Skagit Climate Science Consortium's
Skagit Climate Workshop

September 29, 2011

WSU, Mt Vernon

Workshop Objectives

- Introduce ourselves to Skagit decision-makers.
- Establish an ongoing dialogue.
- Share information.
- We hope that your expertise as local decision-makers will help us shape our effort and our research is of use to you and others.

Today's Agenda

Welcome and Background Information *(9-9:45)*

Climate Matters *(9:45-11:30) - Dr. Alan Hamlet*

Lunch *(11:30-12:15)*

Skagit-Specific Climate Science Findings *(12:30-3:50)*

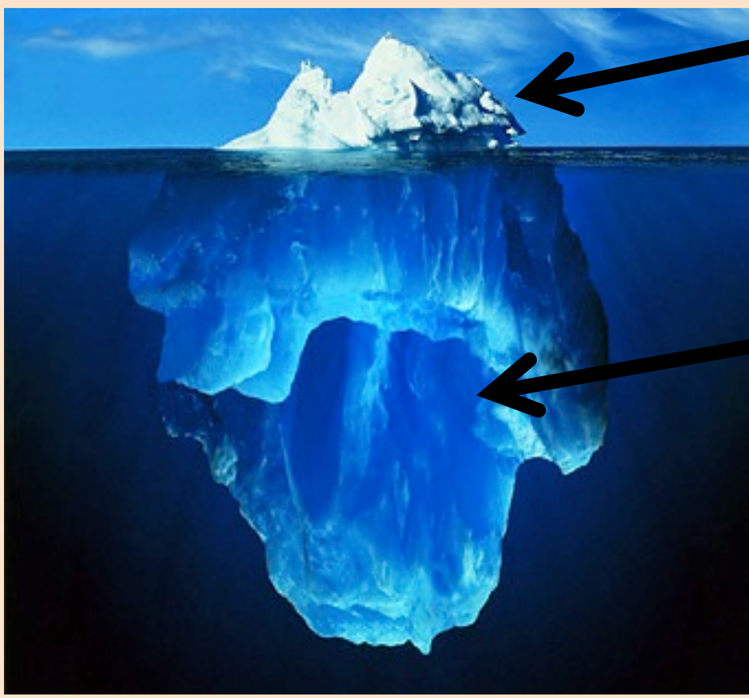
- Glaciers - *Dr. Jon Riedel*
- Hydrology - *Dr. Alan Hamlet*
- Sediment - *Dr. Eric Grossman*
- Sea Level Rise/Storm Surges - *Mr. Roger Fuller*
- Integrated Impacts Discussion - *Dr. Alan Hamlet*

Closing & Next Steps *(3:50-4:00) - Carol MacIlroy & Dr. Alan Hamlet*

Strategy for the Afternoon Sessions

- Short introductory talks from scientists on each of the four topics (about 10 minutes)

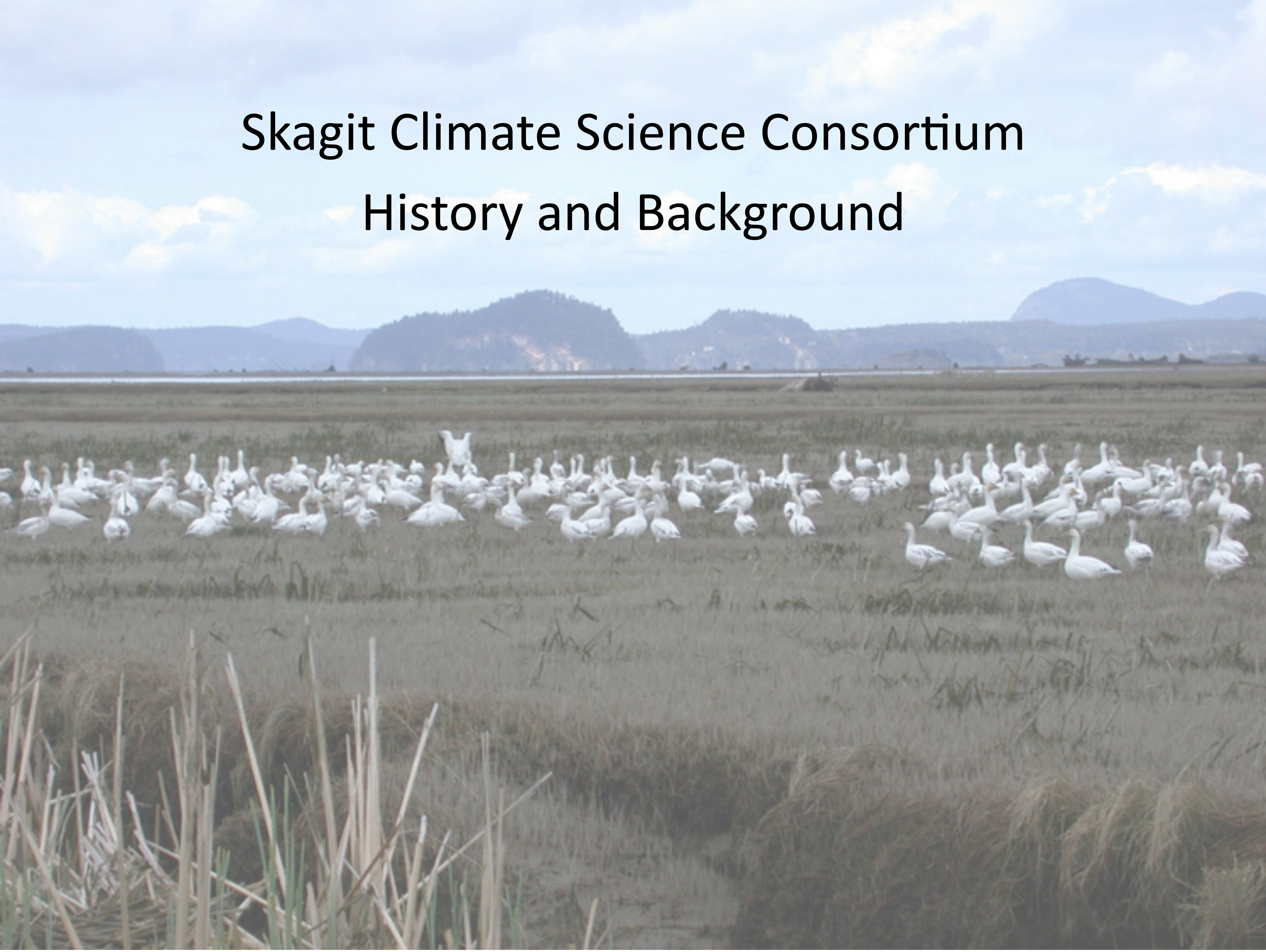
- Subsequent questions and discussion will direct us to more detailed information, or to other related topics not covered.



Initial information from us.

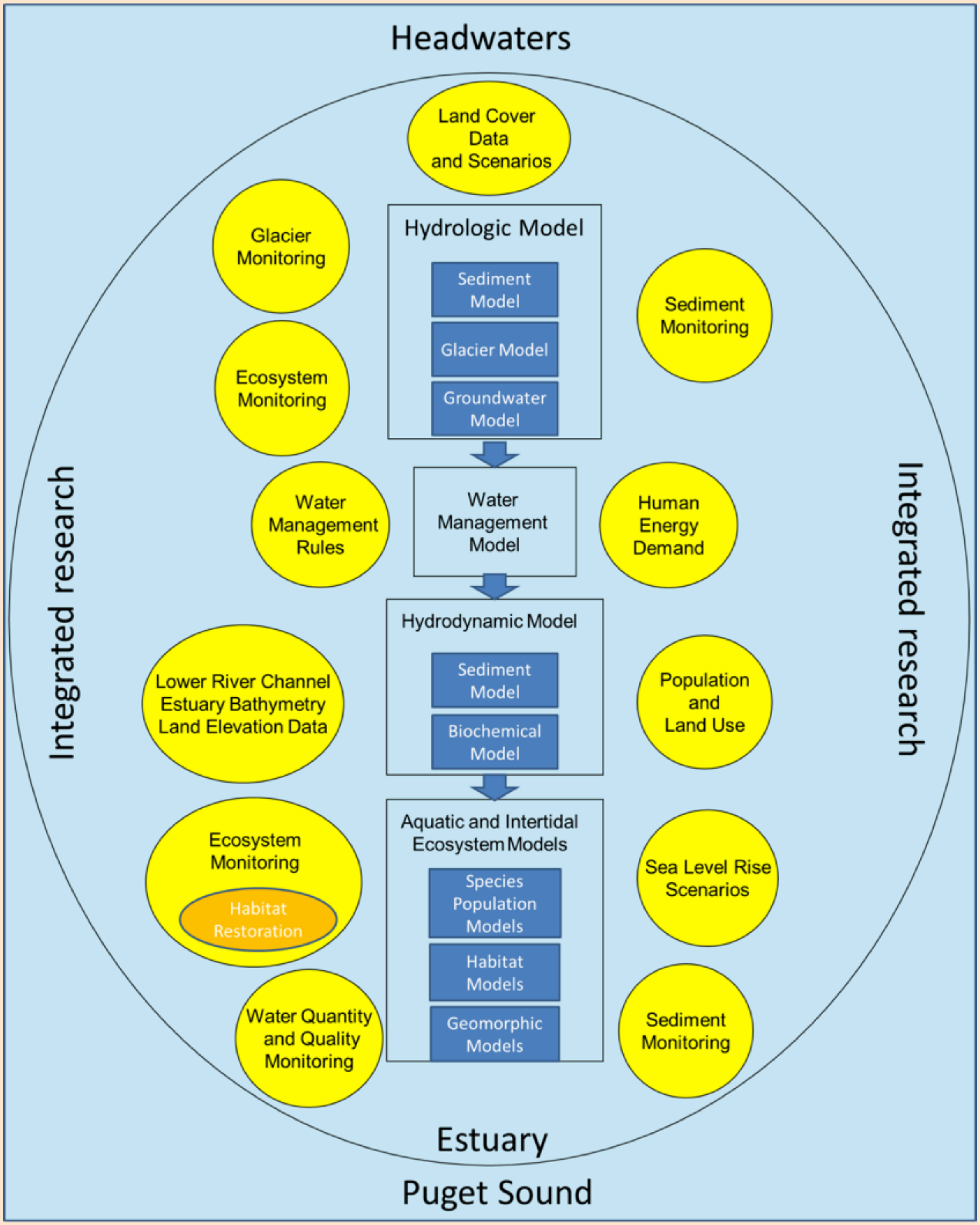
The “Full Monty”

Skagit Climate Science Consortium
History and Background



SC2 Goals

- Collaborative, interdisciplinary research
- Source of scientific information/support
- Identify and fill research needs
- Establish/maintain local relationships
- Create and maintain a web-based clearing-house


Headwaters
Land Cover Data and Scenarios
Glacier Monitoring
Hydrologic Model
Sediment Model
Glacier Model
Groundwater Model
Sediment Monitoring
Ecosystem Monitoring
Water Management Rules
Water Management Model
Human Energy Demand
Integrated research
Integrated research
Hydrodynamic Model
Sediment Model
Biochemical Model
Lower River Channel Estuary Bathymetry Land Elevation Data
Population and Land Use
Ecosystem Monitoring
Habitat Restoration
Aquatic and Intertidal Ecosystem Models
Species Population Models
Habitat Models
Geomorphic Models
Sea Level Rise Scenarios
Water Quantity and Quality Monitoring
Sediment Monitoring
Estuary
Puget Sound

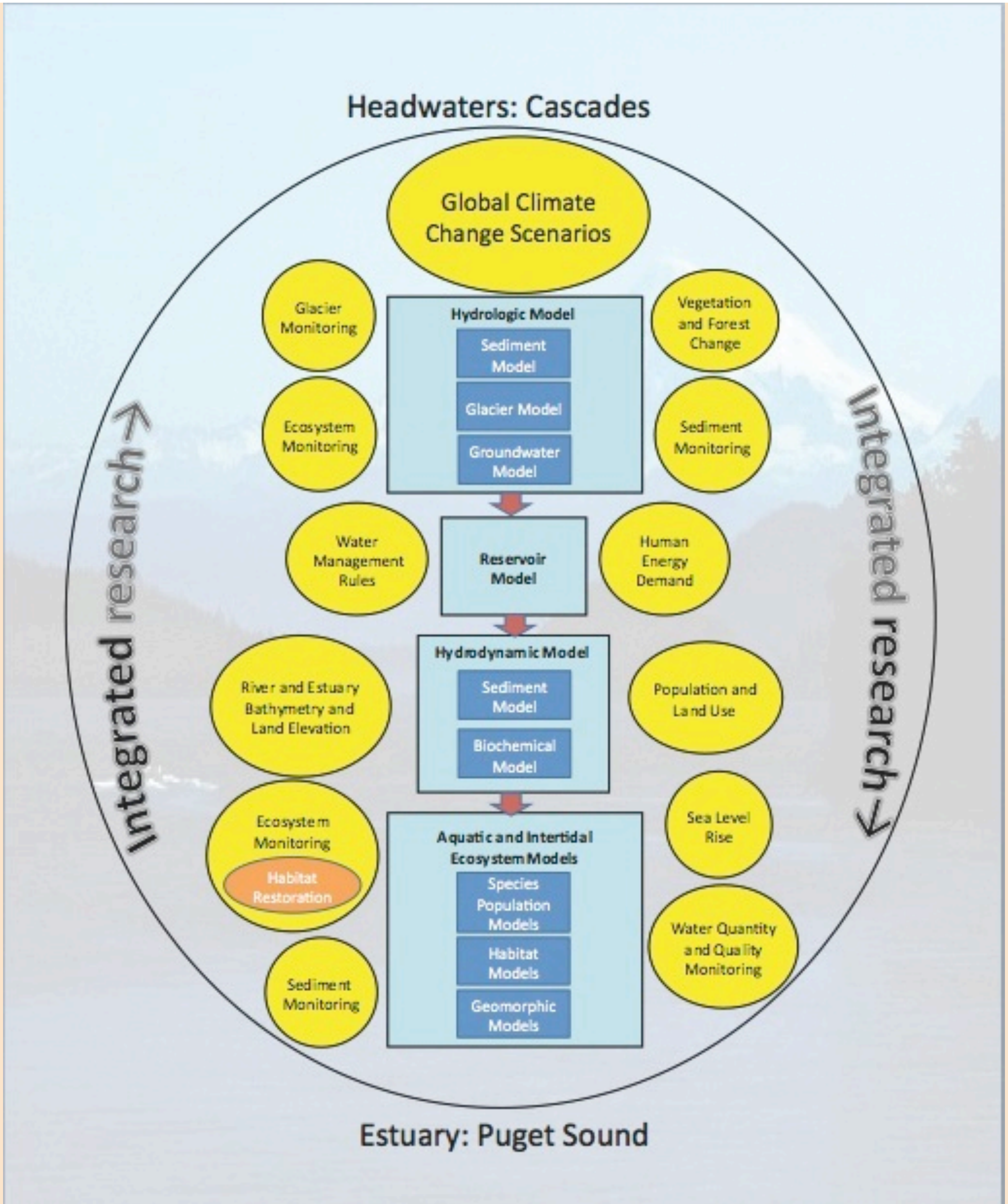
John Rybczyk

Christian Torgersen

Correigh Greene

Today

- What concerns/questions do you have?
- How does what you hear affect your responsibilities – short and long-term?
- What are your highest priorities?
- Where do you need more information?
- What level of detail is useful?
- What next steps/follow actions do you want?


Headwaters: Cascades
Global Climate Change Scenarios
Glacier Monitoring
Hydrologic Model
Sediment Model
Glacier Model
Groundwater Model
Vegetation and Forest Change
Ecosystem Monitoring
Sediment Monitoring
Water Management Rules
Reservoir Model
Human Energy Demand
Hydrodynamic Model
Sediment Model
Biochemical Model
River and Estuary Bathymetry and Land Elevation
Population and Land Use
Ecosystem Monitoring
Habitat Restoration
Sea Level Rise
Aquatic and Intertidal Ecosystem Models
Species Population Models
Habitat Models
Geomorphic Models
Water Quantity and Quality Monitoring
Sediment Monitoring
Integrated research→
Integrated research→
Estuary: Puget Sound

Climate Matters

Climate Overview and Projections for the Pacific Northwest and Skagit River Basin

Dr. Alan F. Hamlet

- Skagit Climate Science Consortium
- Climate Impacts Group
- Dept. of Civil and Environmental Engineering, University of Washington

CLIMATE IMPACTS GROUP

Department of Civil and Environmental Engineering

Terminology and Concepts

Weather:

A “snapshot” of the state of the atmosphere and other related physical variables in a particular place. E.g. the current state of cloud cover, solar radiation, precipitation, temperature, humidity, wind speed and direction, etc.

Time scale: seconds to weeks

Climate:

The long-term *statistics* of weather. E.g. the long-term average temperature for May over the most recent 30-year period in the Pacific Northwest is a statistic of our current regional climate.

Time scale: years to centuries

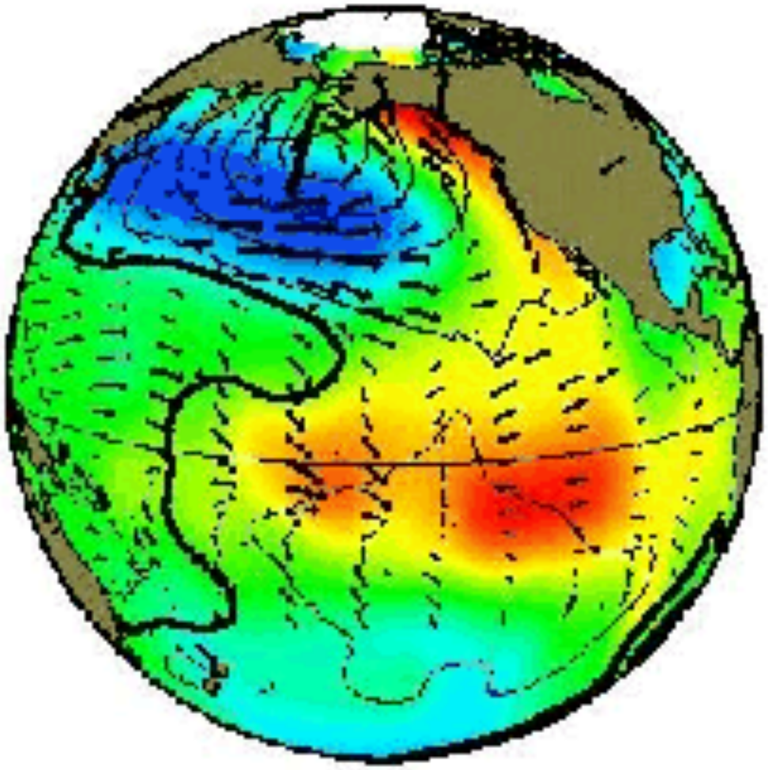
Climate Variability:

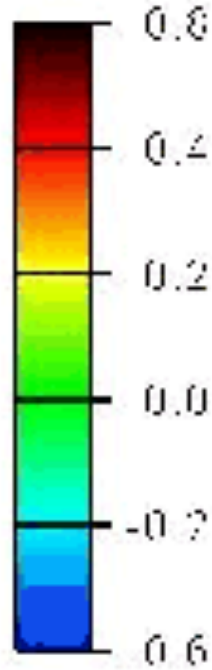
Global, regional, and local climate vary from year-to-year, decade-to-decade, and century-to-century. Some aspects of natural climate variability are associated with random variations (e.g. annual average temperature variations from year-to-year), others are believed to be cyclical in nature (e.g. ice ages)

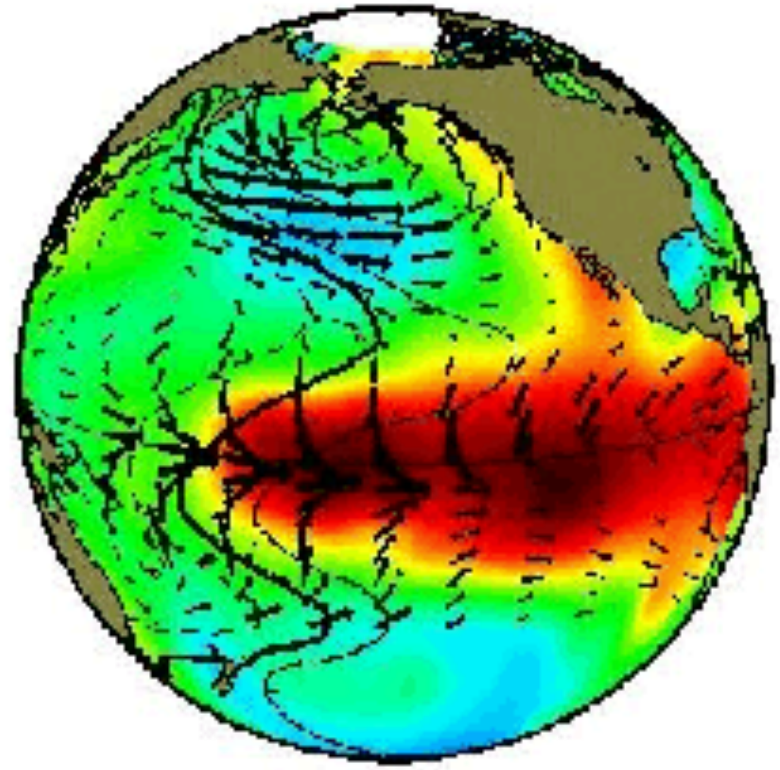
Climate Change:

Climate change refers to systematic changes in the global, regional, or local climate that are directly caused by increasing greenhouse gas concentrations of human origin. Other names include: "Global Warming", "Anthropogenic Climate Change", "Global Climate Disruption"

Sources of Natural Climate Variability in the Pacific Northwest

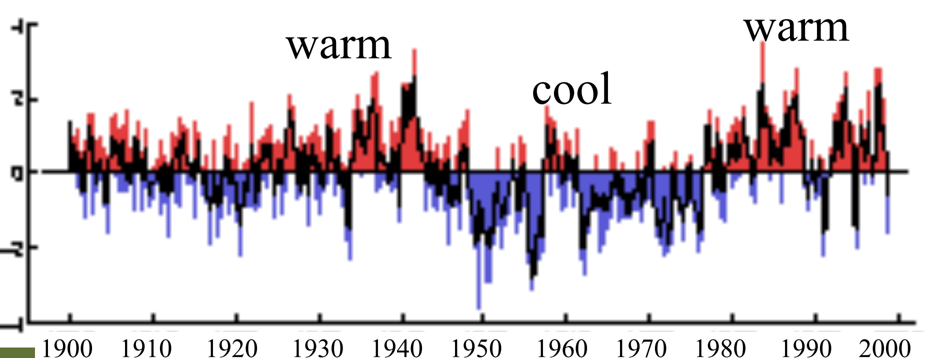






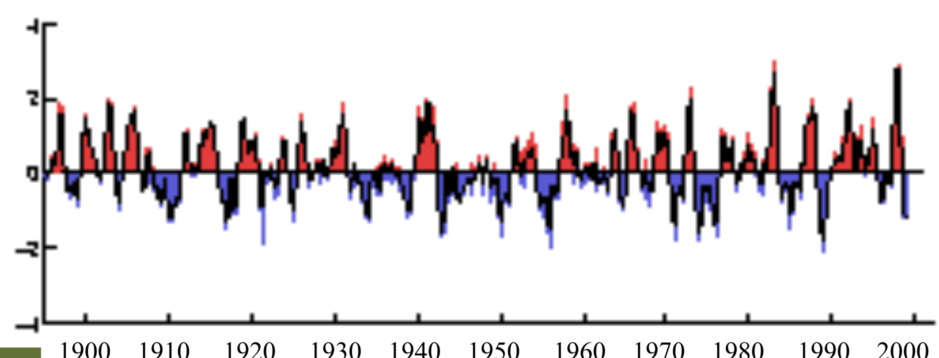
Pacific Decadal Oscillation

A history of the PDO

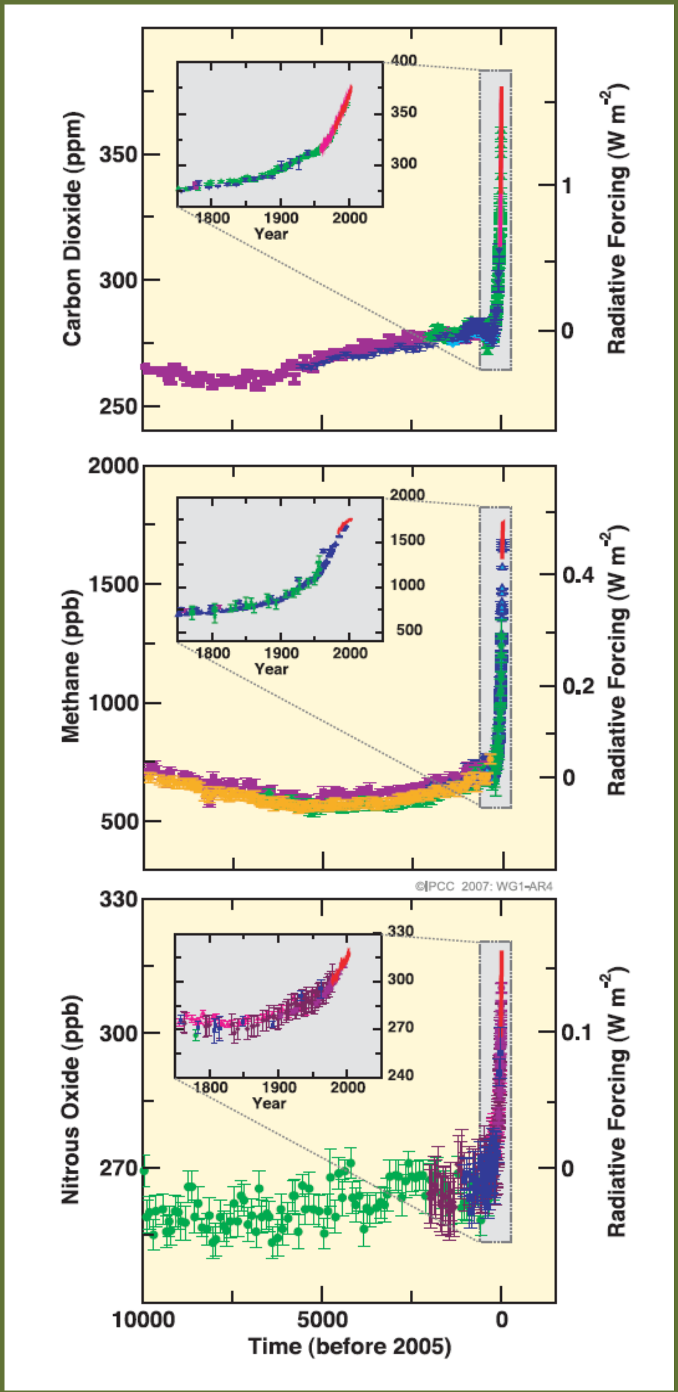


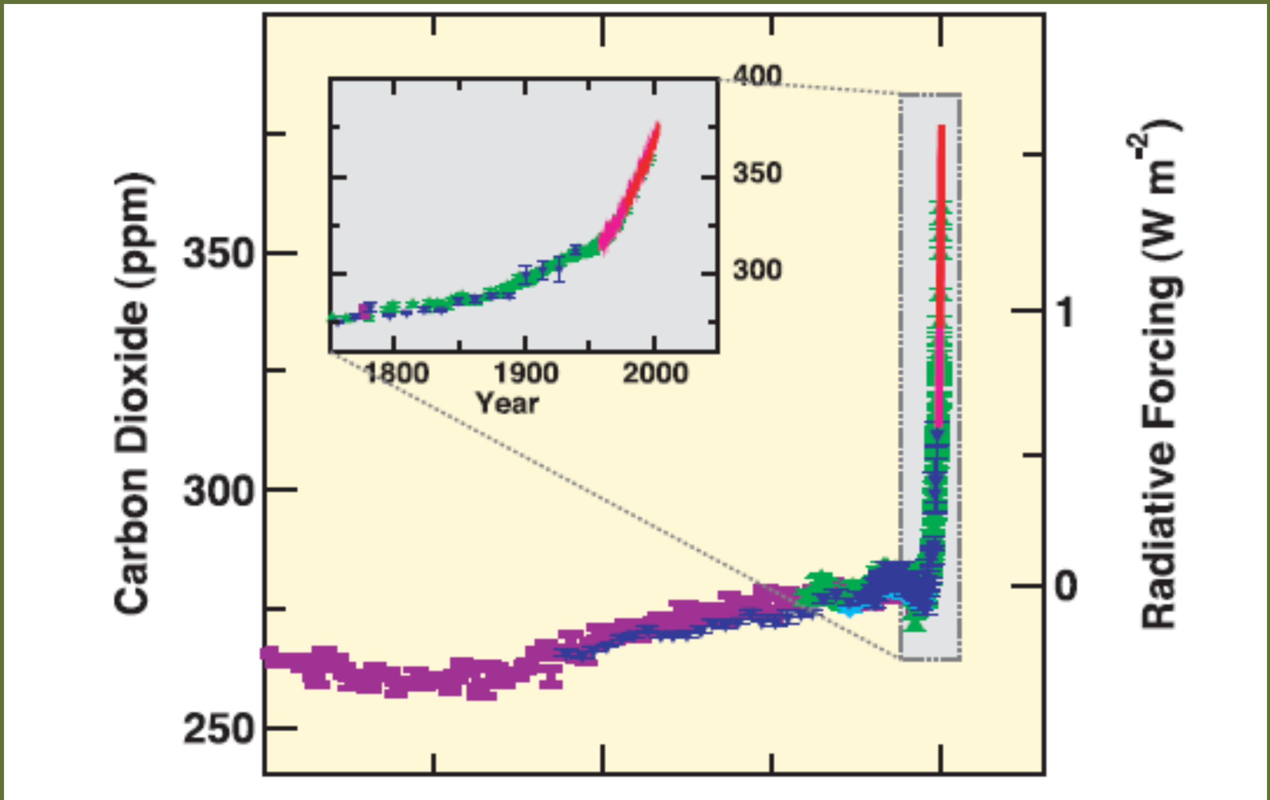
El Niño Southern Oscillation

A history of ENSO



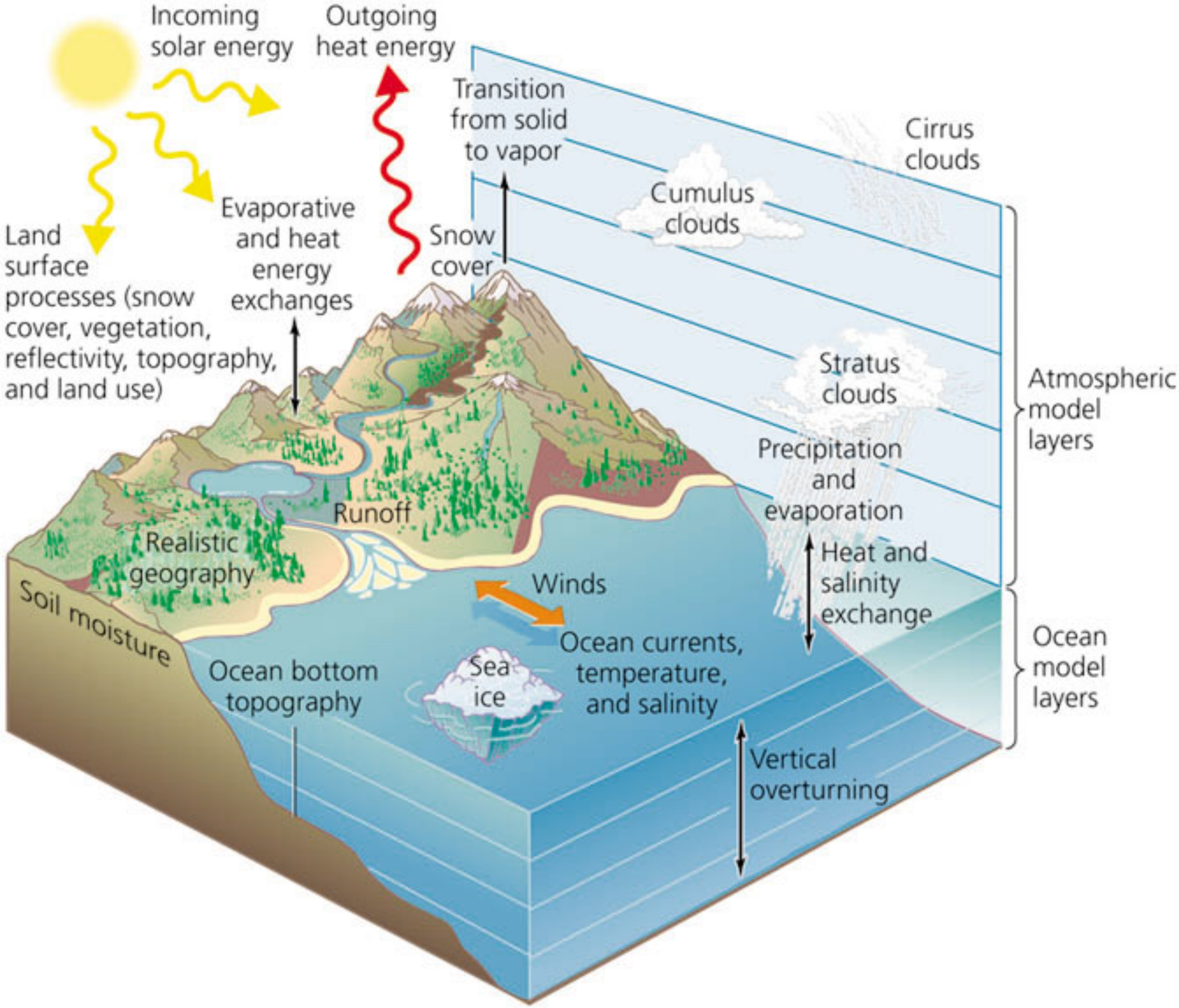
Sources of Climate Change



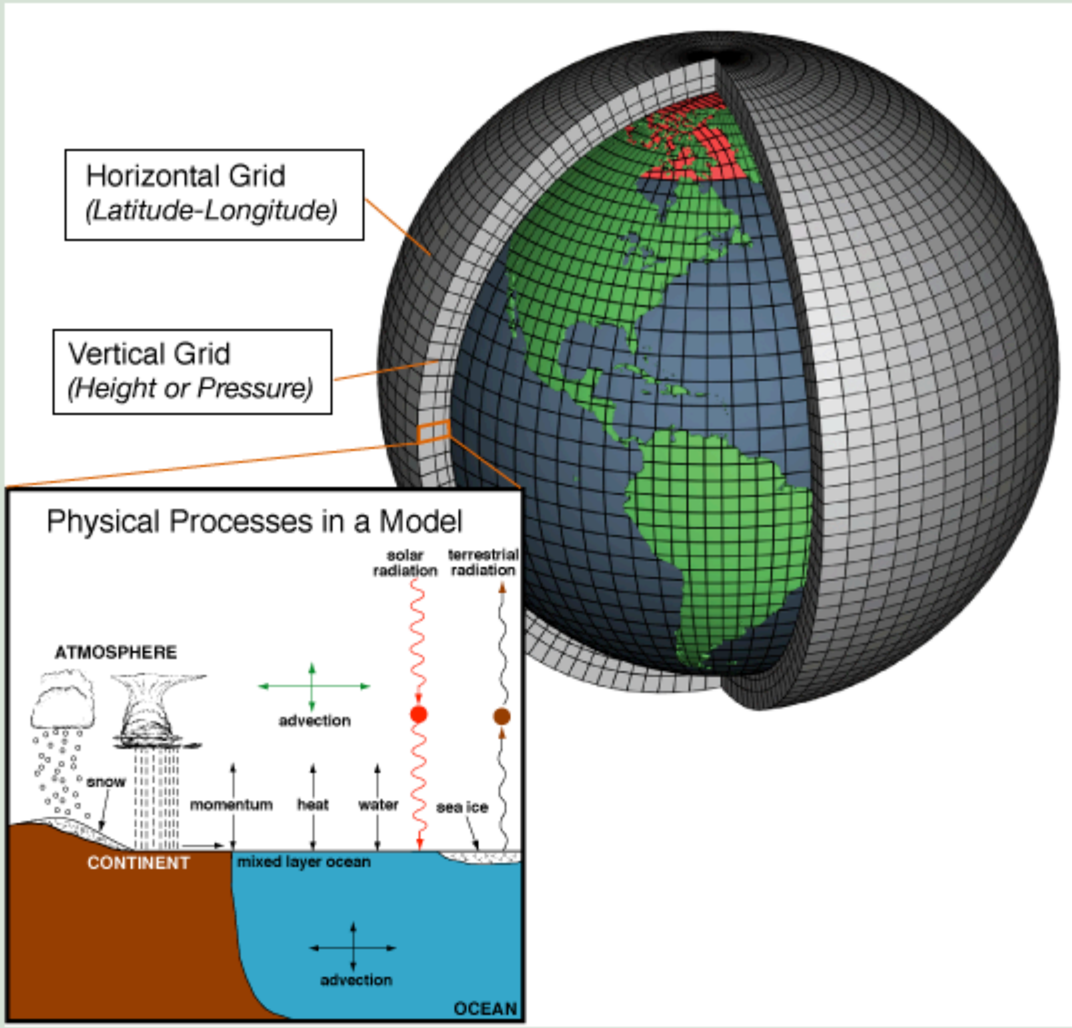


Global Climate Models and Simulations of Historical Climate

Major Processes Effecting the Global Climate System



GCMs are Computer Models of the Global Climate System

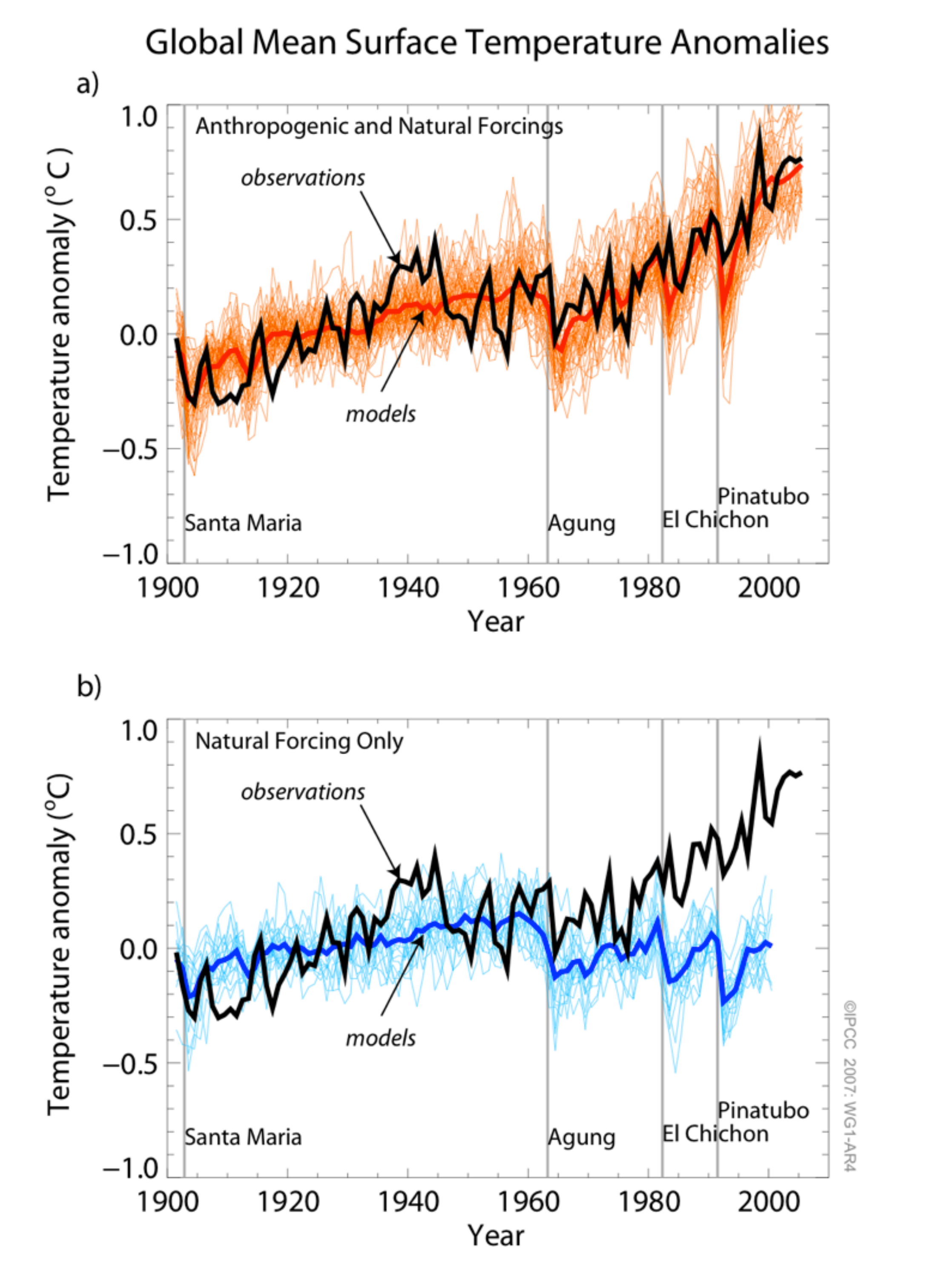


Climate models are systems of differential equations based on the basic laws of physics, fluid motion, and chemistry. To "run" a model, scientists divide the planet into a 3-dimensional grid, apply the basic equations, and evaluate the results. Atmospheric models calculate winds, heat transfer, radiation,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

http://celebrating200years.noaa.gov/breakthroughs/climate_model/modeling_schematic.html

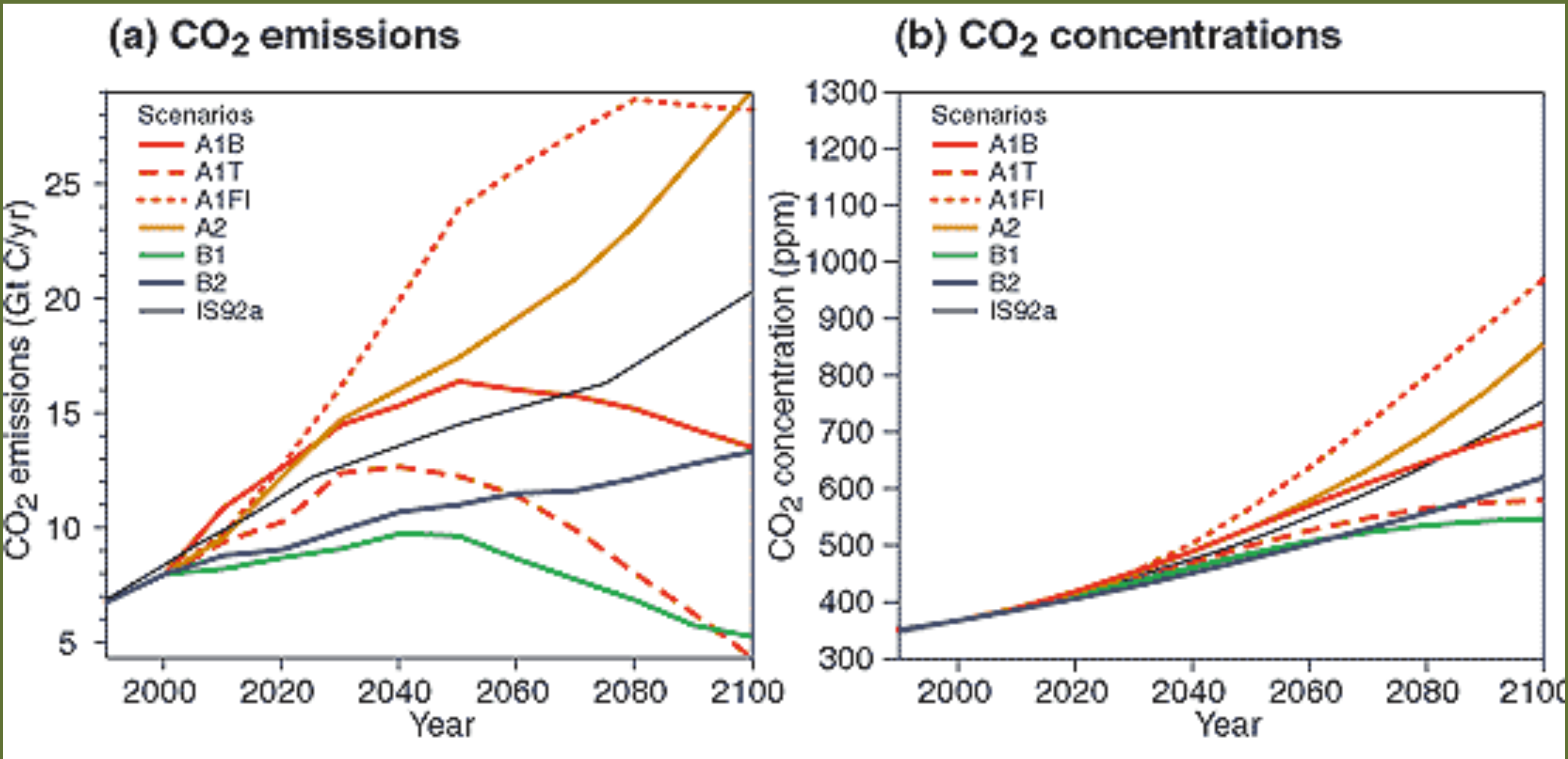
1) Global climate modeling experiments reproduce history of global temperatures remarkably well.

2) Natural forcings (e.g. volcanic eruptions and variations in solar radiation) alone cannot explain the rapid rise in temperature at the end of the 20th century.



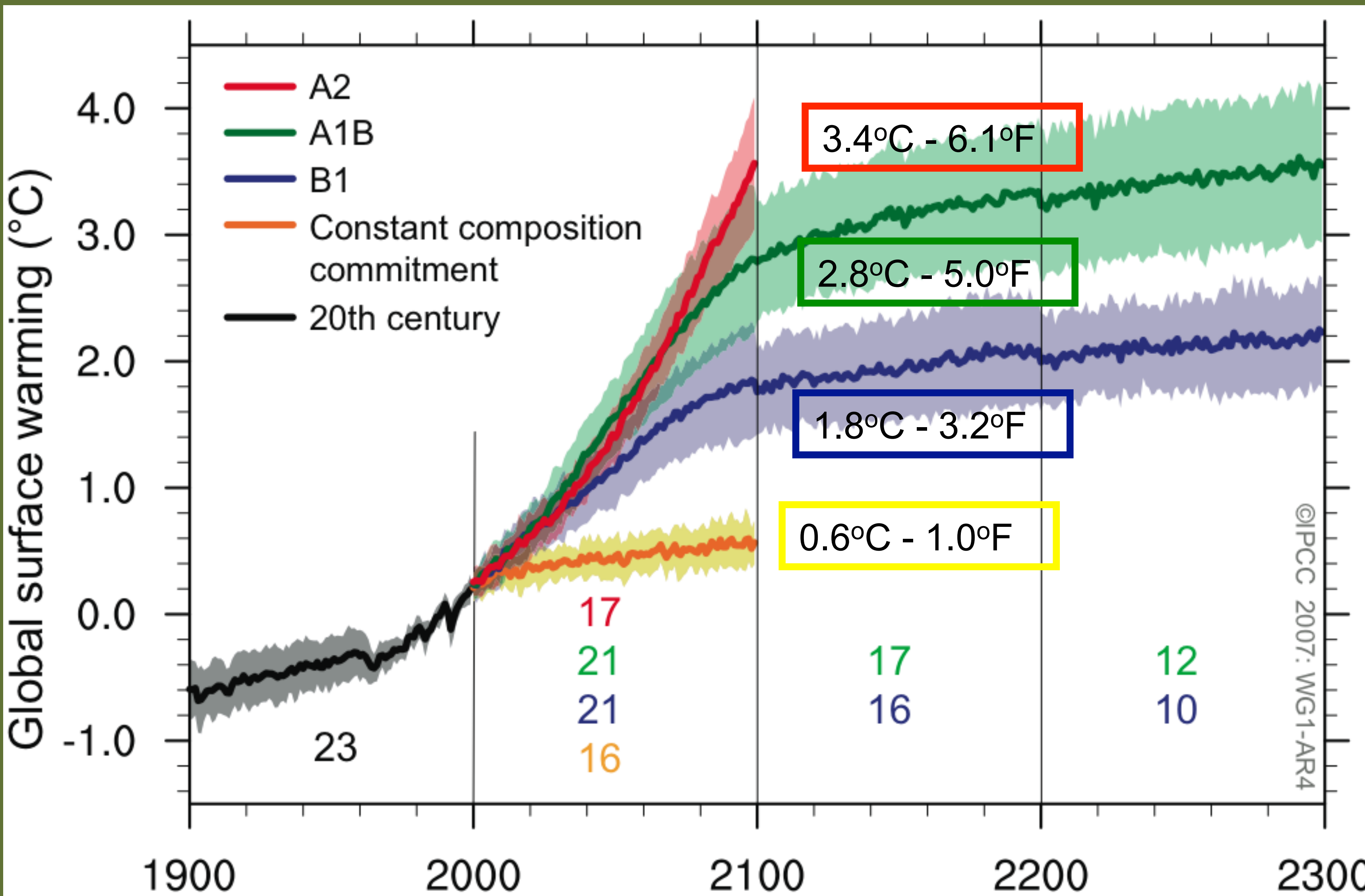
Projections of Future Climate

Summary of the IPCC Emissions Scenarios



Temperature Increases Associated with Greenhouse Gas Emissions Scenarios

Warming will increase if GHGs increase. If GHGs were kept fixed at current levels, a committed 0.6°C of further warming would be expected by 2100. More warming would accompany more emission.



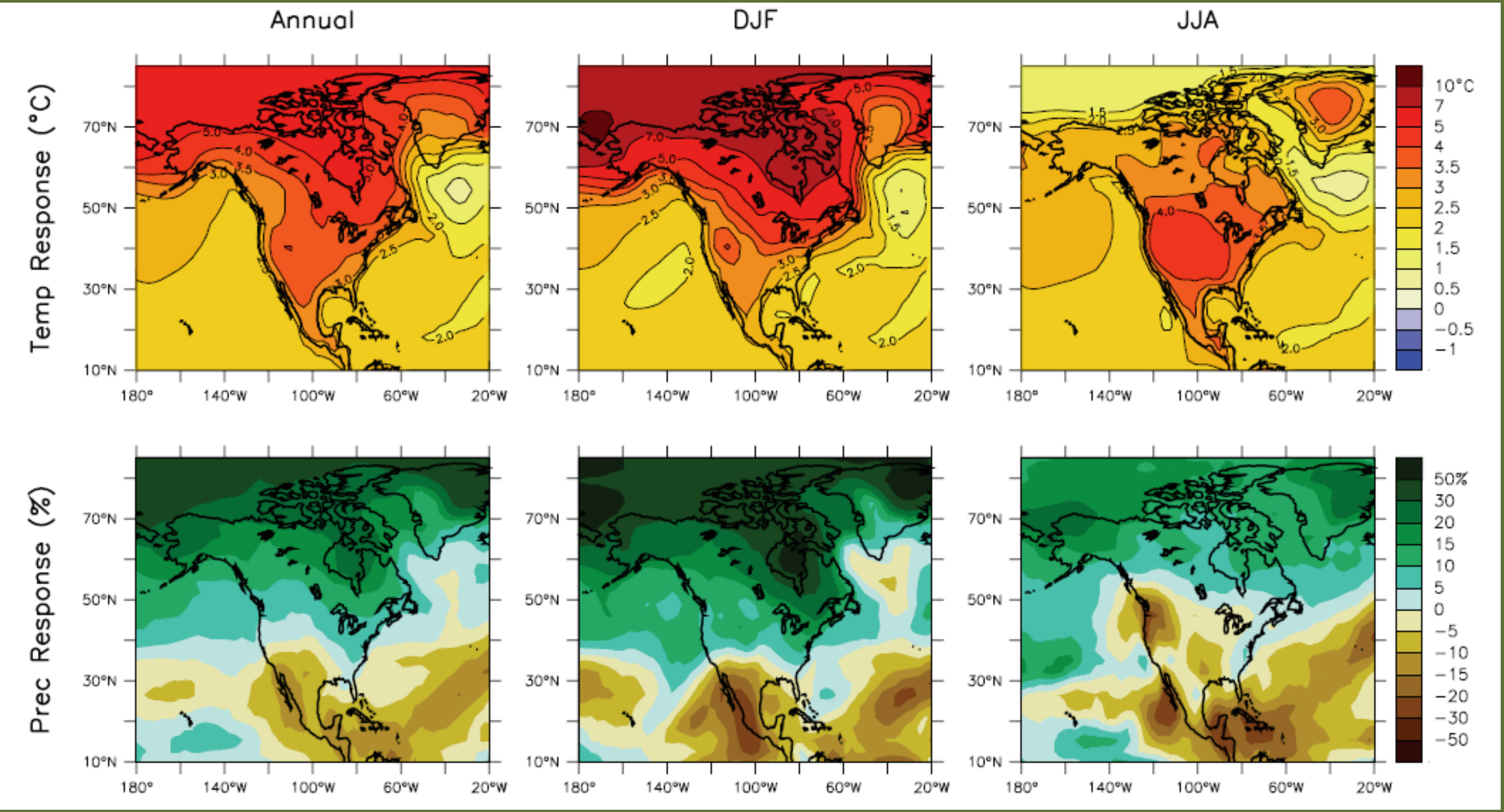
CO2 Eq

850

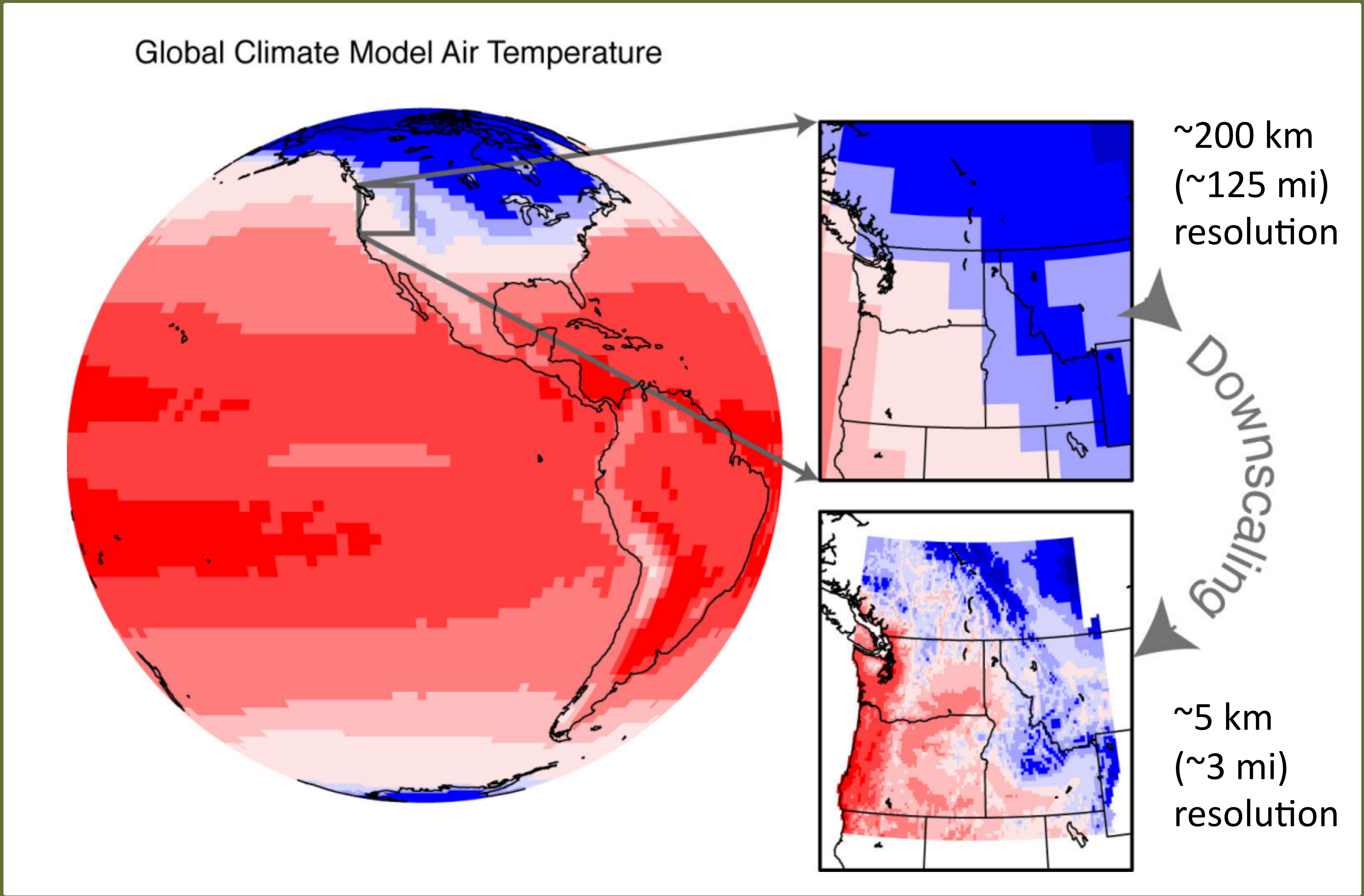
600

400

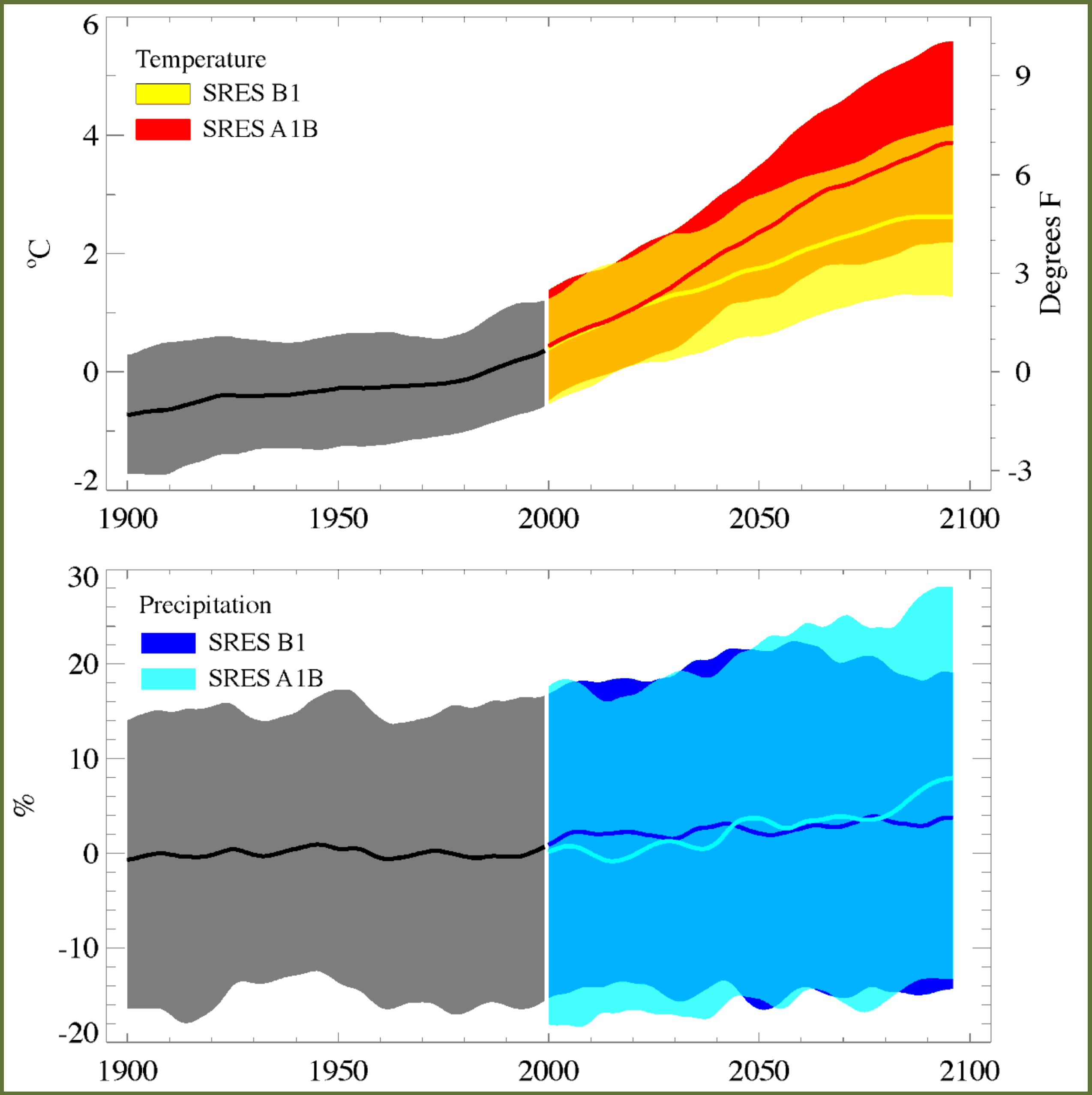
Consensus Forecasts of Temperature and Precipitation Changes from IPCC AR4 GCMs



Downscaling Relates the "Large" to the "Small"



21st Century Climate Impacts for the Pacific Northwest Region



Mote, P.W. and E. P. Salathe Jr., 2010: Future climate in the Pacific Northwest, Climatic Change, DOI: 10.1007/s10584-010-9848-z

Projected Seasonal Precipitation Changes for the Pacific Northwest

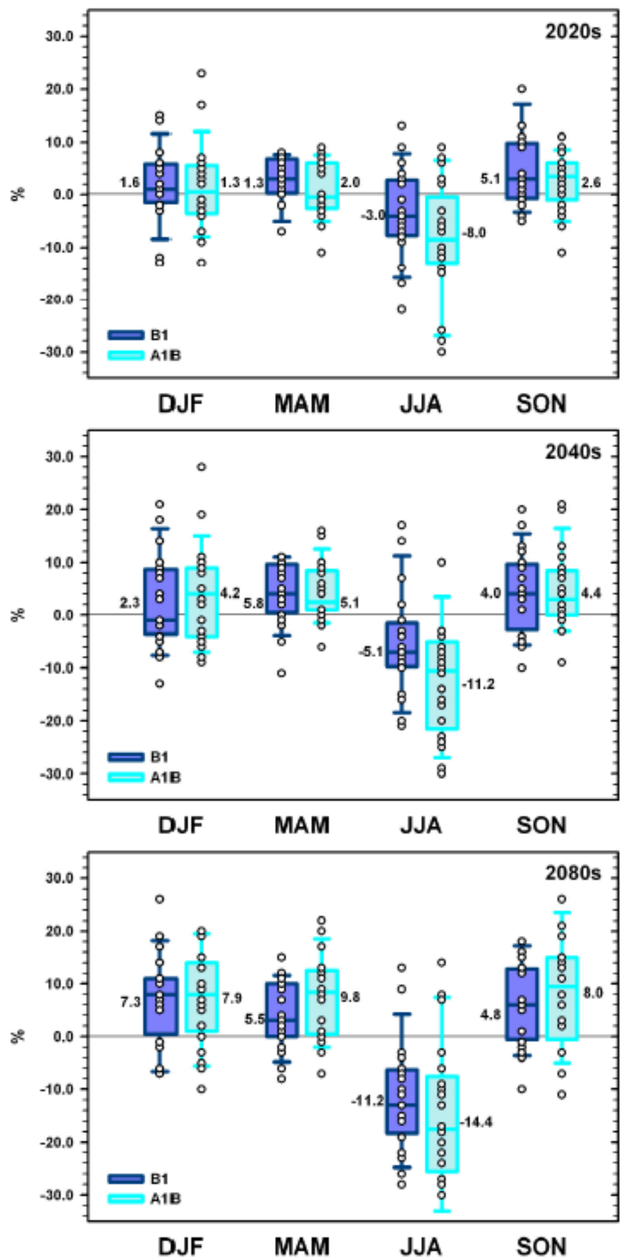
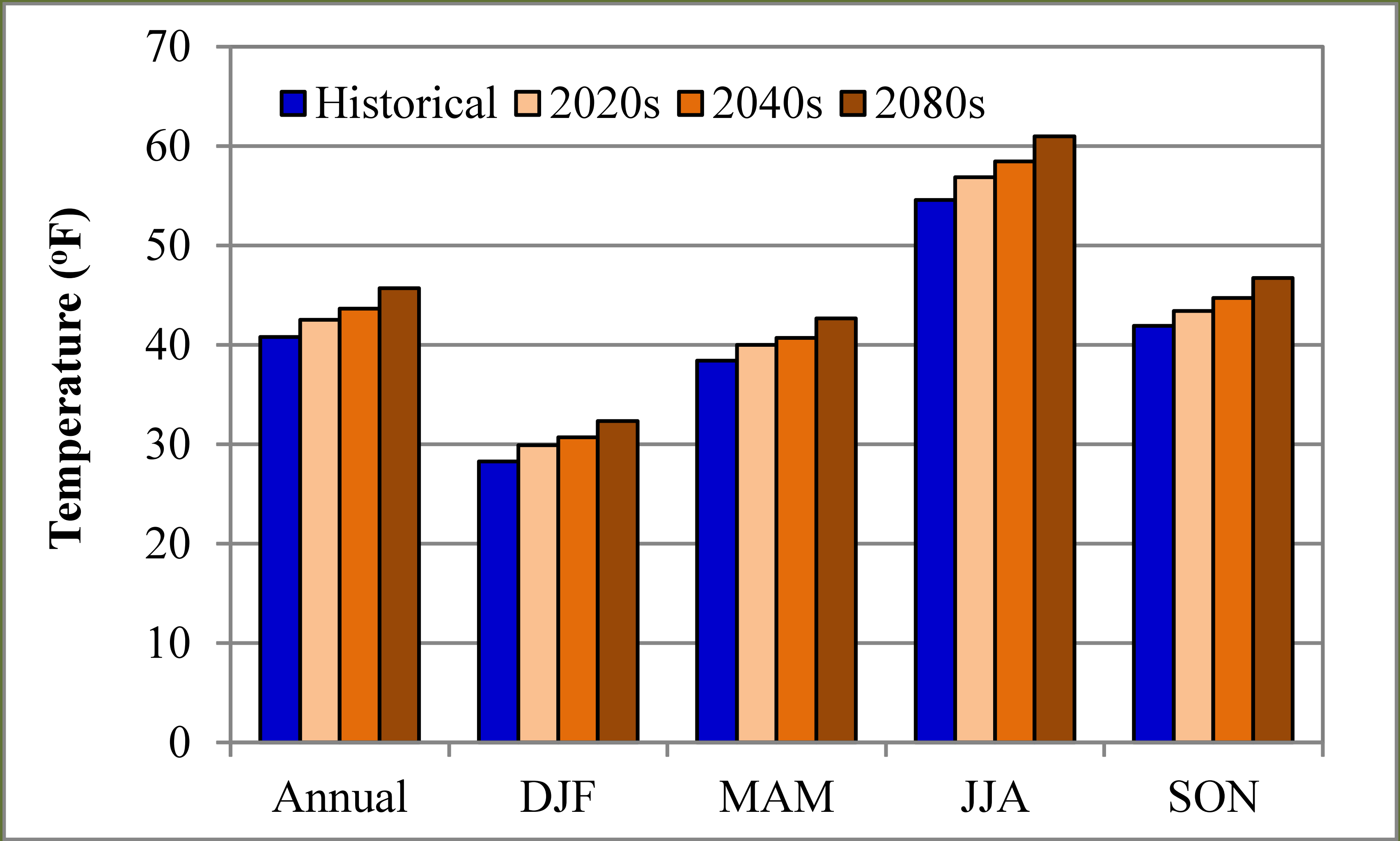


Figure 10. As in Figure 9, but for precipitation. The height of the bars indicates actual water precipitation but the percentages are calculated with respect to a reference value for that season, so that -11% in JJA is much less than -11% in DJF. The reference values for the extremes are that model's 20th century mean for that season (or annual mean), and for the REA average the reference is the all-model 20th century value. Unlike for temperature, for any season some models project increases and some project decreases, though the vast majority project decreases for summer and increases for winter by the 2080s

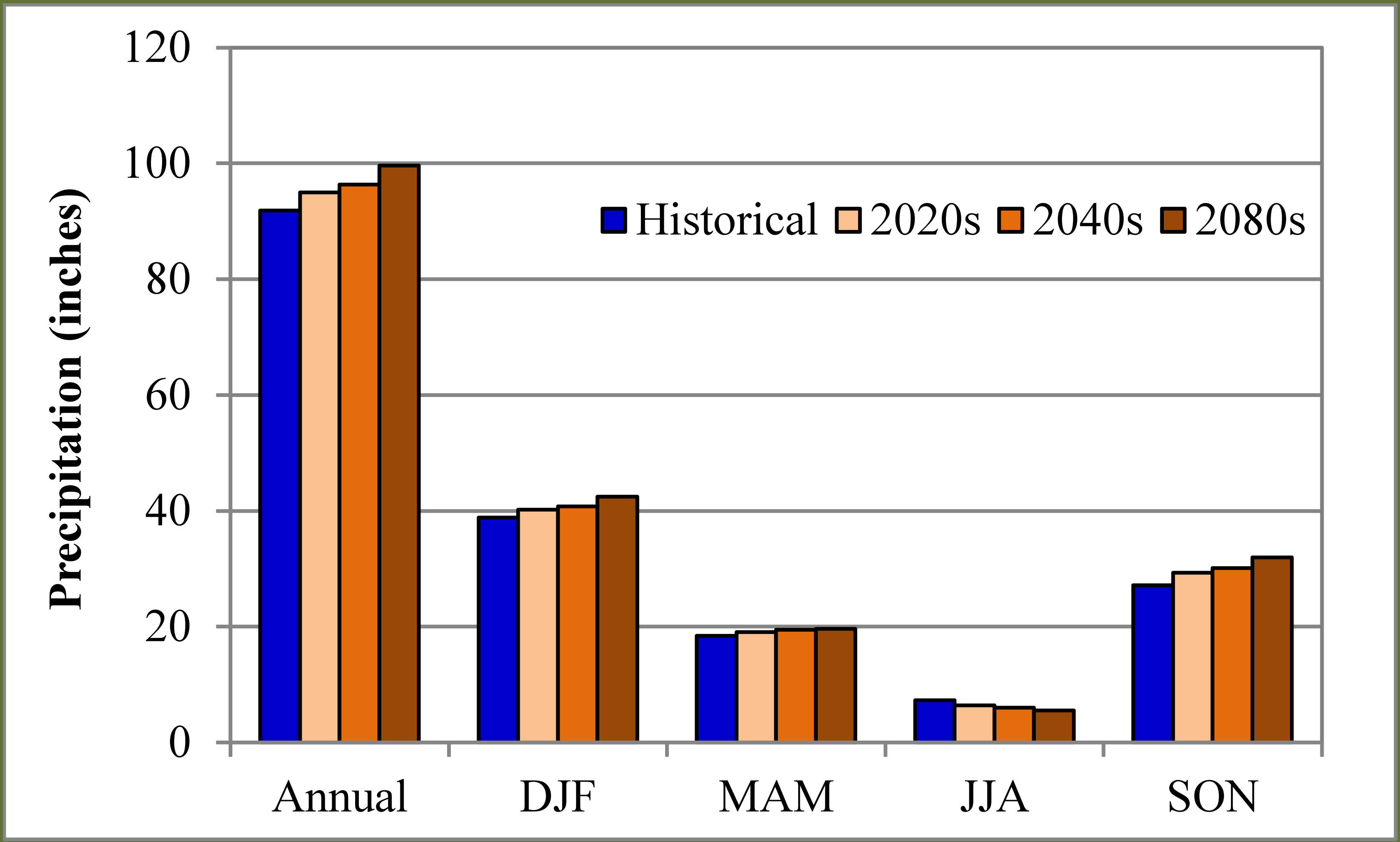
Mote, P.W. and E. P. Salathe Jr., 2010: Future climate in the Pacific Northwest, Climatic Change, DOI: 10.1007/s10584-010-9848-z

Projected Temperature in the Skagit Basin



Summaries of the 20th and 21st century annual and seasonal mean temperatures (in °F) for the A1B and B1 scenarios for the entire Skagit River basin upstream of Mount Vernon. (DJF=winter, MAM=spring, JJA=summer, and SON=fall)

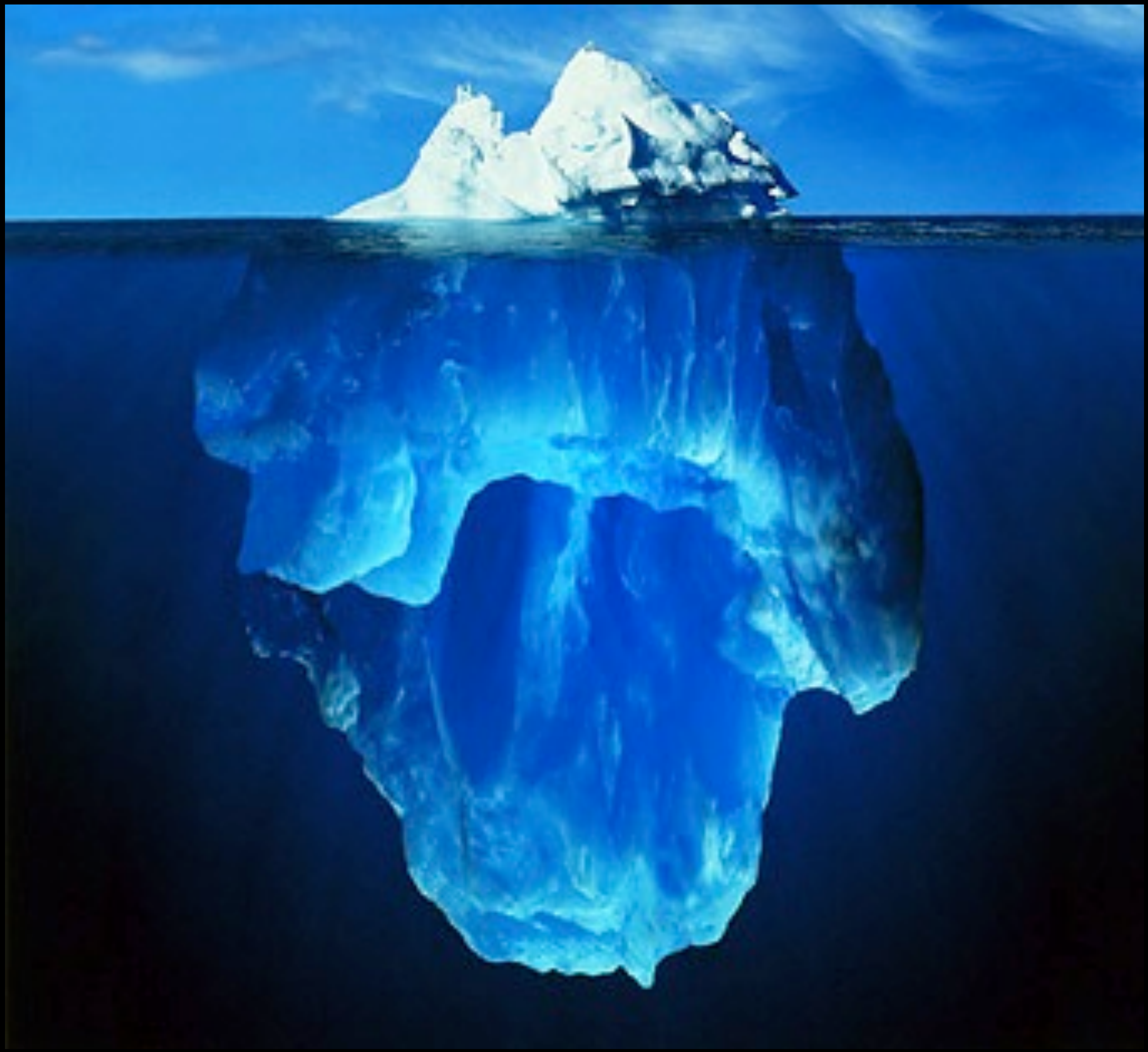
Projected Precipitation in the Skagit Basin



Summaries of 20th and 21st century annual and seasonal precipitation (in inches) for A1B and B1 scenarios for the entire Skagit River basin upstream of Mount Vernon. (DJF=winter, MAM=spring, JJA=summer, and SON=fall).

Lunch

The Skagit Climate Science Consortium

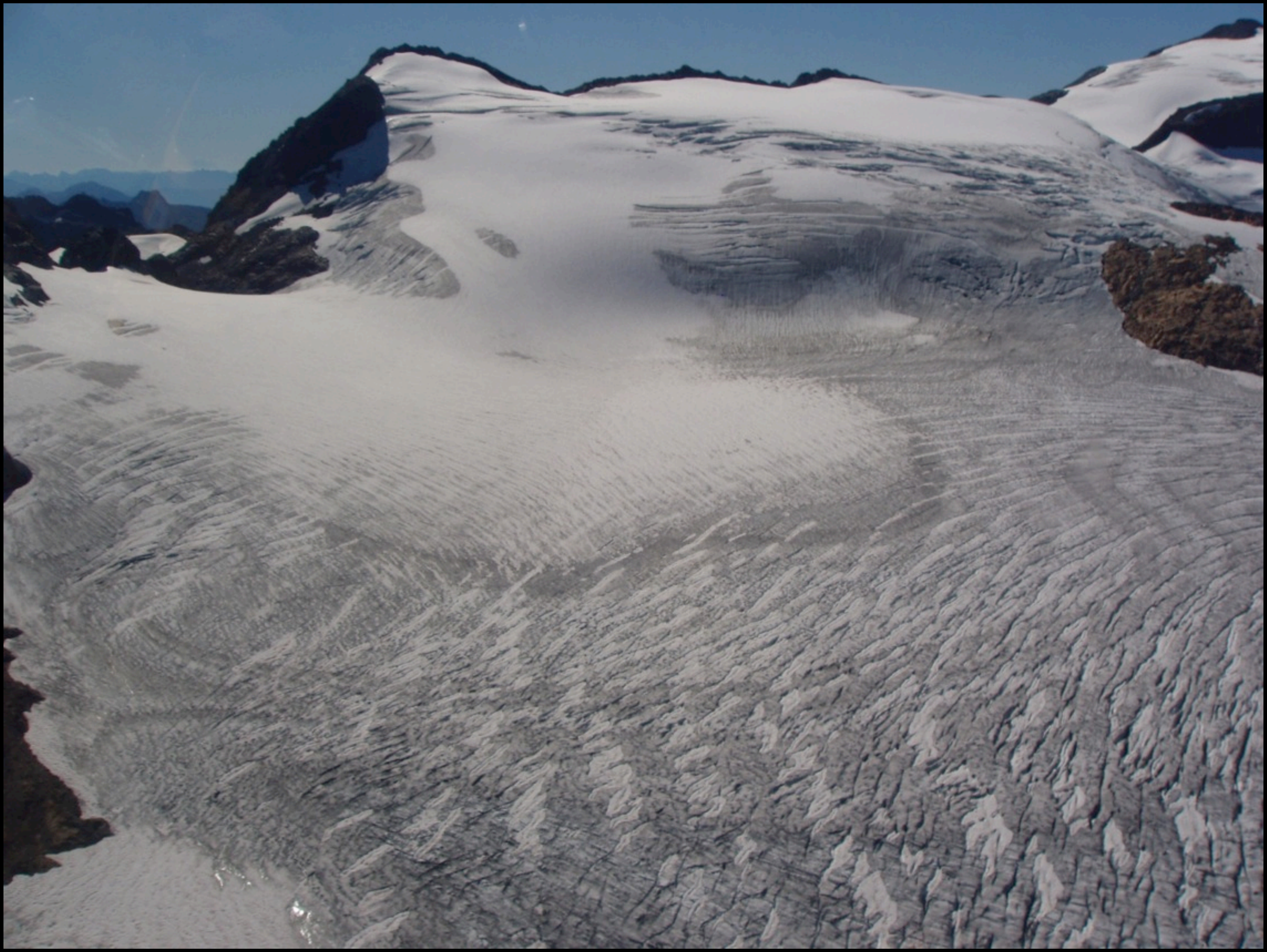


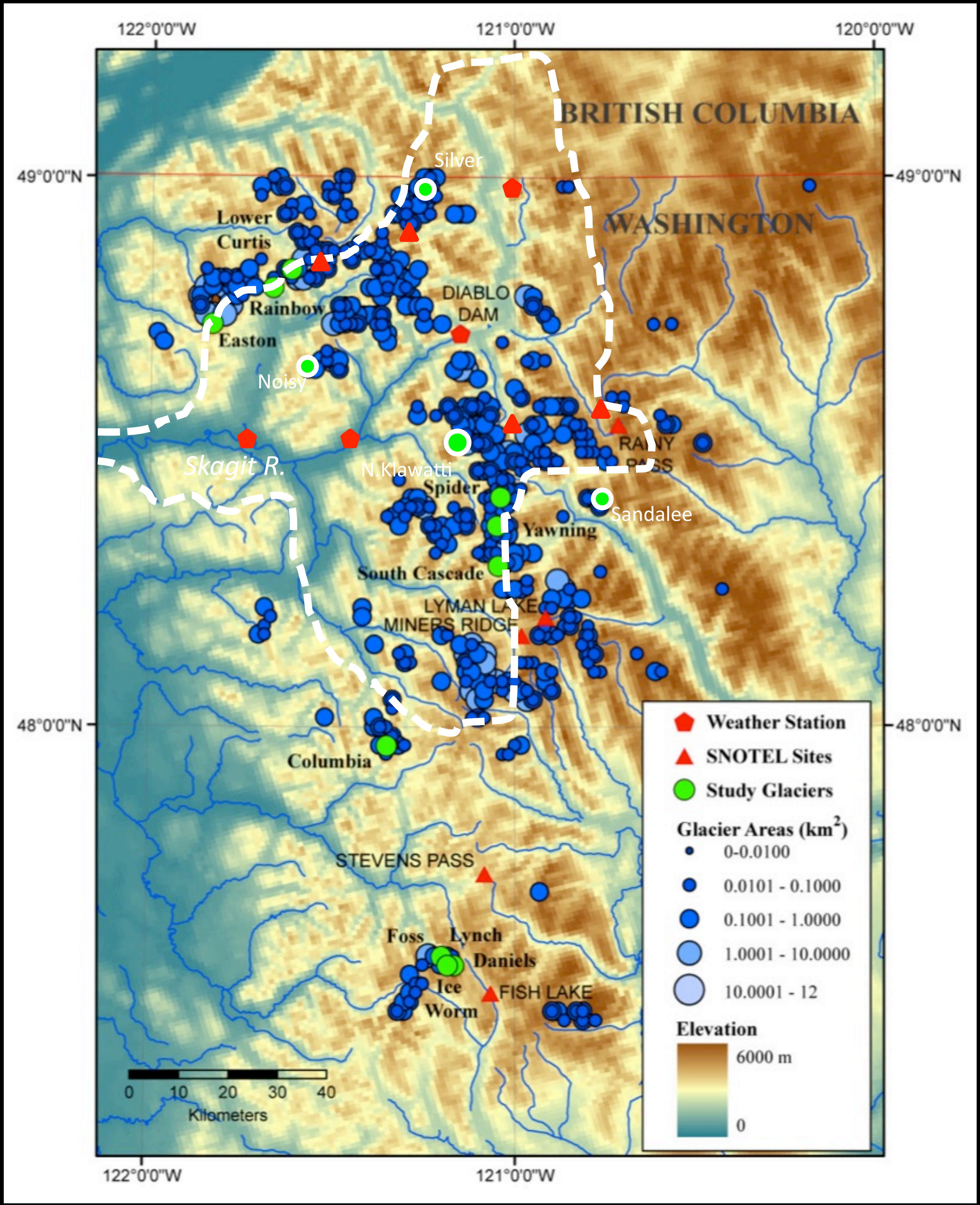
A Dialogue and A Resource

Glaciers and Climate Change In Skagit Basin

Jon L. Riedel, Ph.D., L.G.
Geologist – North Cascades National Park

http://www.nps.gov/noca/naturescience/glacial-mass-balance1.htm





Source NCGCP

There are ~394 glaciers in the Skagit Watershed (Post et al., 1971).


Easton
Glacier


Easton
Glacier
~1900 AD terminus

Silver Glacier, North Cascades National Park

1958 (Post)

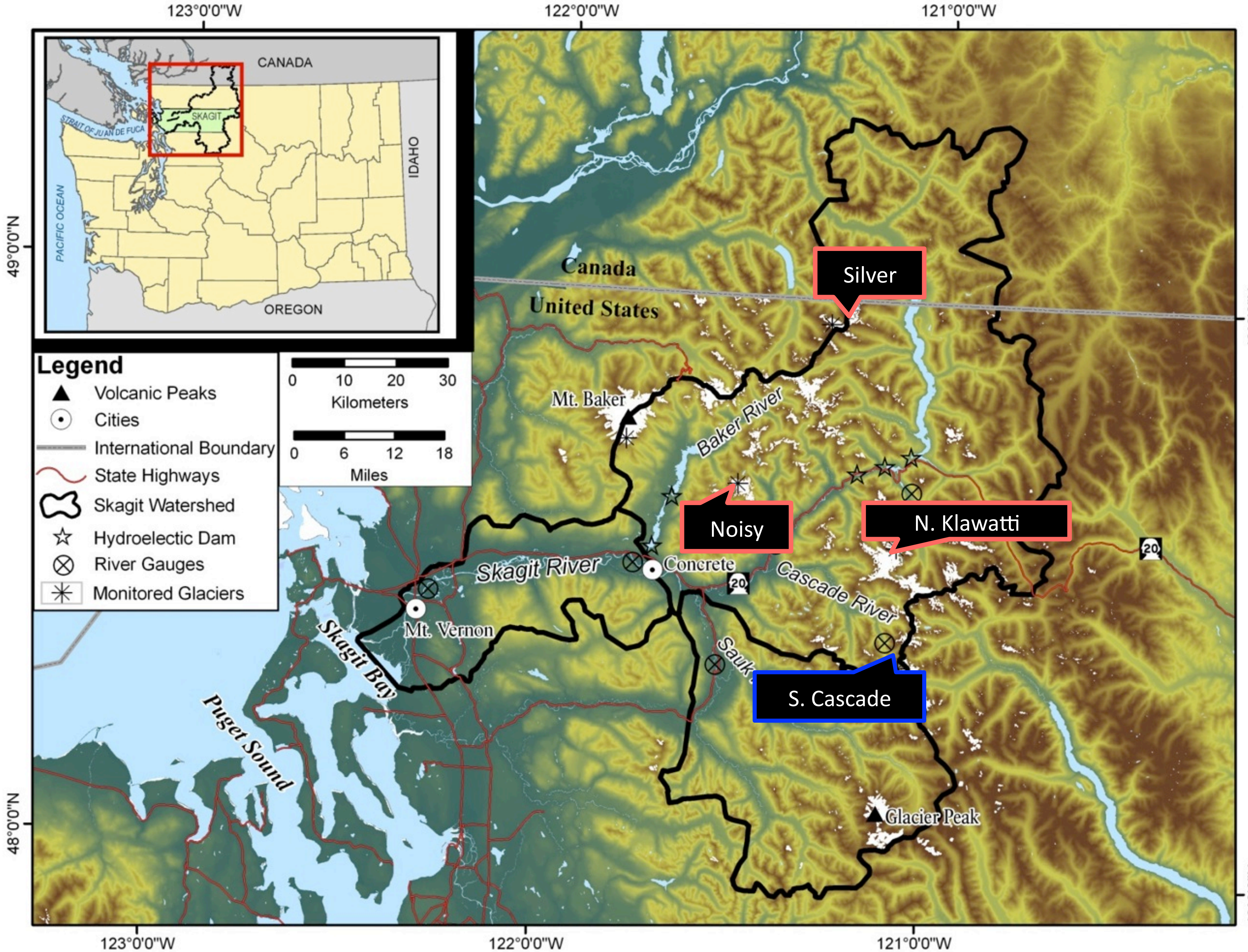
2006 (Scurlock)

Loss of glacial area in the past century:

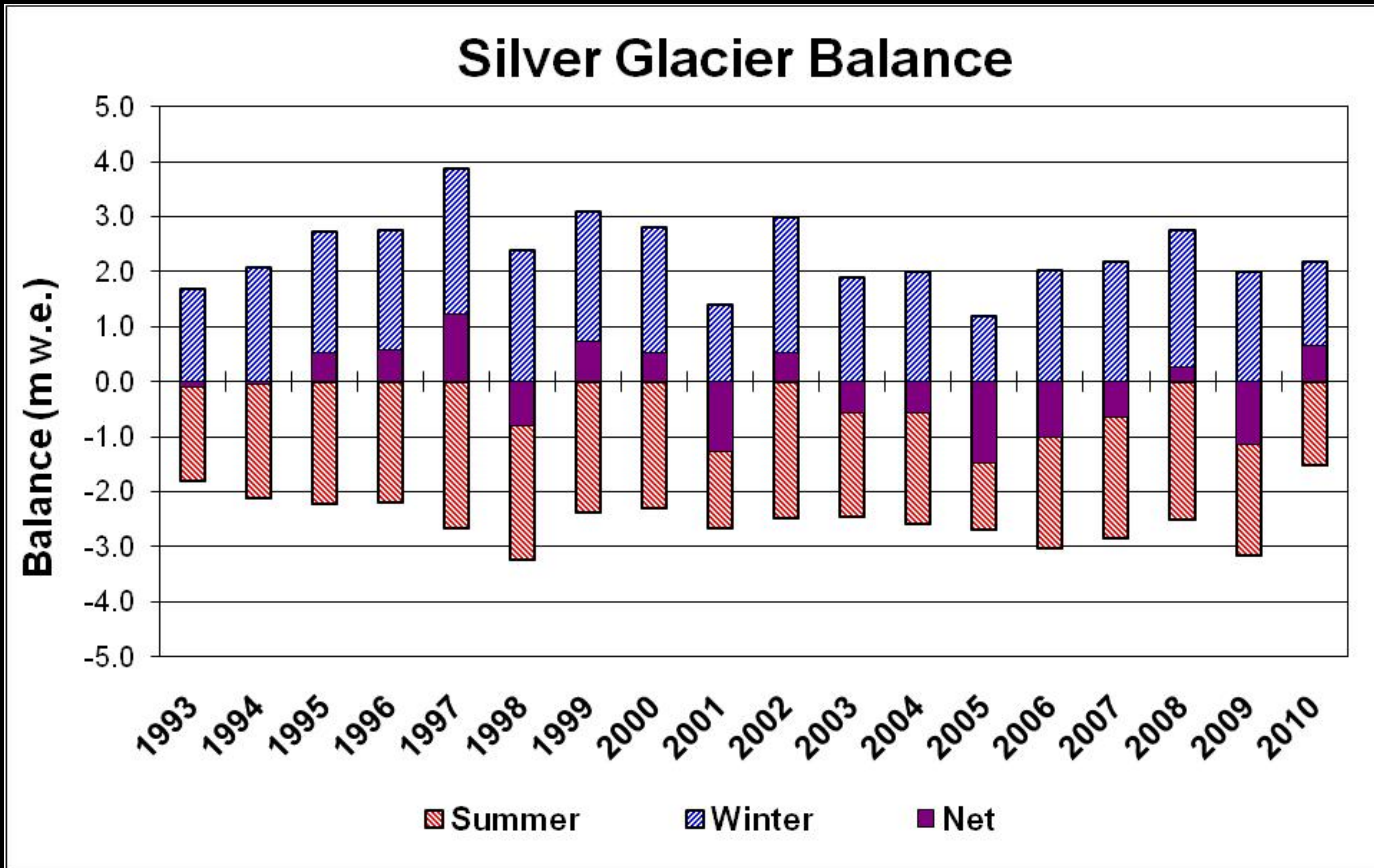
-North Cascades NP ~50% ~1900-1998 (Granshaw, 2002)
-Olympic NP 60% ~1900-2009 (Riedel et al., 2010)
-Mount Rainier NP 21% 1913-1998 (Nylen, 1998)
-Garibaldi PP 44% ~1900-2005 (Koch, 2006)

JS

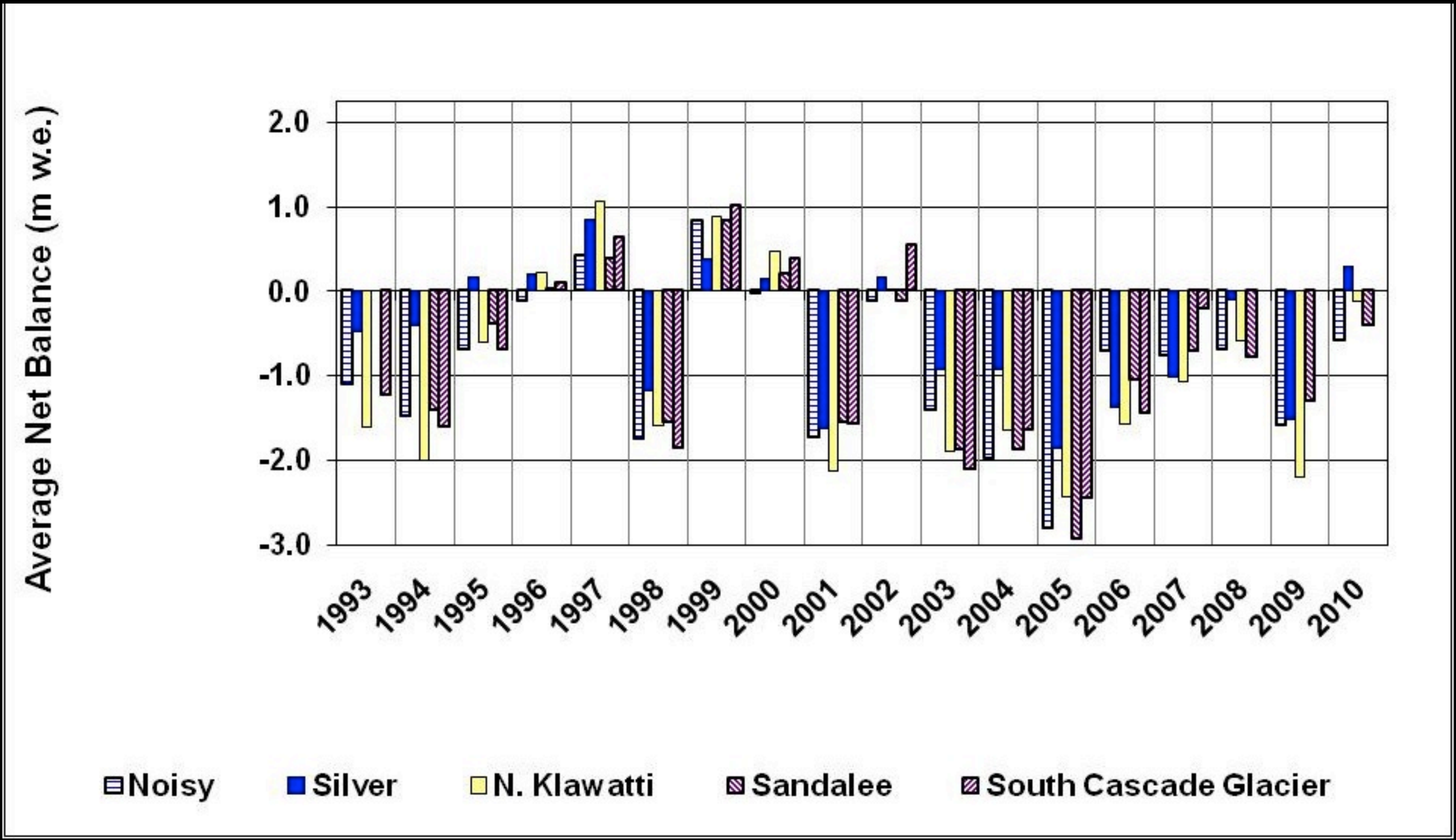
The Skagit's glaciers provide 120-180 billion gallons of fresh water to our rivers and lakes every summer - when we need it most.

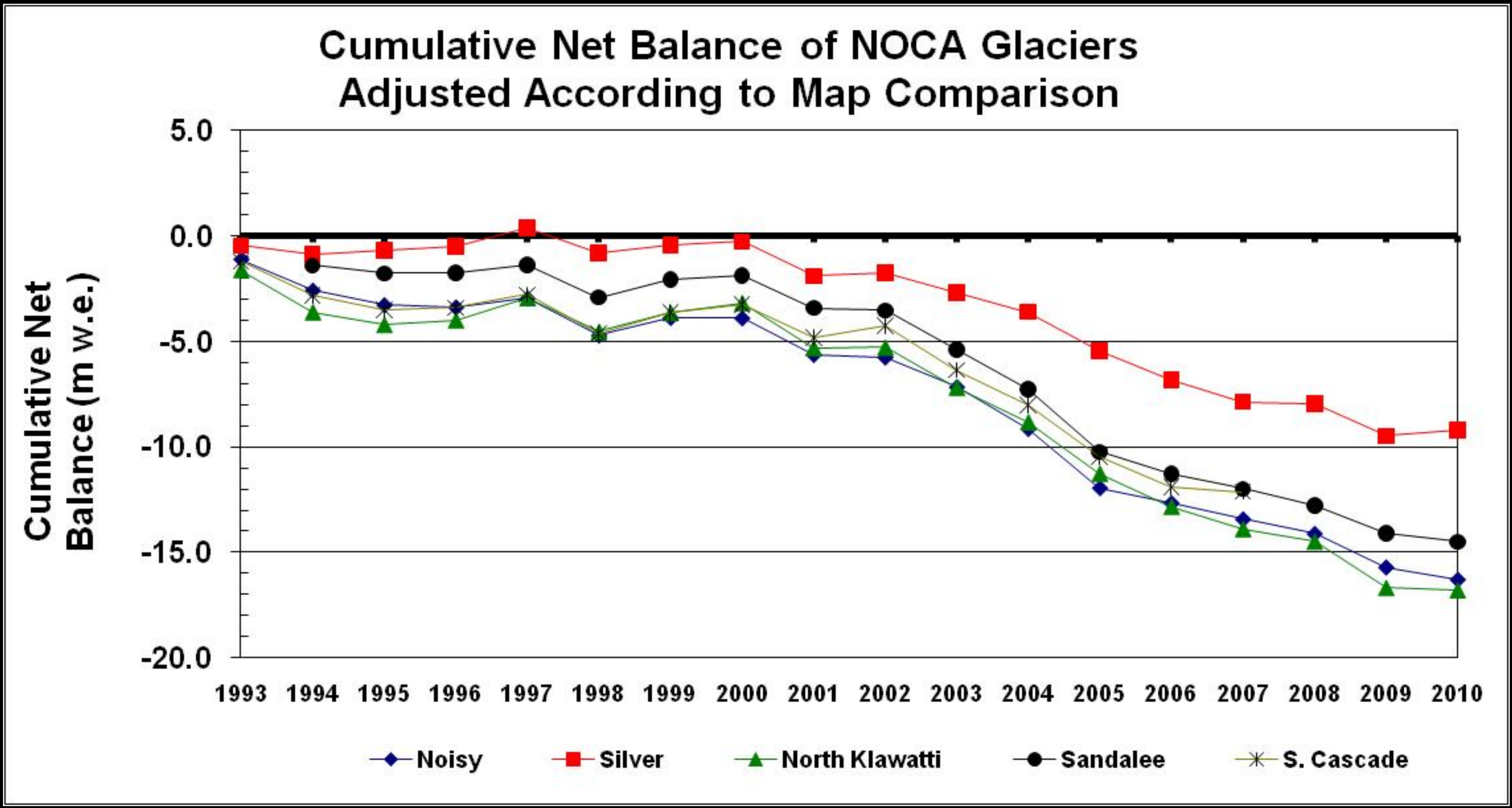


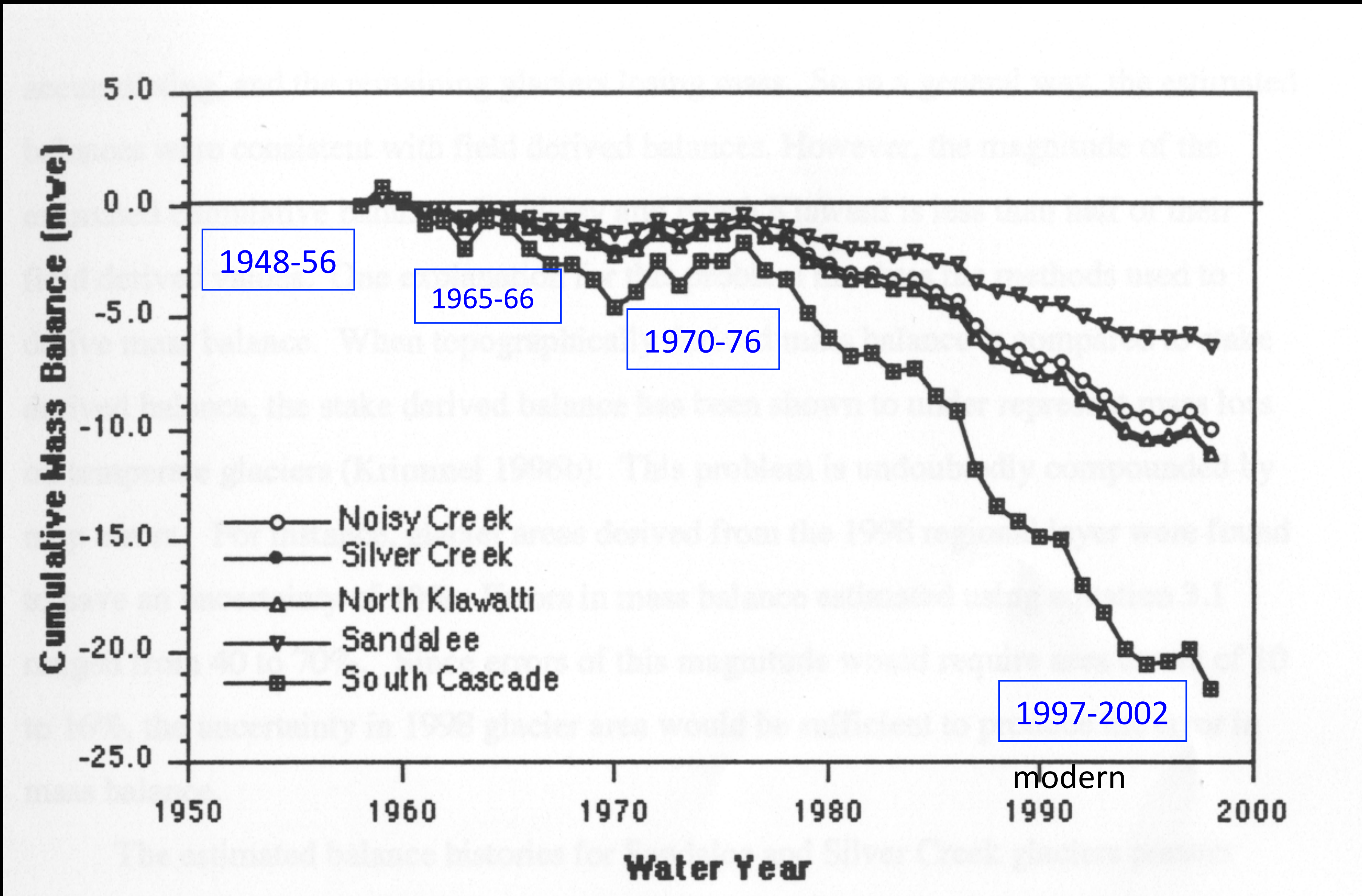
123°0'0"W
122°0'0"W
121°0'0"W
49°0'0"N
48°0'0"N
CANADA
SKAGIT
STRAIT OF JUAN DE FUCA
PACIFIC OCEAN
IDAHO
OREGON
Legend
Volcanic Peaks
Cities
International Boundary
State Highways
Skagit Watershed
Hydroelectic Dam
River Gauges
Monitored Glaciers
0 10 20 30
Kilometers
0 6 12 18
Miles
Canada
United States
Silver
Mt. Baker
Baker River
Noisy
N. Klawatti
Skagit River
Concrete
Cascade River
20
Mt. Vernon
Skagit Bay
Sauk
S. Cascade
Puget Sound
Glacier Peak


Silver Glacier Balance
Balance (m w.e.)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Summer
Winter
Net

Annual Net Mass Balance of NOCA Glaciers



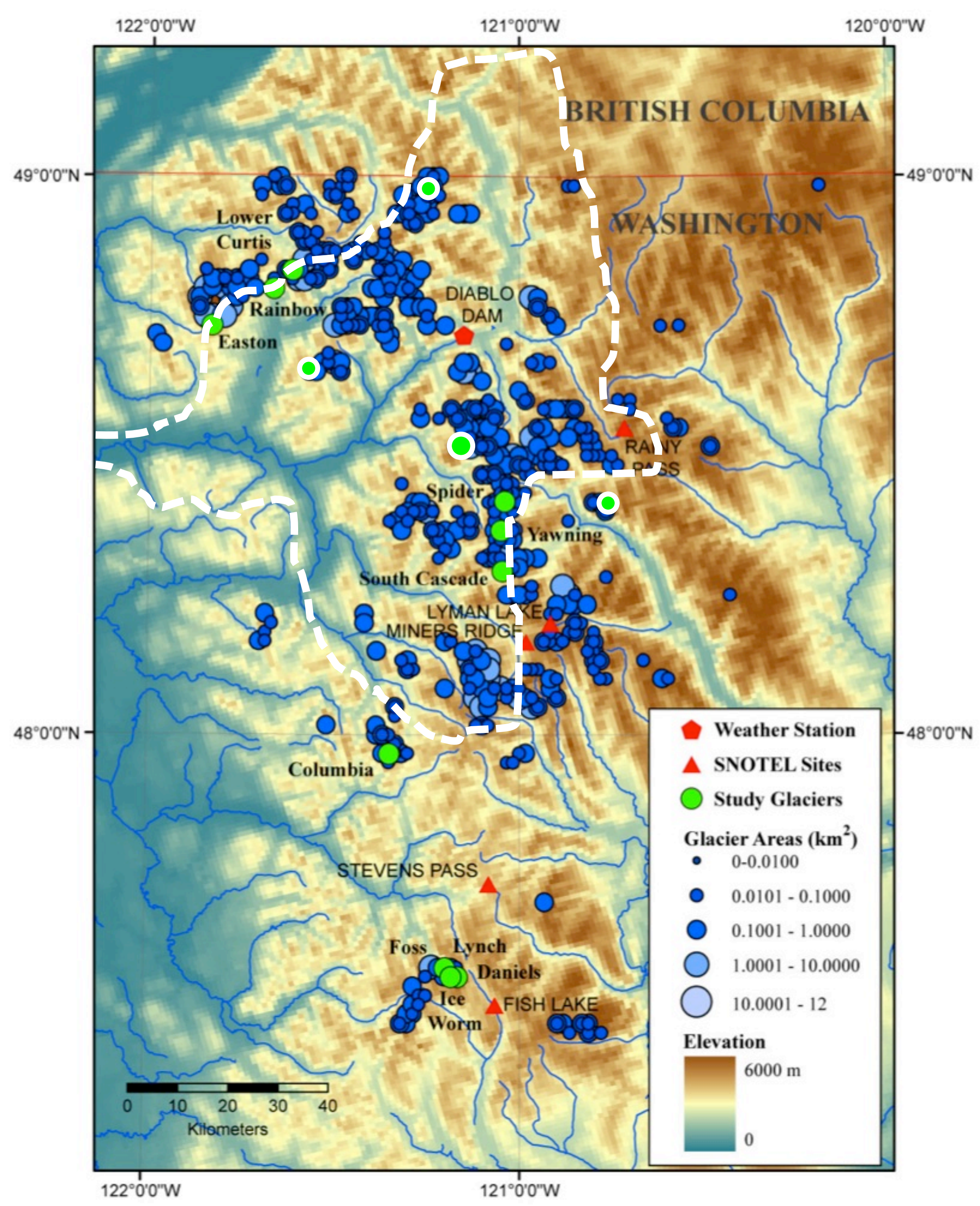

Cumulative Net Balance of NOCA Glaciers
Adjusted According to Map Comparison
Cumulative Net Balance (m w.e.)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Noisy
Silver
North Klawatti
Sandalee
S. Cascade



Cumulative Mass Balance (mwe)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
1950
1960
1970
1980
1990
2000
Water Year
Noisy Creek
Silver Creek
North Klawatti
Sandalee
South Cascade
1948-56
1965-66
1970-76
1997-2002
modern

Thunder Creek Summer Streamflow

- Has declined 31% since 1900
- Would decline an additional 25% if glaciers melt away completely



❖Since 1993, the Skagit's ice reservoir has a net loss of ~400B gallons

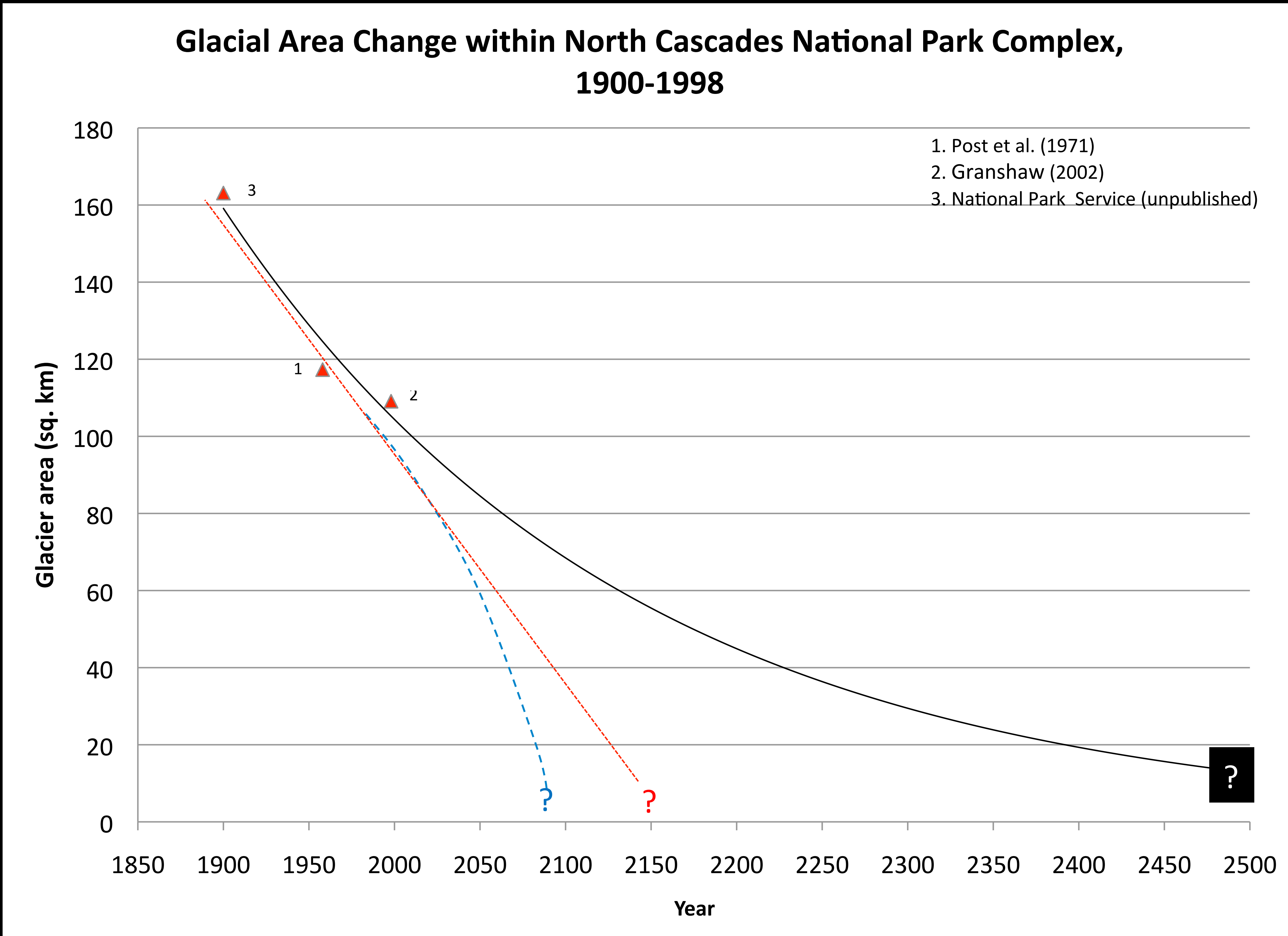
= 1 month continuous flow at Mt. Vernon

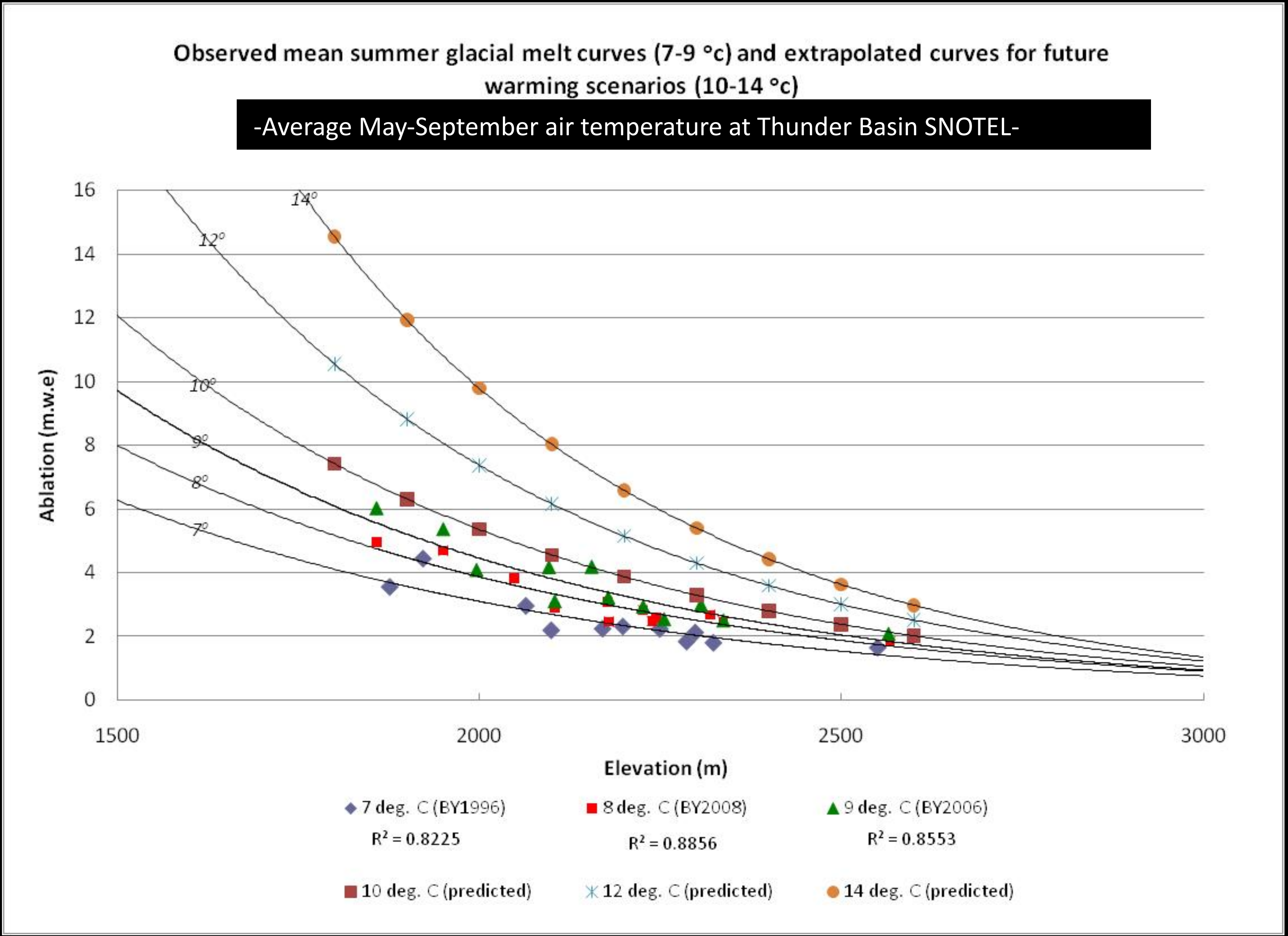
= 44 years water supply @ current use rate of 8.6B gallons/year Skagit County

Glaciers and Climate Change In Skagit Basin

Jon L. Riedel, Ph.D., L.G.
Geologist – North Cascades National Park

http://www.nps.gov/noca/naturescience/glacial-mass-balance1.htm


Glacial Area Change within North Cascades National Park Complex, 1900-1998
1. Post et al. (1971)
2. Granshaw (2002)
3. National Park Service (unpublished)
Glacier area (sq. km)
Year
180
160
140
120
100
80
60
40
20
0
1850
1900
1950
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
3
1
2
?
?
?


Observed mean summer glacial melt curves (7-9 °c) and extrapolated curves for future warming scenarios (10-14 °c)
-Average May-September air temperature at Thunder Basin SNOTEL-
Ablation (m.w.e)
Elevation (m)
14°
12°
10°
9°
8°
7°
7 deg. C (BY1996)
R^2 = 0.8225
8 deg. C (BY2008)
R^2 = 0.8856
9 deg. C (BY2006)
R^2 = 0.8553
10 deg. C (predicted)
12 deg. C (predicted)
14 deg. C (predicted)

Effects of Projected Climate Change on the Hydrology of the Skagit River Basin

Dr. Alan F. Hamlet

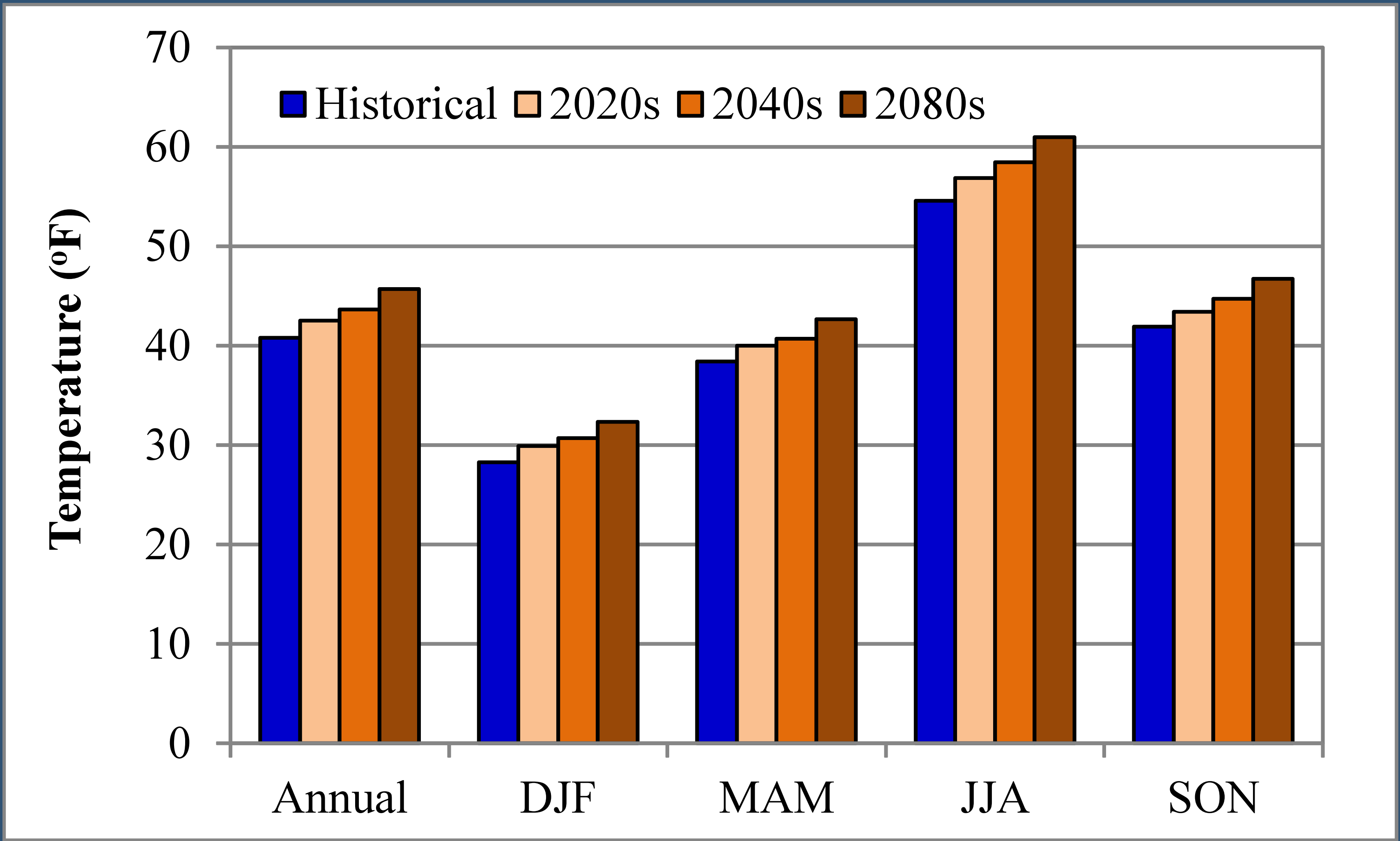
- Skagit Climate Science Consortium
- Climate Impacts Group
- Dept. of Civil and Environmental Engineering
  University of Washington

Department of Civil and Environmental Engineering

University of Washington Research Team
Columbia Basin Climate Change Scenarios Project

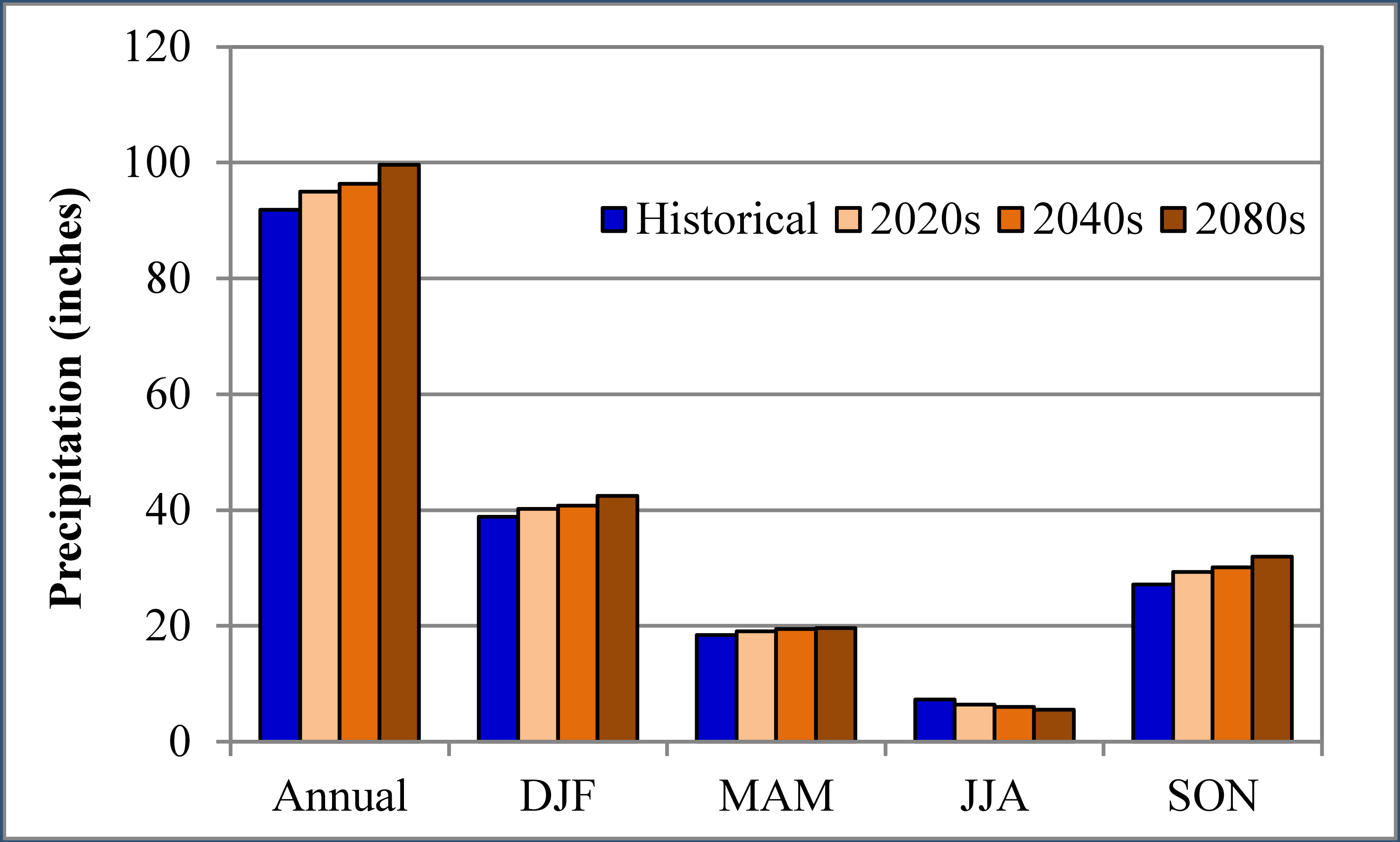
Lara Whitely Binder
Pablo Carrasco
Jeff Deems
Marketa McGuire Elsner
Alan F. Hamlet
Carrie Lee
Se-Yeun Lee
Dennis P. Lettenmaier
Jeremy Littell
Guillaume Mauger
Nate Mantua
Ed Miles
Kristian Mickelson
Philip W. Mote
Rob Norheim
Erin Rogers
Eric Salathé
Amy Snover
Ingrid Tohver
Andy Wood

Projected Temperature in the Skagit Basin



Summaries of the 20th and 21st century annual and seasonal mean temperatures (in °F) for the A1B and B1 scenarios for the entire Skagit River basin upstream of Mount Vernon. (DJF=winter, MAM=spring, JJA=summer, and SON=fall)

Projected Precipitation in the Skagit Basin

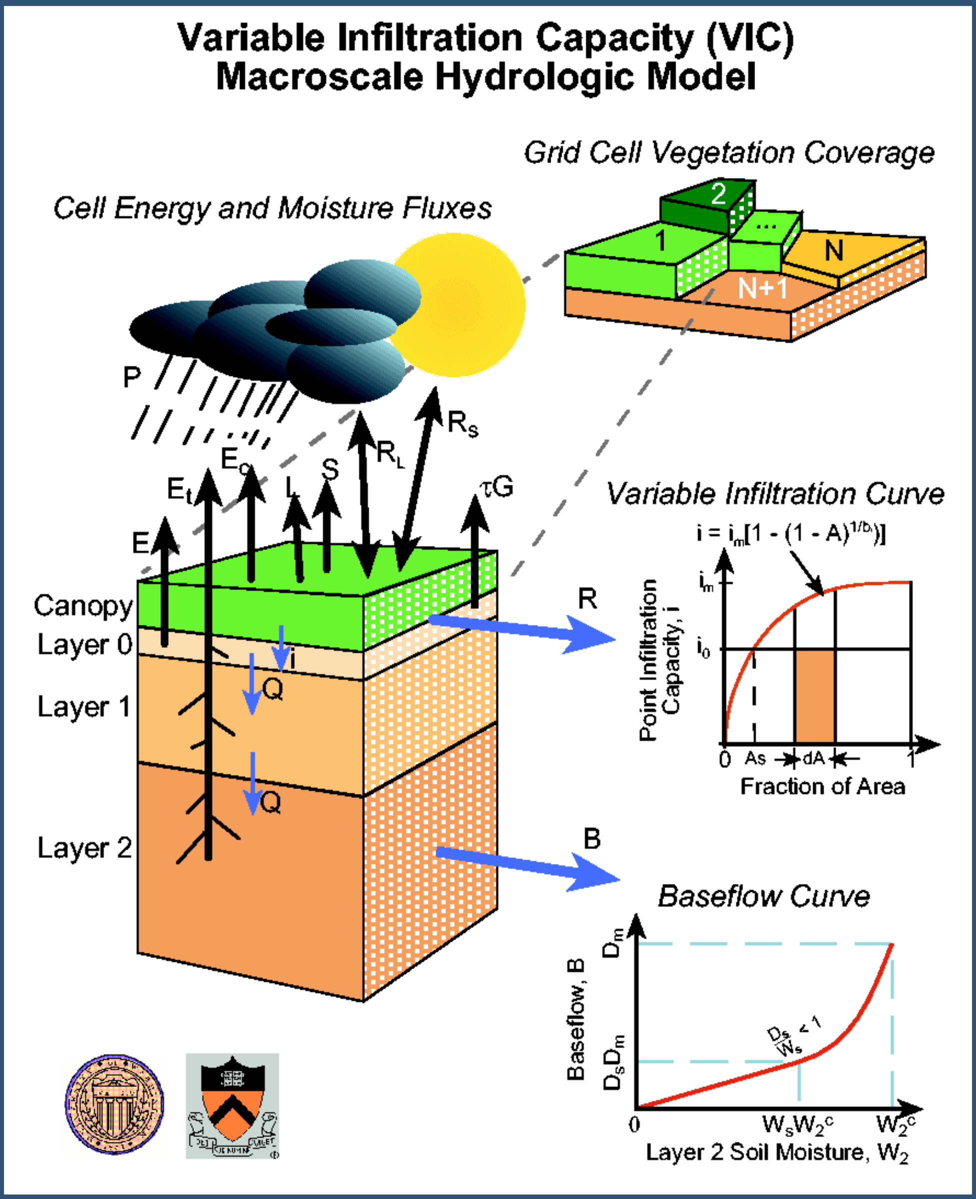


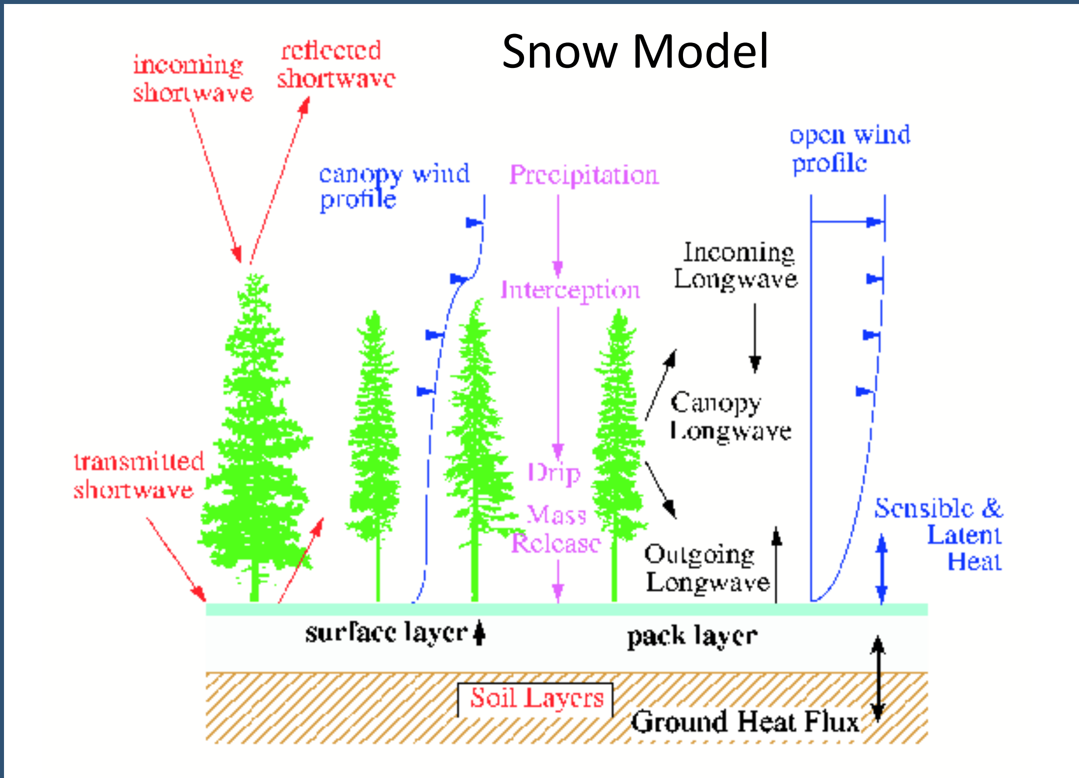
Summaries of 20th and 21st century annual and seasonal precipitation (in inches) for A1B and B1 scenarios for the entire Skagit River basin upstream of Mount Vernon. (DJF=winter, MAM=spring, JJA=summer, and SON=fall).

Hydrologic Projections

Schematic of VIC Hydrologic Model and Energy Balance Snow Model

Hydrology models translate climate information into hydrologic impacts.





Hydrologic Climate Change Scenarios for the Pacific Northwest Columbia River Basin and Coastal Drainages

- Project Home
- Introduction for New Users
- Join Project's Listserve
- Project Report
- Citations and Contacts
- Project Updates
- Climate Scenarios
  - Site-specific Data
  - Primary Data
  - Reservoir Model Input Data

Climate change is projected to have substantial impacts on Pacific Northwest water resources and ecosystems. Recognizing this, resource managers have expressed growing interest in incorporating climate change information into long-range planning. The availability of hydrologic scenarios to support climate change adaptation and long-range planning, however, has been limited until very recently to a relatively small number of selected case studies. More comprehensive resources needed to support regional planning have been lacking. Furthermore, ecosystem studies at the landscape scale need consistent climate change information and databases over large geographic areas. Products using a common set of methods that would support such studies have not been readily available.

To address these needs, the Climate Impacts Group worked with several prominent water management agencies in the Pacific Northwest to develop hydrologic climate change scenarios for approximately 300 streamflow locations in the Columbia River basin and selected coastal drainages west of the Cascades. Study partners are listed below. The scenarios, provided to the public for free via this website, allow planners to consider how hydrologic changes may affect water resources management objectives and ecosystems.

Access to the data and summary products is available from the menu to the left. The hydrologic data produced by the study are based on climate change scenarios produced for the IPCC Fourth Assessment effort. Information on the methods and modeling tools used in the study is provided in the summary report. For new users of the site, a guide to the website and the data resources contained within it is also

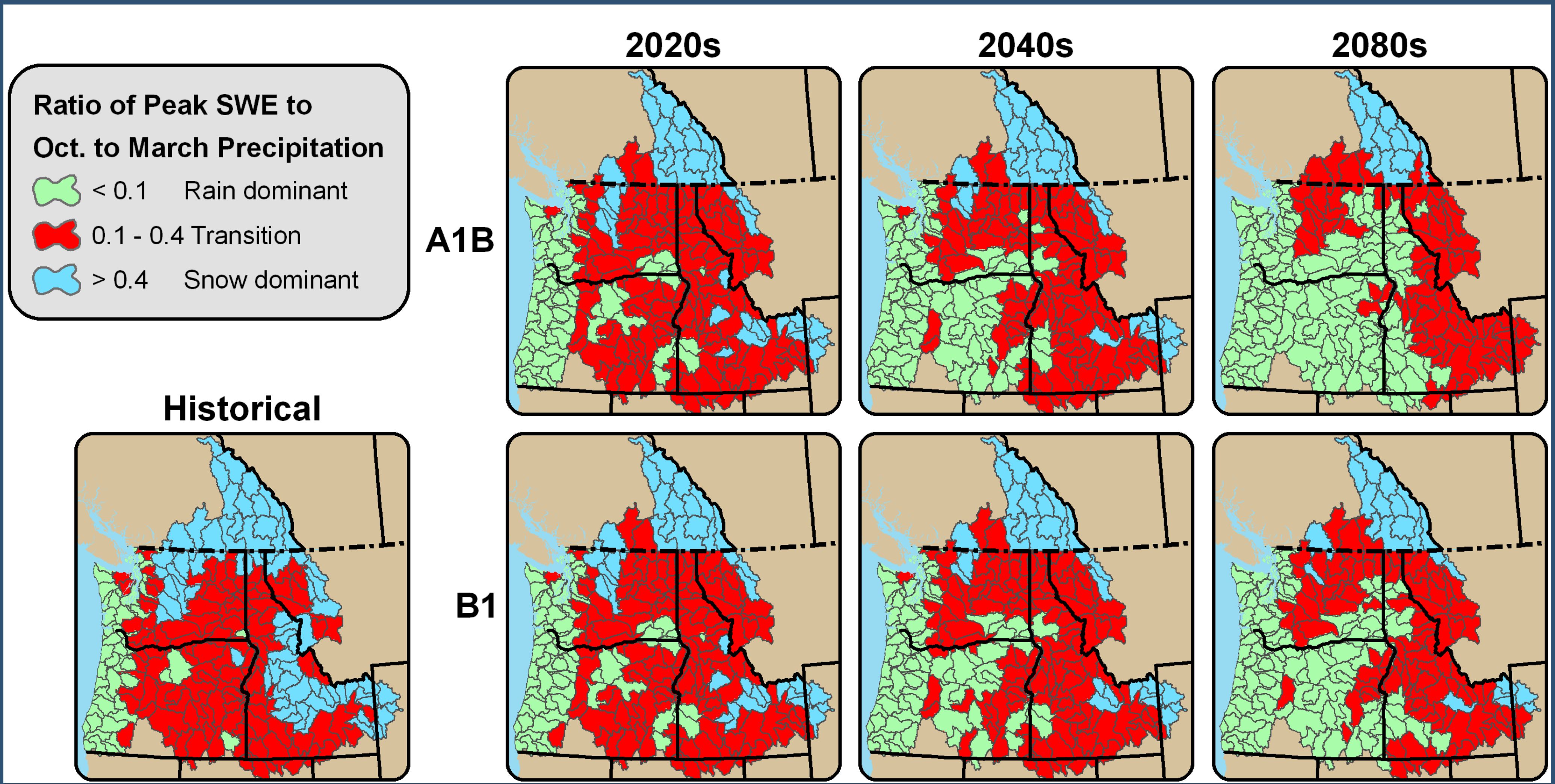
...e Impacts Group was funded by the following research partners to develop ...ia River Basin and coastal drainages climate change scenarios:

- ...State Department of Ecology
- ...eville Power Administration
- Northwest Power and Conservation Council
- Oregon Department of Water Resources
- British Columbia Ministry of Environment

Hydrologic Products

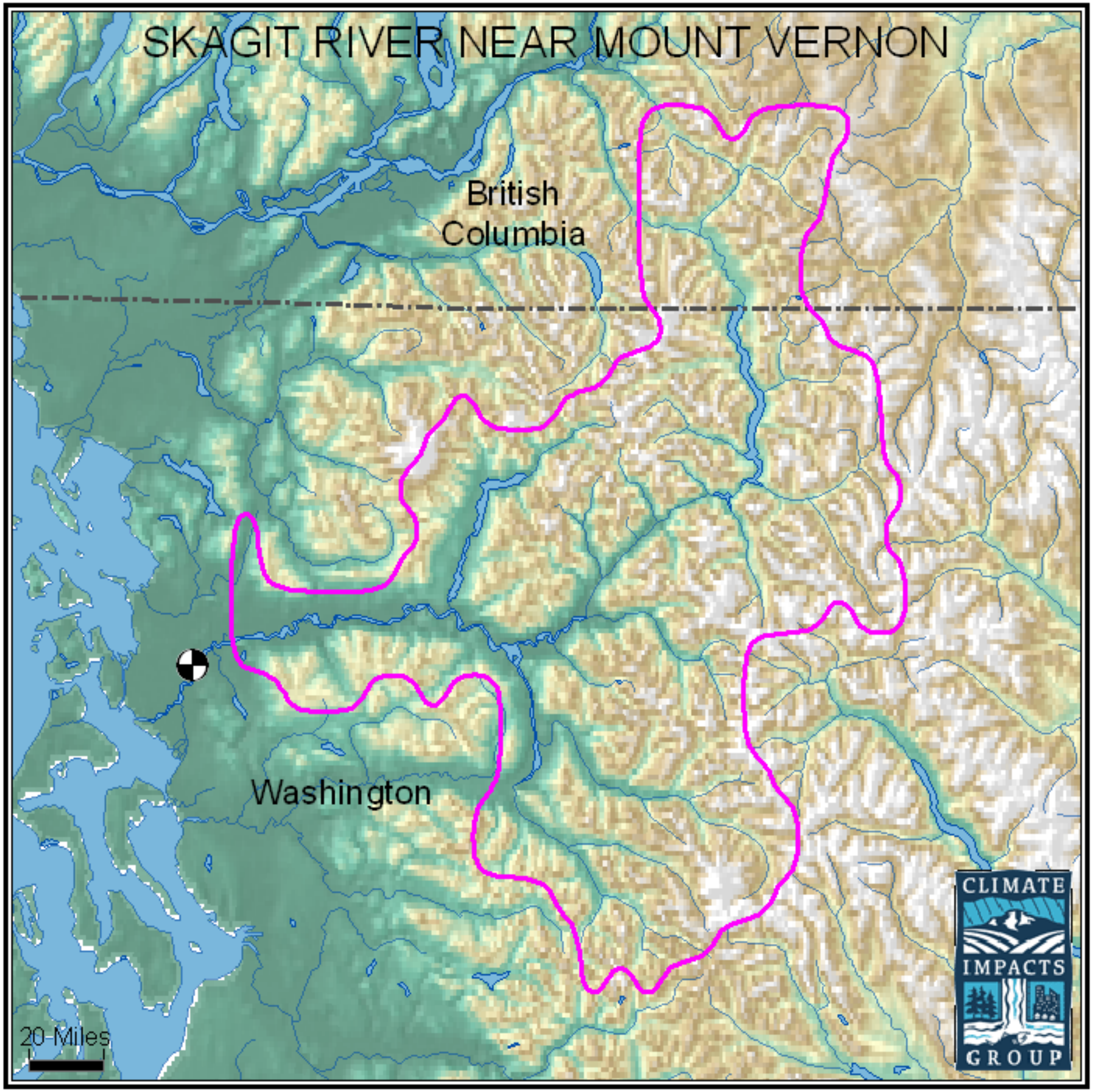
http://www.hydro.washington.edu/2860/

Watershed Classifications:
Transformation From Snow to Rain

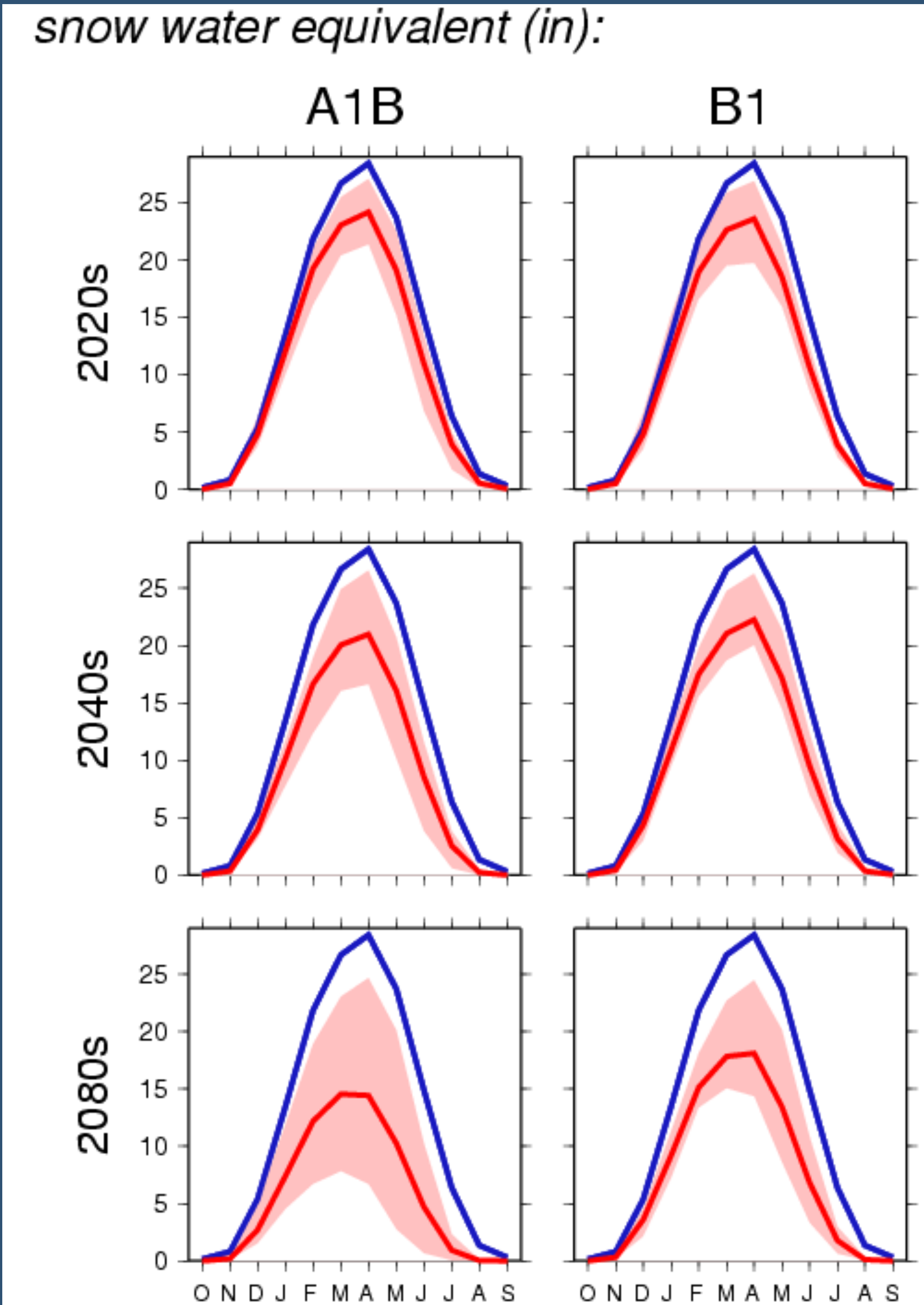


Map: Rob Norheim

Skagit River Basin Projections

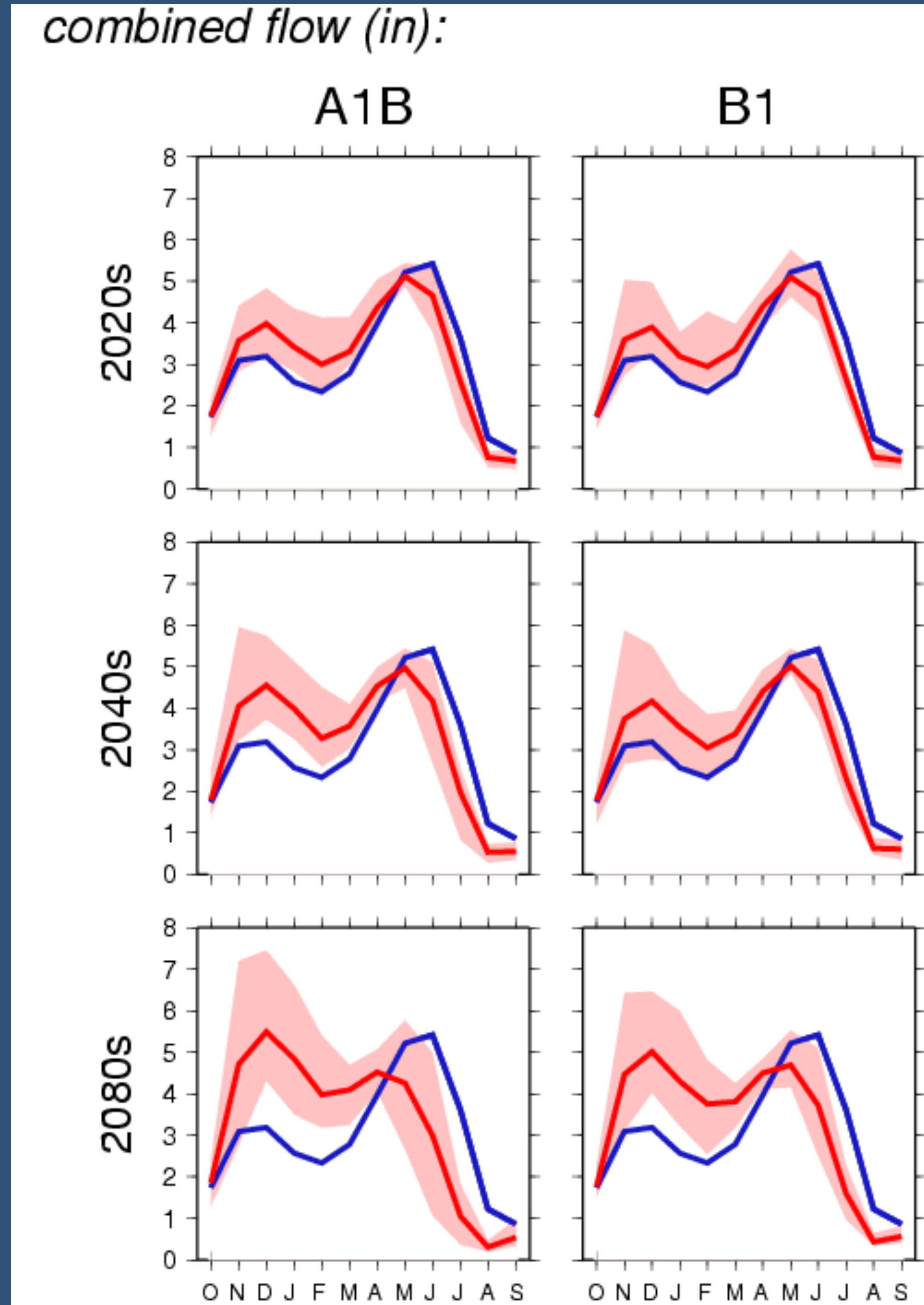

SKAGIT RIVER NEAR MOUNT VERNON
British Columbia
Washington
20 Miles
CLIMATE IMPACTS GROUP

SWE



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

Runoff



combined flow (in):
A1B
B1
2020s
2040s
2080s
0
1
2
3
4
5
6
7
8
O N D J F M A M J J A S

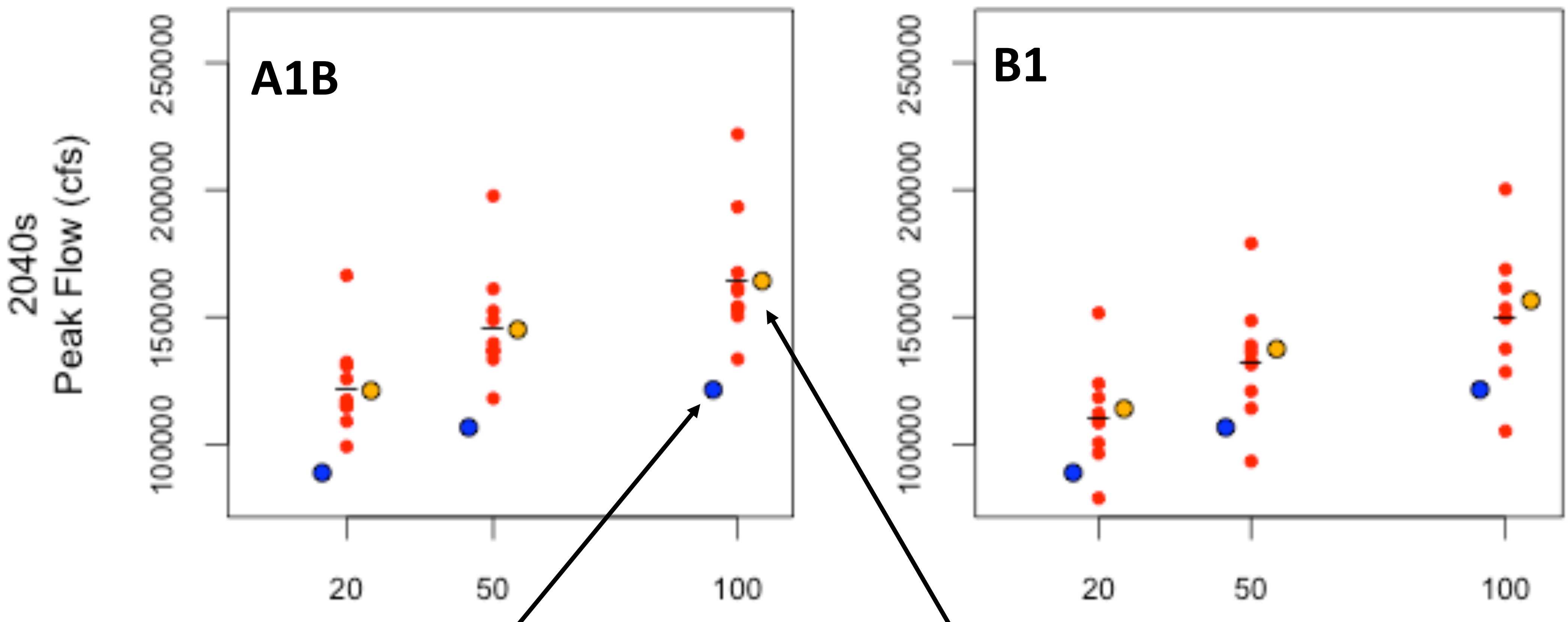
Summary of Flooding Impacts

Rain Dominant Basins:
Possible increases in flooding due to increased precipitation intensity, but no significant change from warming alone.

Mixed Rain and Snow Basins Along the Coast:
Strong increases due to warming and increased precipitation intensity (both effects increase flood risk)

Inland Snowmelt Dominant Basins:
Relatively small overall changes because effects of warming (decreased risks) and increased precipitation intensity (increased risks) are in the opposite directions.

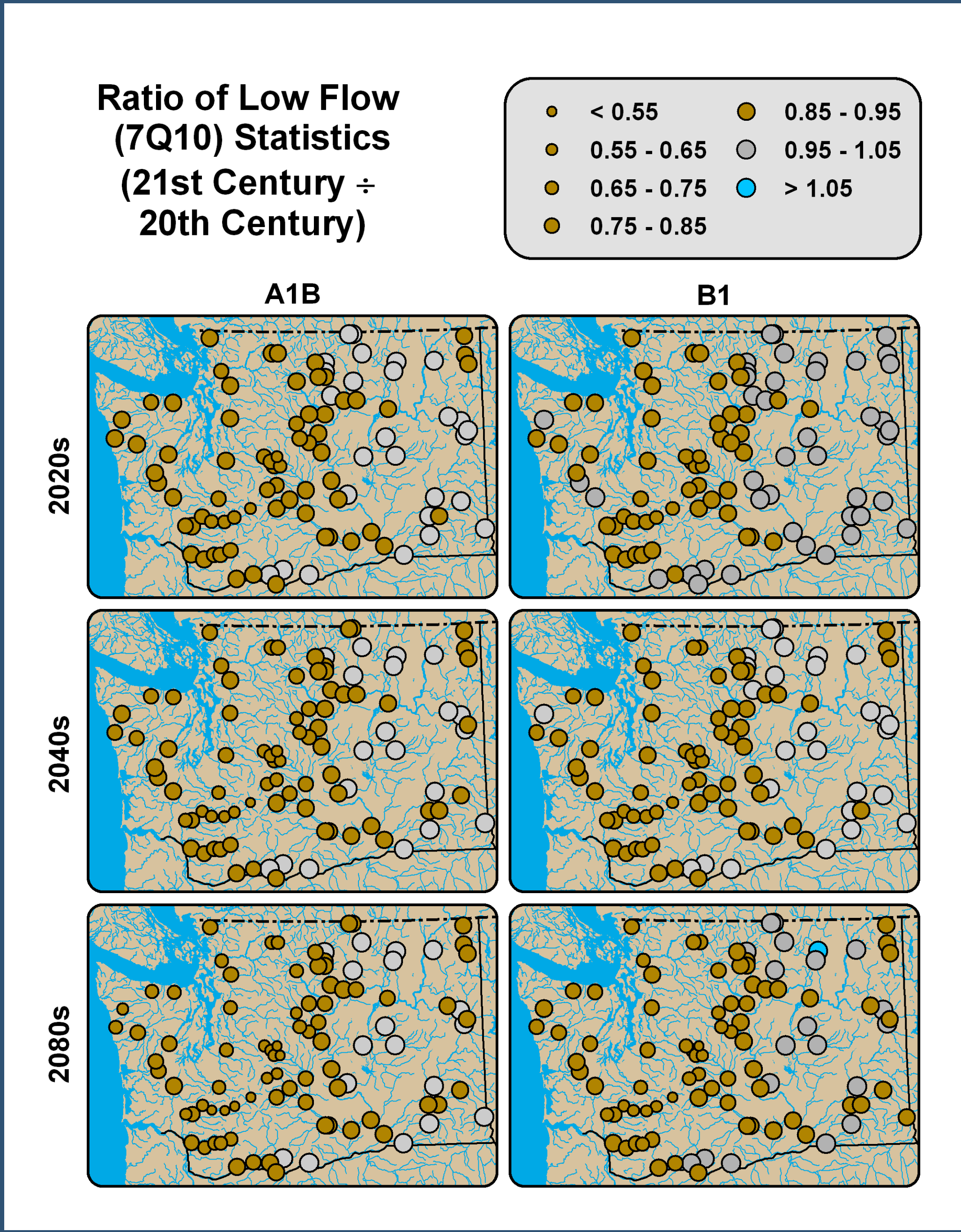
2040s Changes in Flood Risk
Skagit River at Mount Vernon



Historical

10 Member Ensemble
Using the Hybrid Delta
Downscaling Approach

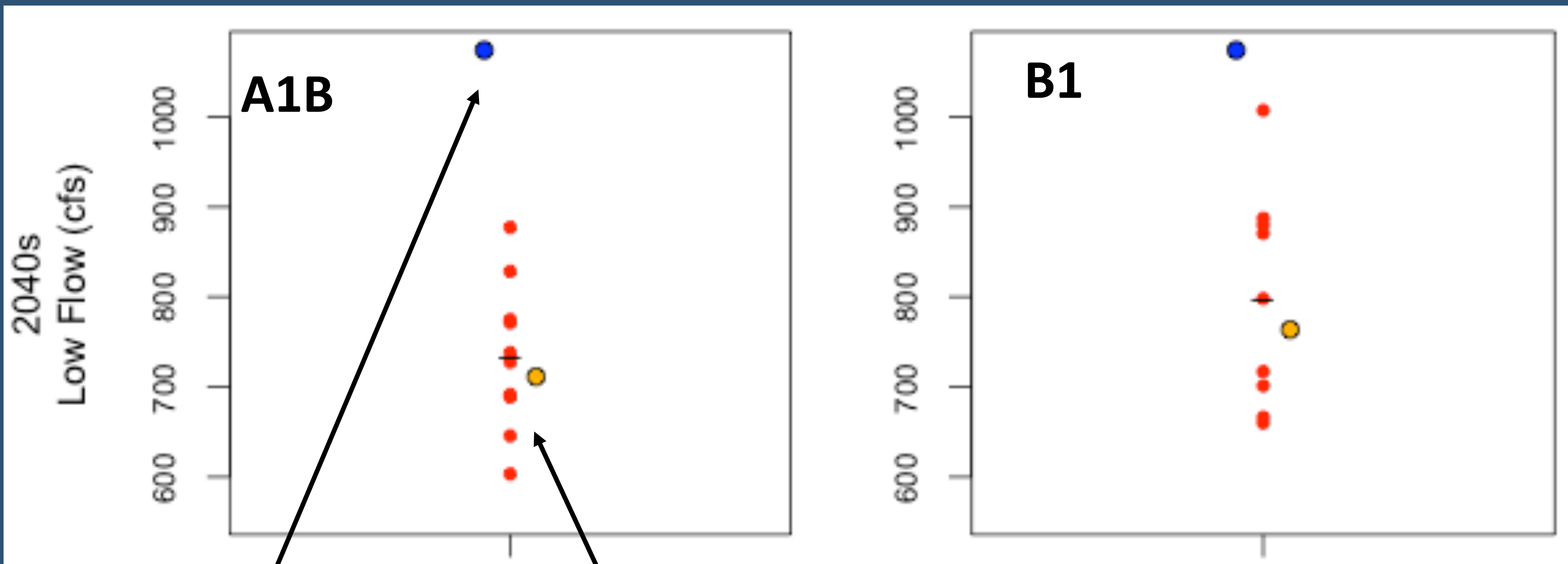
Changes in Low Flows



Extreme 7-day low flow values (7Q10) are projected to systematically decline in western WA due to loss of snowpack and projected dryer summers

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*, doi: 10.1007/s10584-010-9845-2

2040s Changes in Extreme 7-day Low Flow for the Skagit River at Mount Vernon



Historical

10 Member Ensemble Using the Hybrid Delta Downscaling Approach


Loss of glacial runoff in late summer is expected to exacerbate low flow impacts in basins with significant glacial coverage.

Related Impacts

Municipal Water Supply

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

Agriculture

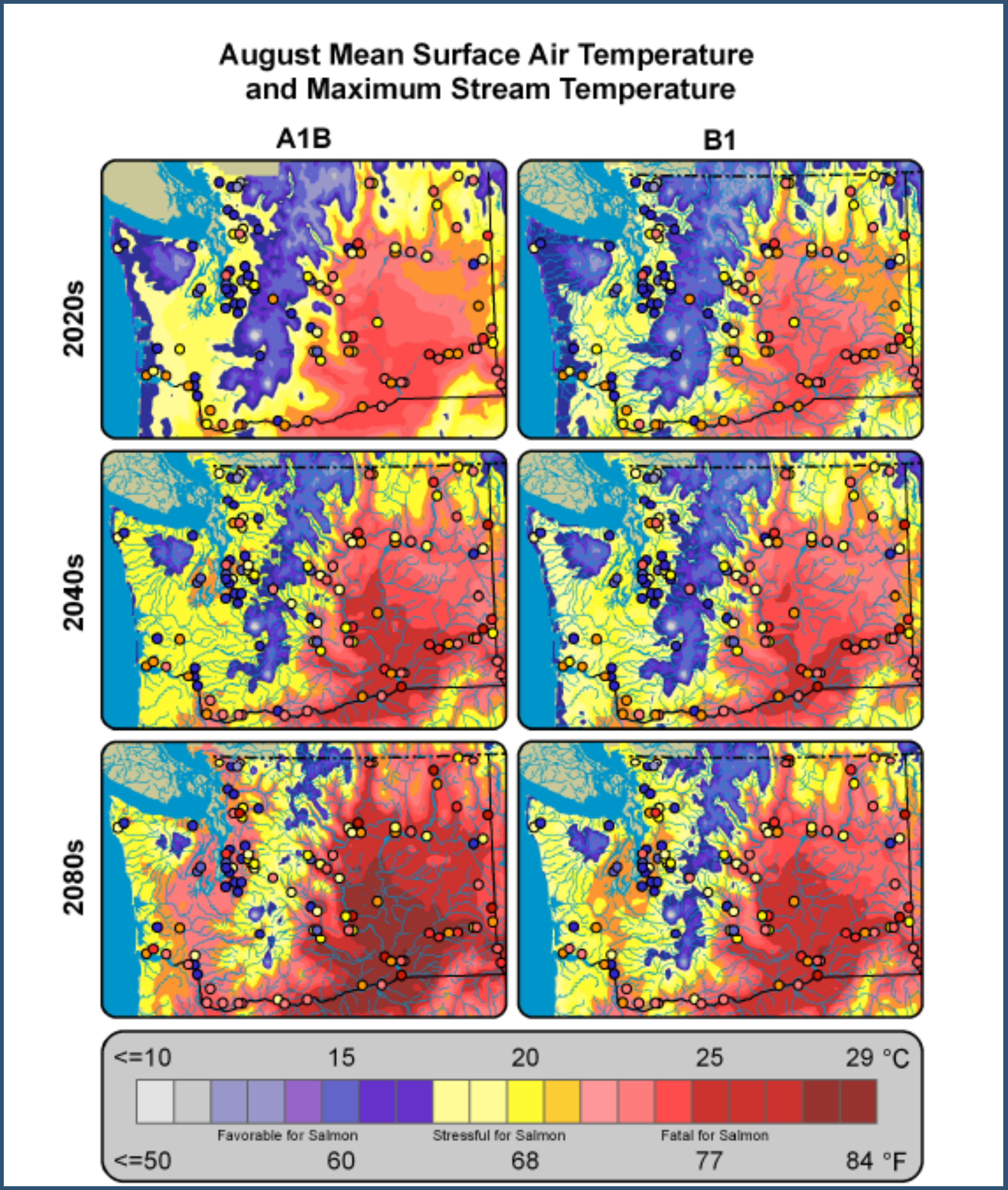
Floodplain Management

Hydropower Production

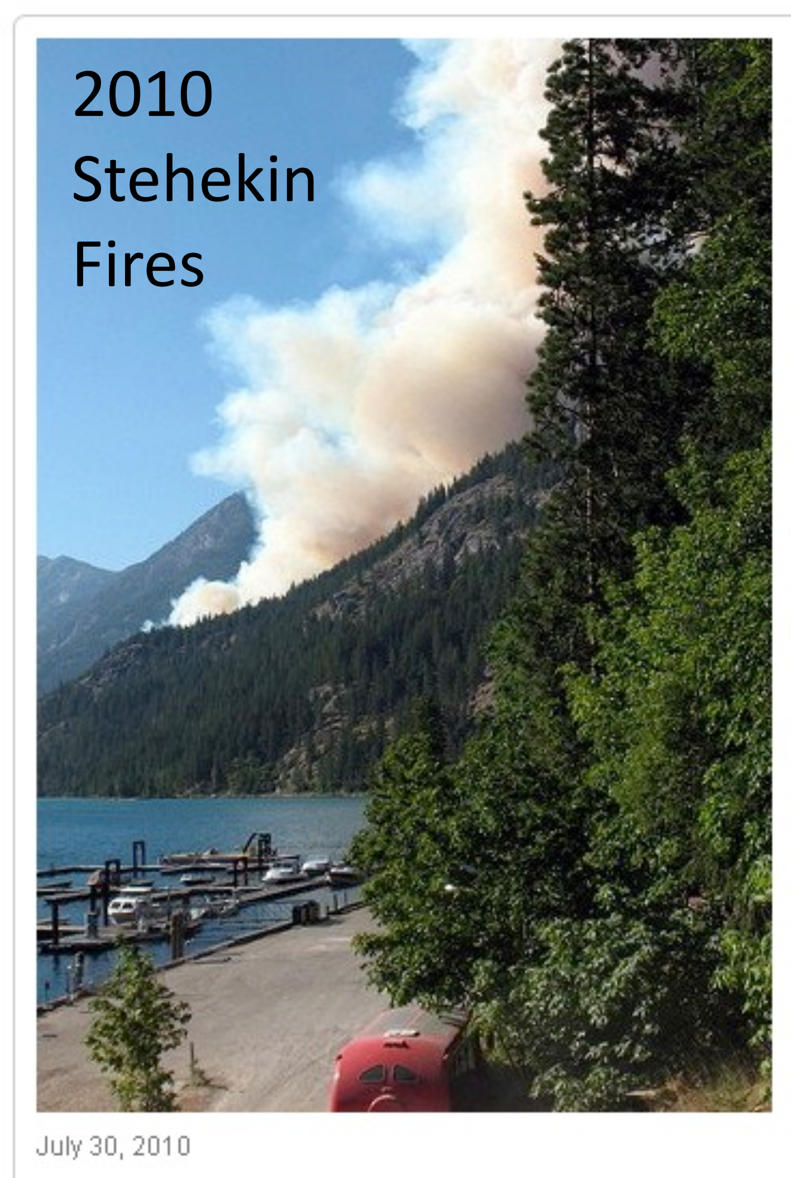
Ross Dam, Seattle City Light

Lake Recreation

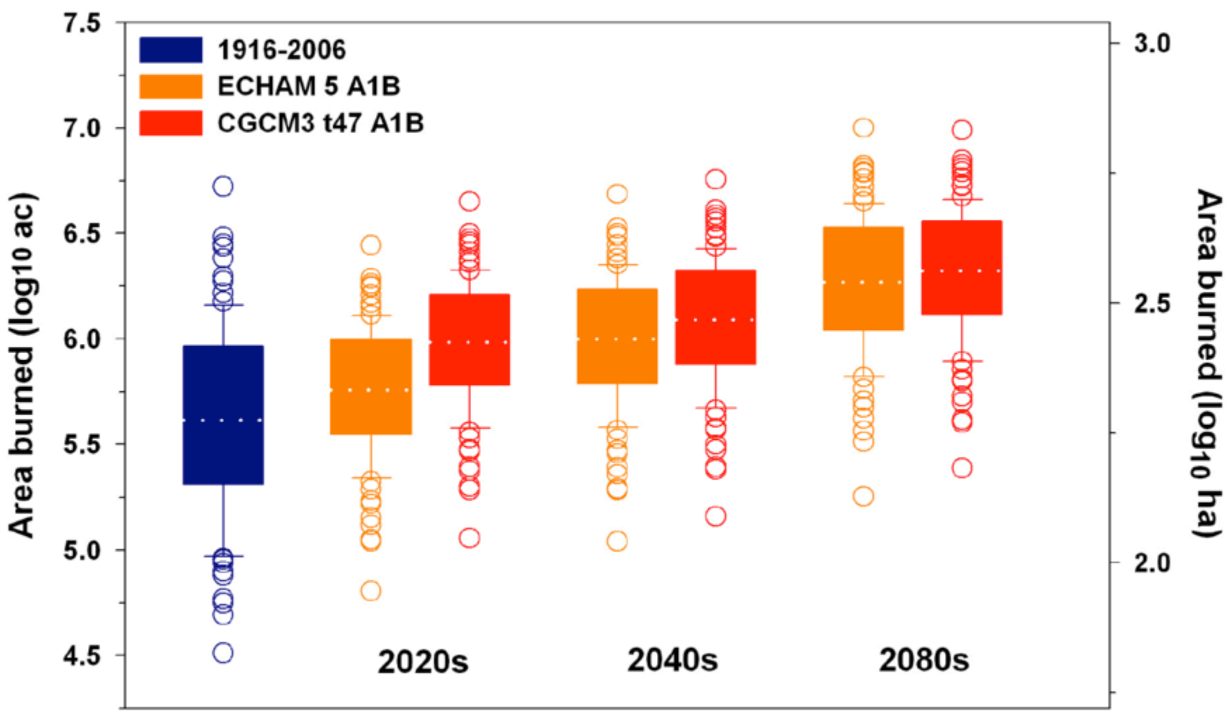
Aquatic Ecosystems



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



Forest Disturbance



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

Near Coastal Environment and Ecosystems

Sediment Transport

Transport, Fate and Impacts of Sediment in the Skagit River-Delta Complex

Dr. Eric Grossman
USGS Coastal & Marine Geology Program
egrossman@usgs.gov

Team:
C. Curran, D. Finlayson, A. Stevens, G. Gelfenbaum, S. Rubin (USGS)
E. Beamer, G. Hood, A. McBride, J. Gibson (SRSC)
R. Fuller (The Nature Conservancy)
Alan Hamlet (University of Washington)
T. Mitchell, S. Akin (Swinomish Indian Tribal Community)

Today's Talk

I. Why sediment? Issues for sediment management

II. New methods and findings regarding sediment transport

III. Proposed next steps

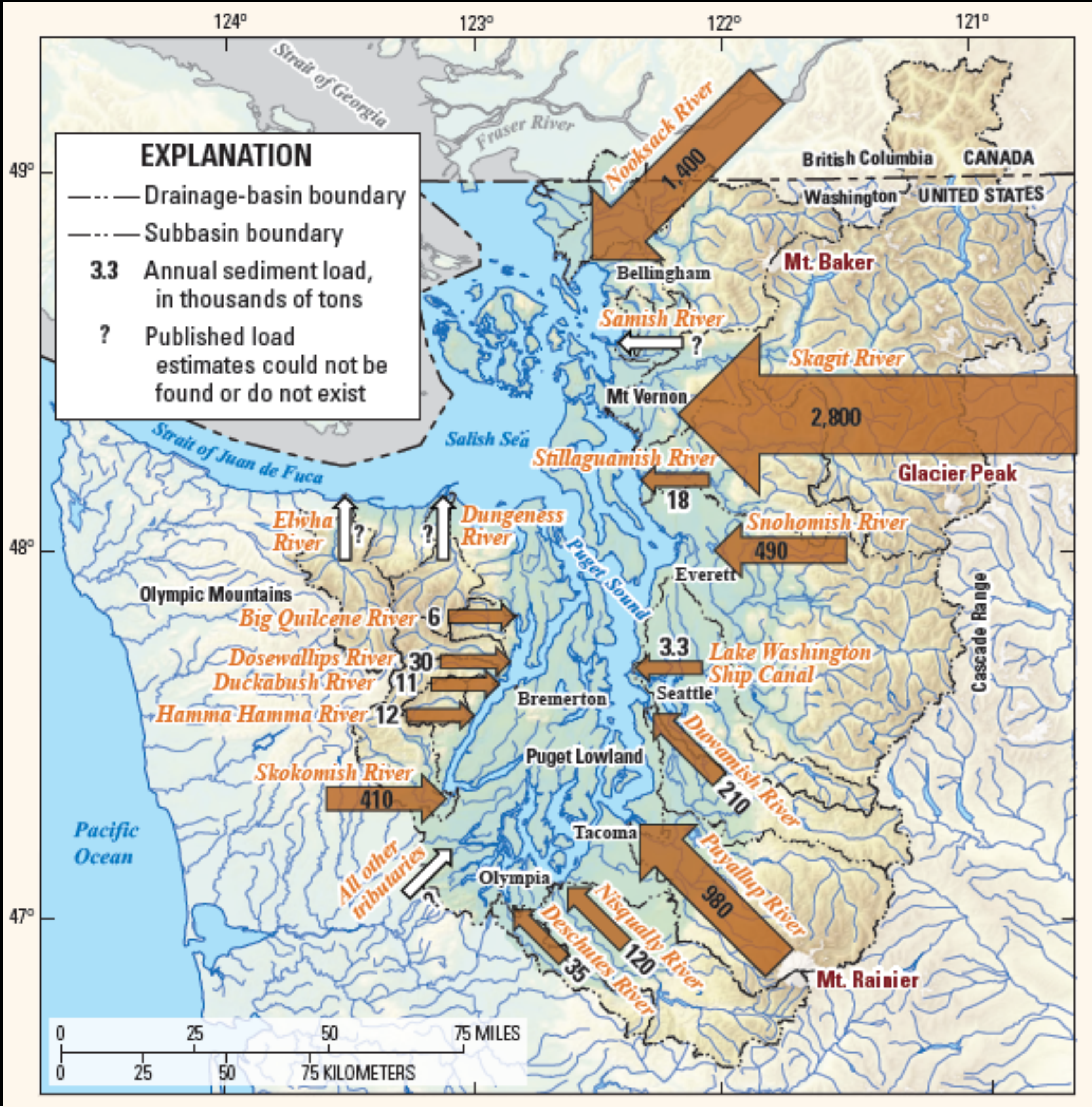
Why? Cost of sediment impacts

North America: Fluvial sediment runoff causes $20-50B/yr in damages (Osterkamp et al. 1998, 2004)

How will costs in Skagit County change in 2020, 2050, 2100?

Puget Sound: Flood recurrence interval more frequent with urbanization (Moscrip & Montgomery 1997)

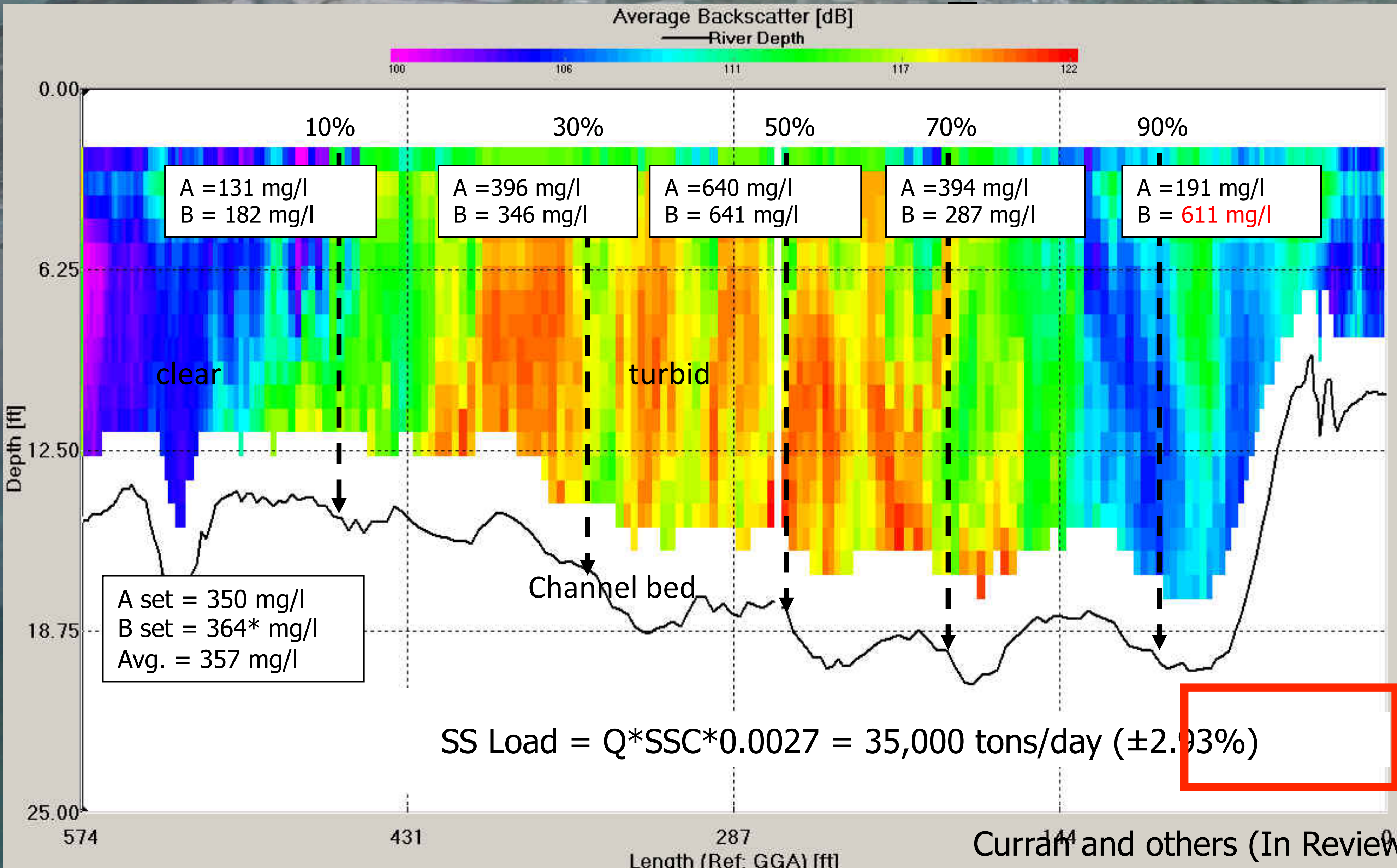
Fluvial sediment delivery to Puget Sound



Czuba et al. (2011)

New Sediment Load Methods

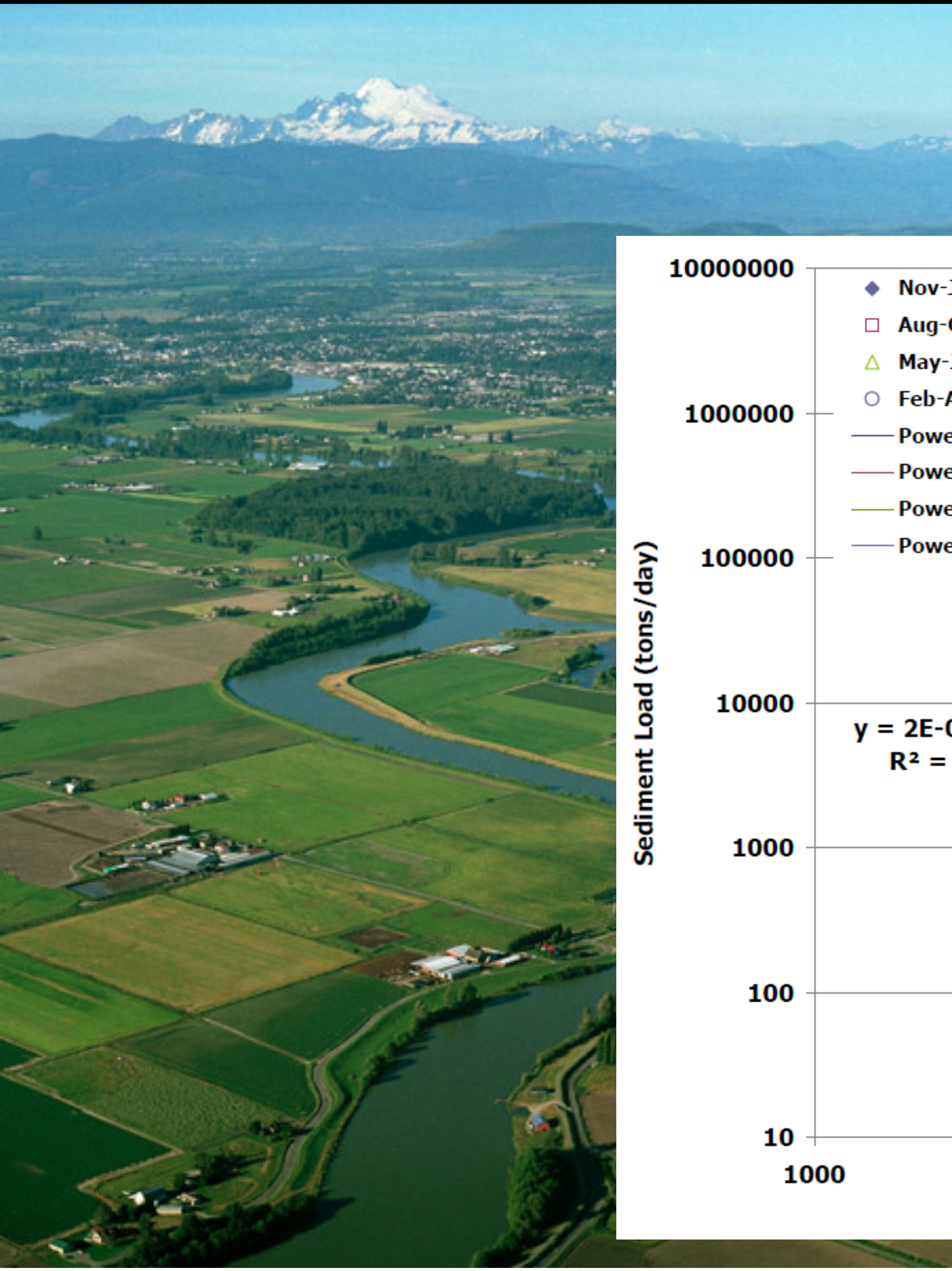
Real-time, lower cost, greater certainty

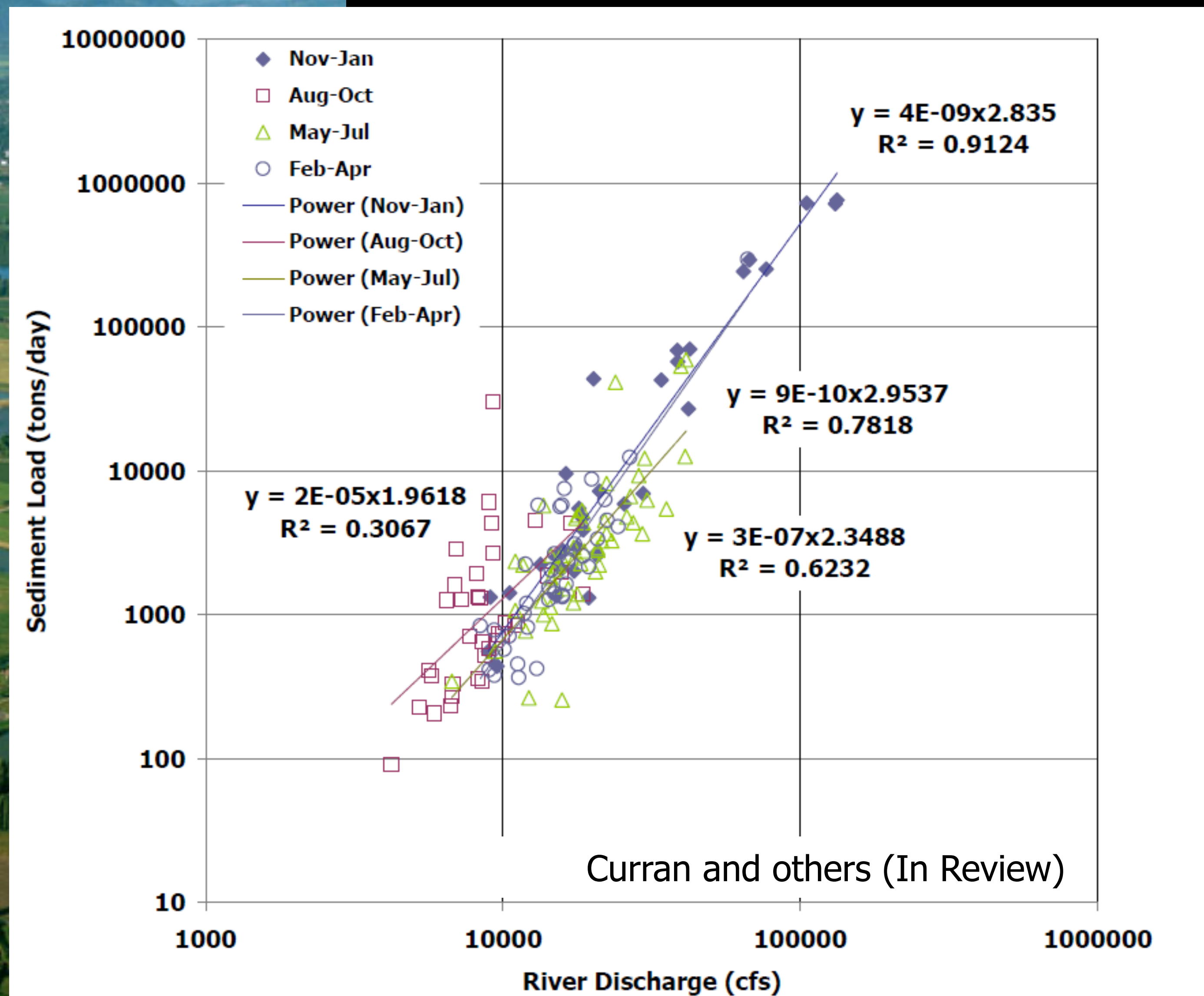


Curran and others (In Review)

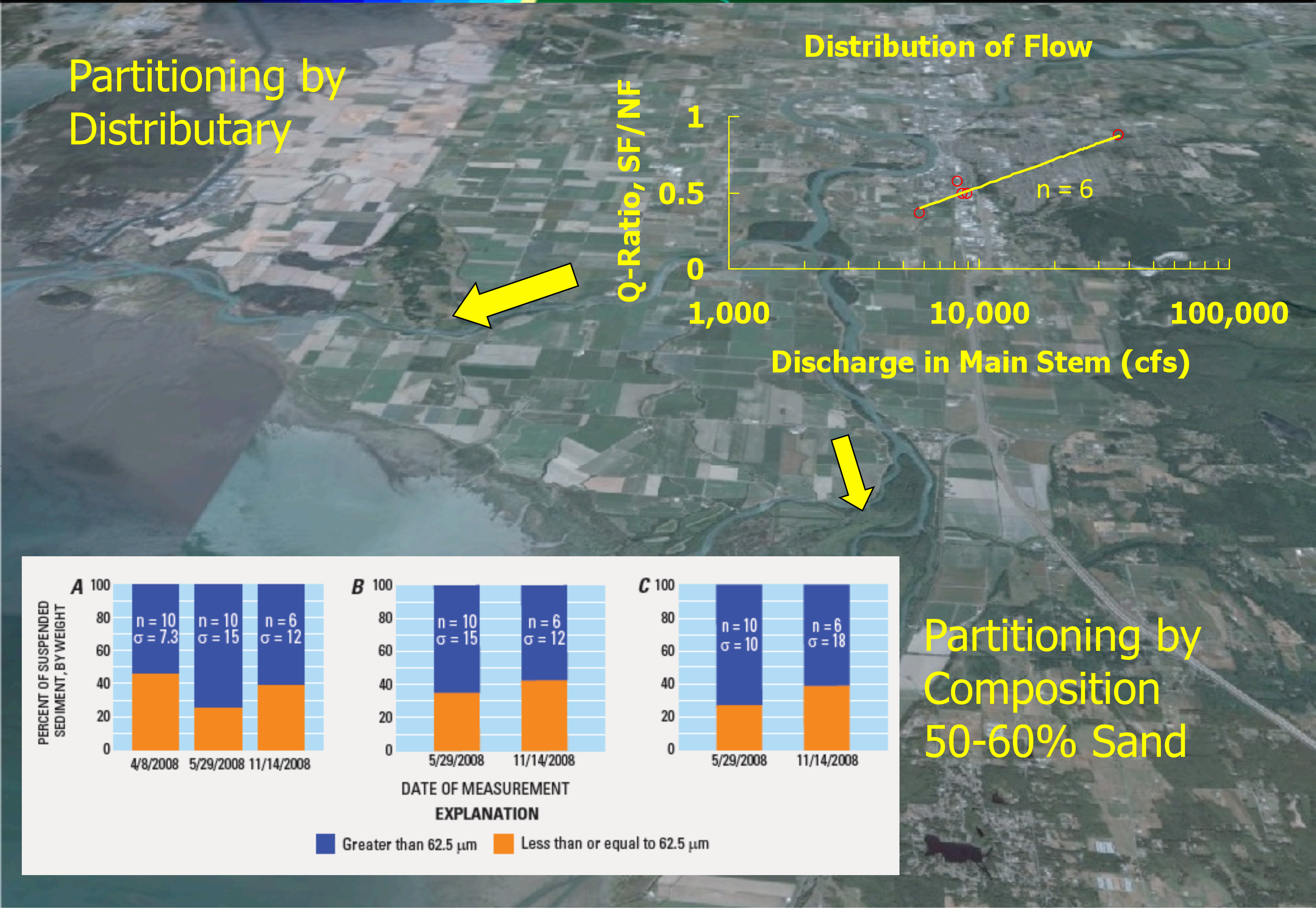
Sediment Rating Curve

Seasonality, Process-Based (rainfall vs. snow-melt)

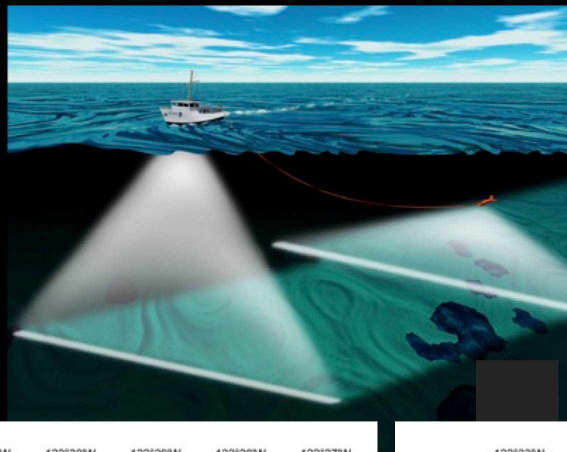




Sediment Distribution



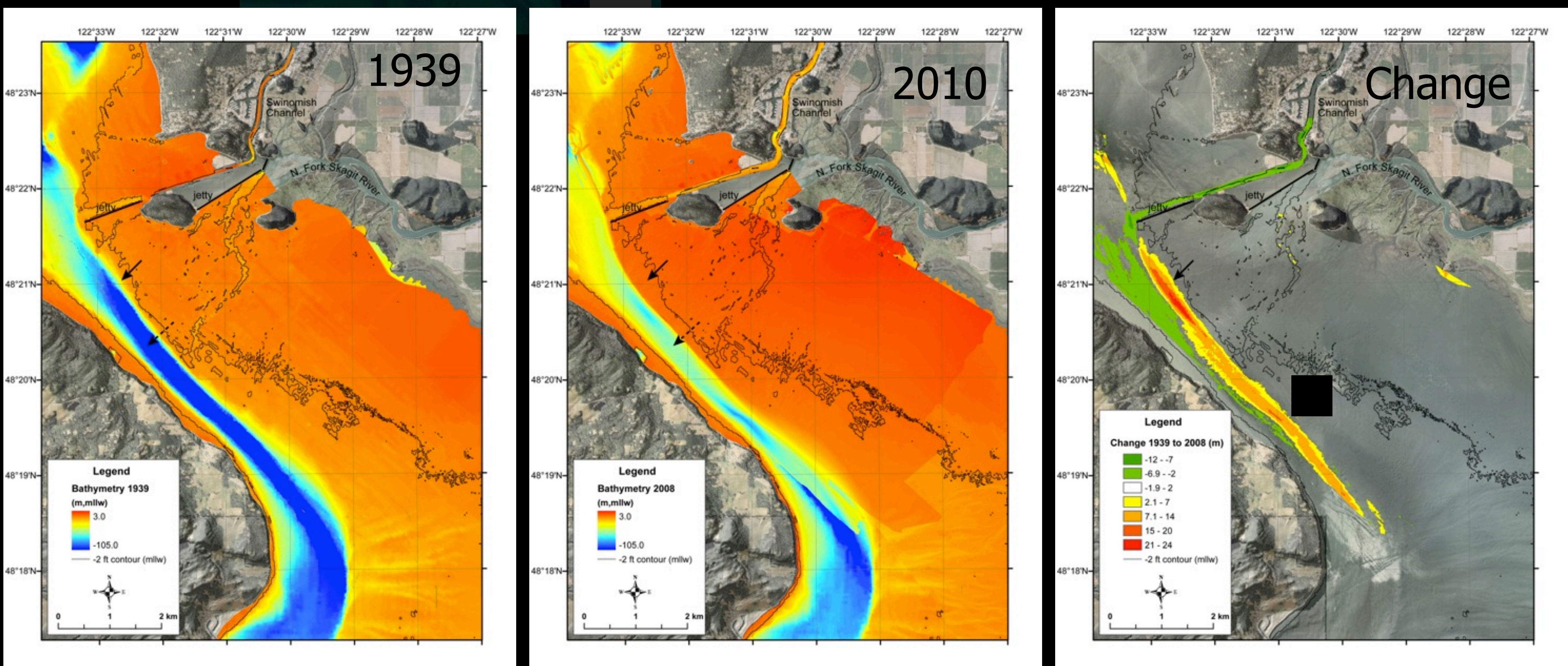
Skagit Delta Historical Change



Repeat Seafloor Mapping

Sediment Budget

- 16.8M m^3
- Sand
- 10-35x increase
- Bypassing tide flats



Grossman et al. (In Review)

Skagit Delta Historical Change

Transformed tide flat from calm mud to energetic sand flat

cross-bedded sand = energetic active bed migration

Top

1850

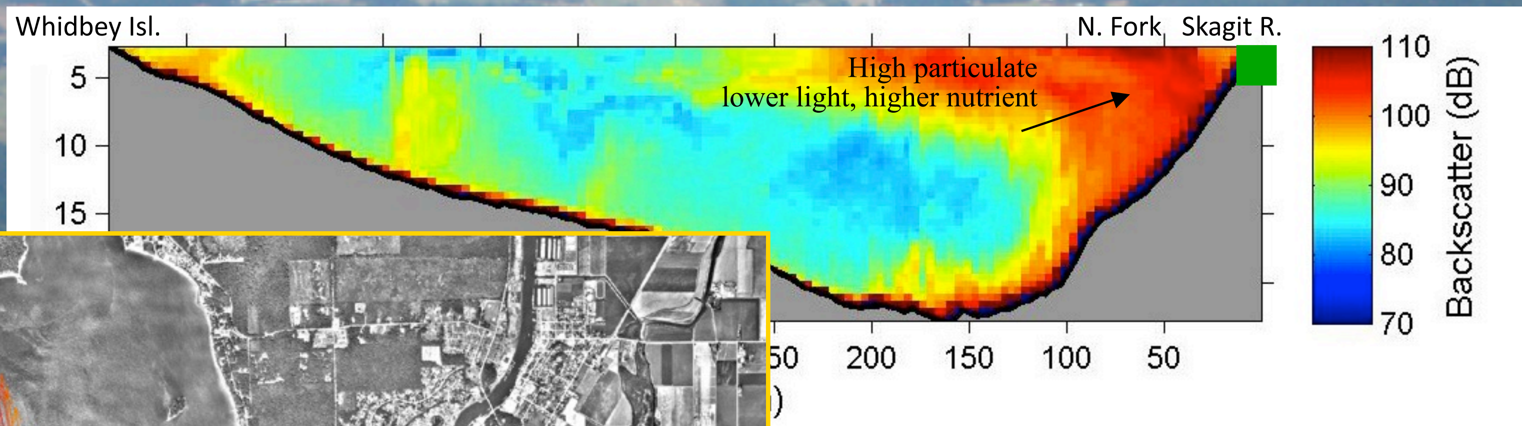
Laminated mud = calm setting

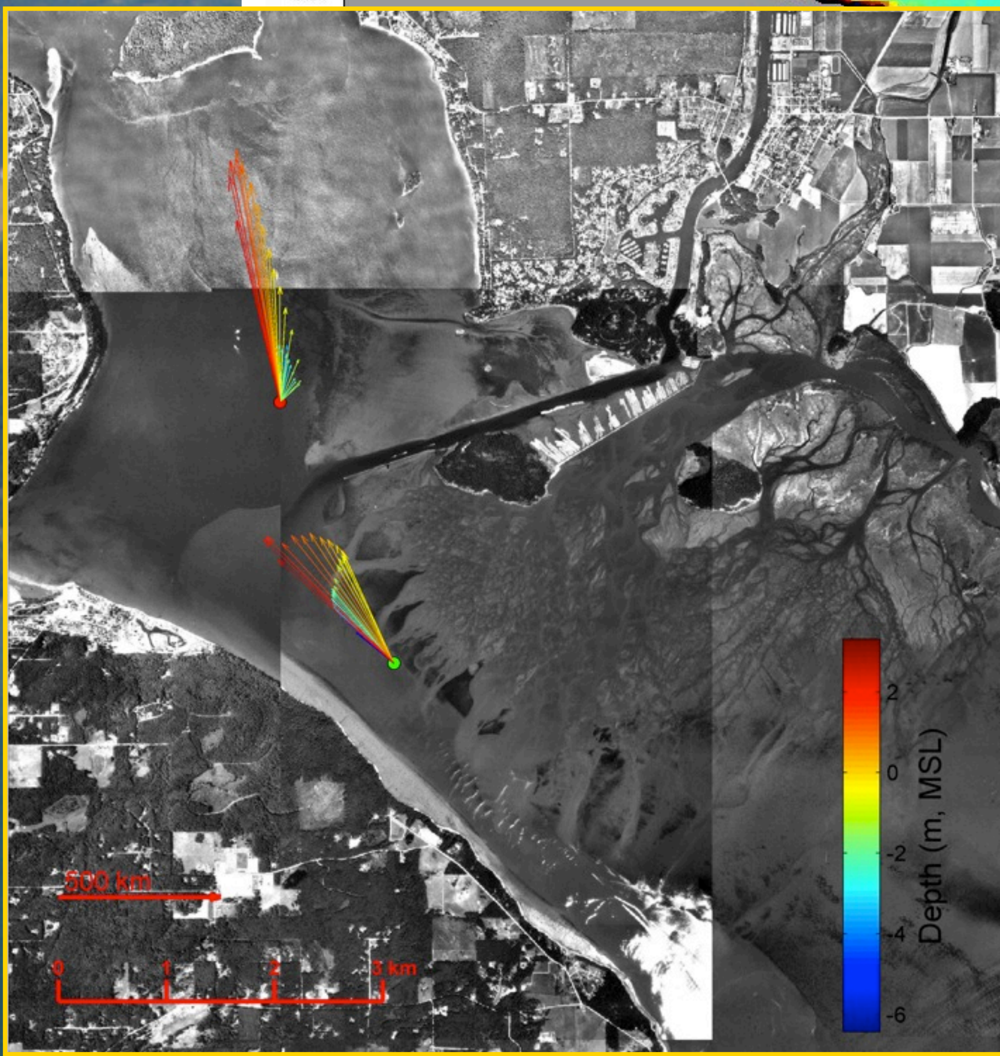
Base

Grossman et al. (2011)

Nearshore Hydrodynamics

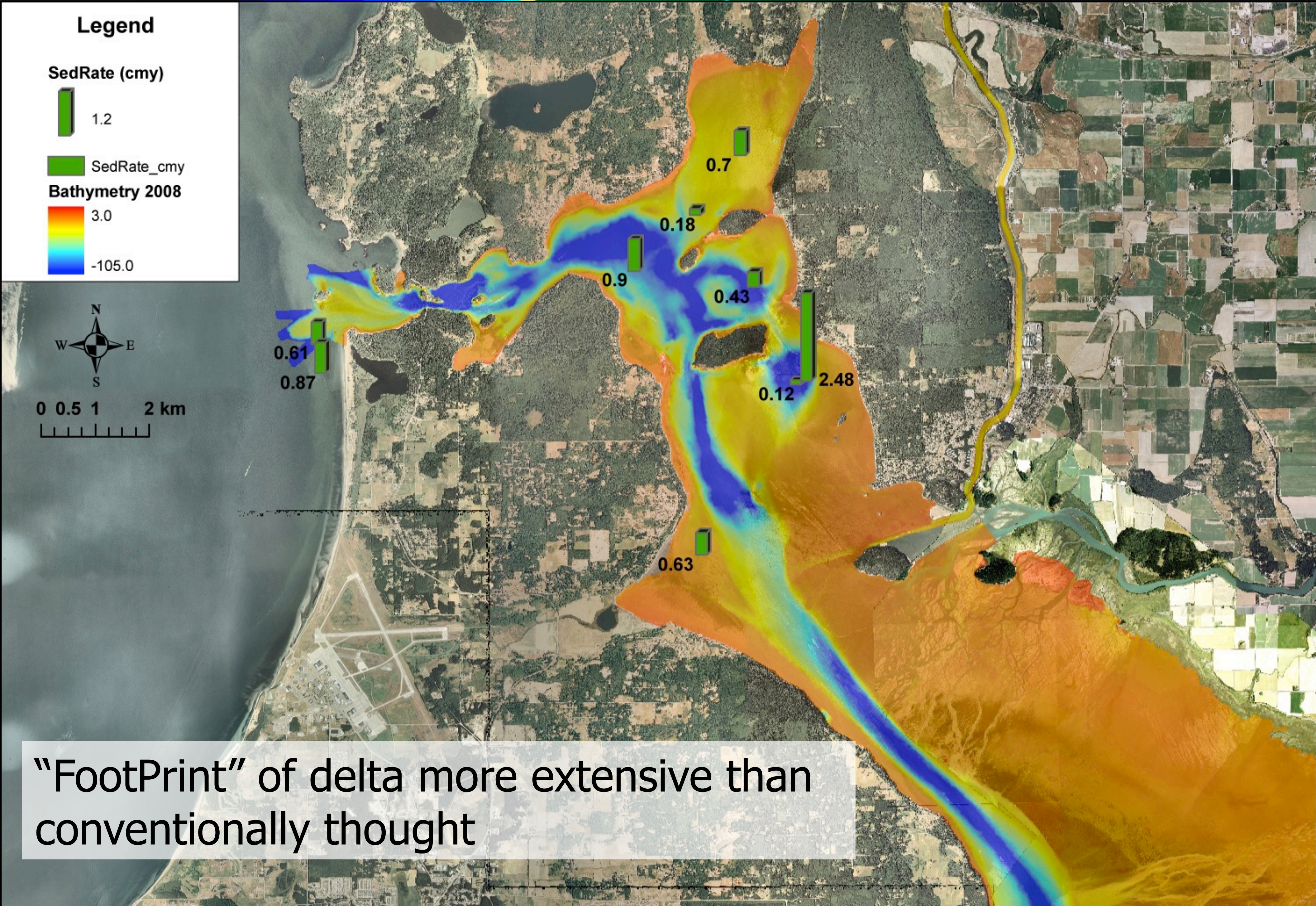
Sediment Fate (fines) - Net North Transport





(Grossman and others 2007)

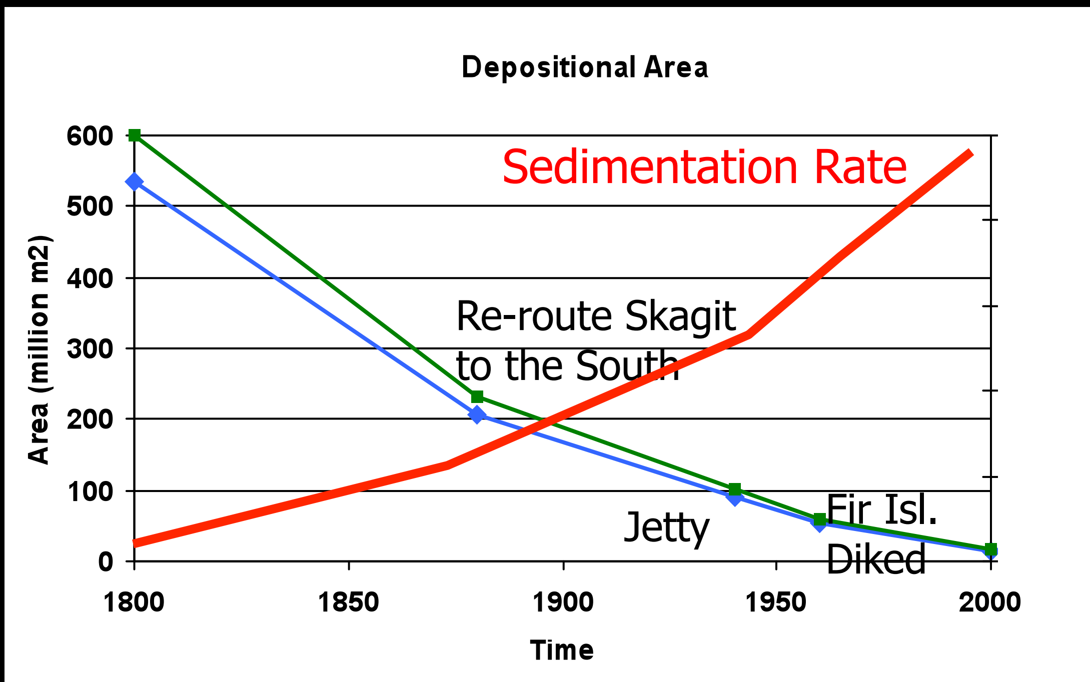
Sediment Fate – Calm, deep sites

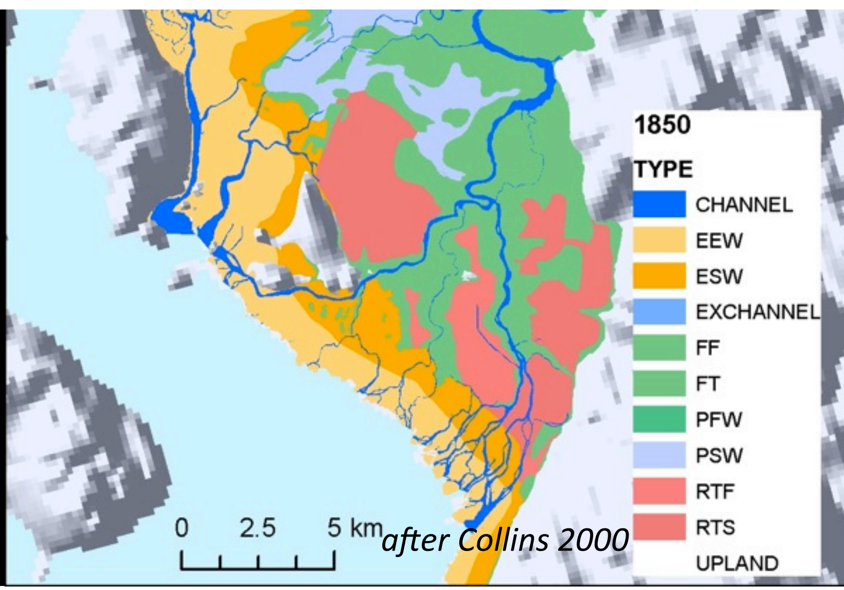


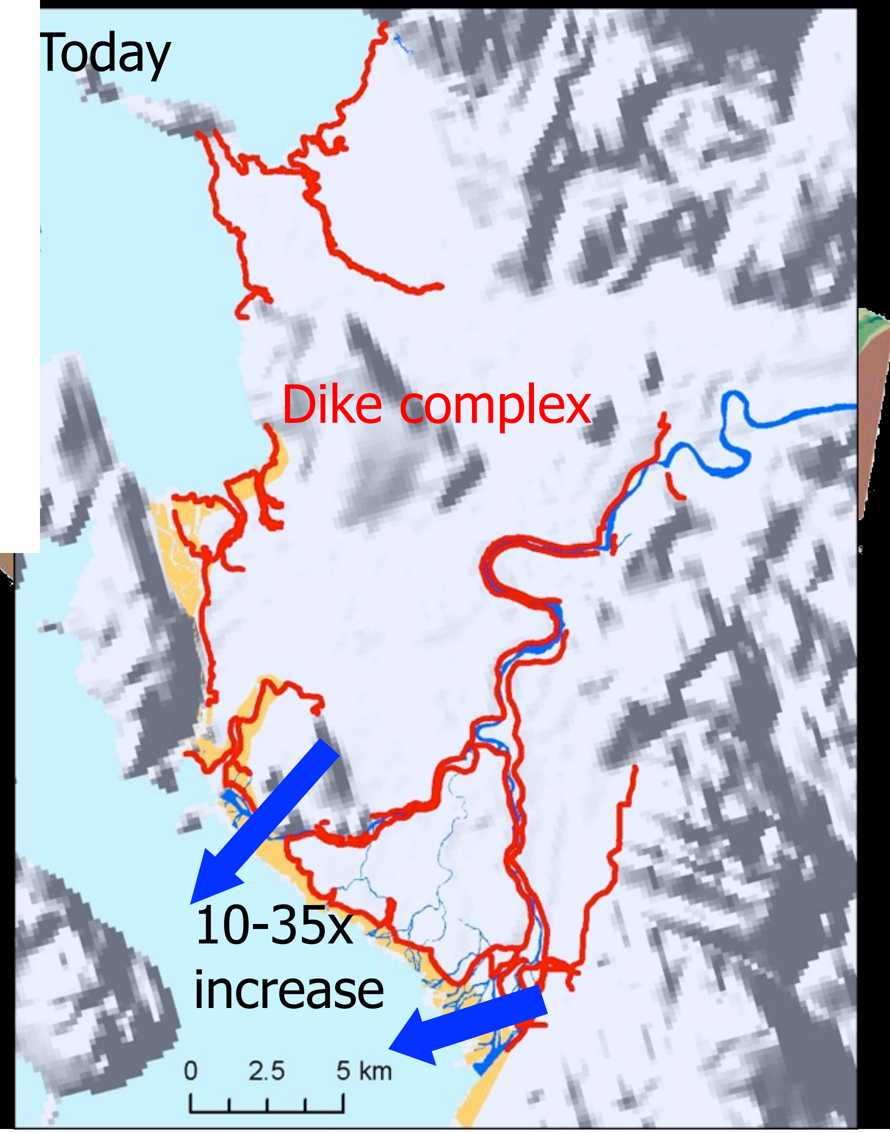
"FootPrint" of delta more extensive than conventionally thought

Extent of Impact in Skagit

80-90% of sediment depositional area reduced; Nearly entire sediment load focused to Skagit Bay.







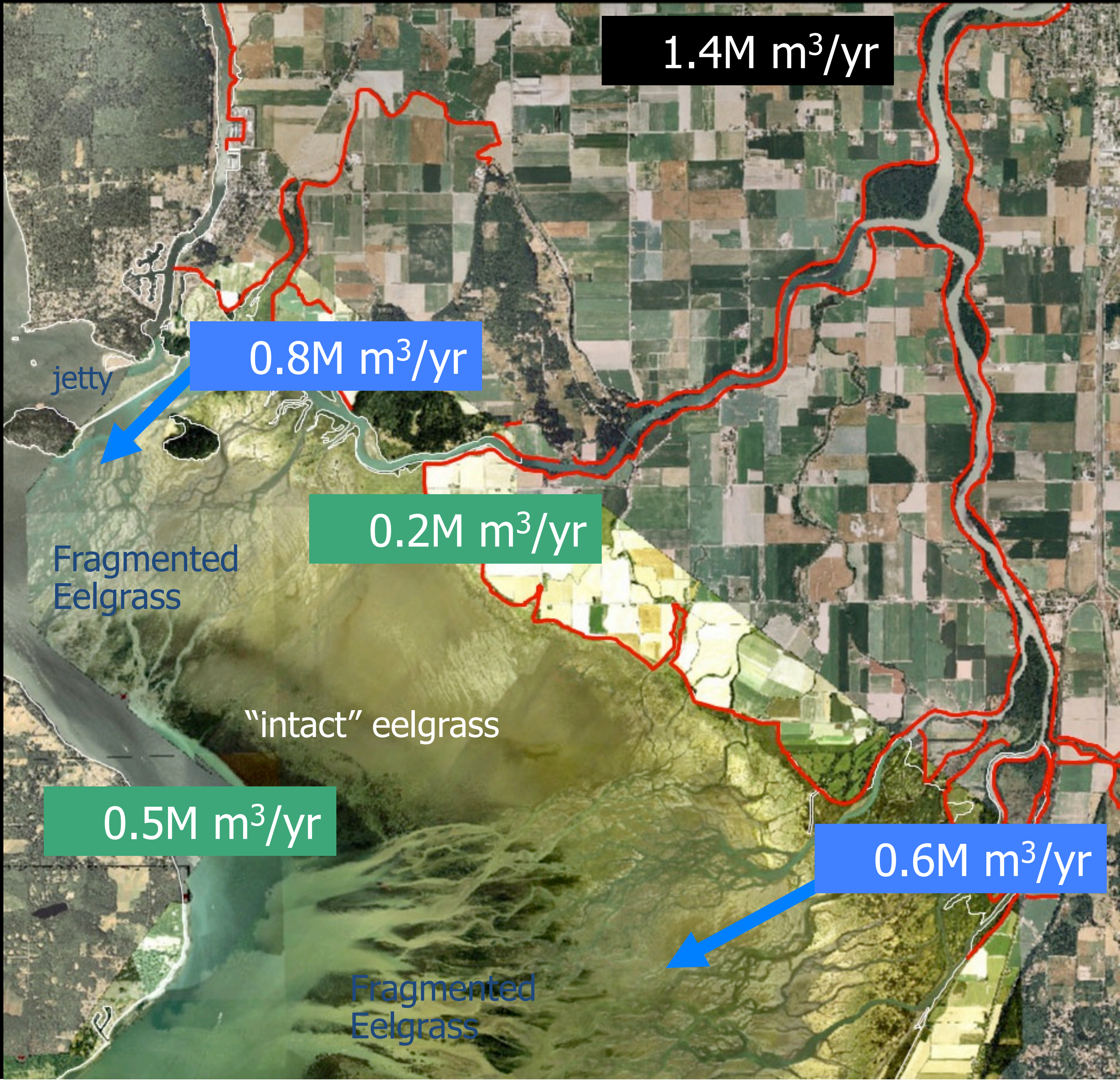
Sediment Budget

Lost resource for Fir Island to mitigate sea-level rise.

Excess fragments, buries eelgrass (~60% loss)

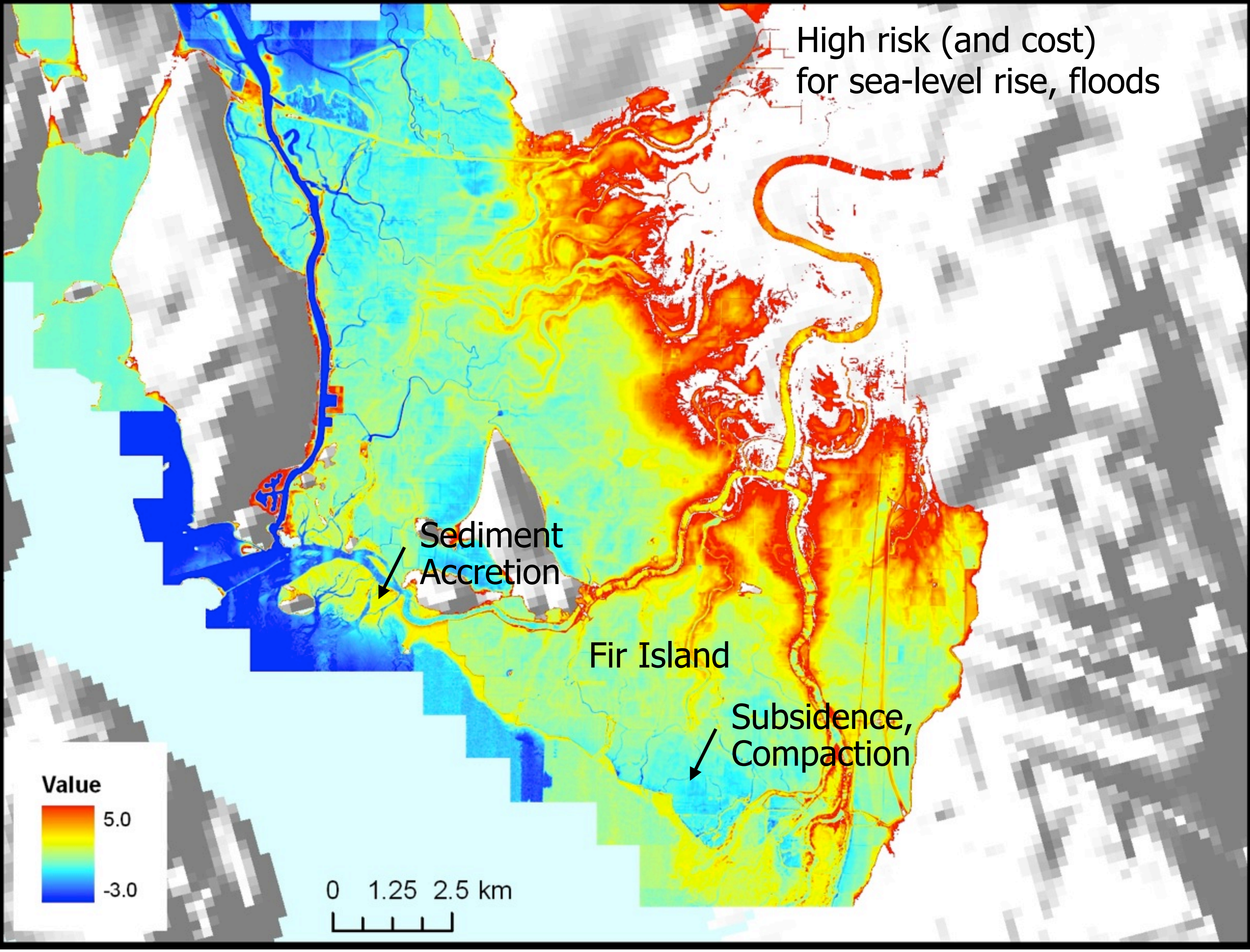
Lost shellfish, food-prey for endangered fish, birds.

1000s acres of potential eelgrass recovery in deltas to reach PSP goal of 20% increase by 2020.



Lost Resource to Fir Island

~1 m subsidence on Fir Island, lost sediment, compaction



Sediment Science Needs

1. Flooding/Navigation:
Channel deposition – capacity
Phasing of sediment movement

2. Water Quality, Contaminants:
A) Turbidity - water quality
B) Transported by fines

3. Habitats/ Ecosystems:
A) Substrate type, transport
B) Thresholds, tolerances
C) Turbidity - photosynthesis

4. Coastal Erosion:
Mitigates sea-level rise

5. Hydropower:
A) Reservoir/turbine life span
B) Scour/gravel augmentation

Conclusions

I. Sediment impacts are costly high and affect human livelihood in many ways, some only recently recognized.

II. New information on sediment transport and fate can be strategically used to forecast future impacts and help planning – we just need to know what you need.

III. Cumulative impacts to nearshore environments will affect ecosystem restoration efforts, salmon recovery.

IV. An integrated sediment management plan linked to county, shoreline, and coastal and marine spatial plans will help alleviate future costs and conflicts and promote community resilience by protecting food, water and human livelihood.

Sea Level Rise and Coastal Storms

photo by Dan Codd

Roger Fuller

The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH

Take Home Messages

- Sea level varies over space and time

  (and effects of a rise in sea level will likewise vary)

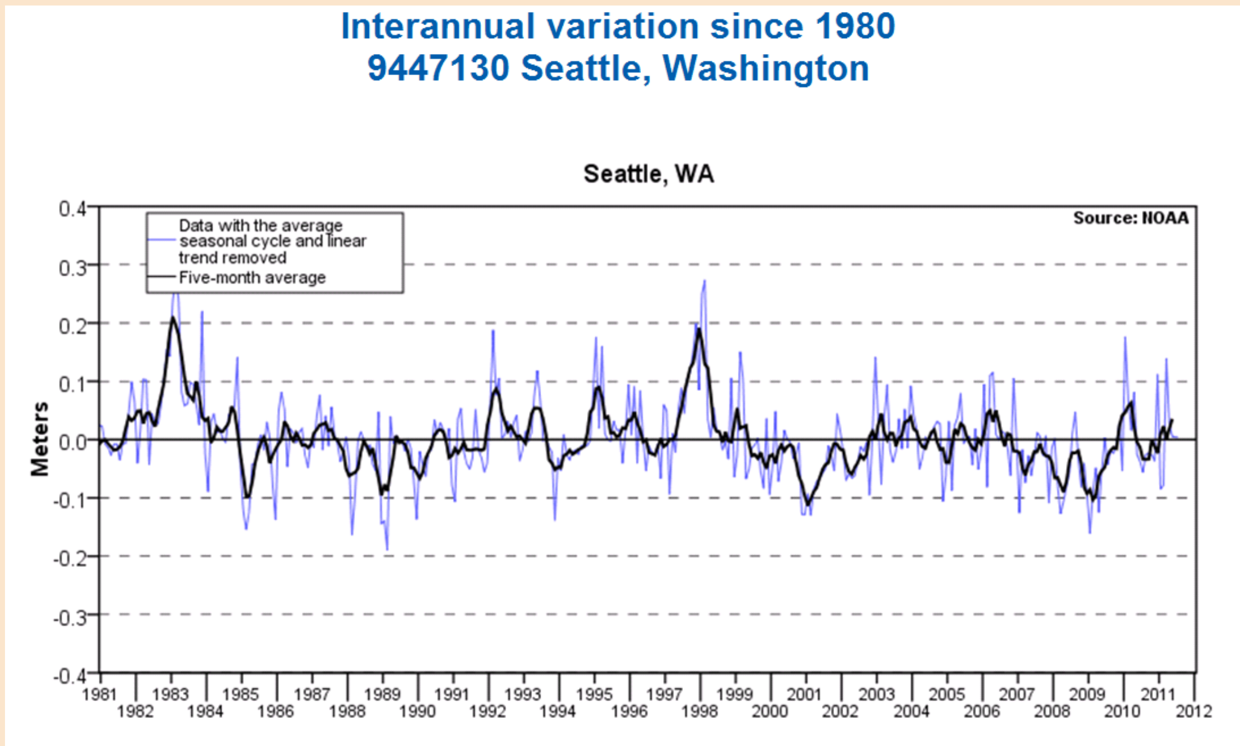
- Current estimate for Skagit: 6 - 50” higher by 2100

- Small changes can have big impacts

- It’s ***Sea Level Rise + Storms*** that matter

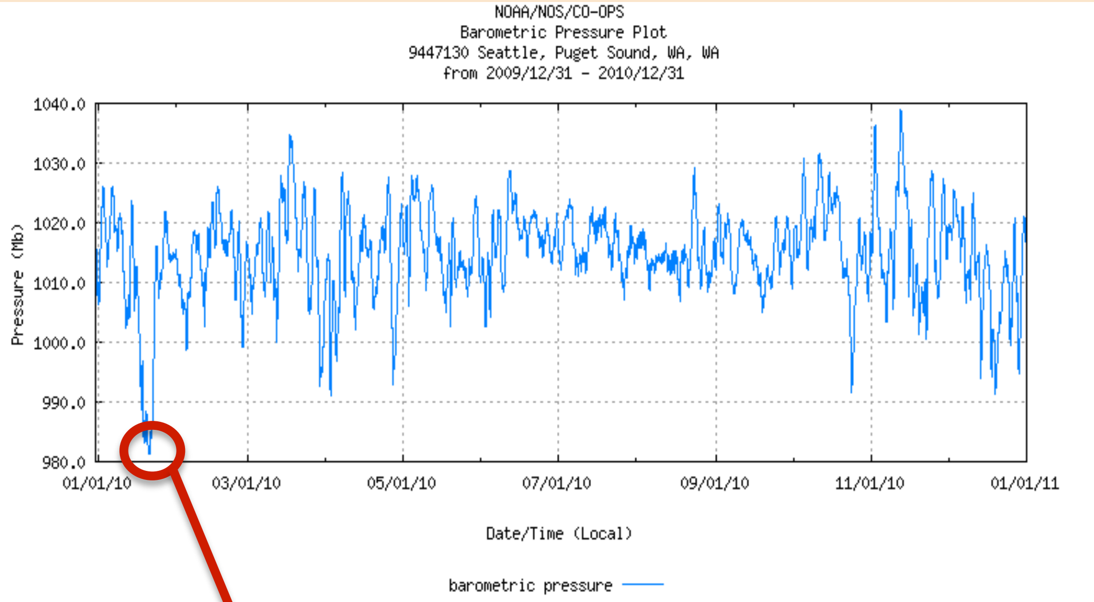
Sea Level is Variable
(even without climate change)

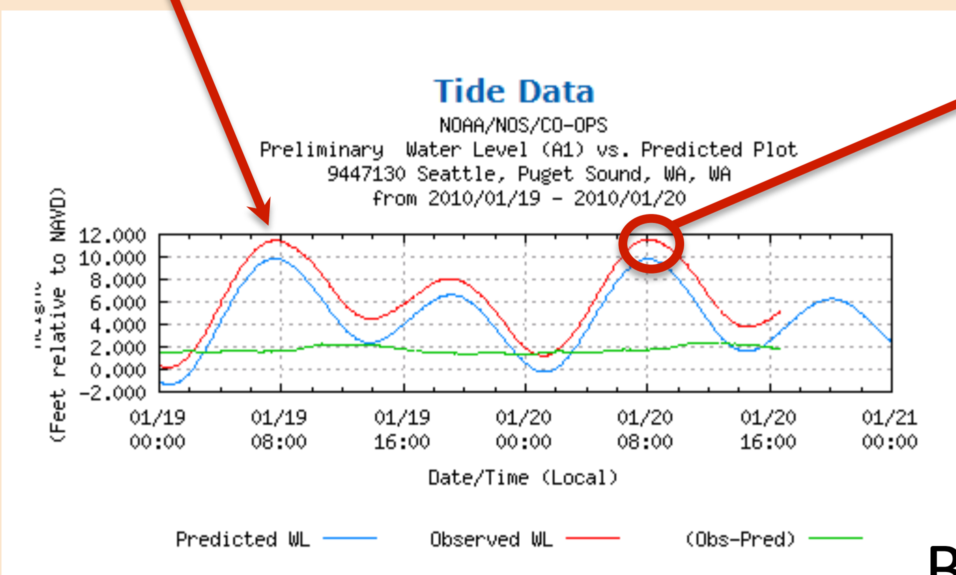
- Wind
- Atmospheric pressure
- Ocean circulation
- Topography
- Subsidence and uplift
- Plate tectonics
- El Nino



18” variability in annual Sea Level

Sea Level and Atmospheric Pressure

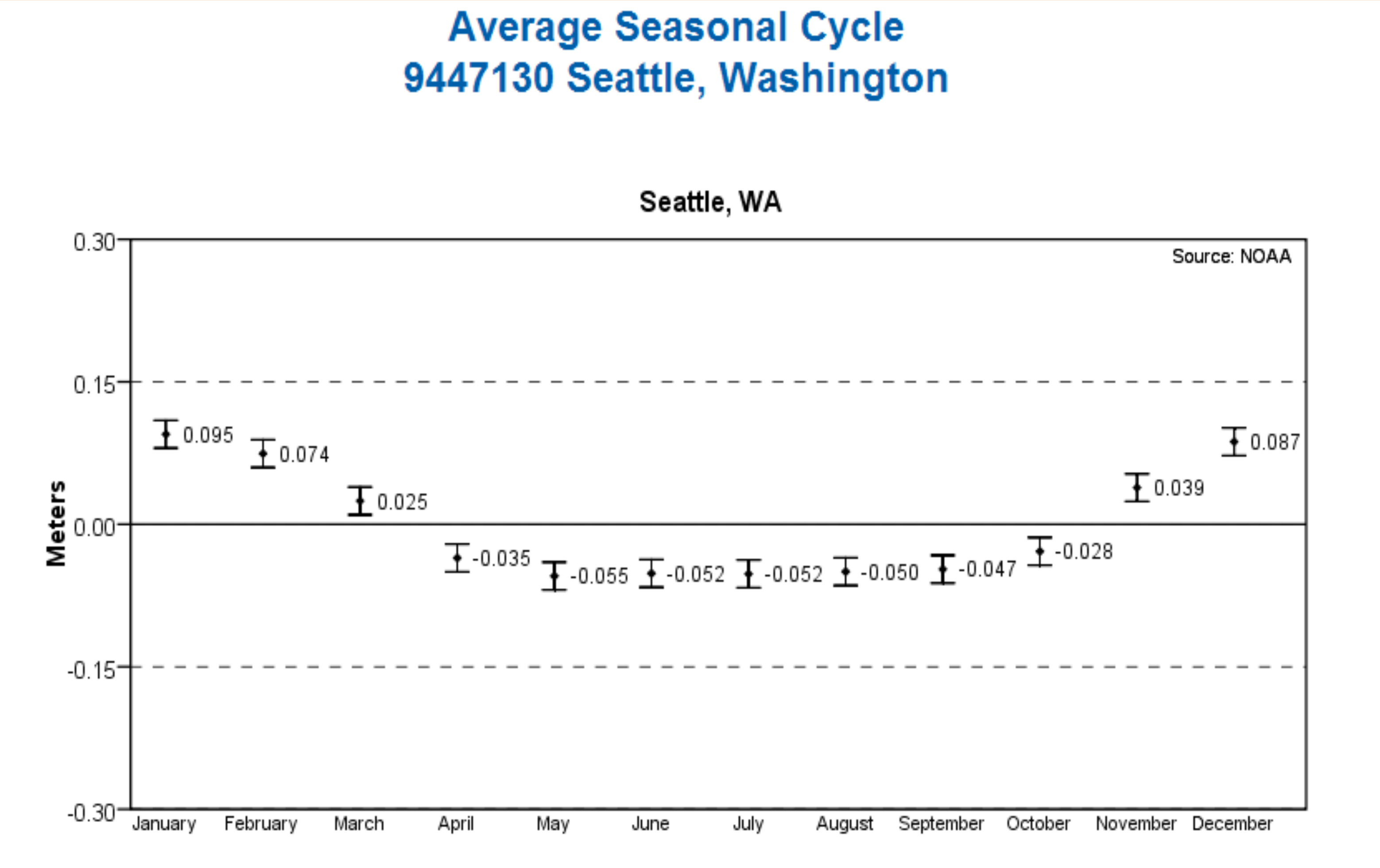




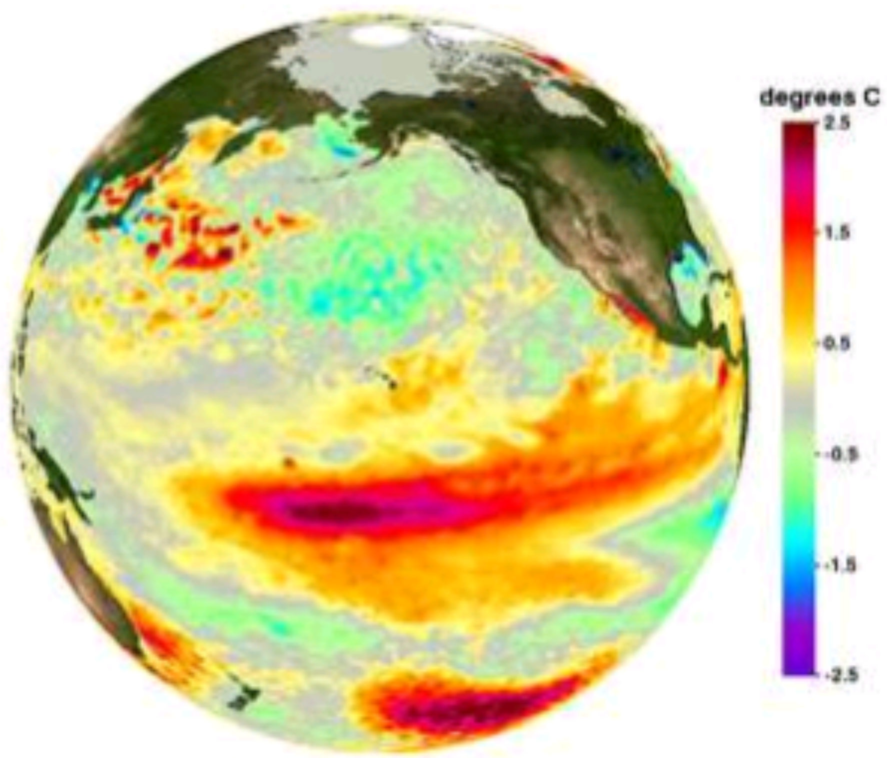
Breached Dike – January 20, 2010

Sea Level and Wind

Winter Sea Level is 20” higher



Sea Level and El Nino



Sea surface temperature anomaly during the peak of the 2009-10 El Niño, the strongest Central Pacific El Niño observed to date.

High resolution (Credit: Image produced by Physical Oceanography Distributed Active Archive Centre (PO.DAAC) of NASA JPL.)

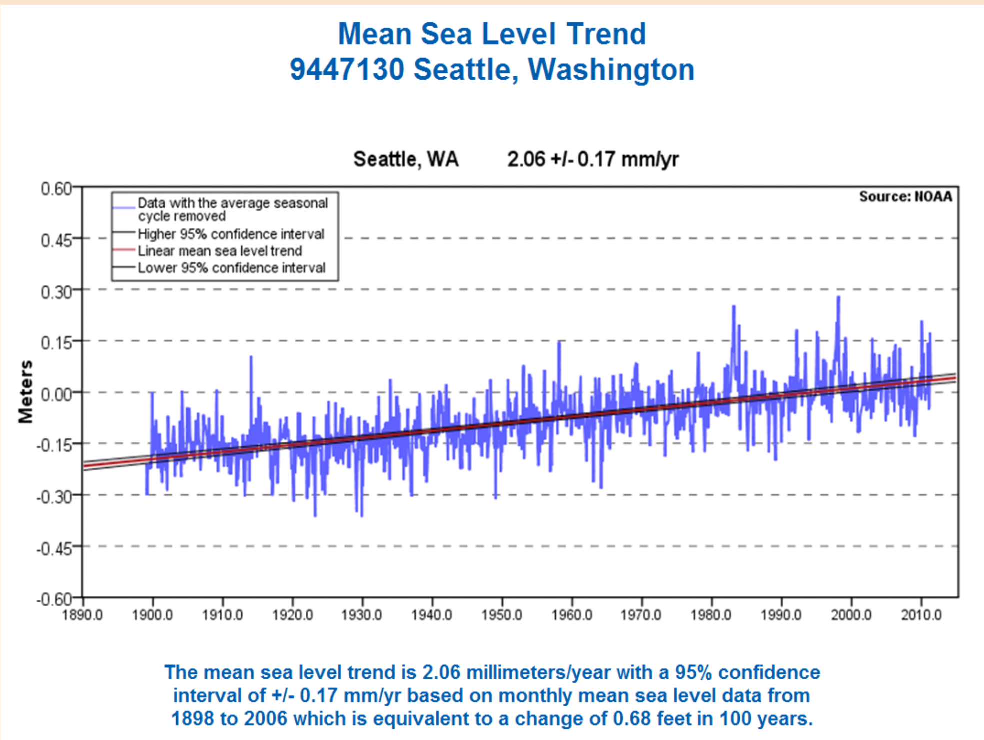
12" higher winter sea level

Bigger waves

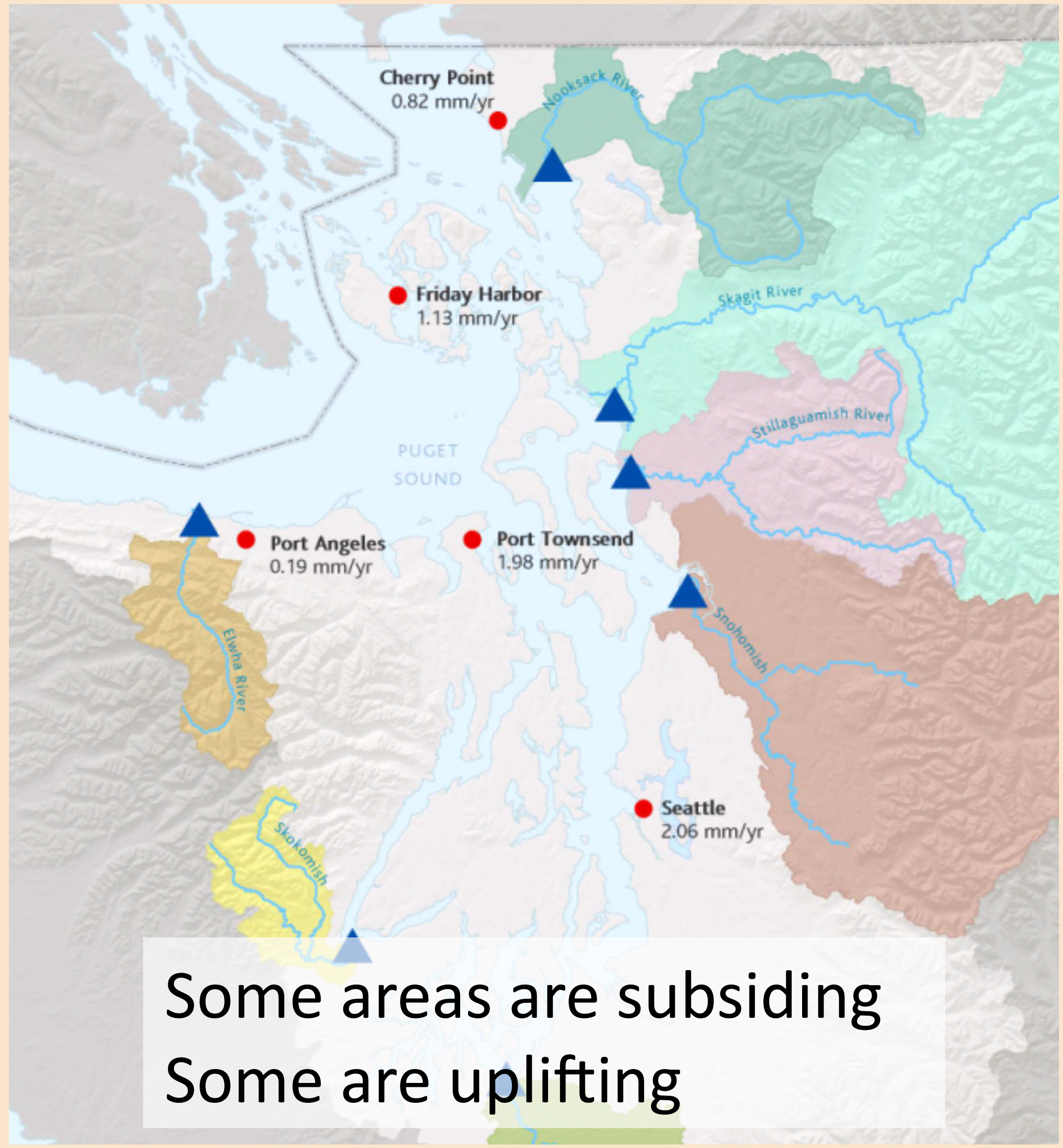
El Nino events are growing stronger

Sea Level Rise Varies Spatially

Seattle – sea level rise 1890 – 2010
9.5 inches

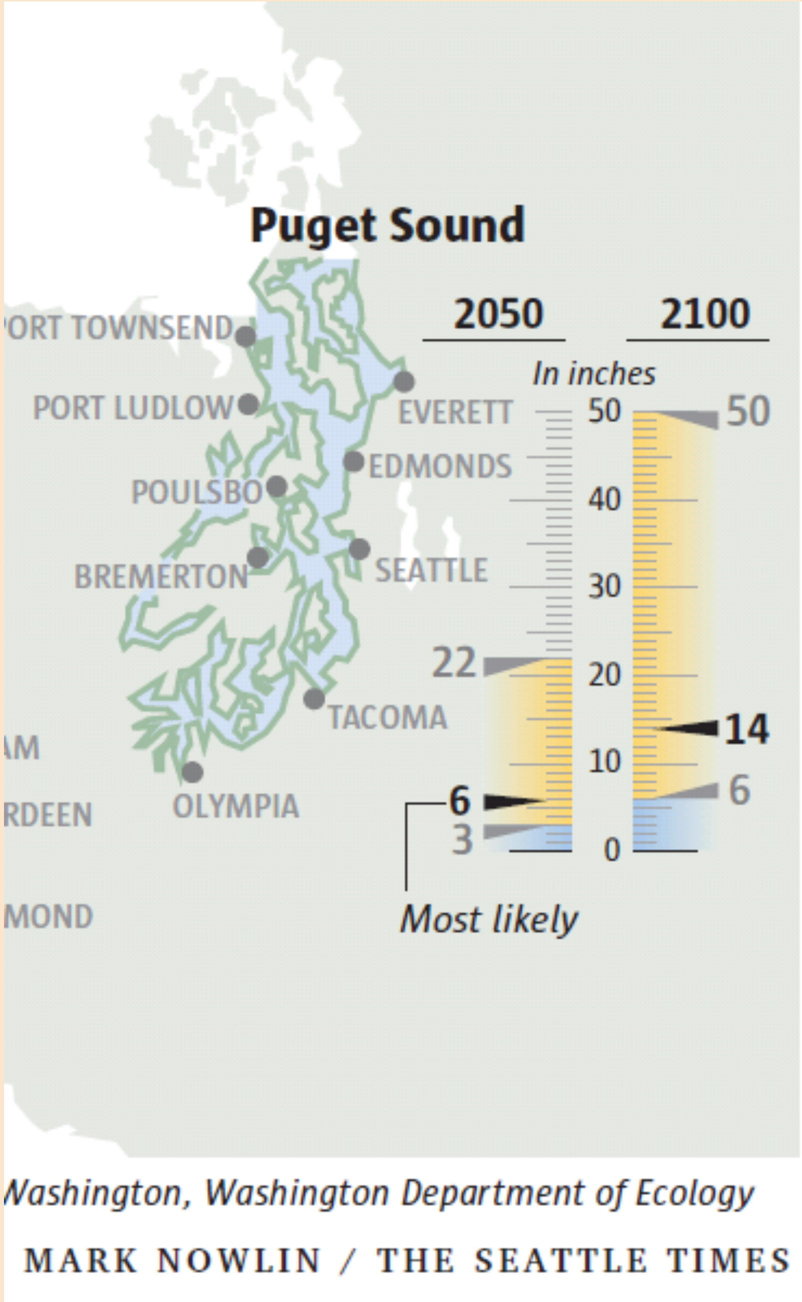


Past Sea Level Rise



Some areas are subsiding
Some are uplifting

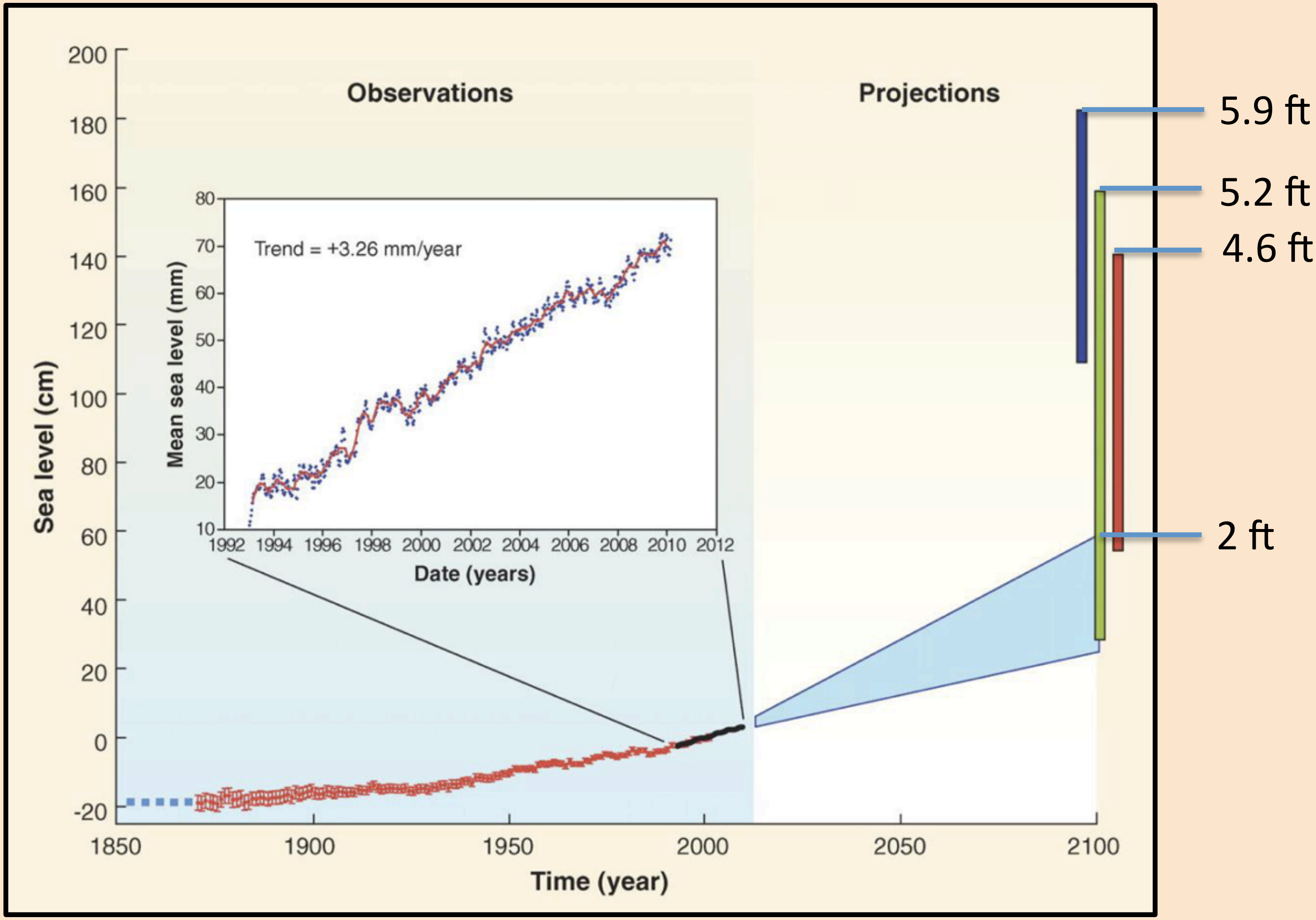
Future Sea Level Rise



Mote et al. 2008

Future Sea Level Rise

(recent research)



(Nicholls and Cazenave 2010)

Sea Level Rise and Coastal Flood Risk

It's the big events you'll notice, not the slow change in sea level.

For much of Puget Sound…

- A one foot of 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.

Anacortes (4 February 2006)

Port Susan Bay Dike Breach (4 February 2006)

Numbers and top photo courtesy of Hugh Shipman, Washington Dept. of Ecology

Sea Level Rise and Coastal Flood Risk
(Big events happen when multiple factors co-occur)

January 5, 2010

King Tide plus light breeze from the north

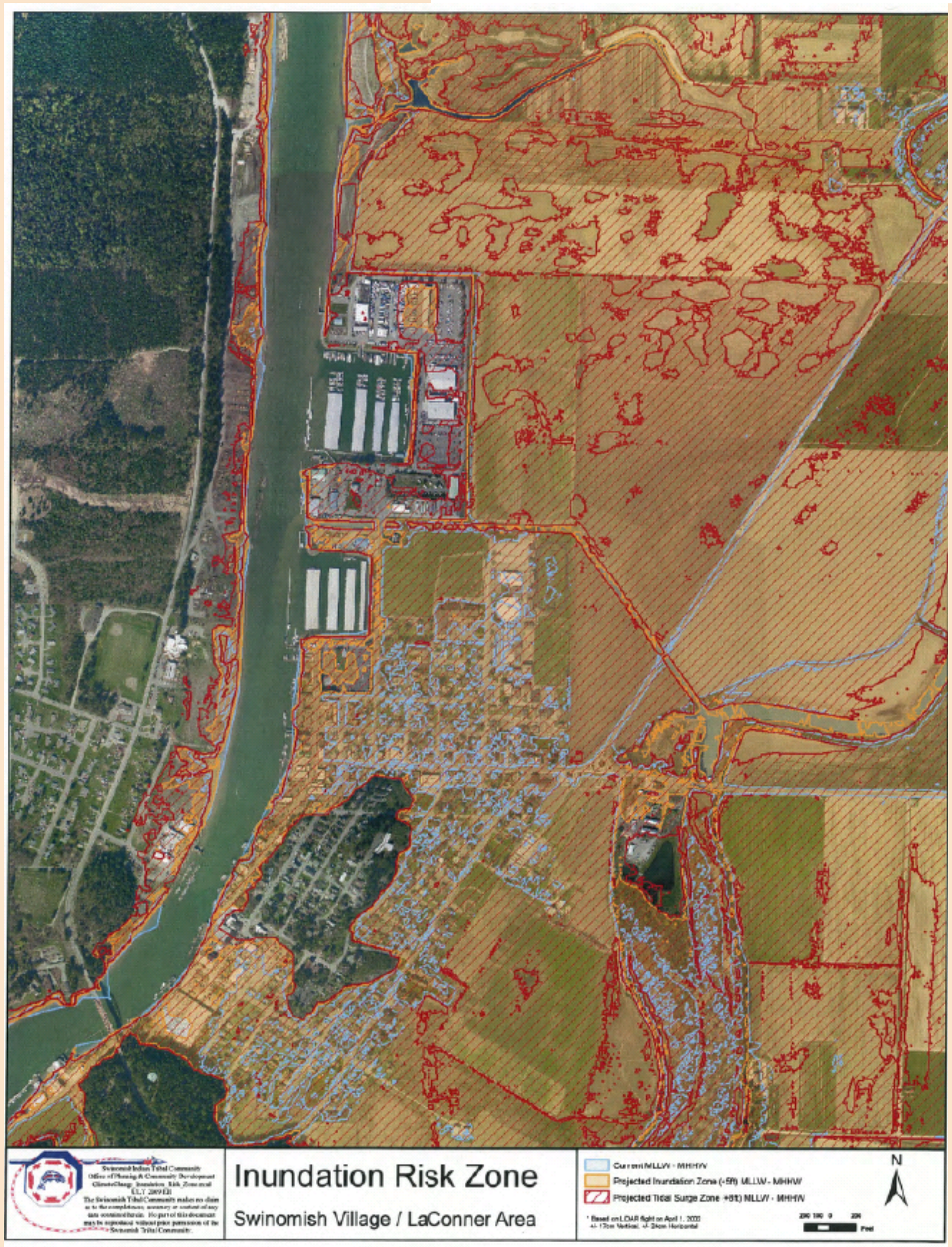
February 4, 2006

King Tide plus 44 knot wind from the south

Breached Dike

Swinomish Climate Change Initiative

Impact Assessment Technical Report



Reservation infrastructure vulnerable to sea level rise and storm surge

160 homes @ $83 million

18 non-residential buildings @ $19 million

Sea Level Rise Risks

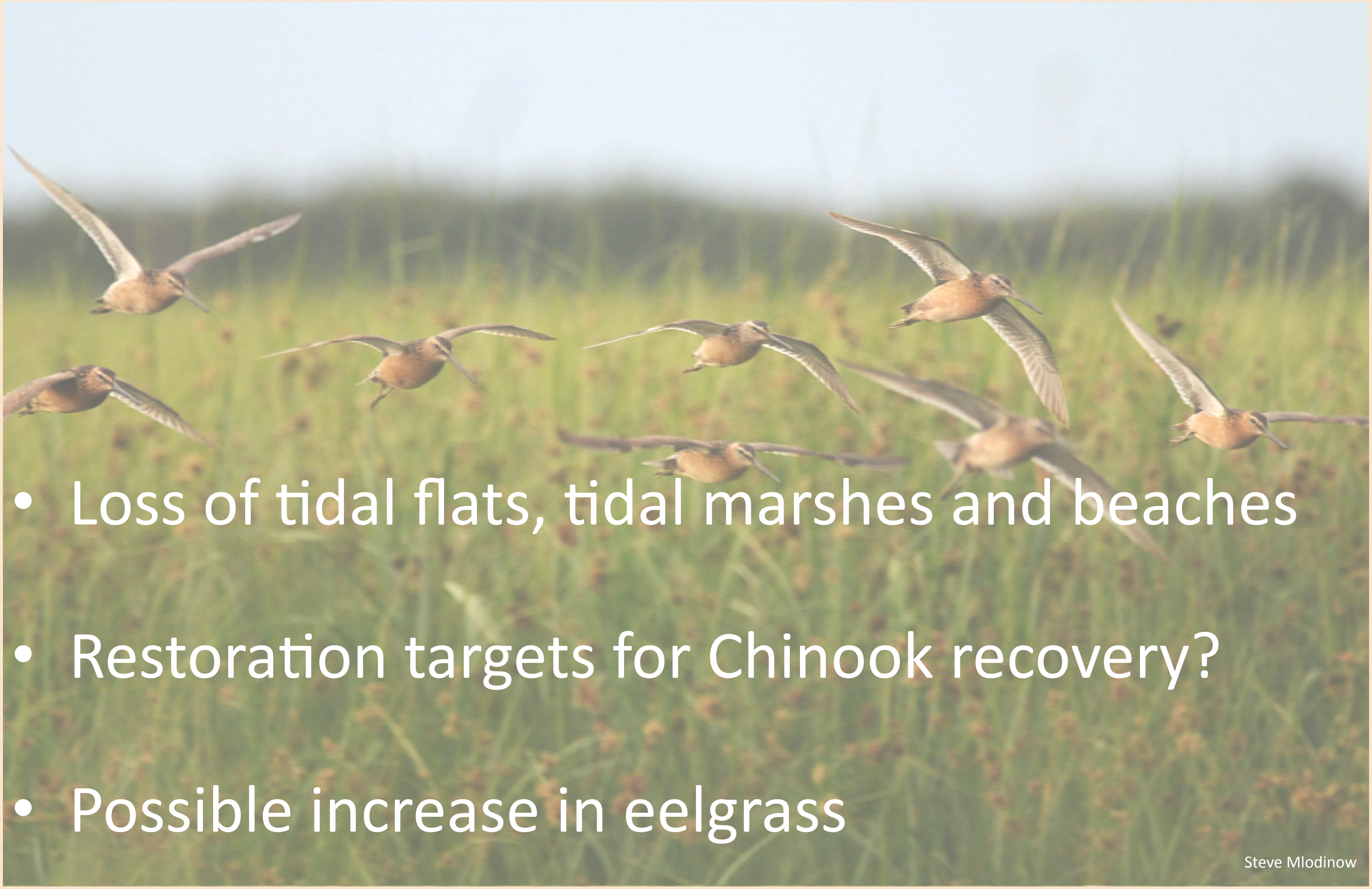
Increased risk of:

- coastal flooding
- drainage on farmland and low-lying areas
- coastal erosion
- salt intrusion into coastal aquifers and farmland
- higher dike costs
- transportation disruption
- loss of nearshore habitat
- bluff landsliding

Certainty of Sea Level Science

- Sea level rise is one of the areas of greatest certainty in climate science
- Science is changing rapidly (lots of research)
- Some areas of uncertainty, such as wind changes and glacial dynamics, appear to be happening more quickly than expected

Ecosystems, Habitats and Ecosystem Services



- Loss of tidal flats, tidal marshes and beaches
- Restoration targets for Chinook recovery?
- Possible increase in eelgrass

Steve Mlodinow

Estuarine Impacts

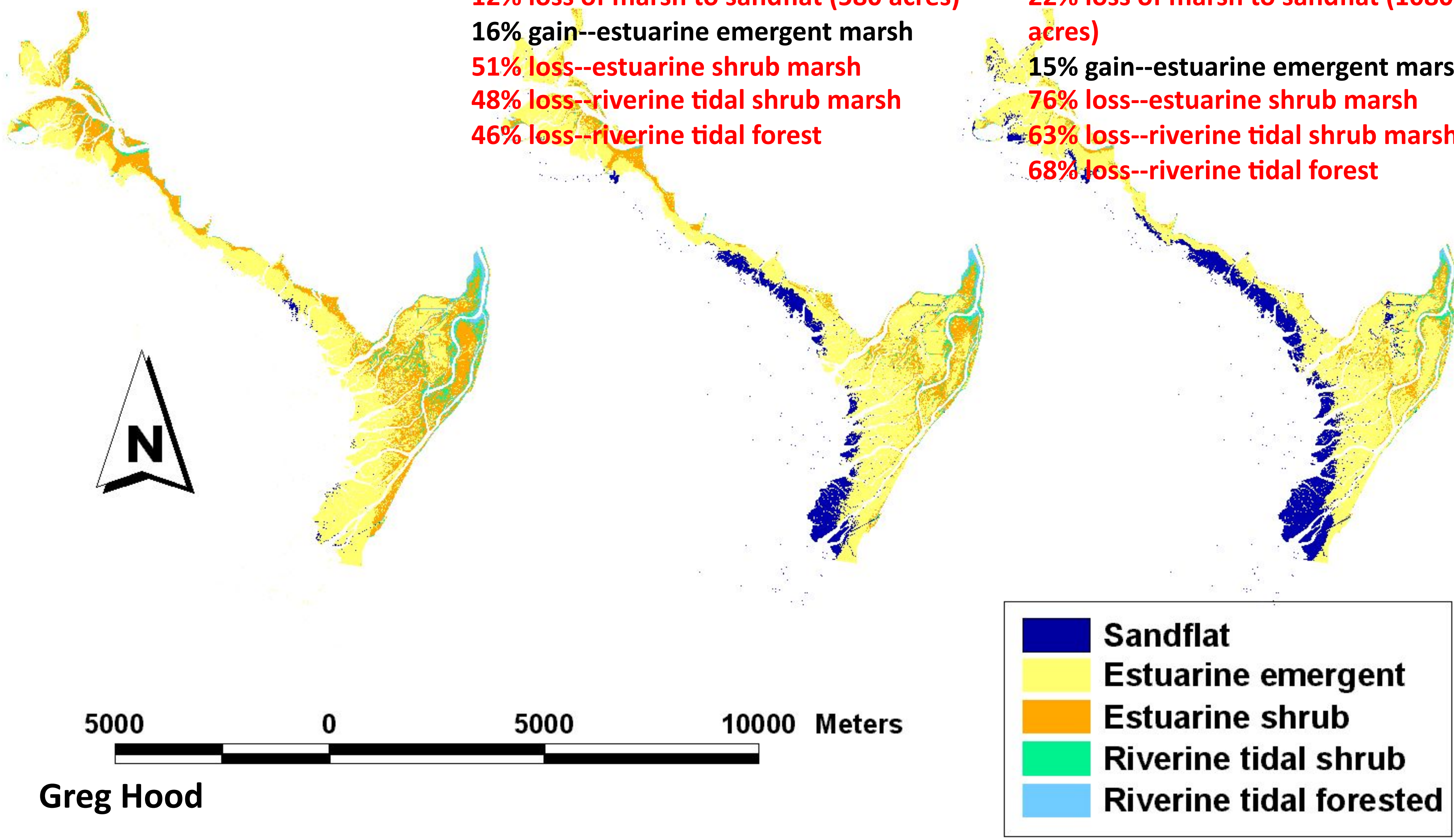
no rise in sea level

18 inch rise in sea level

12% loss of marsh to sandflat (580 acres)
16% gain--estuarine emergent marsh
51% loss--estuarine shrub marsh
48% loss--riverine tidal shrub marsh
46% loss--riverine tidal forest

32 inch rise in sea level

22% loss of marsh to sandflat (1080 acres)
15% gain--estuarine emergent marsh
76% loss--estuarine shrub marsh
63% loss--riverine tidal shrub marsh
68% loss--riverine tidal forest



Greg Hood

Take Home Messages

- Sea level varies over space and time

  (and effects of a rise in sea level will likewise vary)

- Current estimate for Skagit: 6 - 50” higher by 2100

- Small changes can have big impacts

- It’s ***Sea Level Rise + Storms*** that matter

Photo: Keith Lazelle

Integrated Impacts

THANK YOU!

Visit or contact us via

www.skagitclimatescience.org

This project has been funded in part by the United States Environmental Protection Agency under assistance agreement 00J30901-0 to the Swinomish Tribe. The contents of this website do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. Additional support has graciously been provided by the City of Anacortes and Seattle City Light.