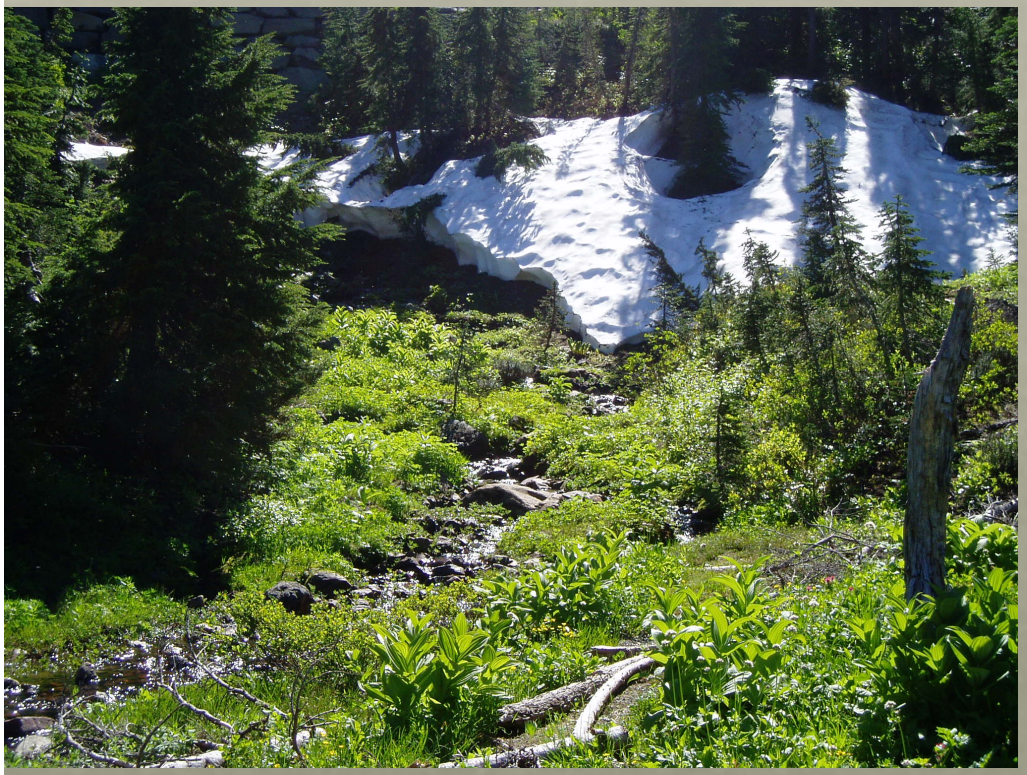
How will the Skagit Basin respond to a changing climate?

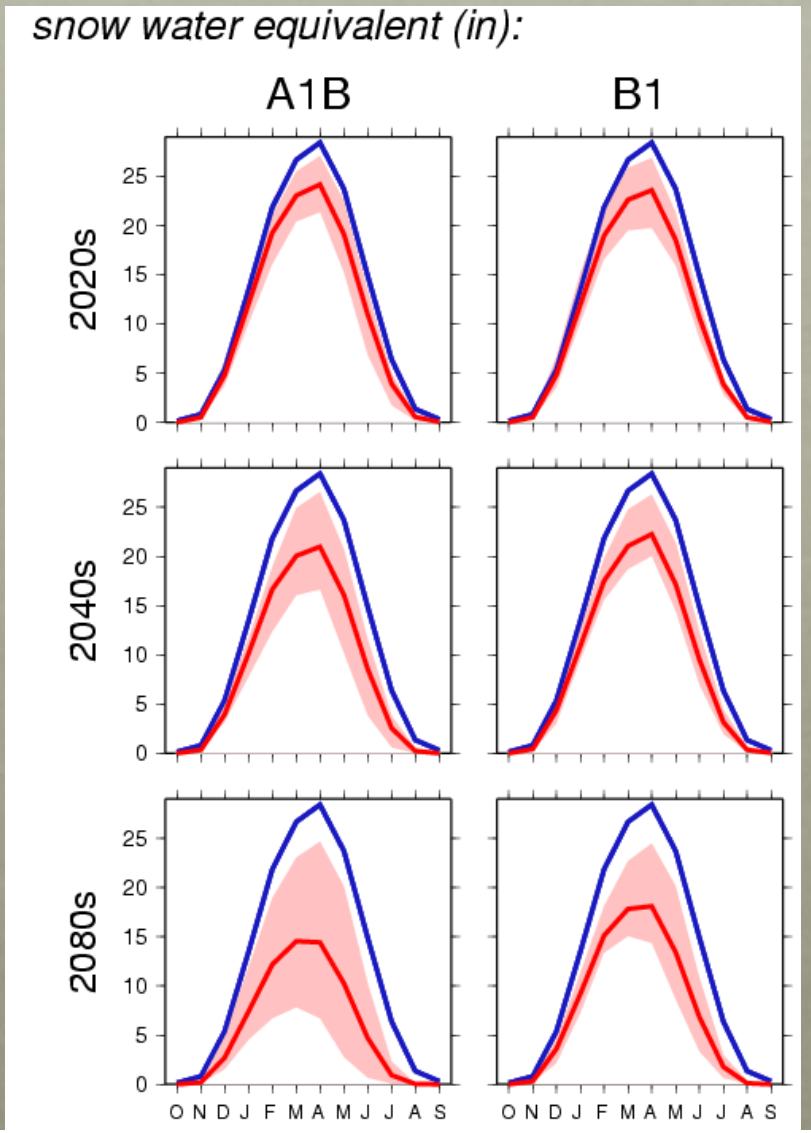
CHANGING HYDROLOGY

CHANGING LOCAL HYDROLOGY

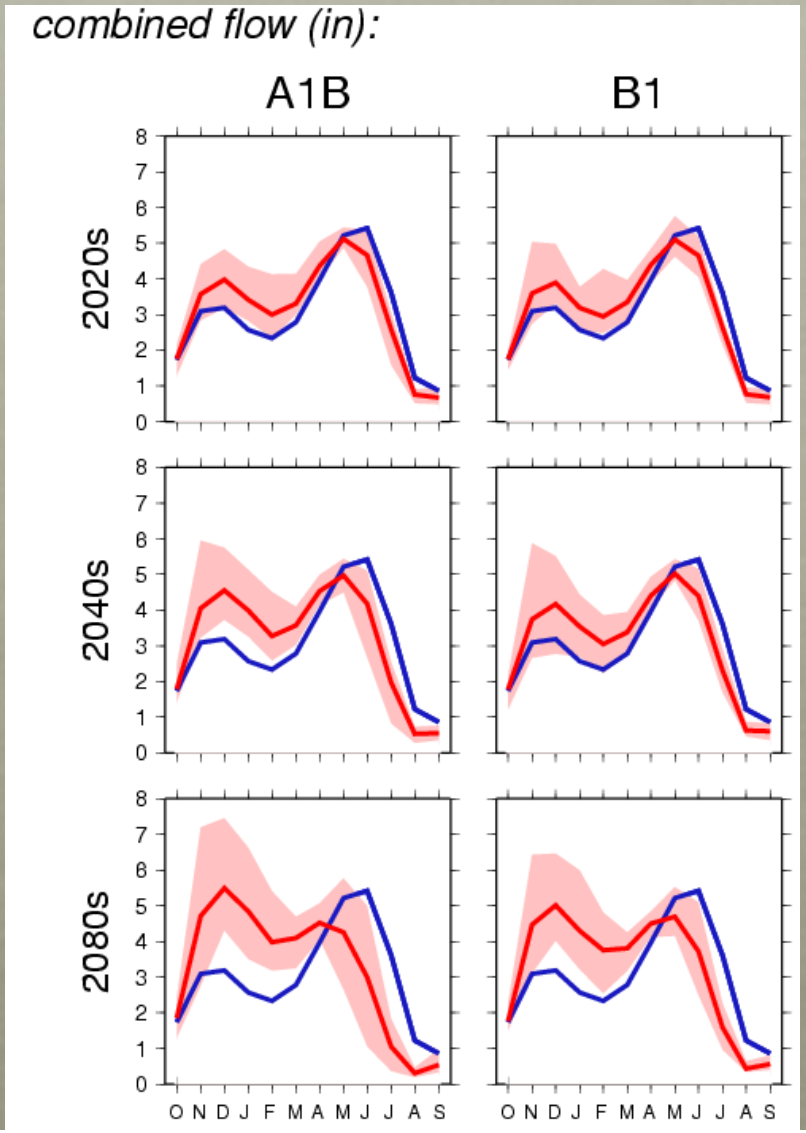


REDUCTIONS IN SNOWPACK

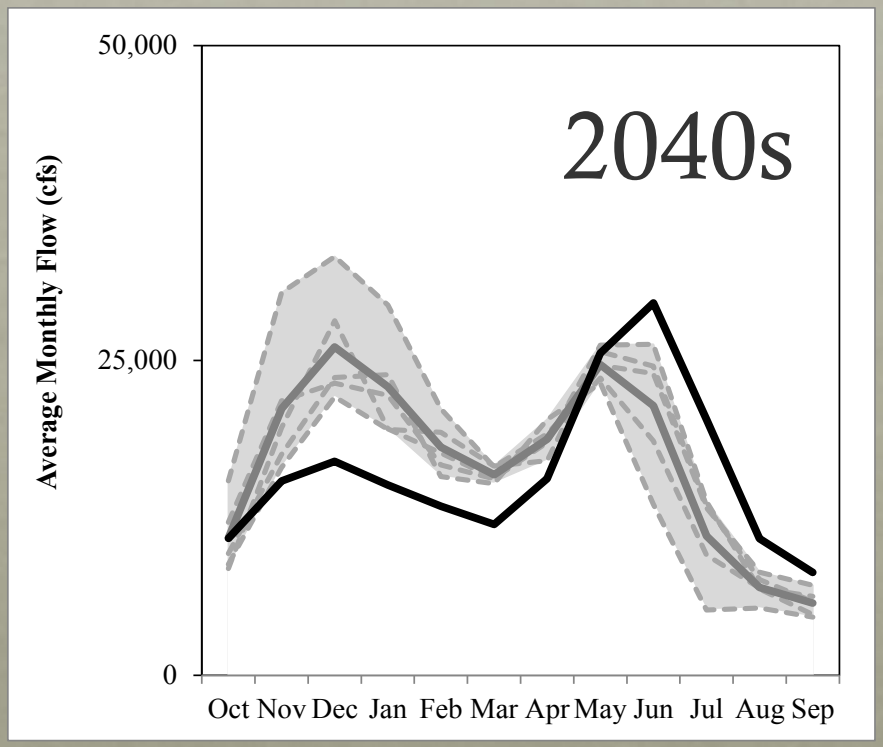


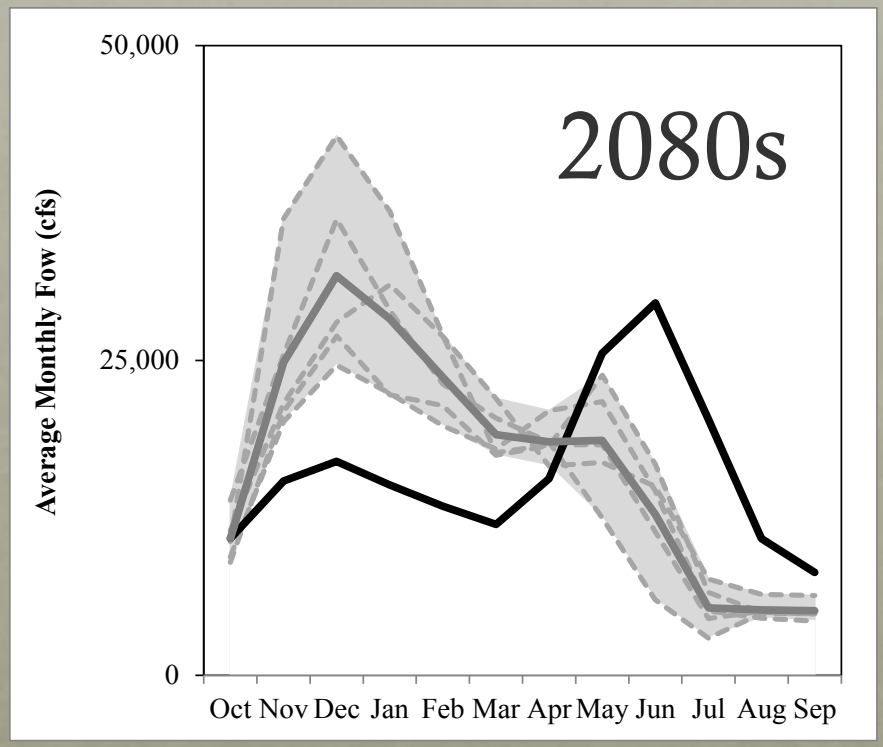


CHANGES IN MAGNITUDE AND SEASONAL TIMING OF STREAMFLOW



CHANGES IN REGULATED STREAMFLOW





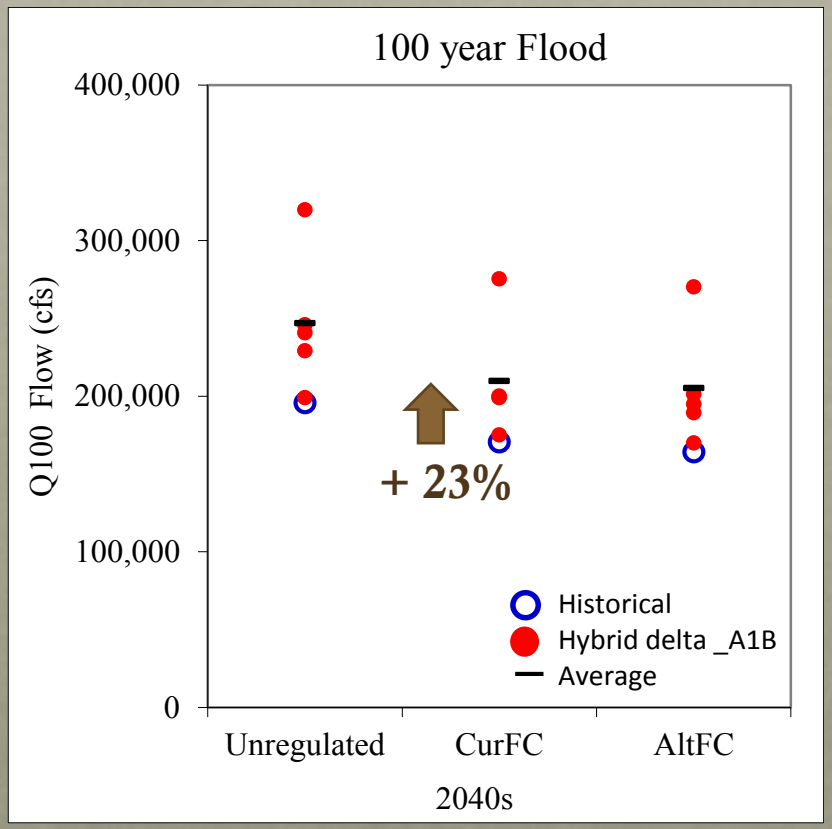
Skagit River at Mount Vernon

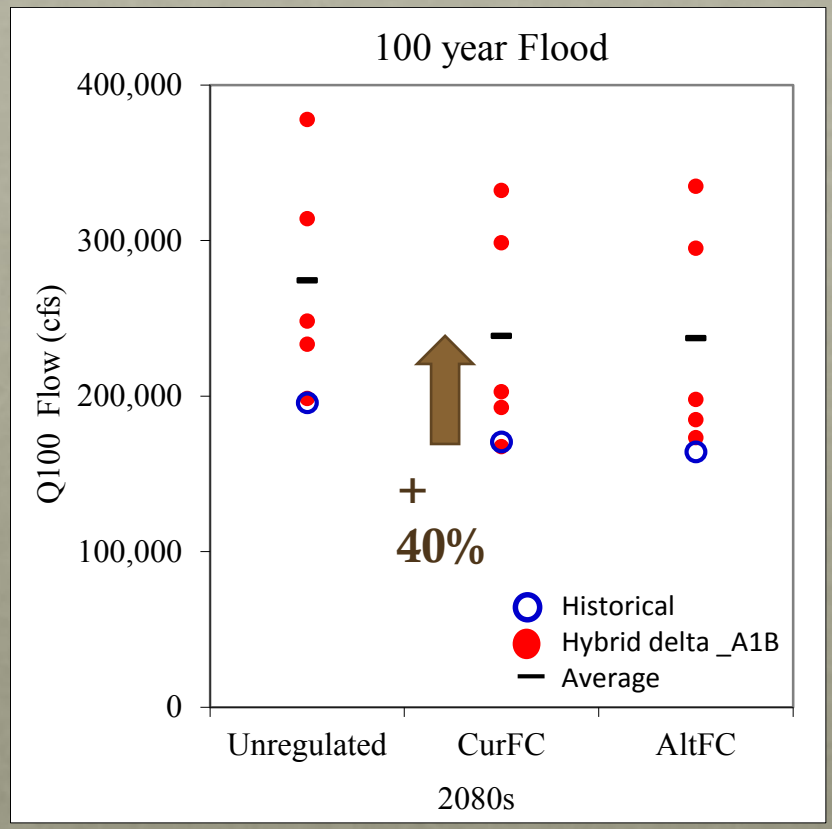
Lee, Se-Yeun, A.F. Hamlet, 2012: Effects of Climate Change on Hydrology and Water Management in the Skagit River Basin (in prep).

HYDROLOGIC EXTREMES

CHANGES IN THE NATURAL AND REGULATED 100-YEAR FLOOD AT MT. VERNON

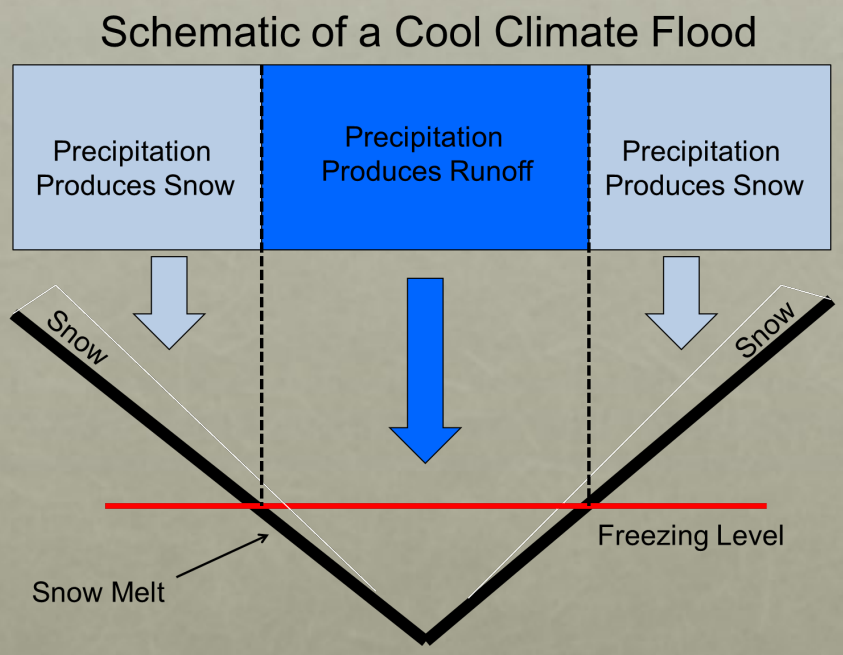
Skagit dams reduce flooding, but most of the runoff production during floods is downstream of headwater dams, which limits the role that reservoir operations can play in protecting the lower basin from projected larger future floods.

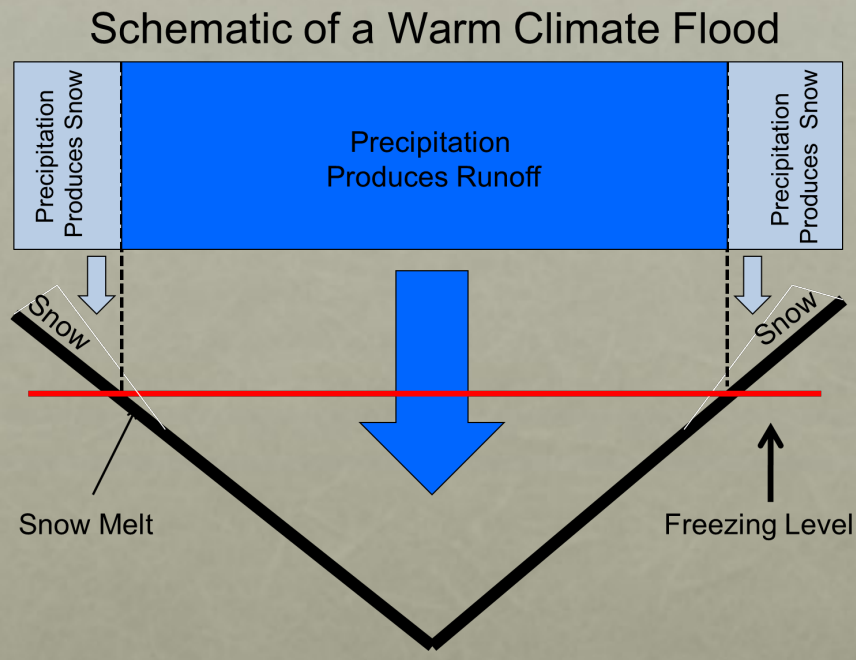




Source: Lee & Hamlet, 2012

CHANGING SNOW LINE AND EFFECTIVE BASIN AREA

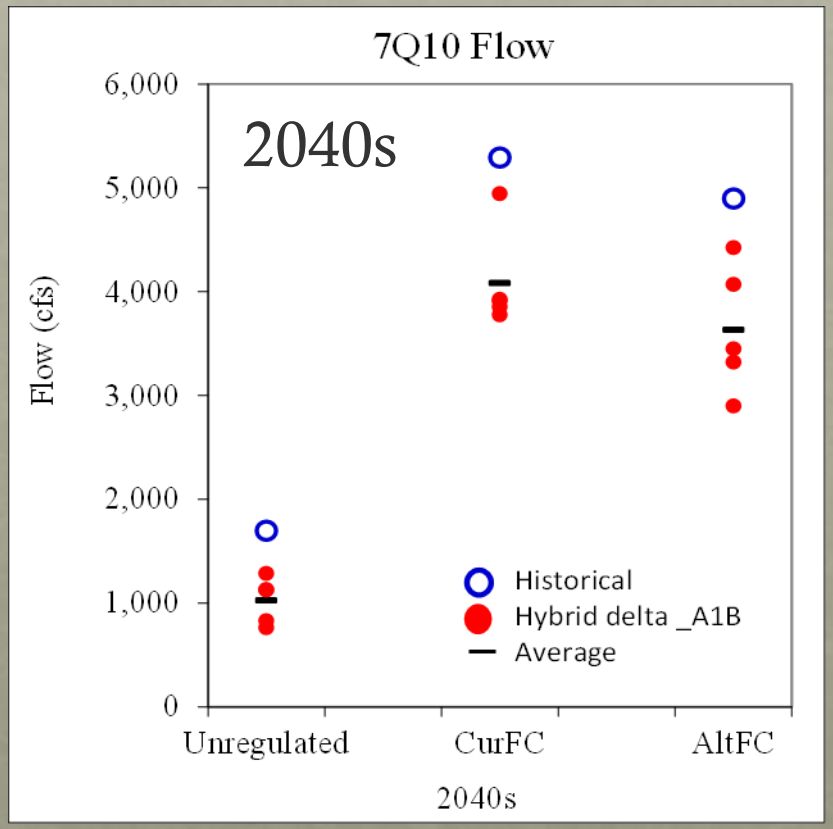


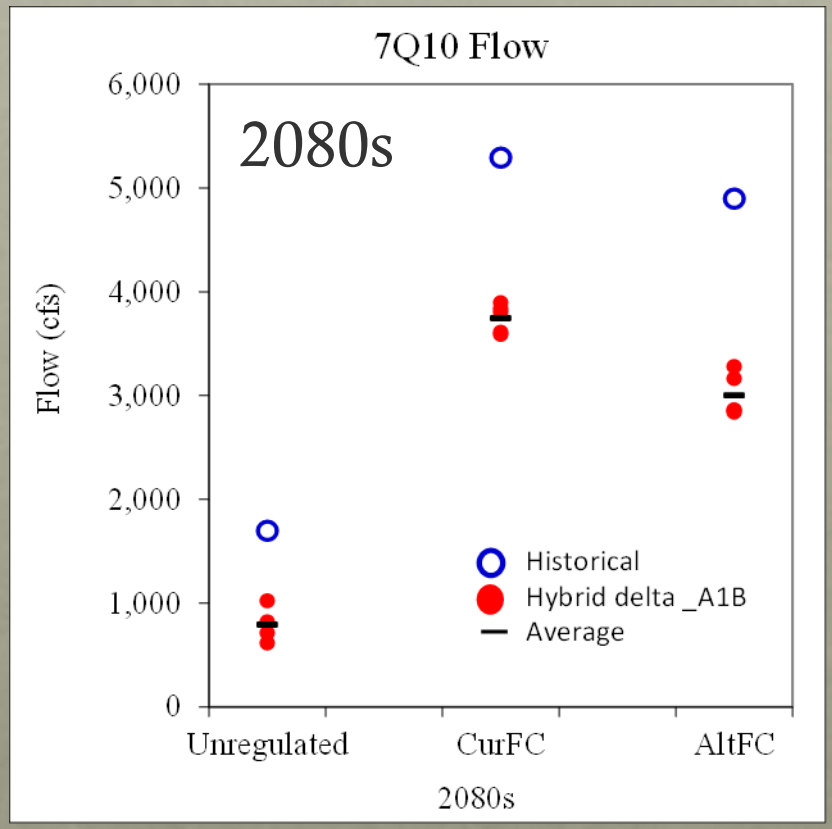


Since 1958 the average winter freezing elevation is estimated to have risen more than 600 feet in the Skagit basin. A higher freezing elevation increases the effective basin area that produces runoff during winter storms.

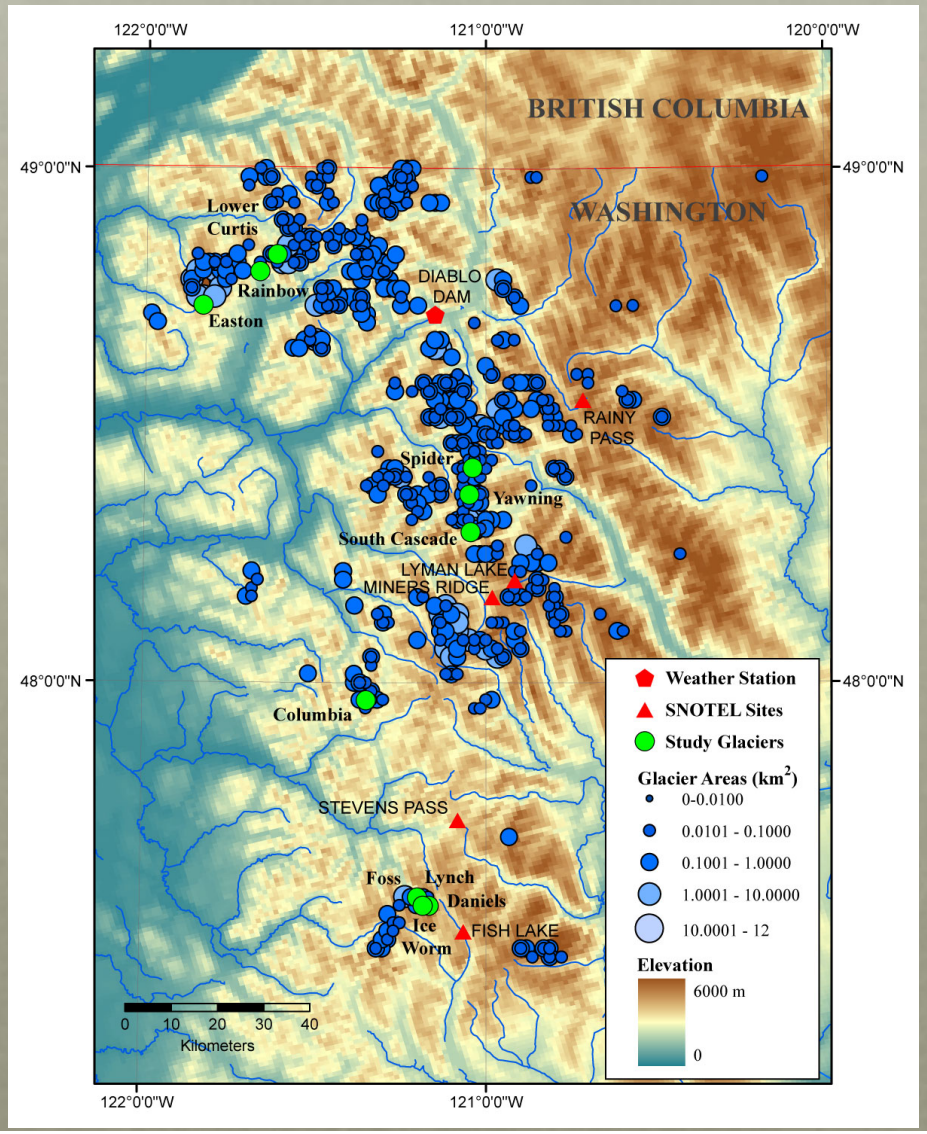
CHANGES IN REGULATED LOW FLOWS (7Q10)

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





CHANGING GLACIERS



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

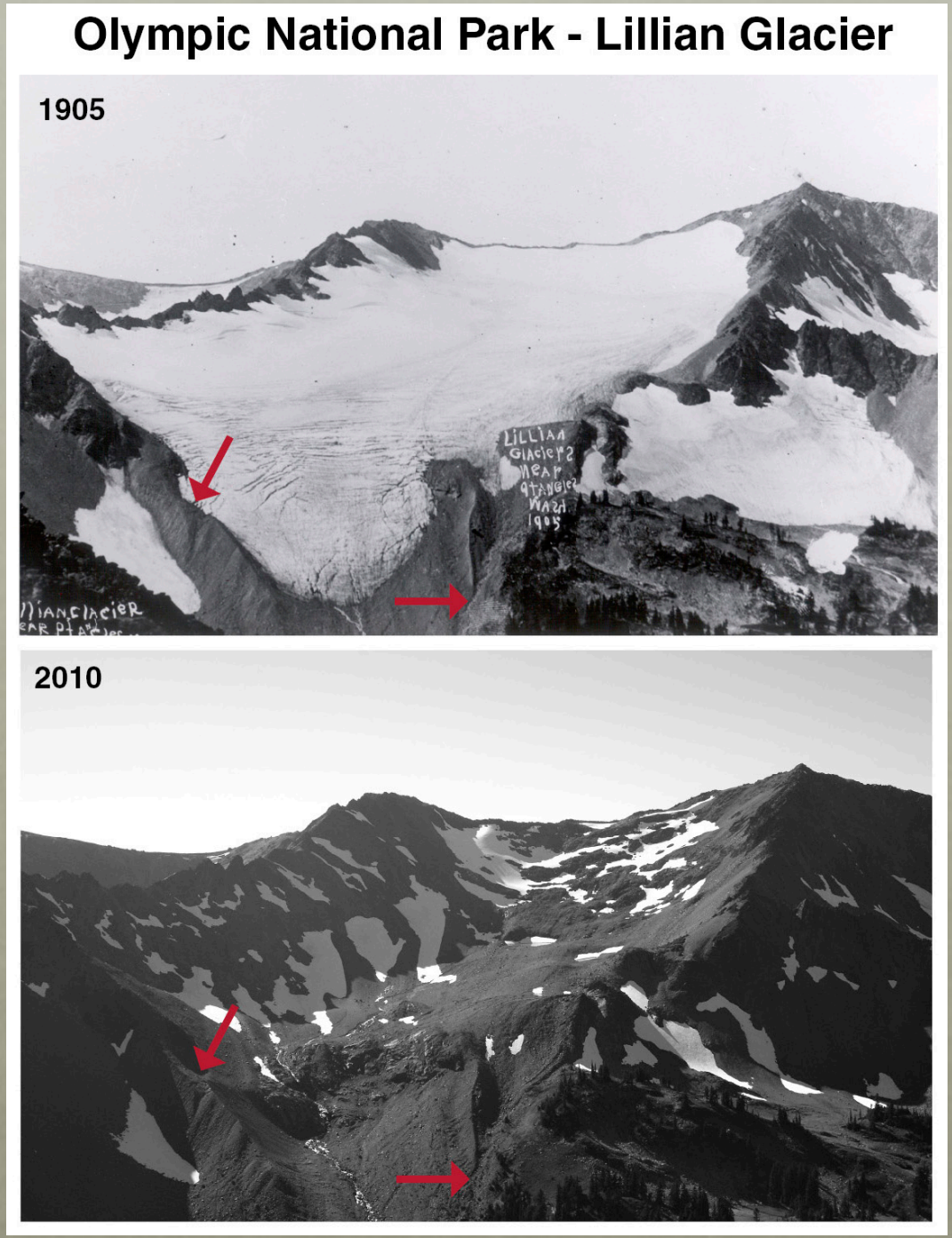
Between 1900-1998 the North Cascades lost ~ 50% of its glacial area (Granshaw, 2002)

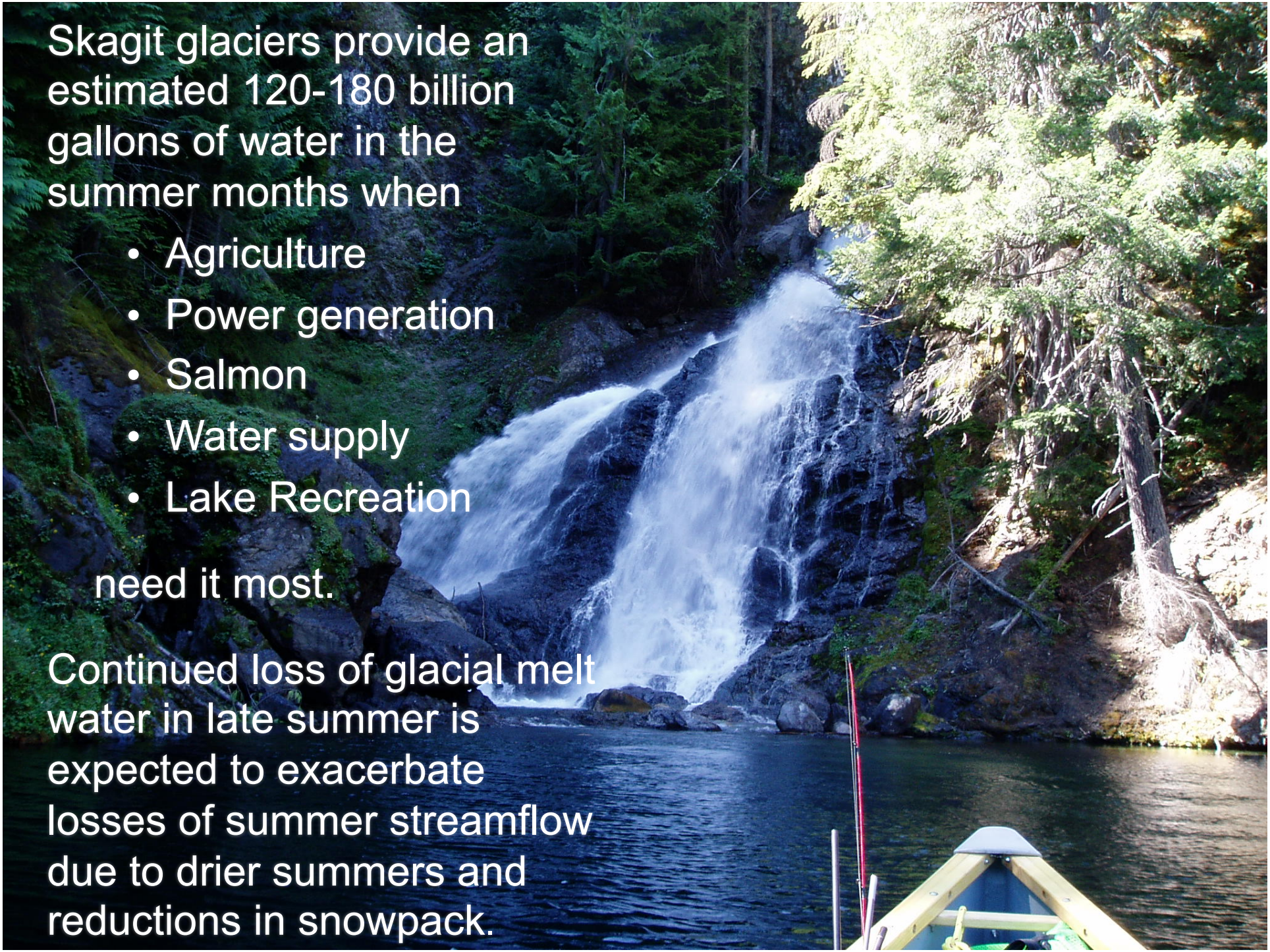
SILVER GLACIER

1958 2006

Other Pacific Northwest glaciers are also rapidly receding.

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





Skagit glaciers provide an estimated 120-180 billion gallons of water in the summer months when

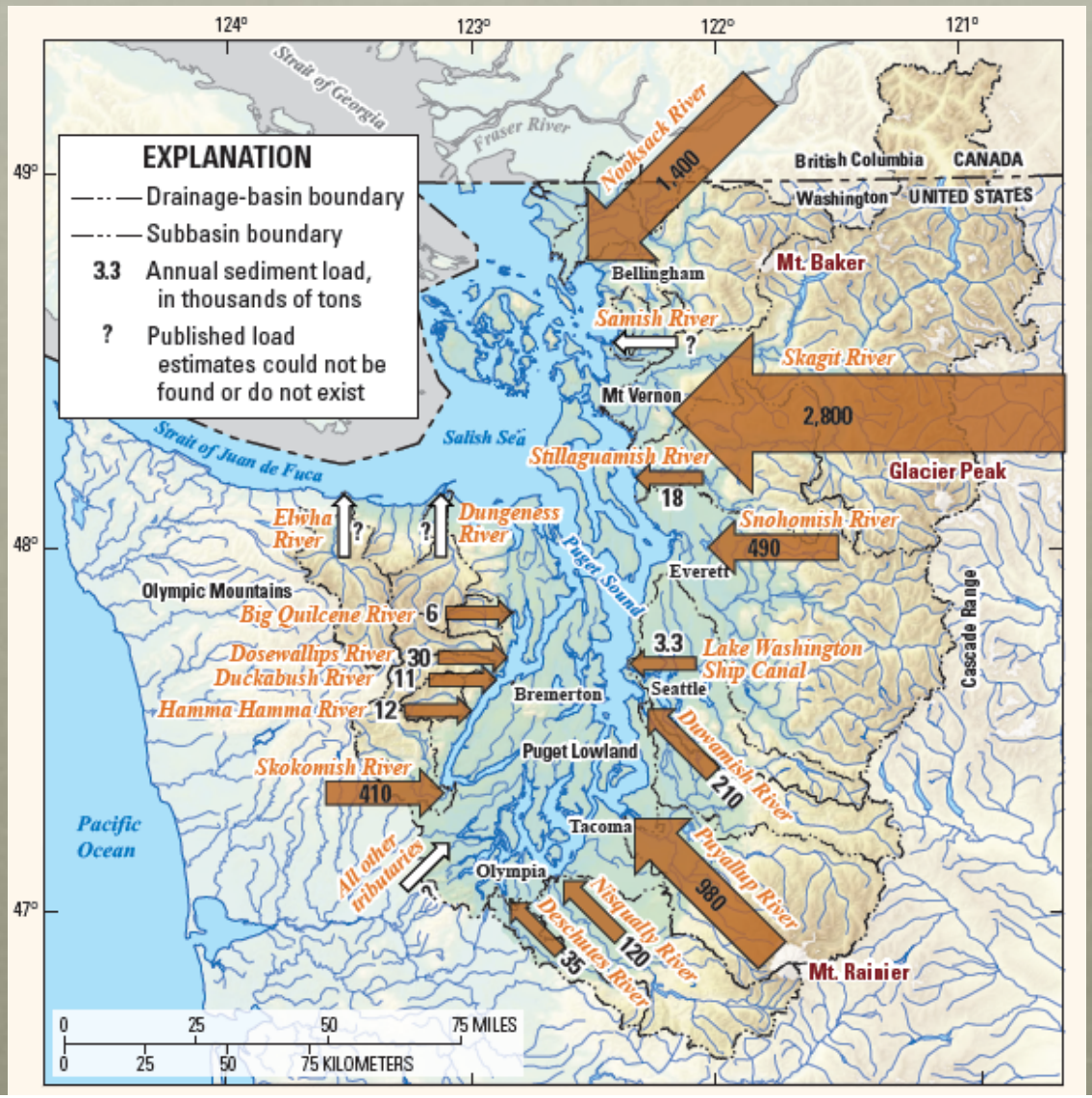
- Agriculture
- Power generation
- Salmon
- Water supply
- Lake Recreation

need it most.

Continued loss of glacial melt water in late summer is expected to exacerbate losses of summer streamflow due to drier summers and reductions in snowpack.

CHANGING SEDIMENT TRANSPORT RATES

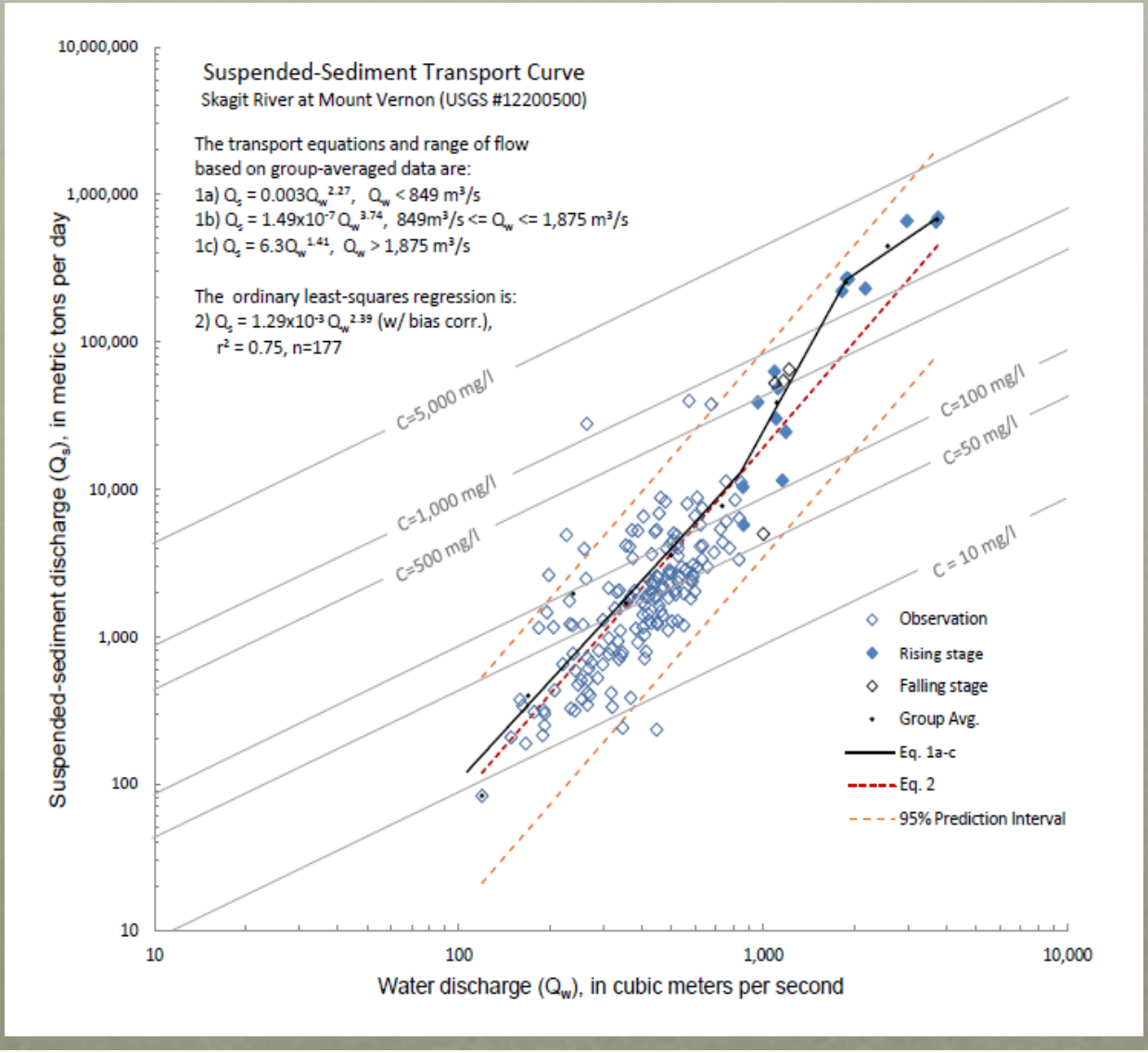
IMPORTANCE OF SKAGIT SEDIMENT TRANSPORT



The Skagit River already moves a tremendous amount of sediment in comparison with other Puget Sound rivers.

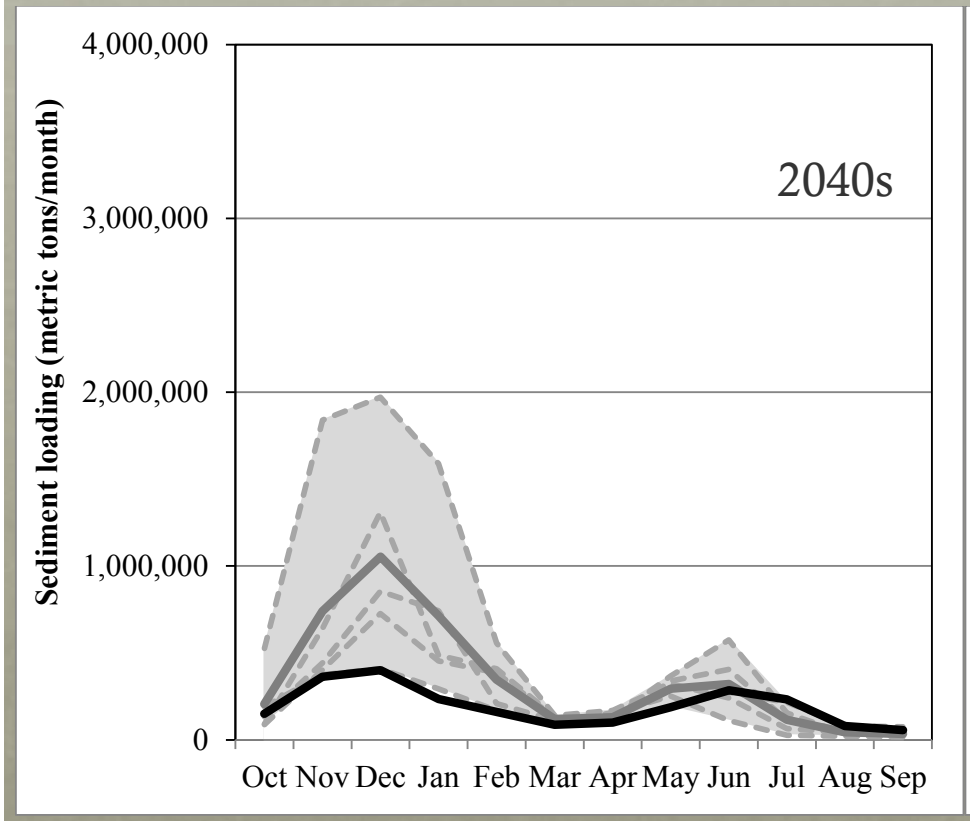
Retreating glaciers, declining snowpack and increased fire frequencies are hypothesized to increase sediment production in the future.

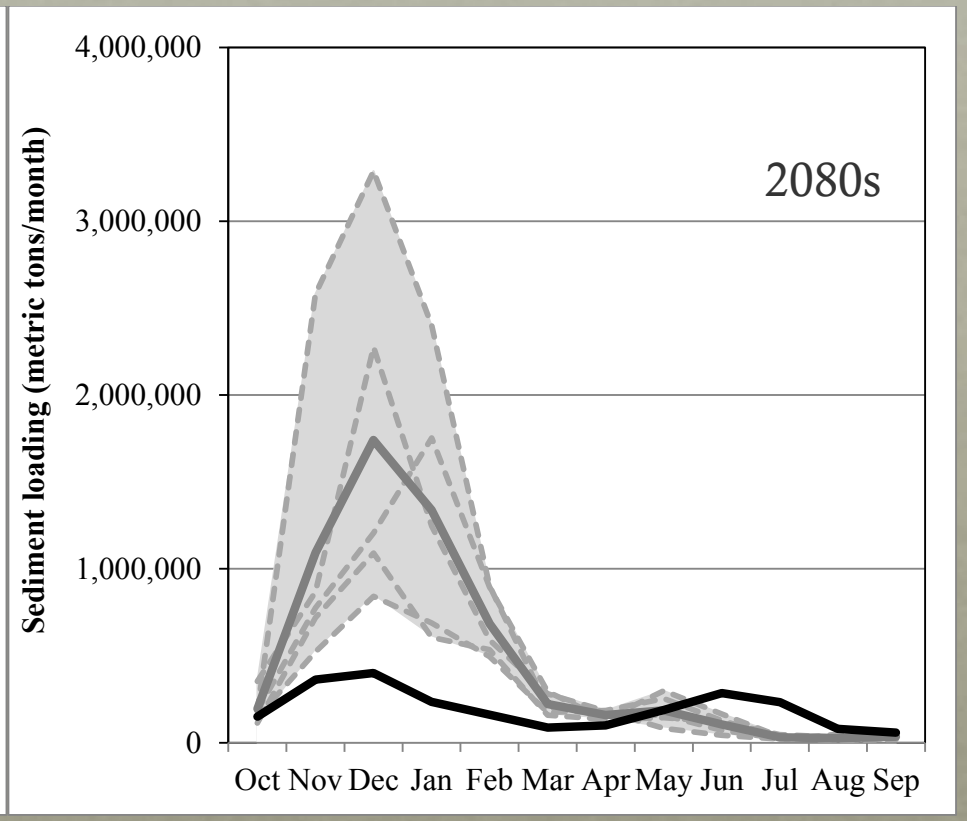
CURRENT SEDIMENT RATING CURVE AT MT. VERNON



(Source: Curran, Grossman et al. 2011)

DAILY FLOW REGIME ALONE CHANGES SEDIMENT TRANSPORT

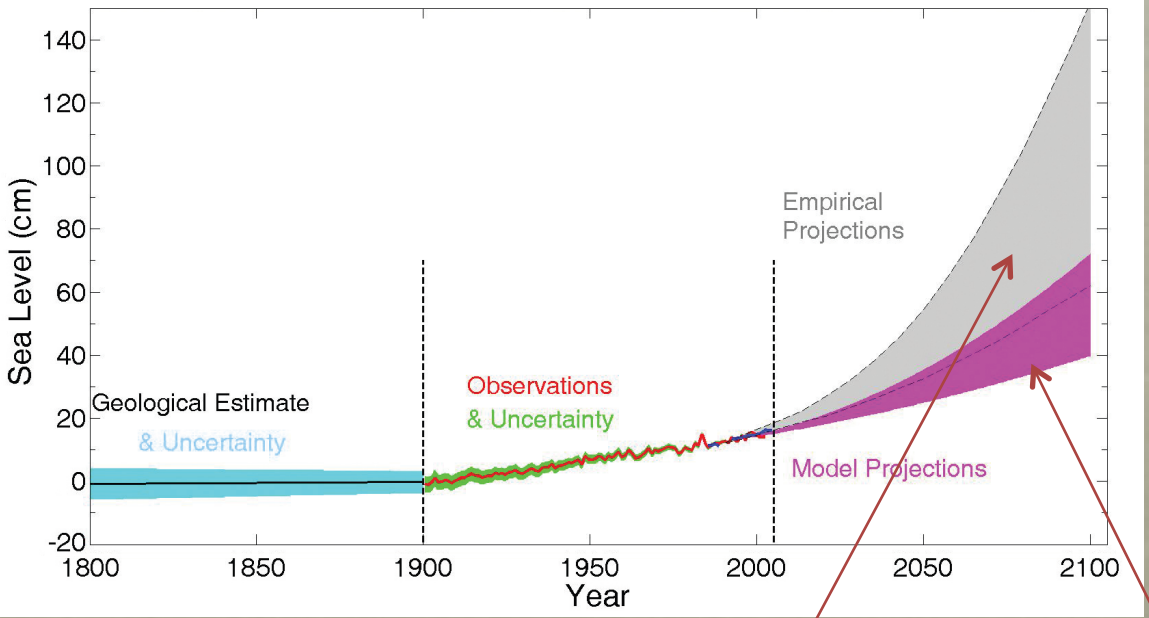


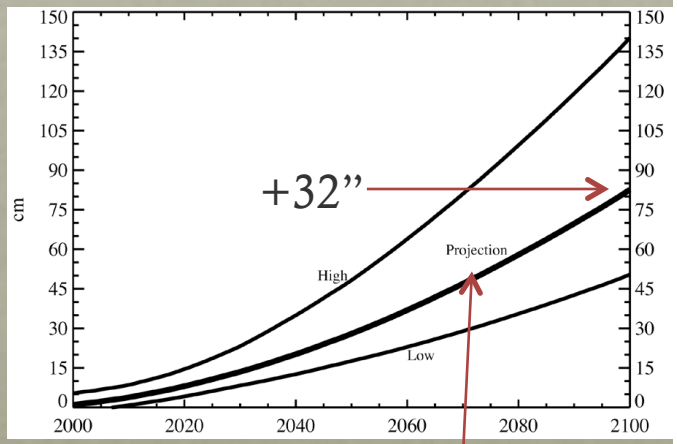


Black lines show historical sediment transport
Grey shading and lines show the range and average of 5 climate change scenarios

CHANGING SEA LEVELS

GLOBAL SEA LEVEL RISE PROJECTIONS





More Recent Empirical Studies

IPCC, 2007

Nat Acad. Sci, 2012

Source: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/sea-level-rise-brief-final.pdf

PROJECTED WEST COAST SEA LEVEL RISE IMPACTS

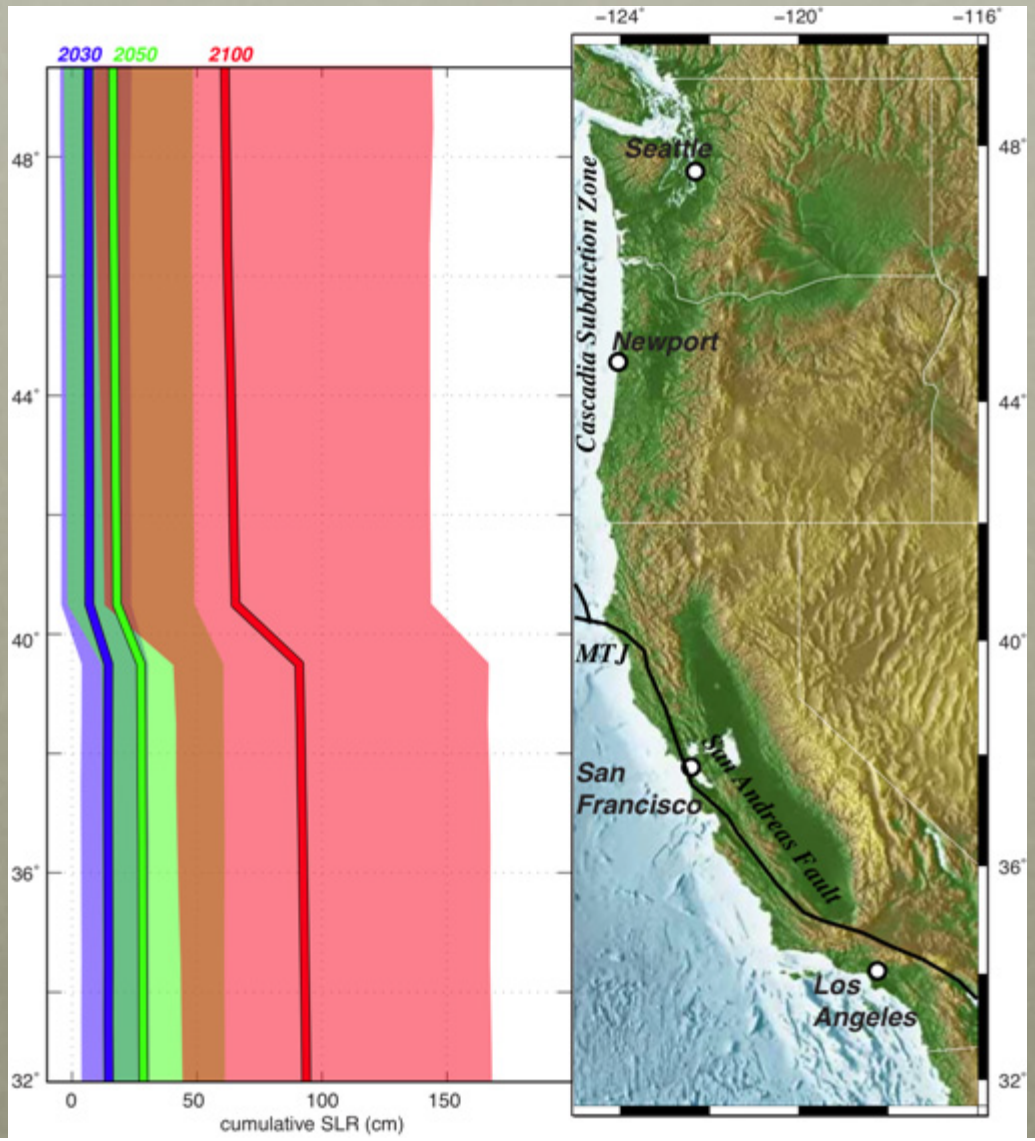
2030: -2 to +9 inches

2050: -1 to +19 inches

2100: +4 to +56 inches

Source: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/sea-level-rise-brief-final.pdf

For comparison, Mote et al. (2008) projected a range of +6 to +50 inches by 2100.



PUGET SOUND SEA LEVEL RISE CHANGING RISKS

Anacortes (4 February 2006)

6” to 50” rise projected by 2100 (Mote et al. 2008)

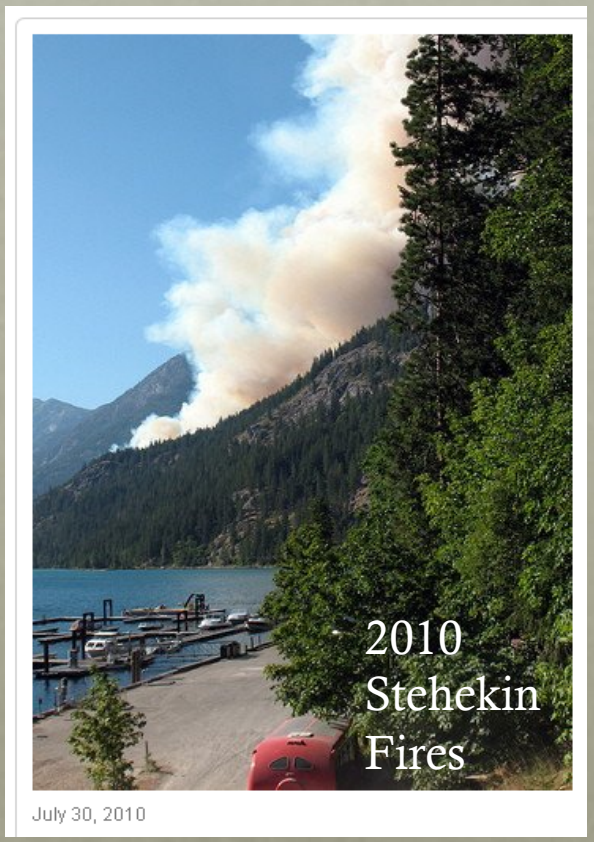
12” of rise turns 100-year coastal flooding even into a 10-year event

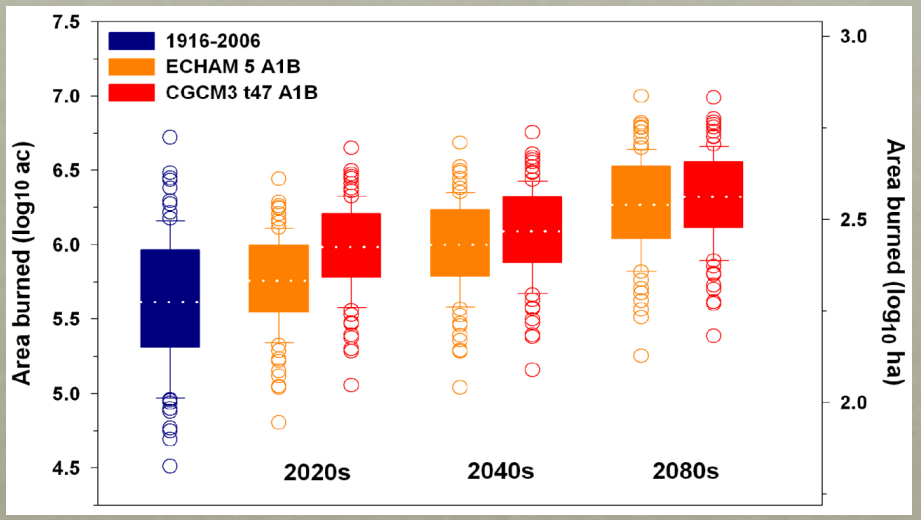
24” of SLR turns a 100-year coastal flooding event into an annual event

ECOSYSTEM IMPACTS

IMPACTS TO AQUATIC ECOSYSTEMS

CHANGING FOREST DISTURBANCE FROM 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

CHANGING FOREST DISTURBANCE FROM INSECT ATTACK

Mountain Pine Beetle Damage in British Columbia

IMPACTS TO HUMAN COMMUNITIES

FLOODPLAIN MANAGEMENT

COASTAL IMPACTS

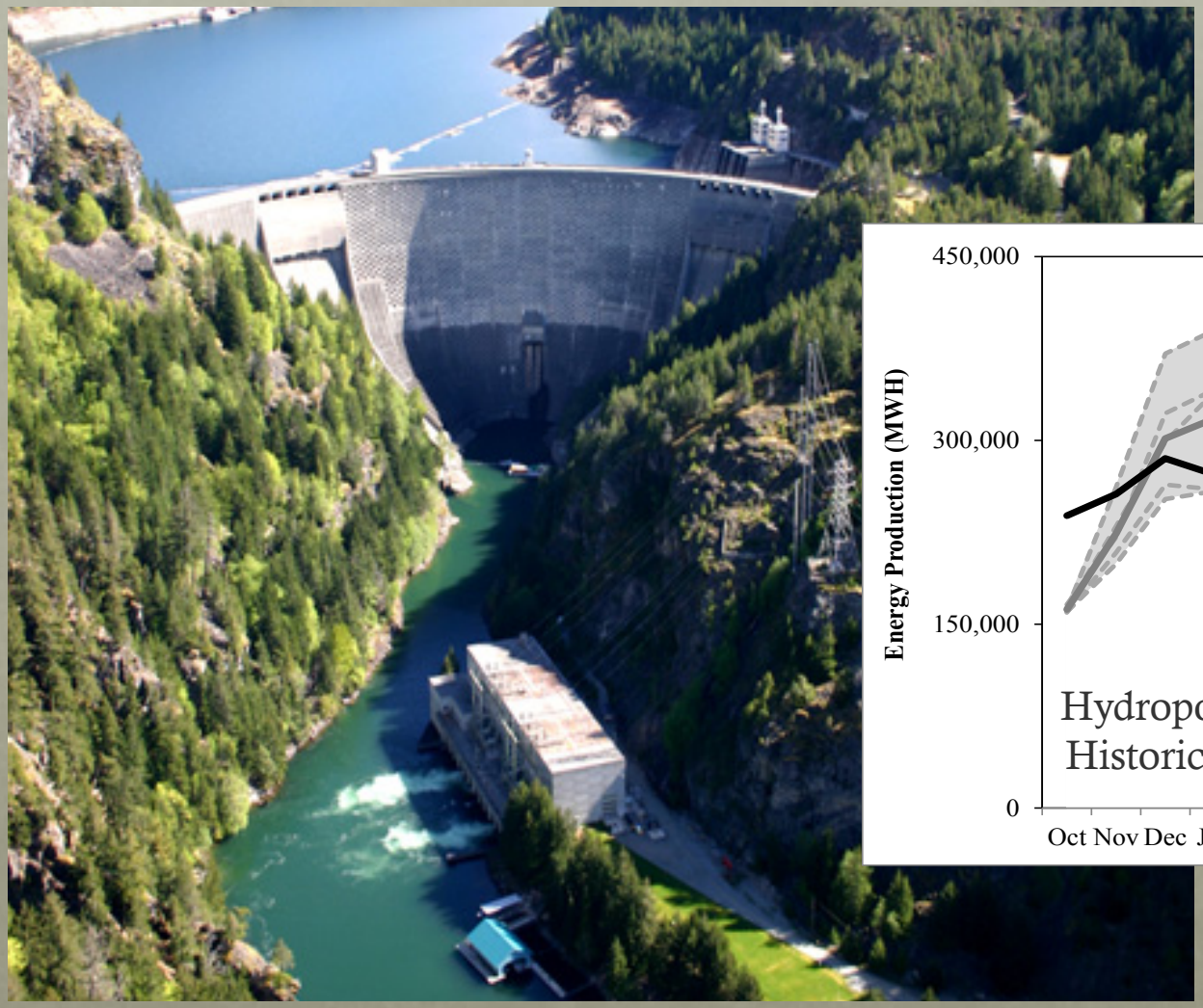
Effects of a "King Tide" at the Nisqually Wildlife Refuge in Sound Puget Sound on Feb 2, 2010 (photo by Russ McMillan).

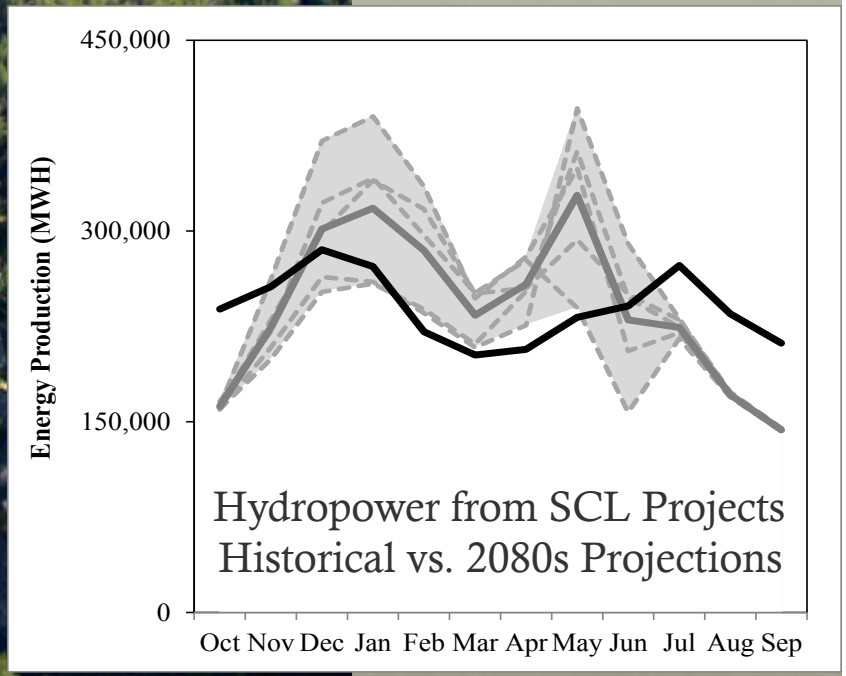
MUNICIPAL WATER SUPPLY

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

AGRICULTURE

HYDROPOWER PRODUCTION





Ross Dam, Seattle City Light

RECREATION

In subsequent talks today we will focus on additional details in three specific areas:

- **Floodplains** – Jon Riedel and Ed Connor
- **Estuary** – John Rybczyk and Greg Hood
- **Salmon Responses** to Climate Drivers – Correigh Greene