Glacier Runoff Impact on Stream Temperature and Discharge in the Headwaters of the Nooksack River

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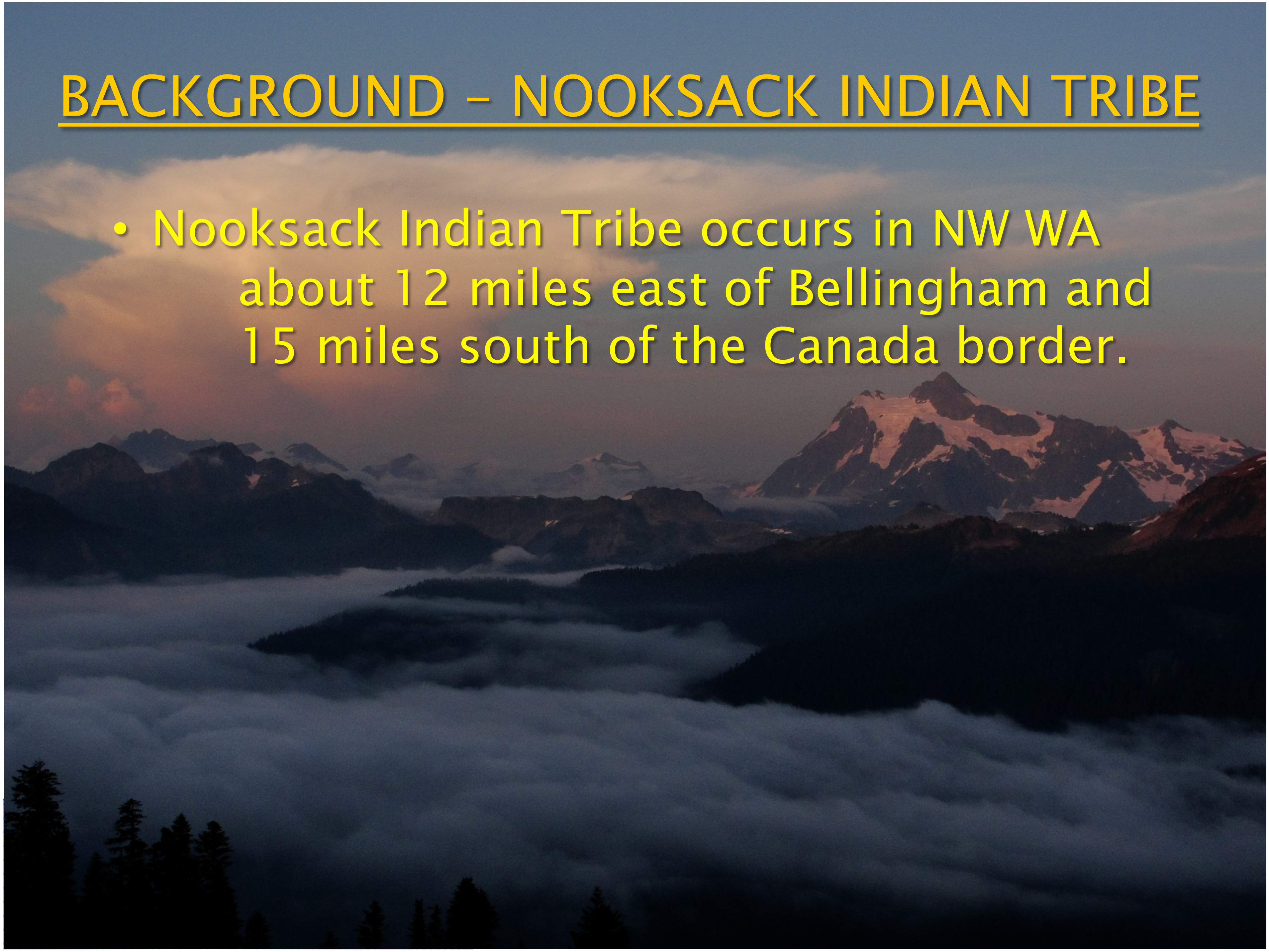
Nooksack Indian Tribe
Nichols College

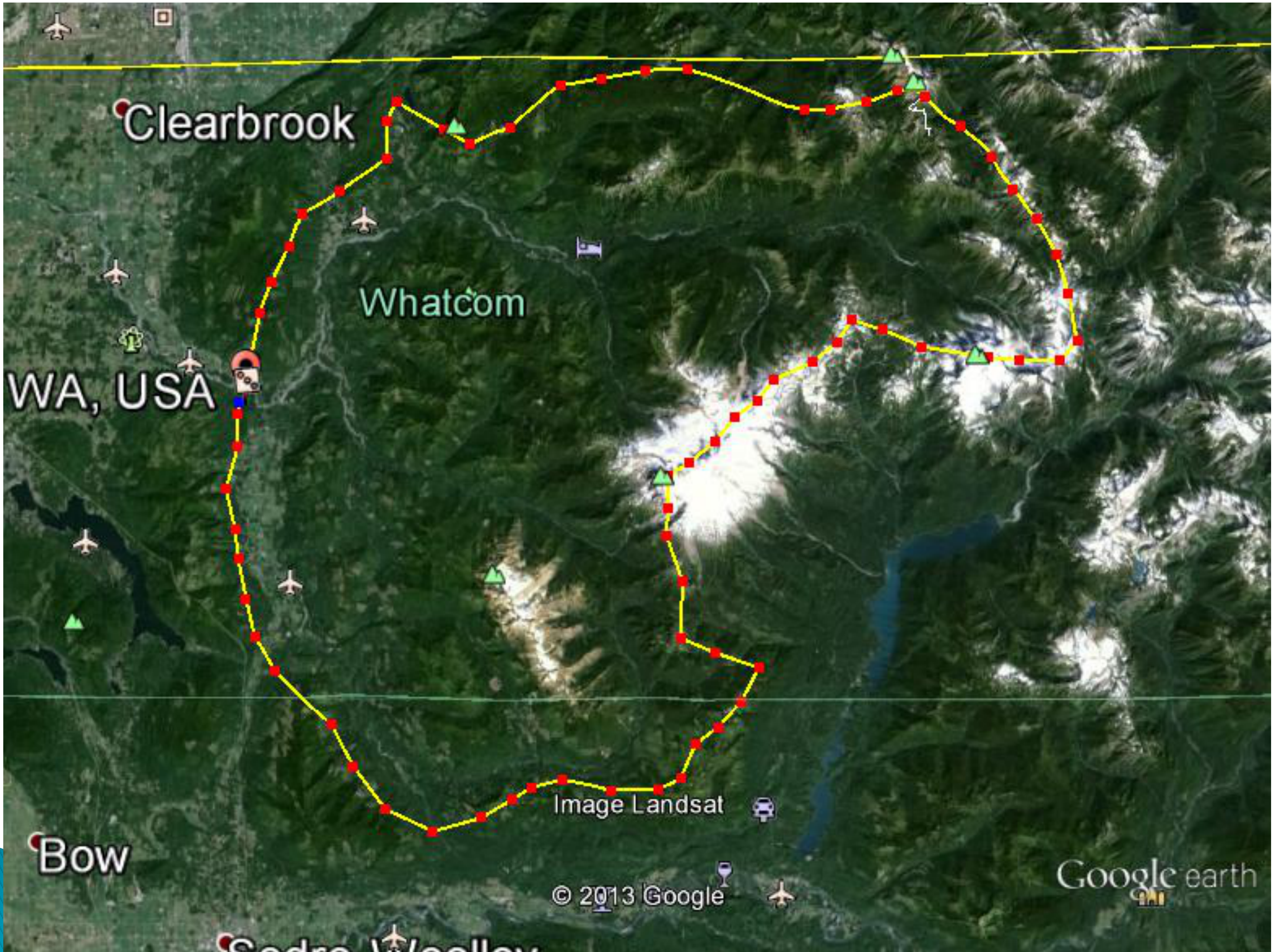
BACKGROUND – NOOKSACK INDIAN TRIBE



BACKGROUND – NOOKSACK INDIAN TRIBE

- Nooksack Indian Tribe occurs in NW WA about 12 miles east of Bellingham and 15 miles south of the Canada border.

CANADA
Nooksack River
North Fork Nooksack
Glacier
Deming
Middle Fork Nooksack
Bellingham
Acme
South Fork Nooksack
Seattle



Clearbrook
Whatcom
WA, USA
Image Landsat
Bow
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Google earth

BACKGROUND – NOOKSACK INDIAN TRIBE

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- Salmon are currently and will continue to be stressed by climate change impacts—altered stream flows and temperature.
- Huge efforts are directed towards in-stream restoration to enhance salmon recovery.
- Other watershed restoration actions will be necessary to ensure persistence and continued recovery of Pacific salmon.

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- The Tribe has initiated a climate change project aimed at evaluating the impacts of climate change on the hydrology of the Nooksack River and salmon survival.

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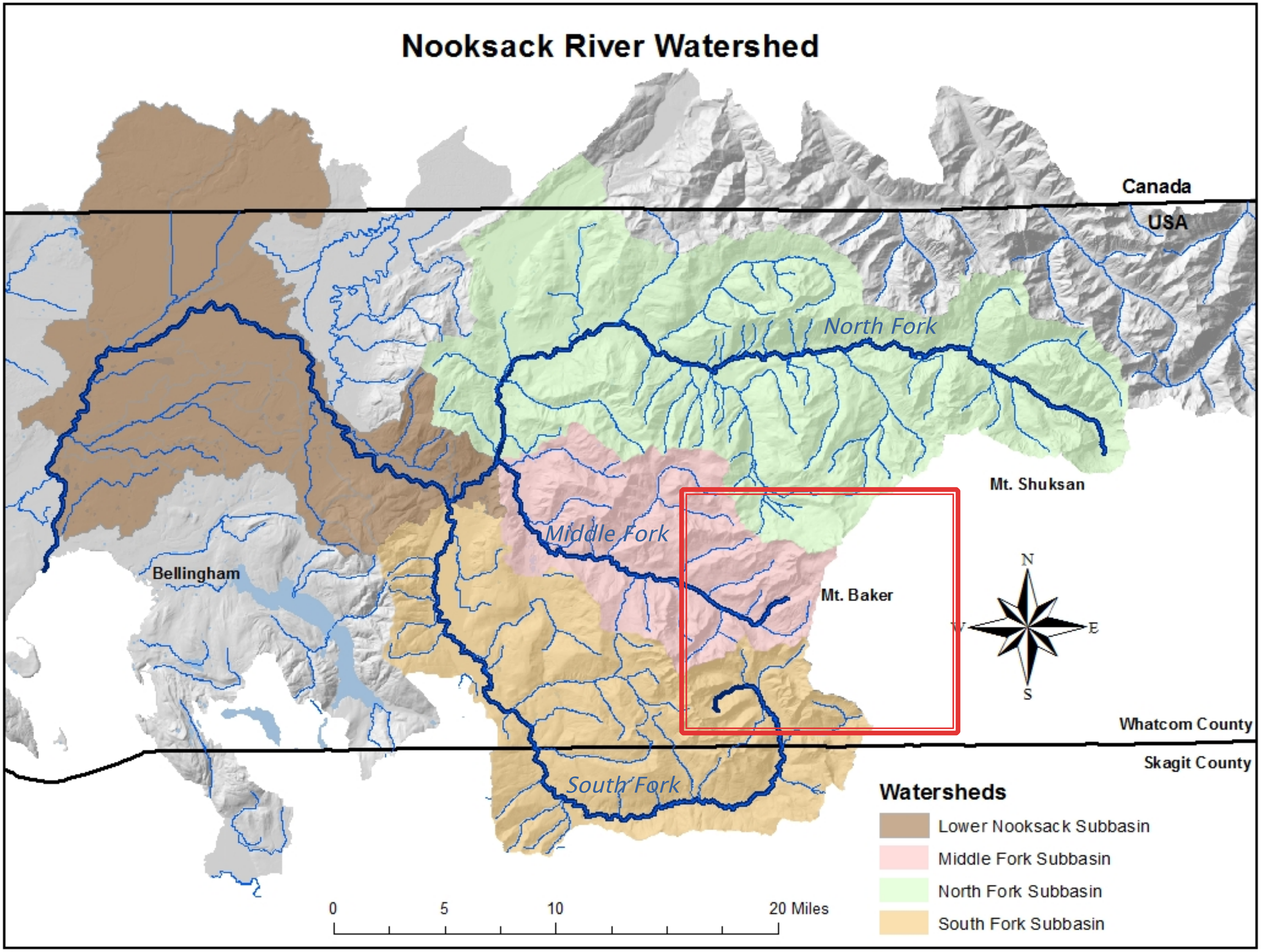
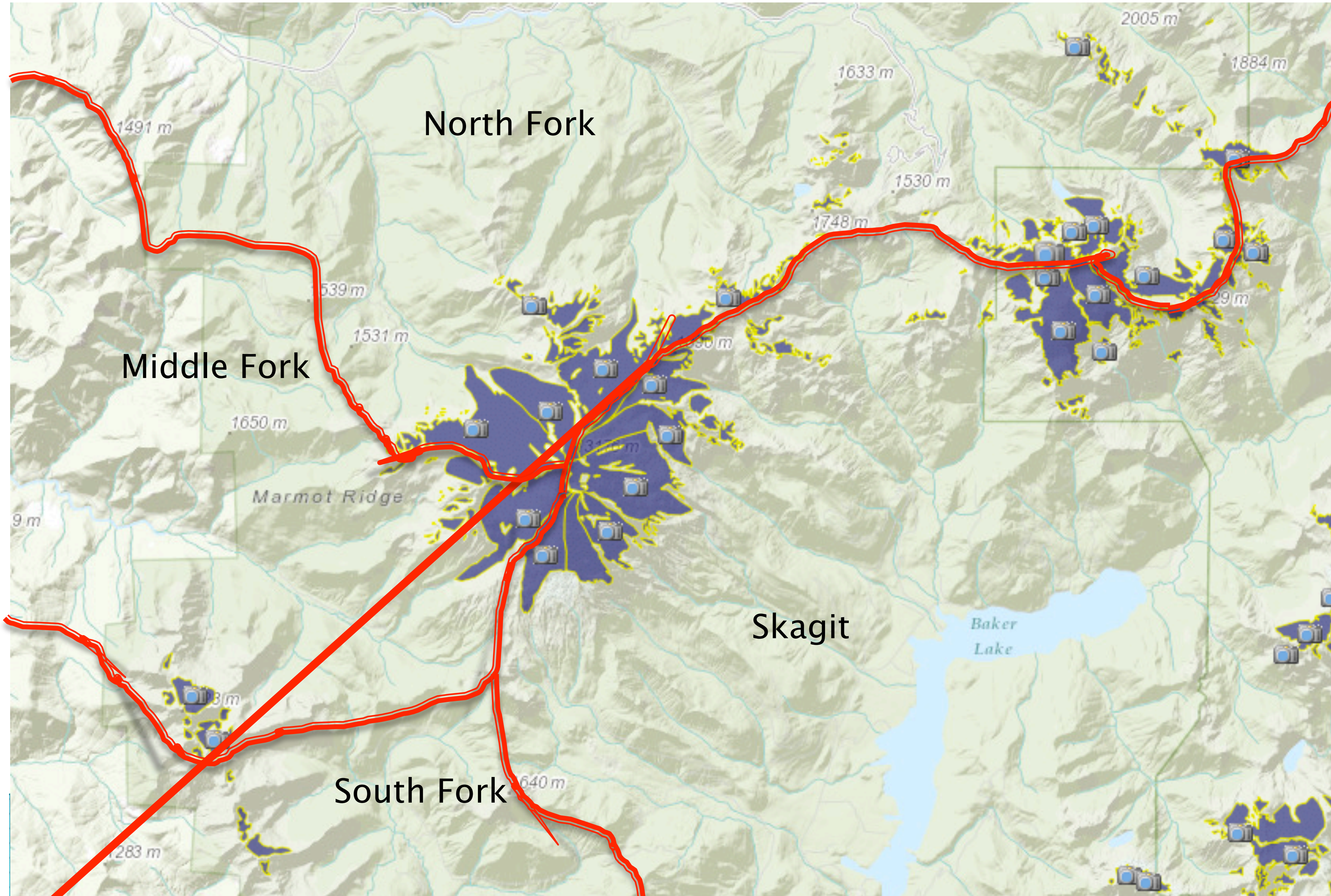
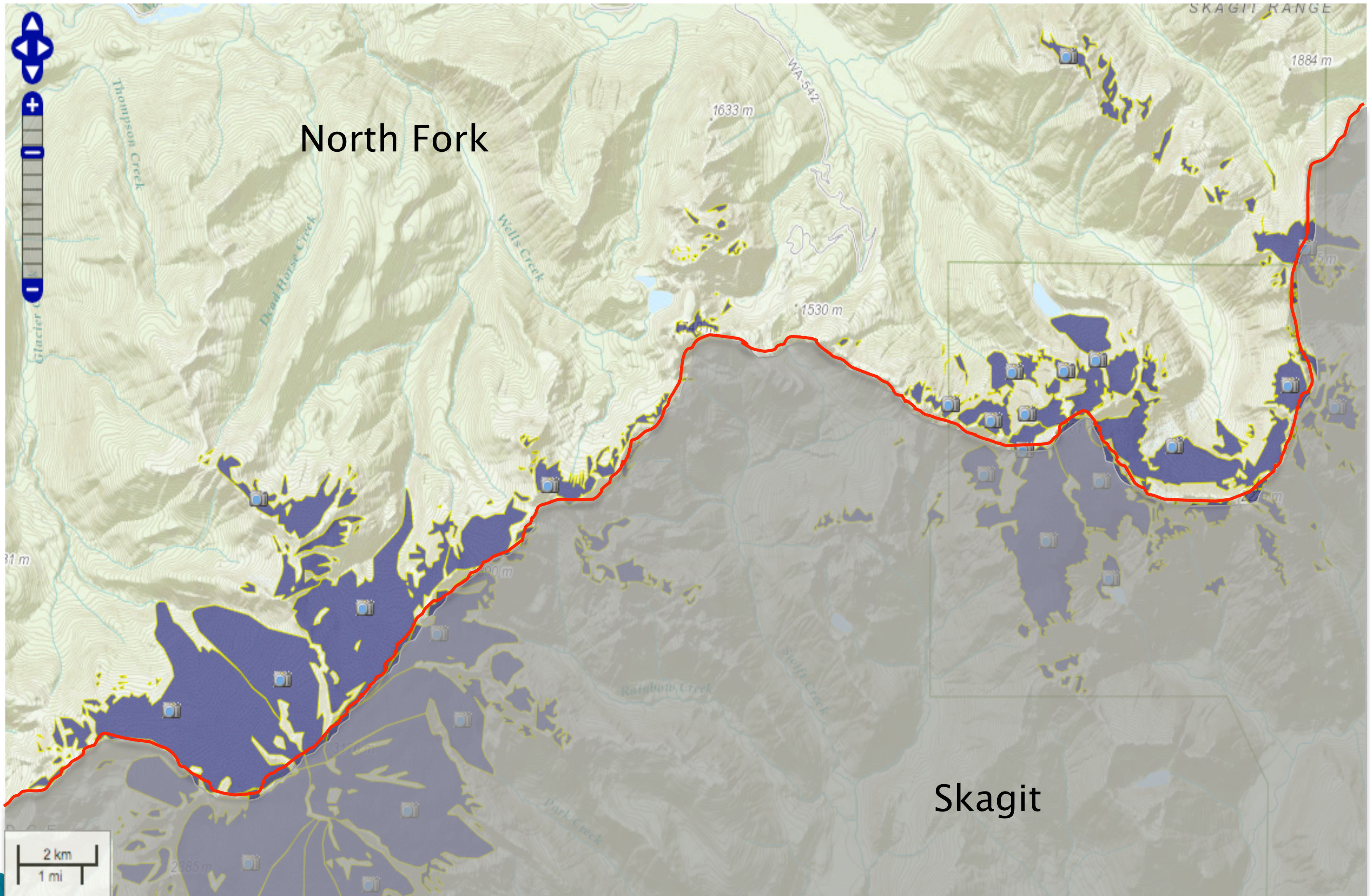
BACKGROUND – NOOKSACK INDIAN TRIBE

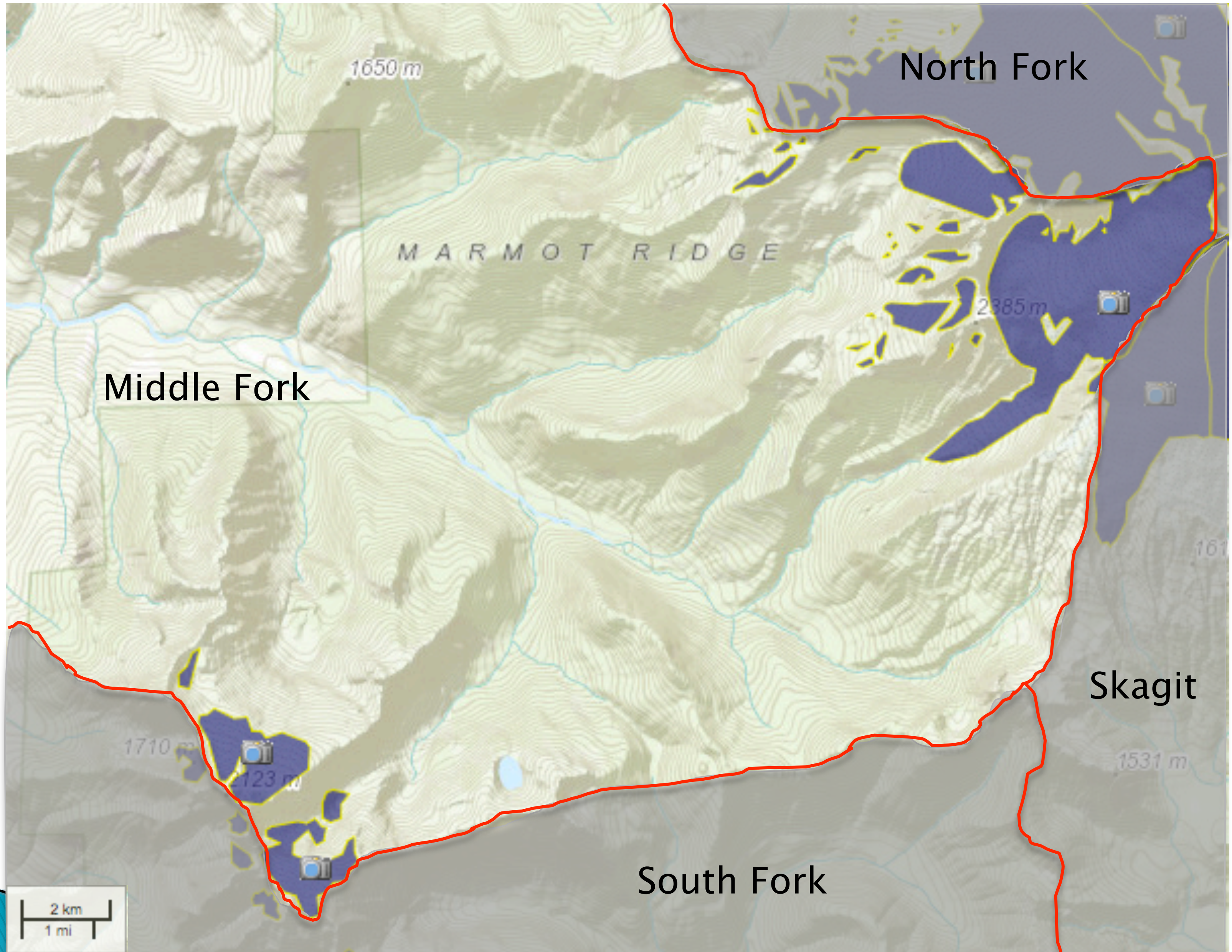
- The Tribe has initiated a climate change project aimed at evaluating the impacts of climate change on the hydrology of the Nooksack River and salmon survival.
- This information is needed to plan for effective habitat restoration measures that address the additional stresses of future climate change.
- Our climate change project will also address water resources management issues of other water users in the Nooksack River basin.

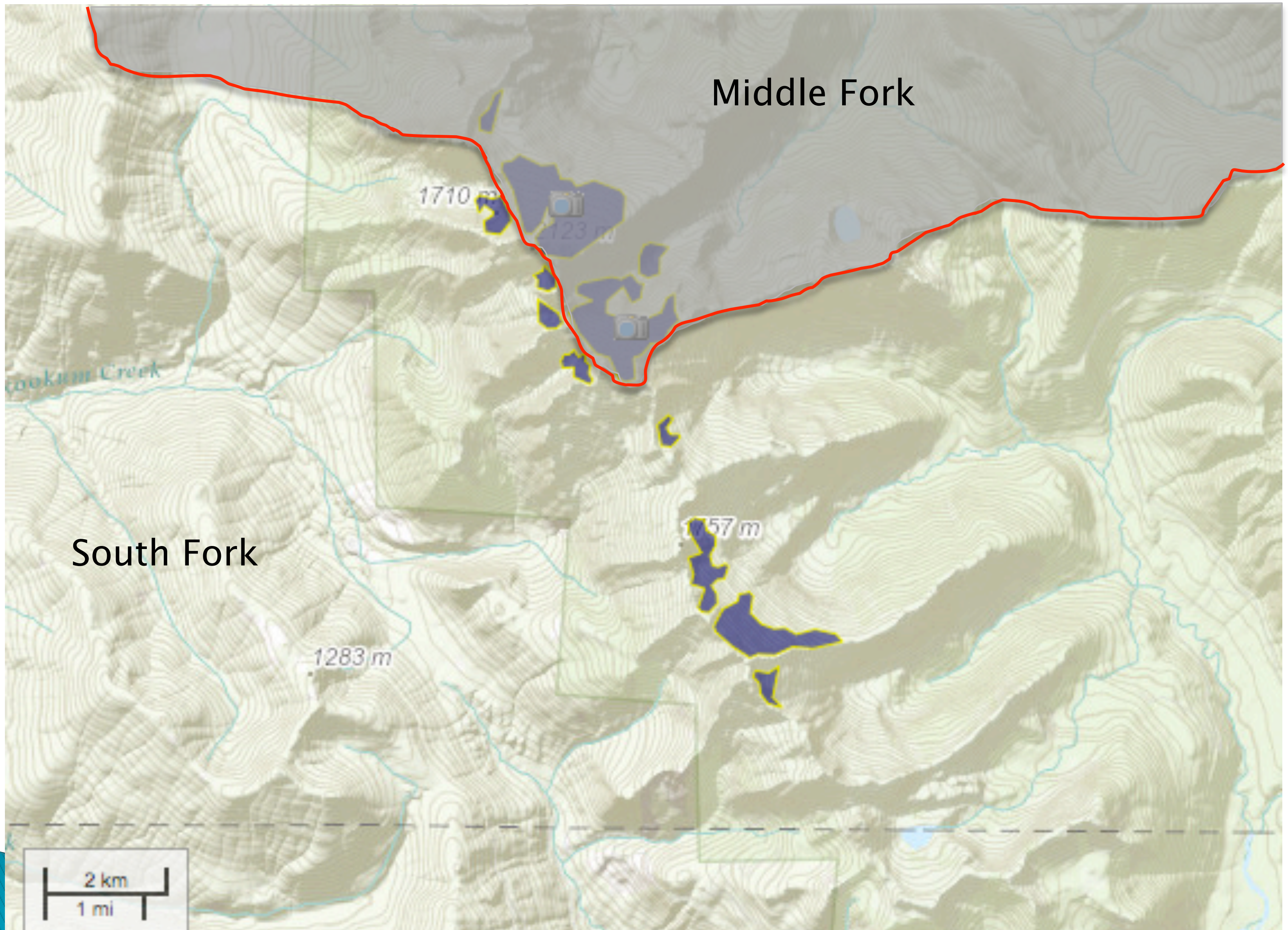

Nooksack River Watershed
Canada
USA
North Fork
Middle Fork
South Fork
Mt. Shuksan
Mt. Baker
Bellingham
N
W
E
S
Whatcom County
Skagit County
Watersheds
Lower Nooksack Subbasin
Middle Fork Subbasin
North Fork Subbasin
South Fork Subbasin
0
5
10
20 Miles



(source: http://glaciers.geos.pdx.edu/).


North Fork
Skagit
SKAGIT RANGE
1884 m
1633 m
1530 m
WA-542
Thompson Creek
Dead Horse Creek
Wells Creek
Rainbow Creek
Park Creek
2 km
1 mi


North Fork
1650 m
MARMOT RIDGE
2385 m
Middle Fork
161
Skagit
1710 m
2123 m
1531 m
South Fork
2 km
1 mi


Middle Fork
1710 m
South Fork
1283 m
2 km
1 mi

Nooksack River Basin

- **North Fork**– 727 km^2 –glacier area 23.9 km^2
- Substantial glacier area–Coleman, Roosevelt, Mazama, Heliotrope, Sholes, Hadley, Bastille
- **Middle Fork**–190 km^2–glacier area 6.7 km^2
- Moderate glacier area– Deming, Thunder, Twin Sisters
- **South Fork** –272 km^2 – glacier area 0.1 km^2
- Minimal Glacier area and lower mean elevation

Key Investigation questions

- How do warm weather events affect discharge and water temperature of the three Nooksack Forks?
- What are the key differences between their responses?
- What is the contribution of glacier runoff during late summer streamflow?
- How will glacier contribution change in the future with continued climate change.

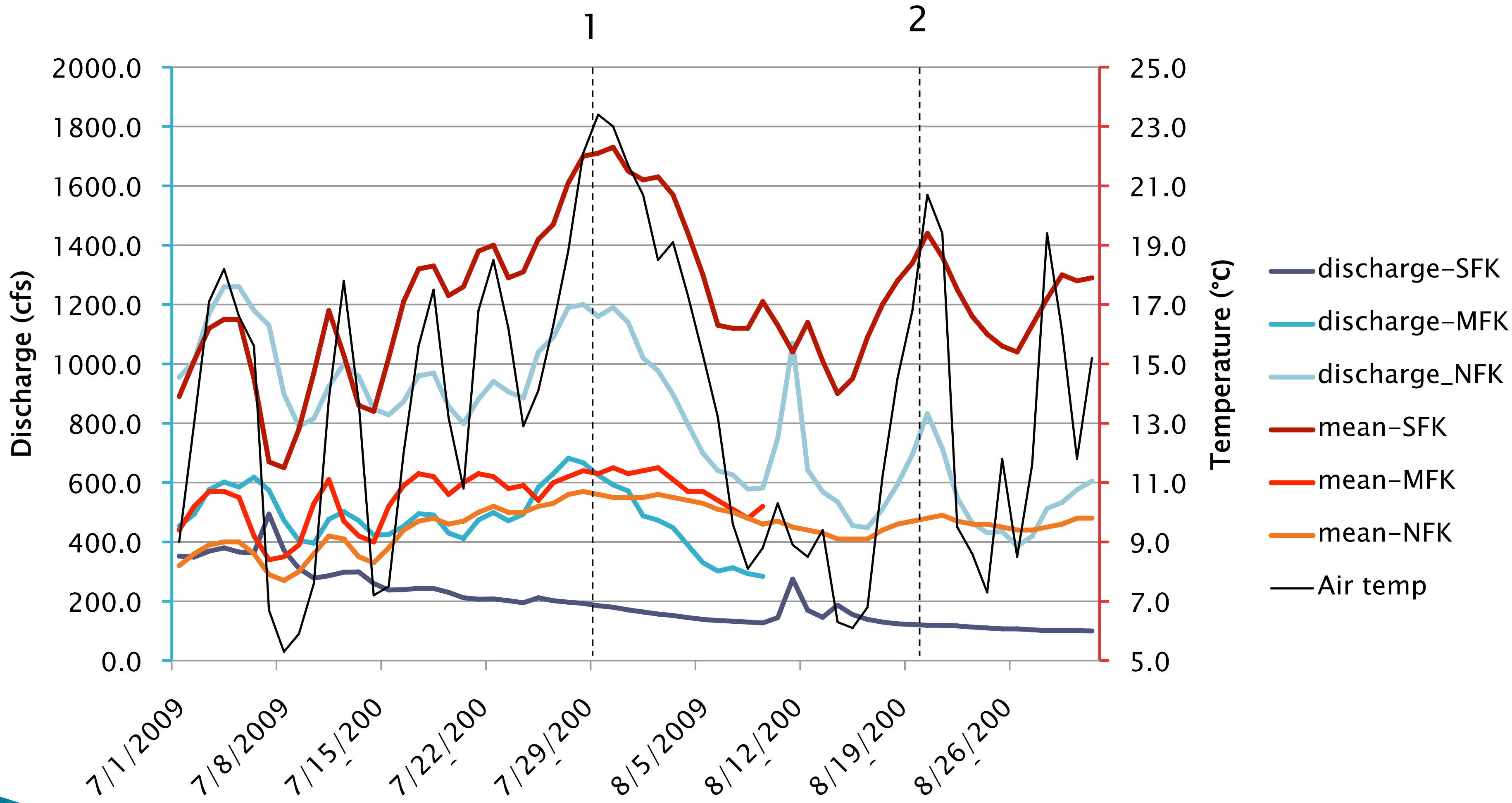
Glacier Runoff

- Annual glacier runoff is the product of *annual ablation* and *glacier area*.
- Recent warm summers have 5-10% higher ablation rates than the 1984-2013 mean.
- Combined with the 10 % reduction in glacier area from 1984-2013 this yields a small reduction in overall glacier runoff despite higher ablation rate.
- Continued glacier decline will only lead to further runoff decreases in late summer.

USGS Gage comparison for the three Nooksack watersheds

- Stream discharge
- Stream temperature
- Air Temperature from North Fork Nooksack SNOTEL site for late summer of 2009-2013
- Analysis of this data suggests different responses of the three forks to warm weather events in 2009, 2010, 2012, and 2013

2009



1
2
2000.0
1800.0
1600.0
1400.0
1200.0
1000.0
800.0
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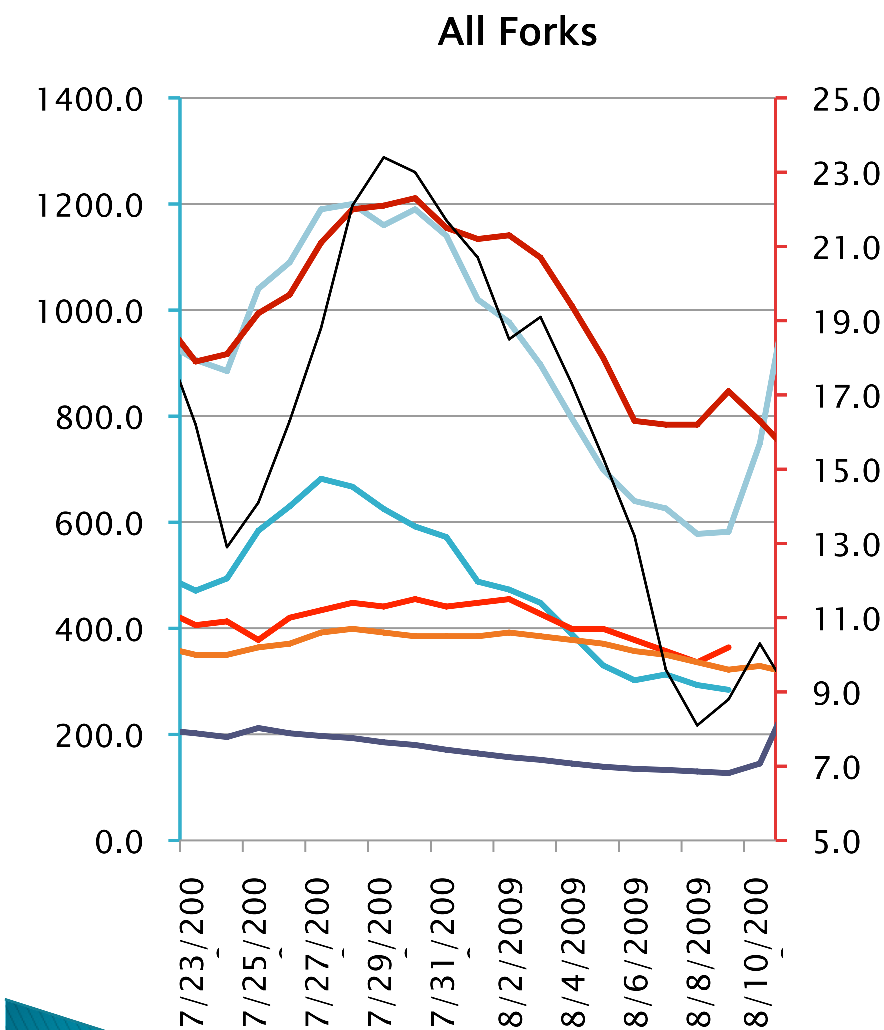
200.0
0.0
Discharge (cfs)
25.0
23.0
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
Temperature (°C)
7/1/2009
7/8/2009
7/15/200
7/22/200
7/29/200
8/5/2009
8/12/200
8/19/200
8/26/200
discharge-SFK
discharge-MFK
discharge_NFK
mean-SFK
mean-MFK
mean-NFK
Air temp

2009


All Forks
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15.0
13.0
11.0
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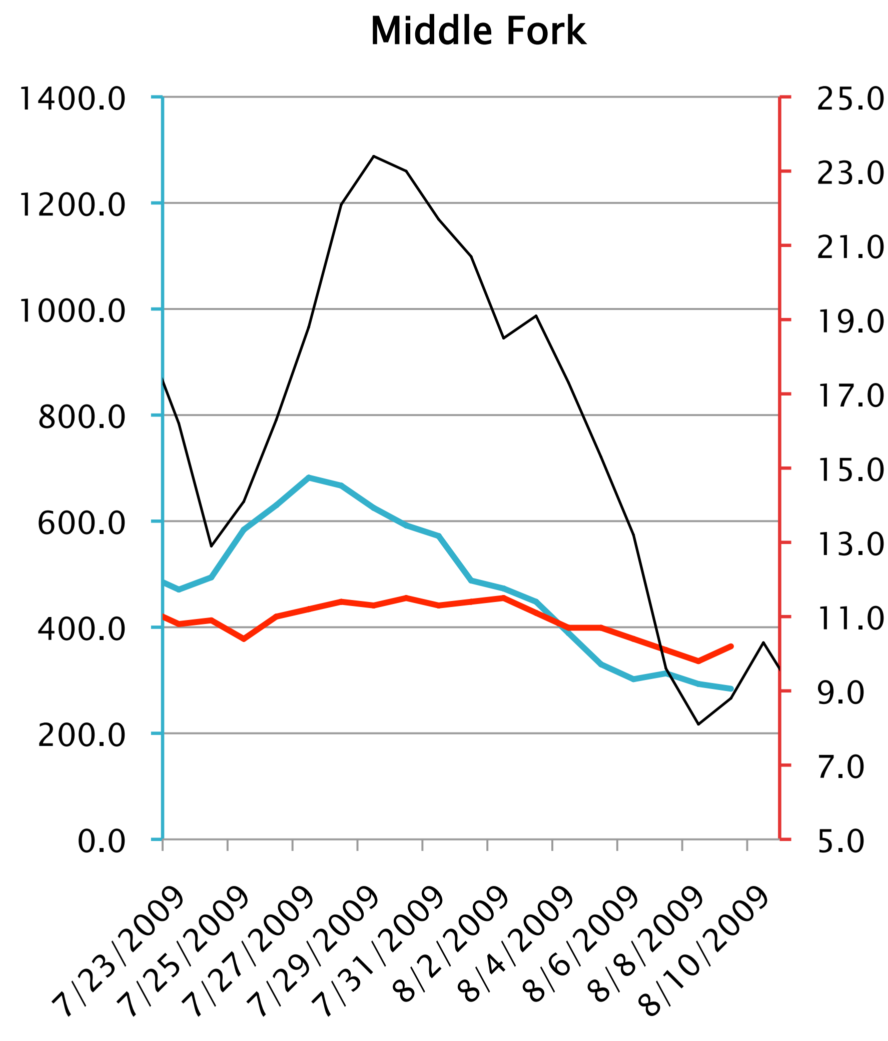
7.0
5.0
7/23/200_
7/25/200_
7/27/200_
7/29/200_
7/31/200_
8/2/2009
8/4/2009
8/6/2009
8/8/2009
8/10/200_


Middle Fork
1400.0
1200.0
1000.0
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17.0
15.0
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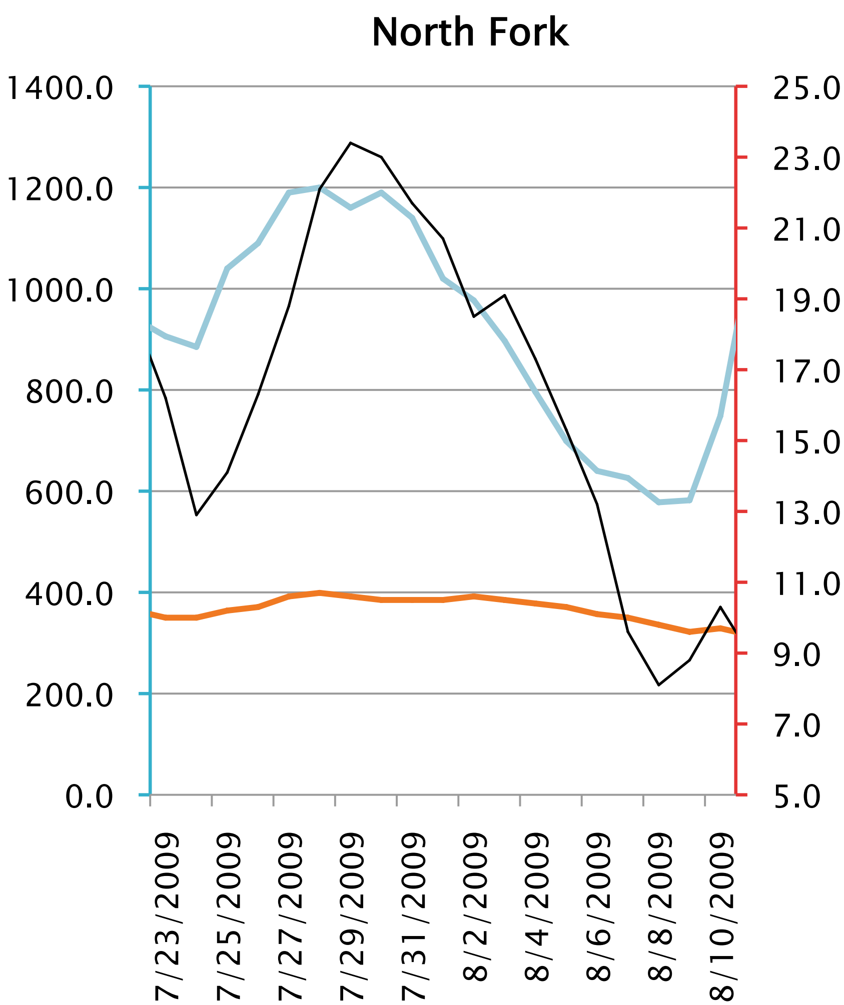
11.0
9.0
7.0
5.0
7/23/2009
7/25/2009
7/27/2009
7/29/2009
7/31/2009
8/2/2009
8/4/2009
8/6/2009
8/8/2009
8/10/2009

2009


North Fork
1400.0
1200.0
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17.0
15.0
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9.0
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5.0
7/23/2009
7/25/2009
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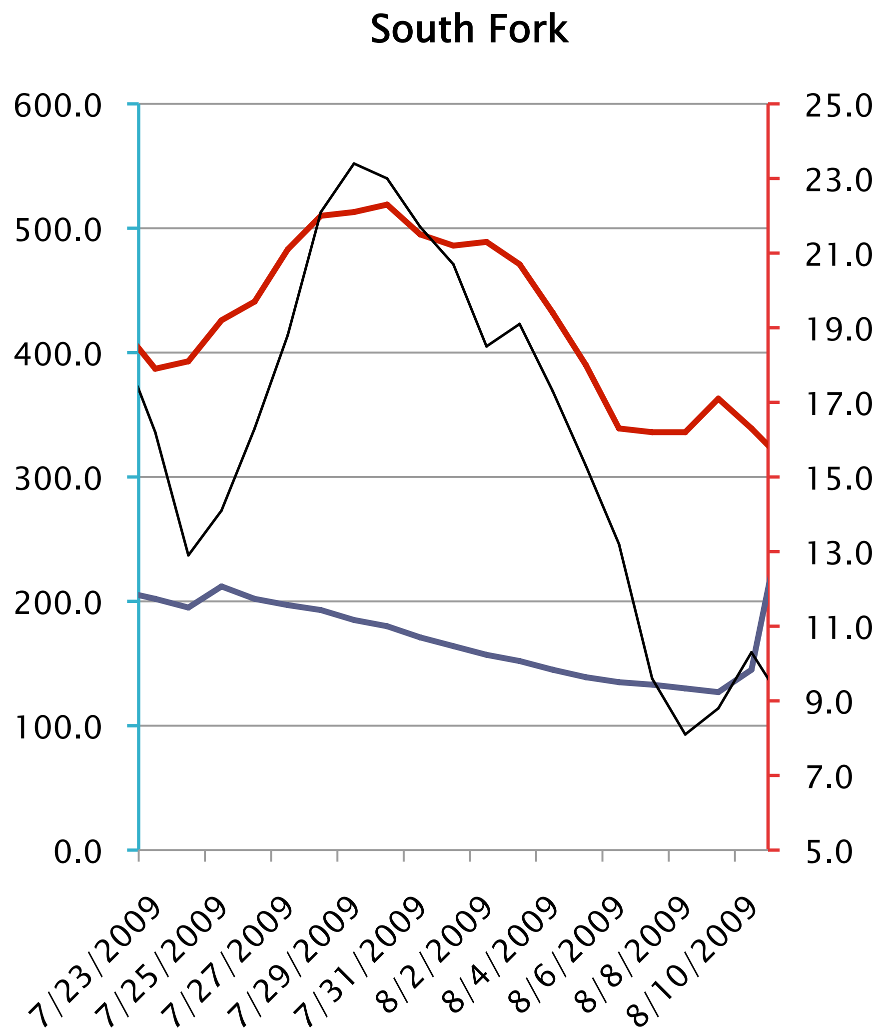
8/6/2009
8/8/2009
8/10/2009


South Fork
600.0
500.0
400.0
300.0
200.0
100.0
0.0
25.0
23.0
21.0
19.0
17.0
15.0
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11.0
9.0
7.0
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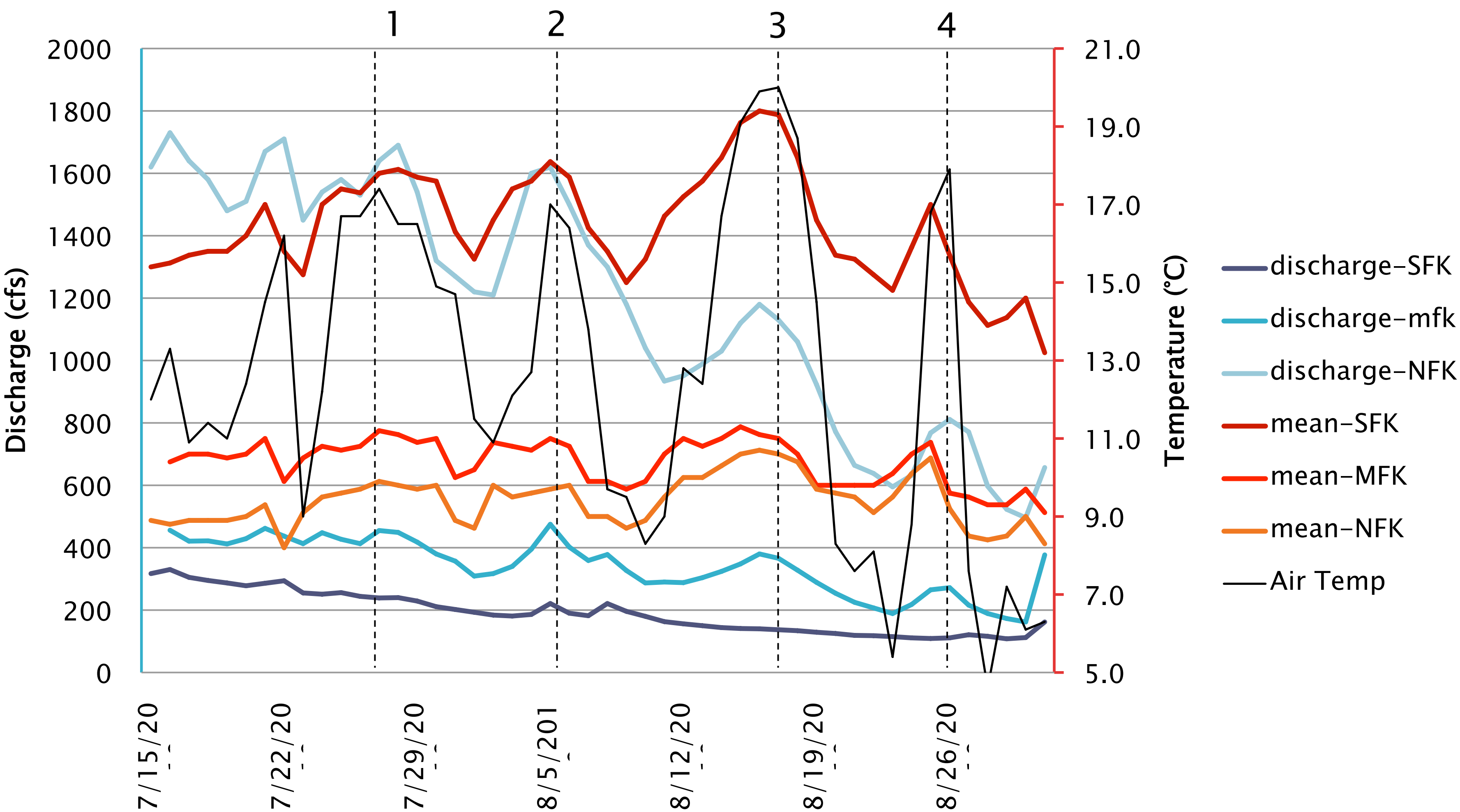
7/23/2009
7/25/2009
7/27/2009
7/29/2009
7/31/2009
8/2/2009
8/4/2009
8/6/2009
8/8/2009
8/10/2009

2010



1
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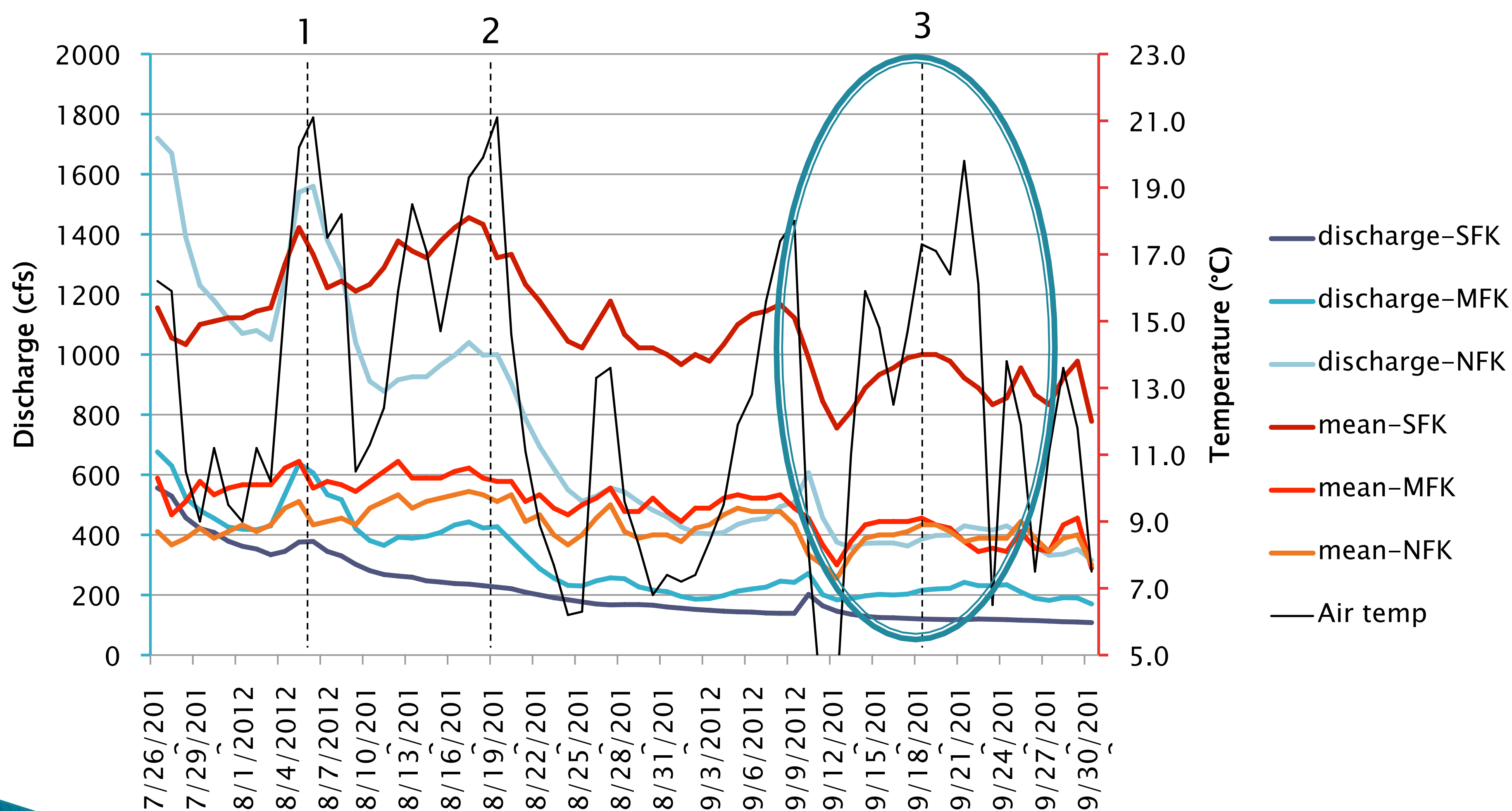
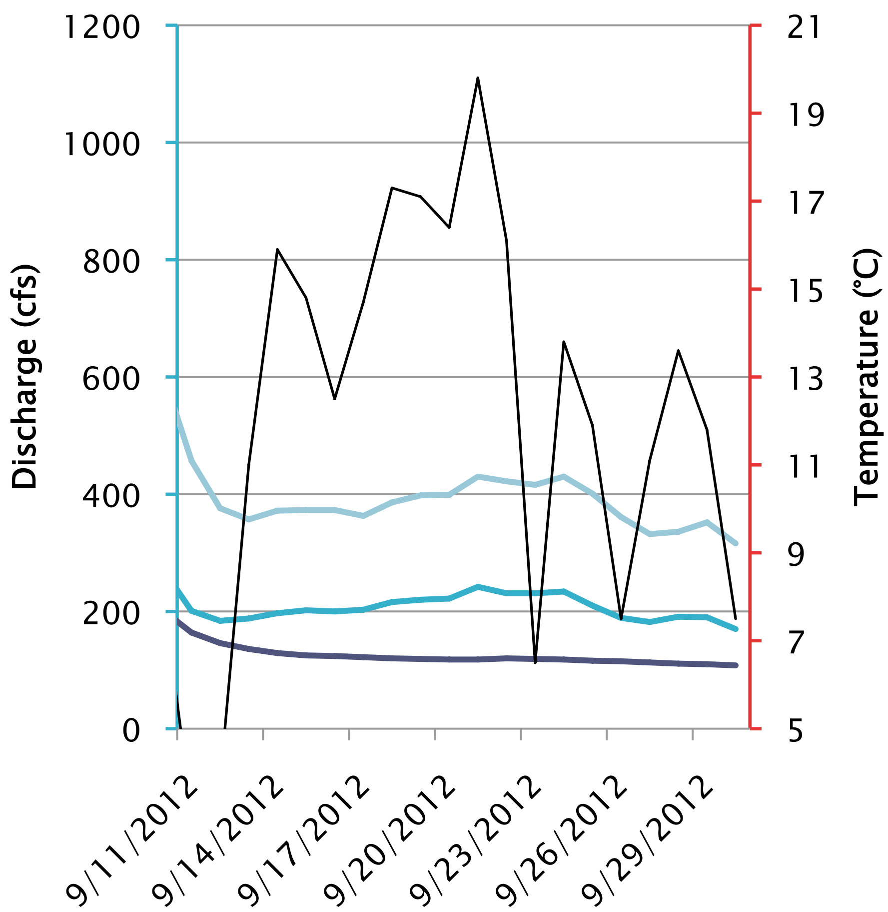
3
4
Discharge (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Temperature (°C)
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
7/15/20
7/22/20
7/29/20
8/5/201
8/12/20
8/19/20
8/26/20
discharge-SFK
discharge-mfk
discharge-NFK
mean-SFK
mean-MFK
mean-NFK
Air Temp

2012

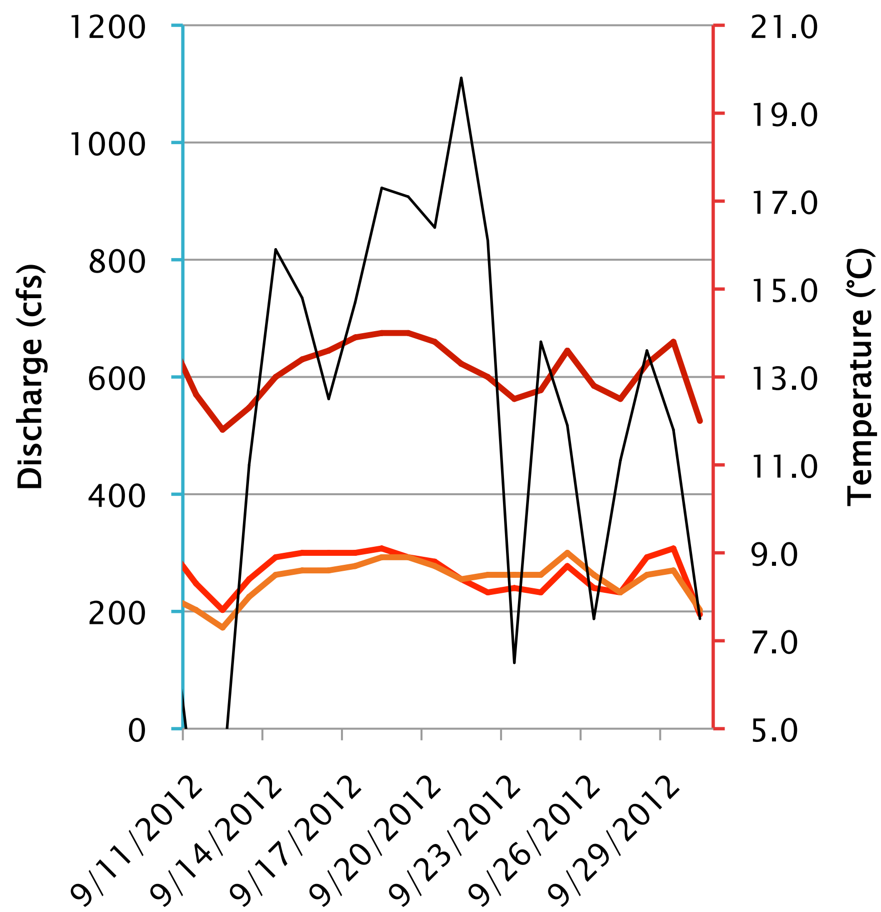


1
2
3
Discharge (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Temperature (°C)
23.0
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
7/26/201
7/29/201
8/1/2012
8/4/2012
8/7/2012
8/10/201
8/13/201
8/16/201
8/19/201
8/22/201
8/25/201
8/28/201
8/31/201
9/3/2012
9/6/2012
9/9/2012
9/12/201
9/15/201
9/18/201
9/21/201
9/24/201
9/27/201
9/30/201
discharge-SFK
discharge-MFK
discharge-NFK
mean-SFK
mean-MFK
mean-NFK
Air temp

2012

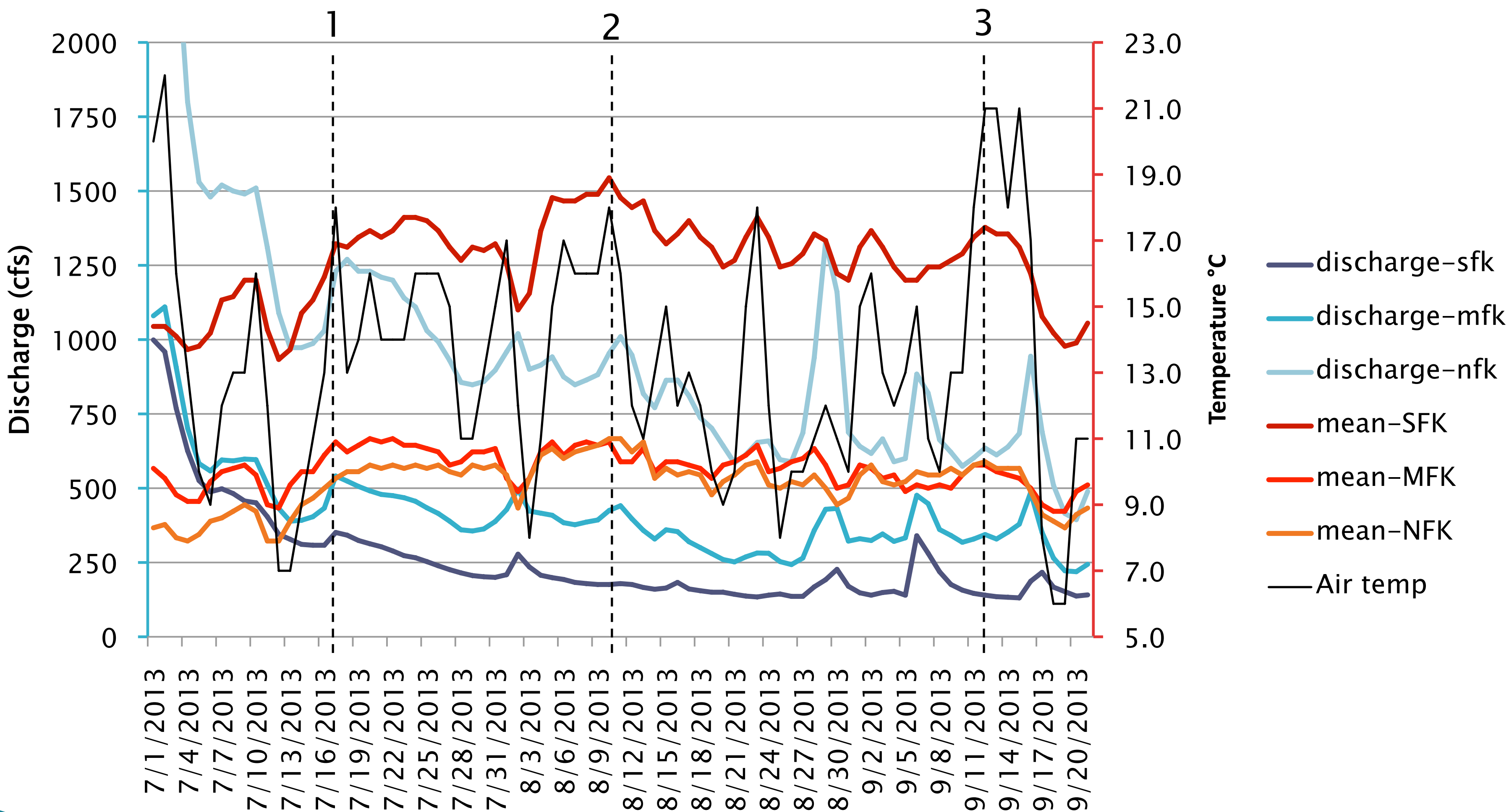


1200
1000
800
600
400
200
0
Discharge (cfs)
21
19
17
15
13
11
9
7
5
Temperature (°C)
9/11/2012
9/14/2012
9/17/2012
9/20/2012
9/23/2012
9/26/2012
9/29/2012



1200
1000
800
600
400
200
0
Discharge (cfs)
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
Temperature (°C)
9/11/2012
9/14/2012
9/17/2012
9/20/2012
9/23/2012
9/26/2012
9/29/2012

2013



1
2
3
Discharge (cfs)
2000
1750
1500
1250
1000
750
500
250
0
Temperature °C
23.0
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
7/1/2013
7/4/2013
7/7/2013
7/10/2013
7/13/2013
7/16/2013
7/19/2013
7/22/2013
7/25/2013
7/28/2013
7/31/2013
8/3/2013
8/6/2013
8/9/2013
8/12/2013
8/15/2013
8/18/2013
8/21/2013
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8/27/2013
8/30/2013
9/2/2013
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9/8/2013
9/11/2013
9/14/2013
9/17/2013
9/20/2013
discharge-sfk
discharge-mfk
discharge-nfk
mean-SFK
mean-MFK
mean-NFK
Air temp

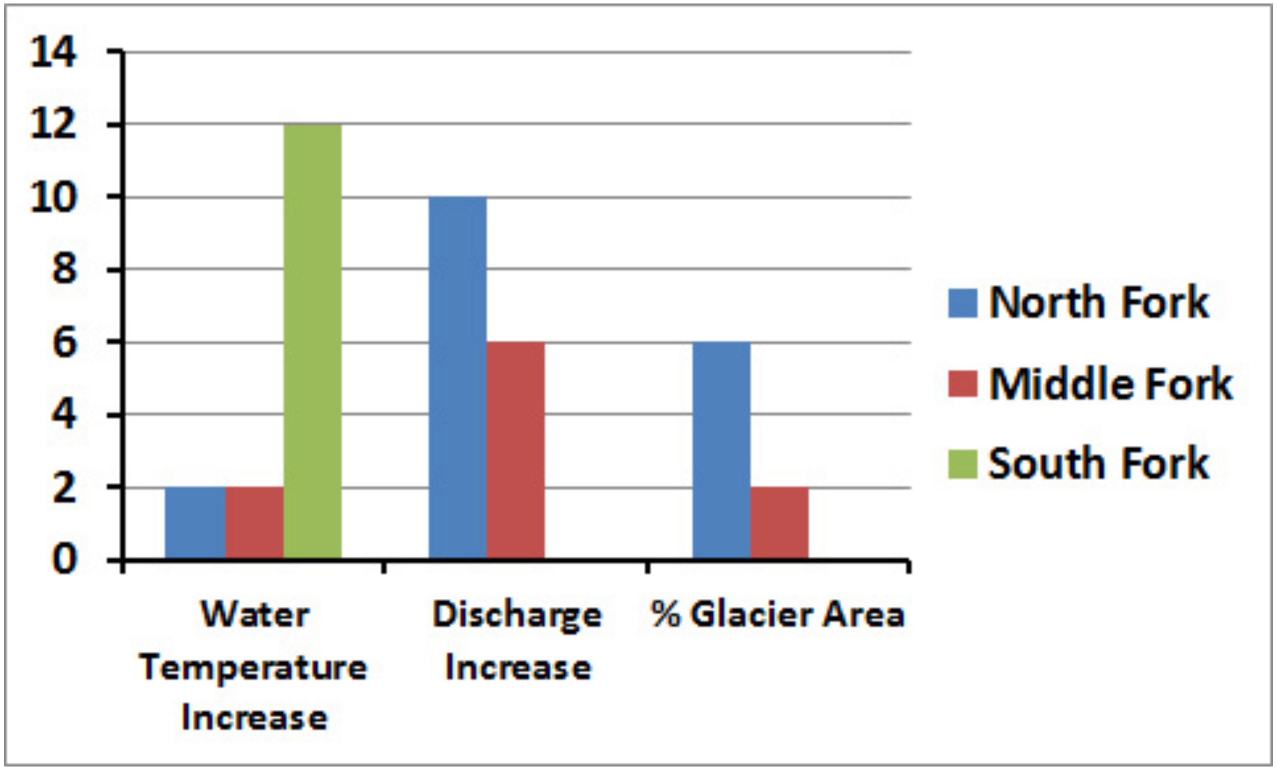
Overall Trends:

South Fork: lowest overall Q, little to no detectable variability in Q, greatest variability in T, exceeding 2°C in all 12 events.

Middle Fork: moderate Q, with moderate increases during warm events. Attenuated variability in T, changes not exceeding 2°C.

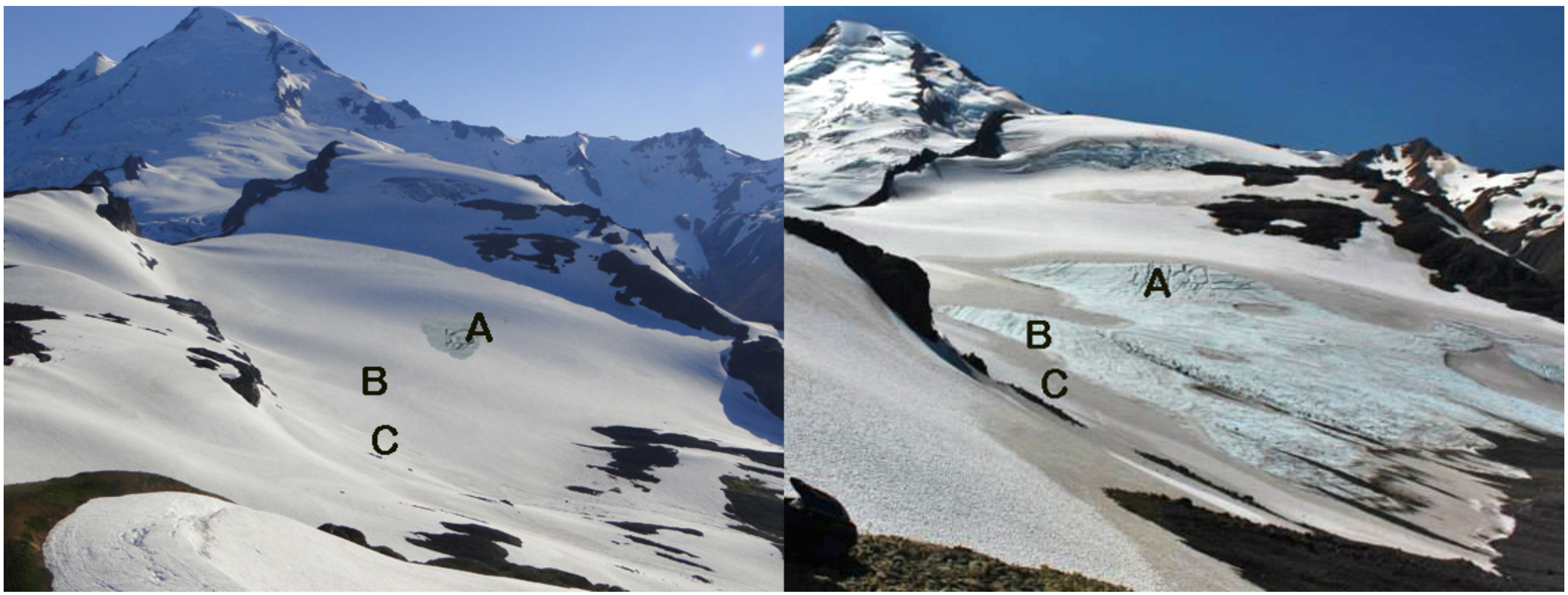
North Fork: greatest overall Q, with greatest increases in Q during warm events. Variability in T nearly identical to Middle Fork.

Of the 12 warm weather events the number that led to significant temperature (+2 C)or discharge increase (+10%).

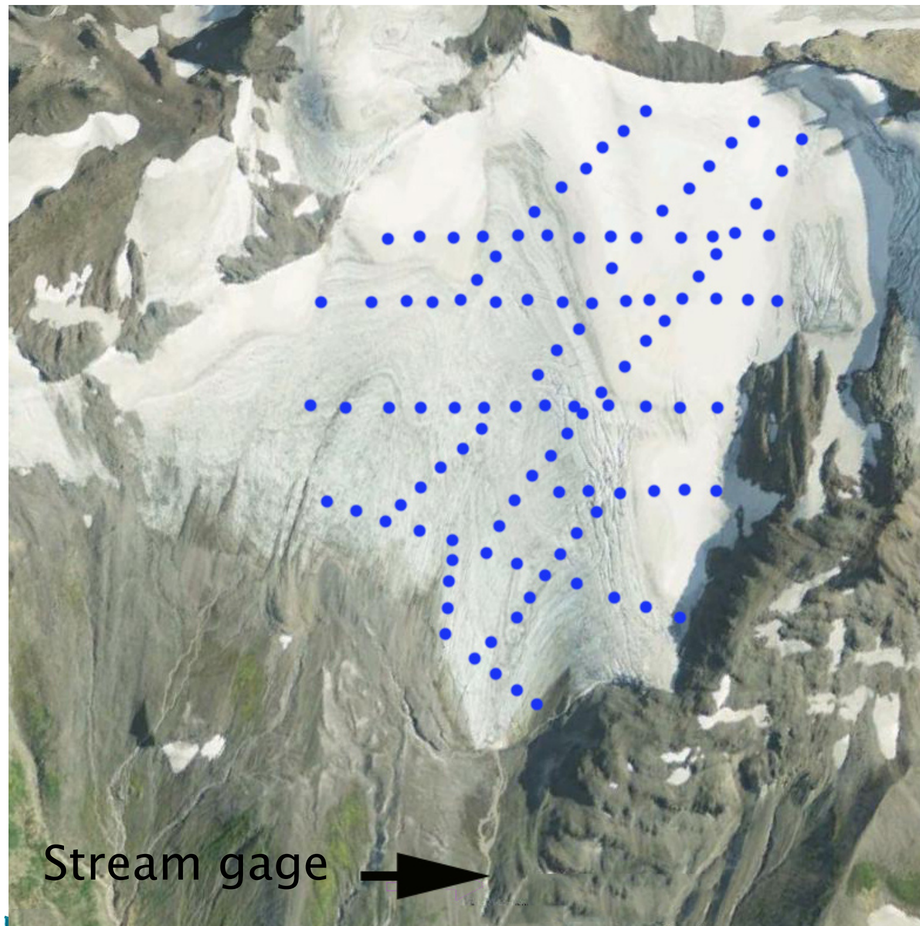


Glacier Ablation Runoff Contribution:

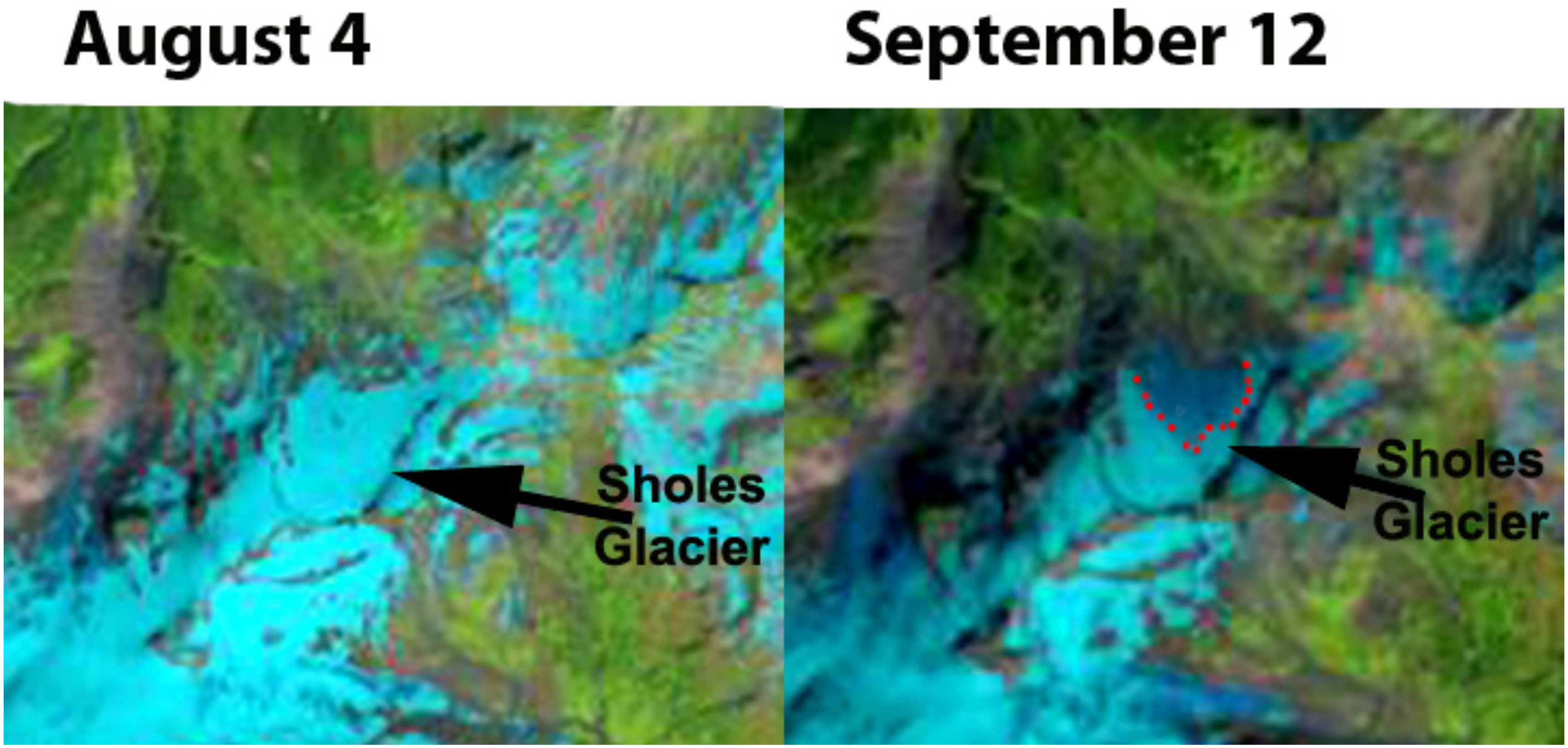
Sholes Glacier Aug 4th and Sept. 12th 2013



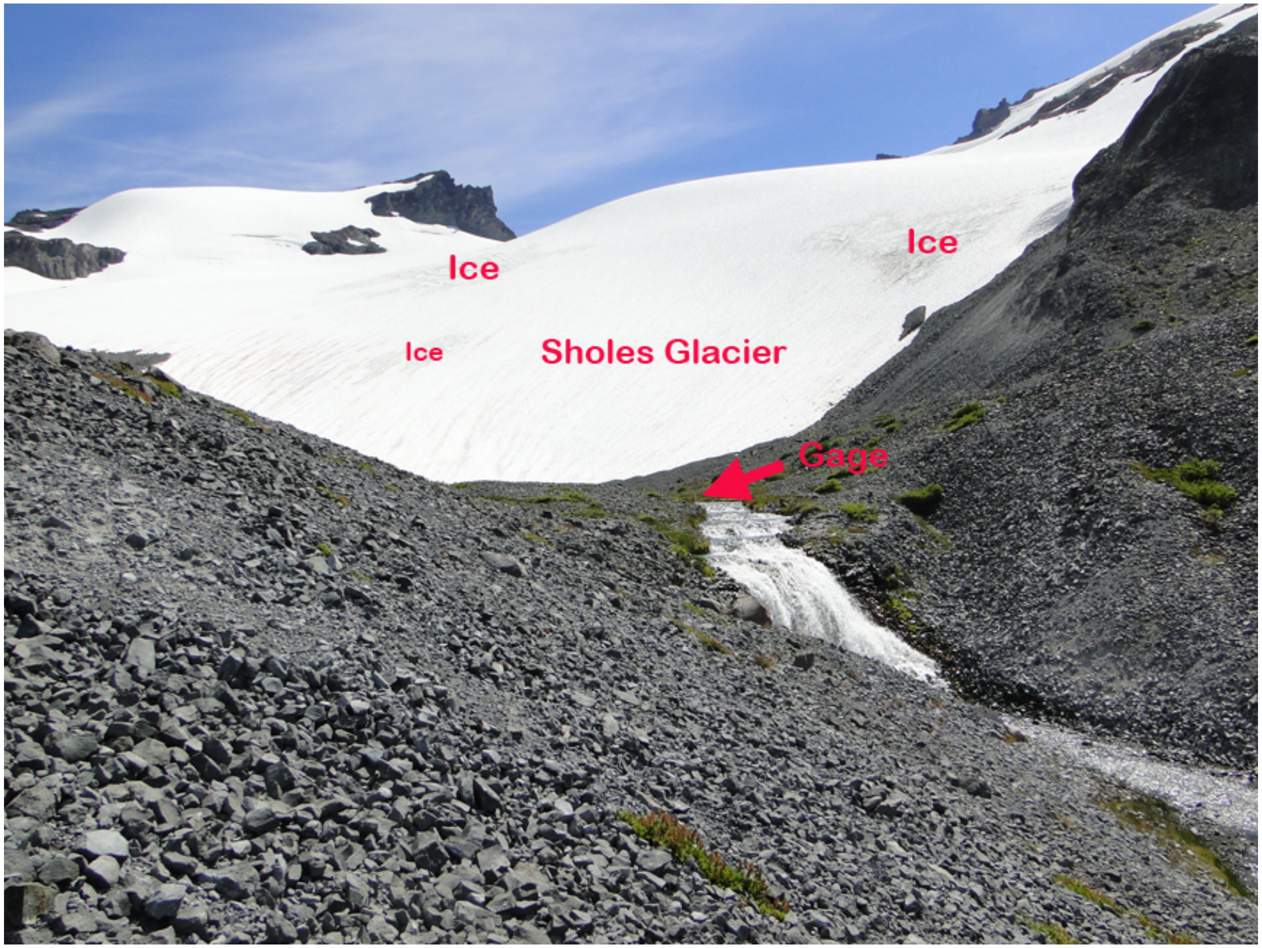
Probing:
Measure snowpack depth across the glacier



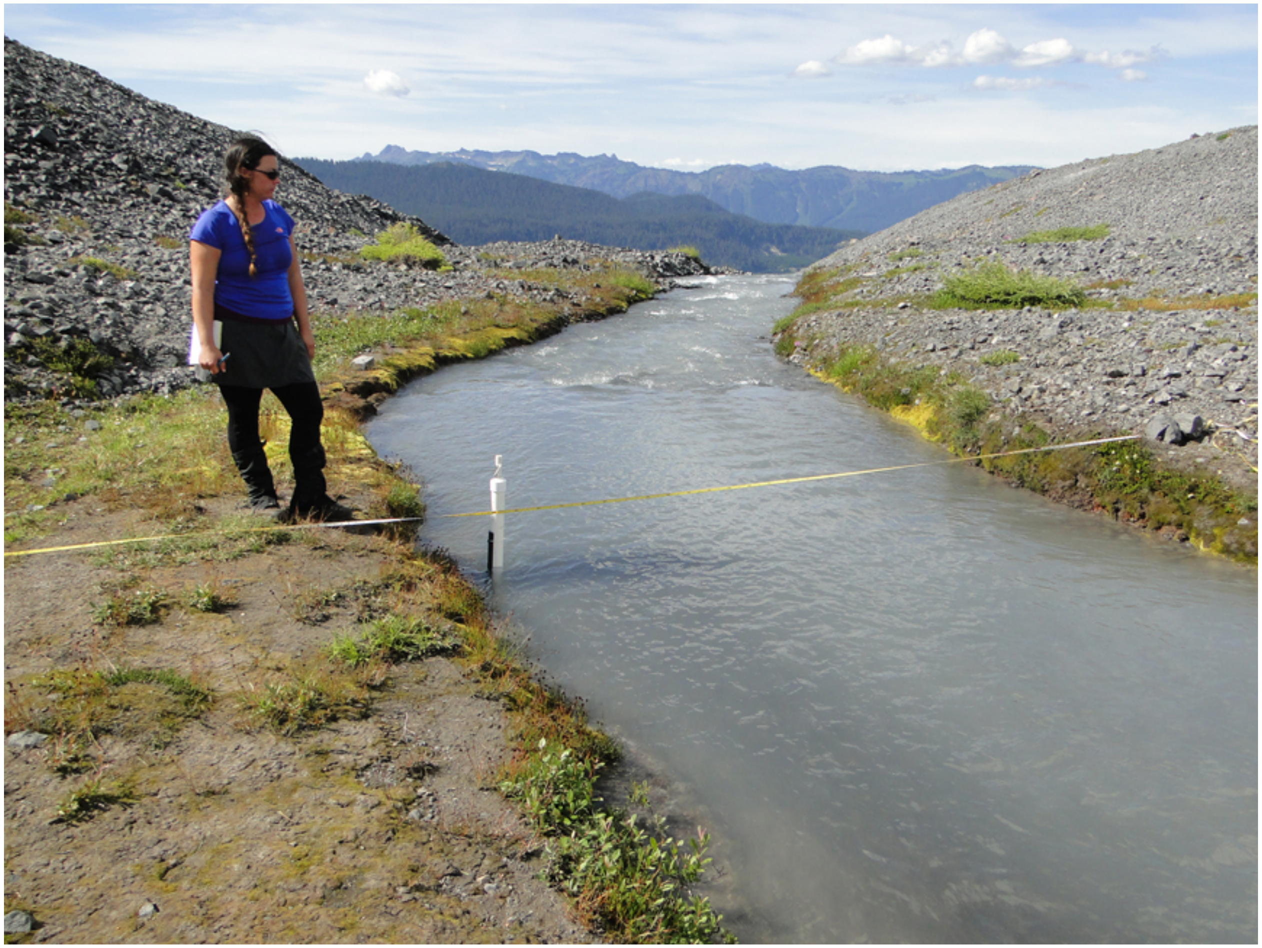
Glacier and Snow Areal Extent



The measured snowpack and ice melt is compared to runoff measured below the glacier.



Sholes Gage



Glacier Runoff Volume during warm weather events

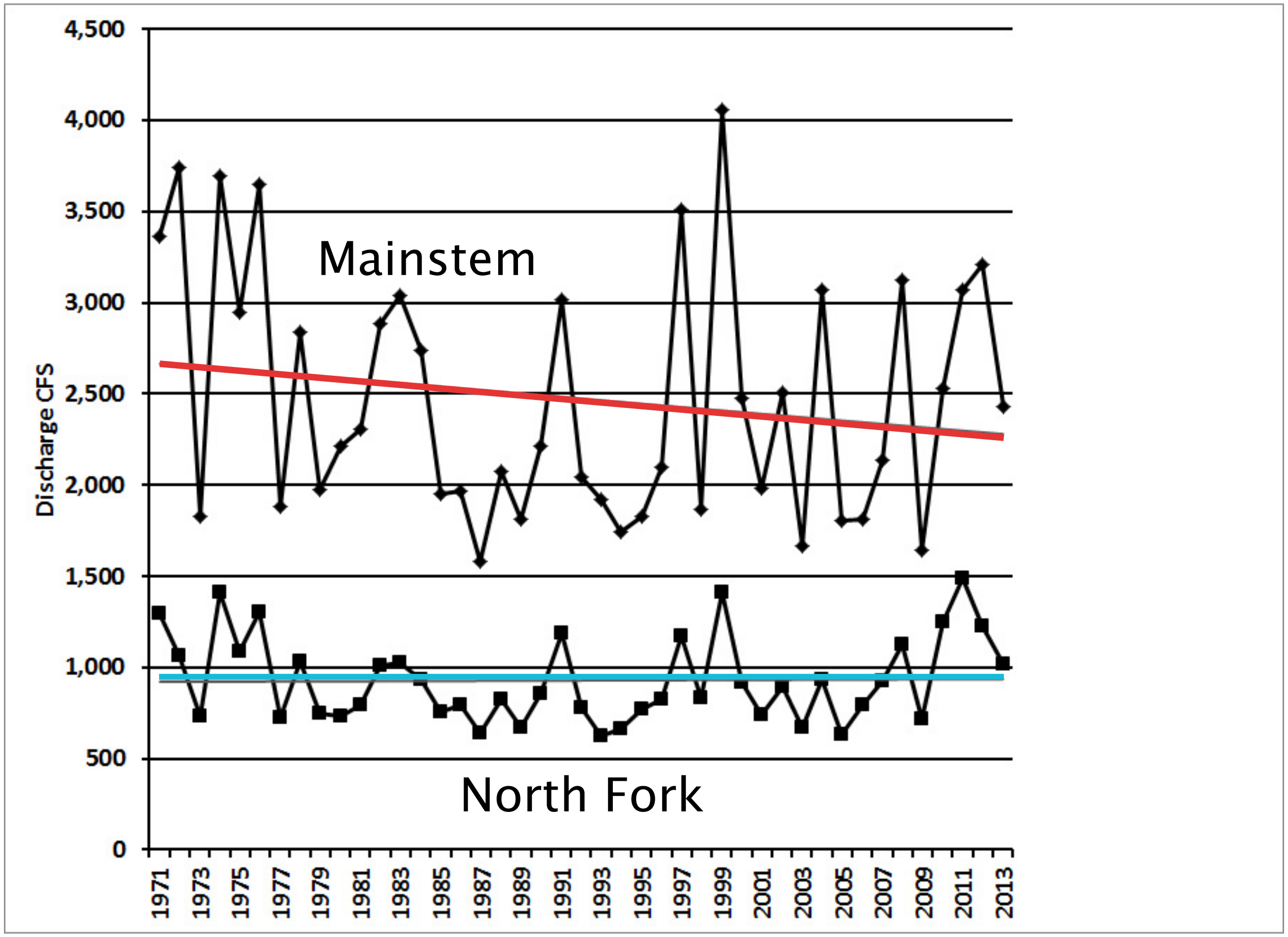
- Daily ablation ranging from 0.05–0.06 m/d (0.17–0.2 ft/d) which for the North Fork currently yields 12–14.5 cms (424–512 cfs).
- This is 50–60% of the mean August discharge in the North Fork of 24 cms (847 cfs).

2013 glacier ablation in NFK

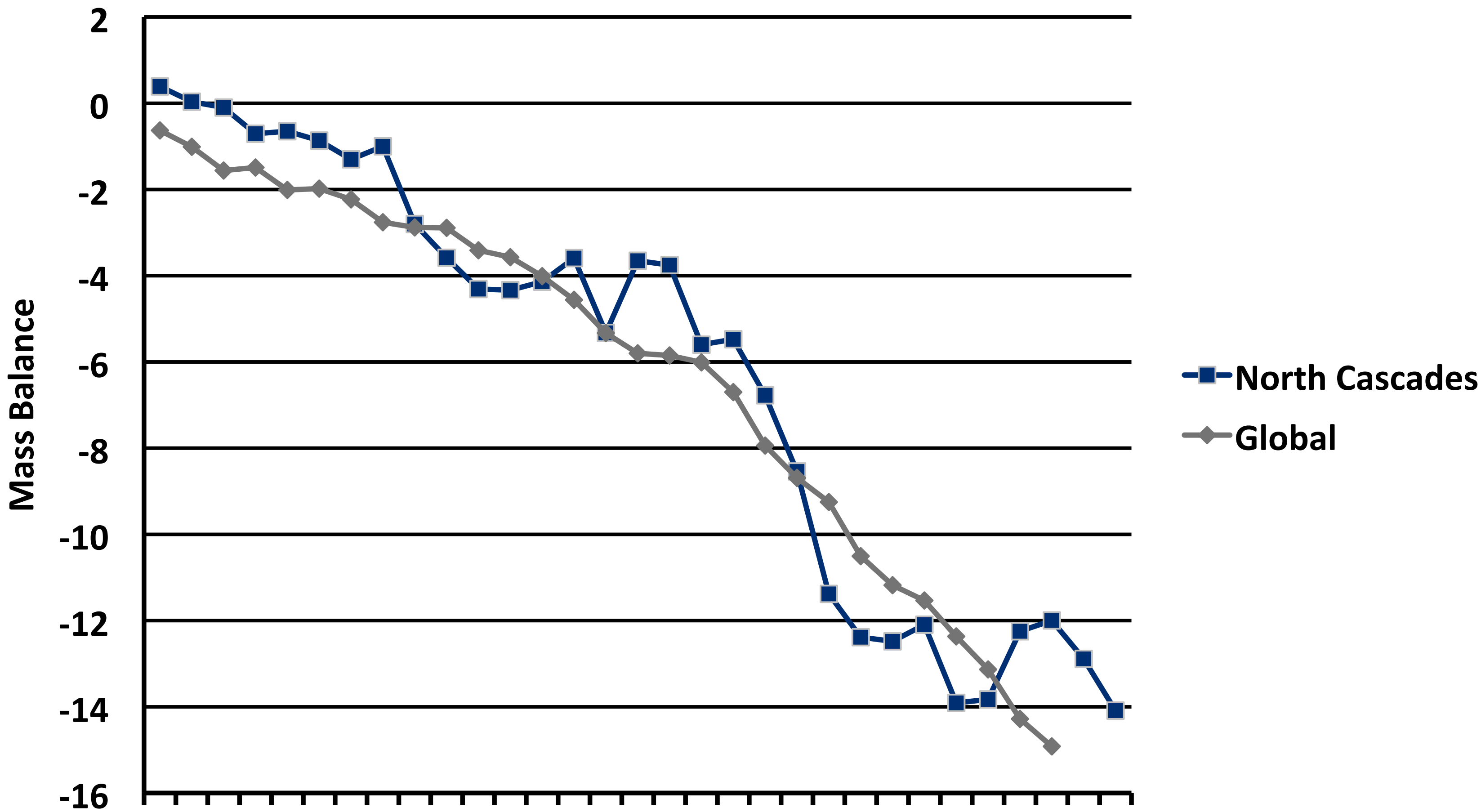
- 8/4-8/20:
  - Stream Q= 850 cfs,
  - Glacier Q= 340 cfs
- 8/20-9/12
  - Stream Q= 715 cfs
  - Glacier Q= 315 cfs

- Change in glacier runoff is only -7.3%
- Change in total North Fork runoff is -18.9%

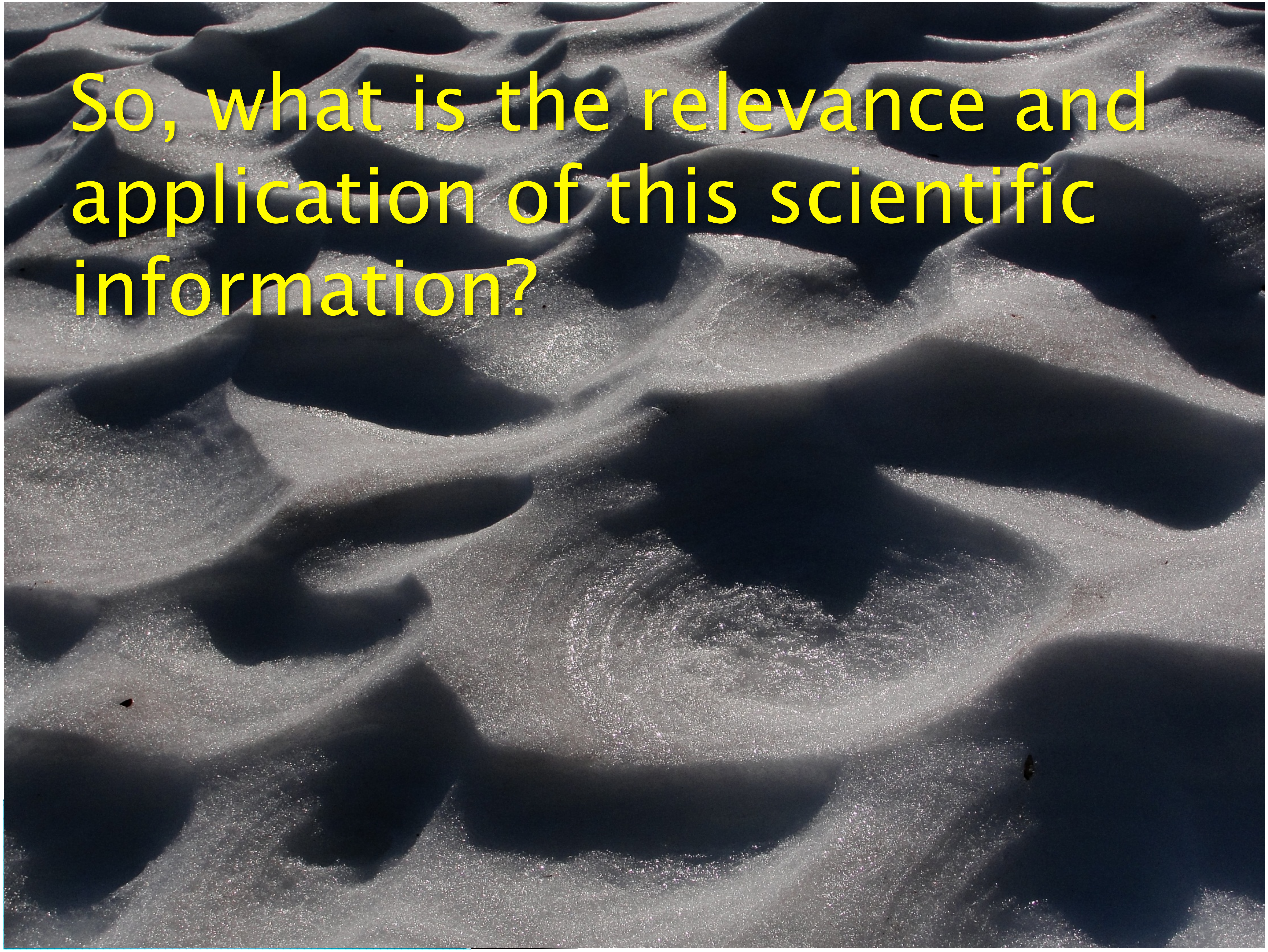
Nooksack River mean summer discharge from 1971-2013

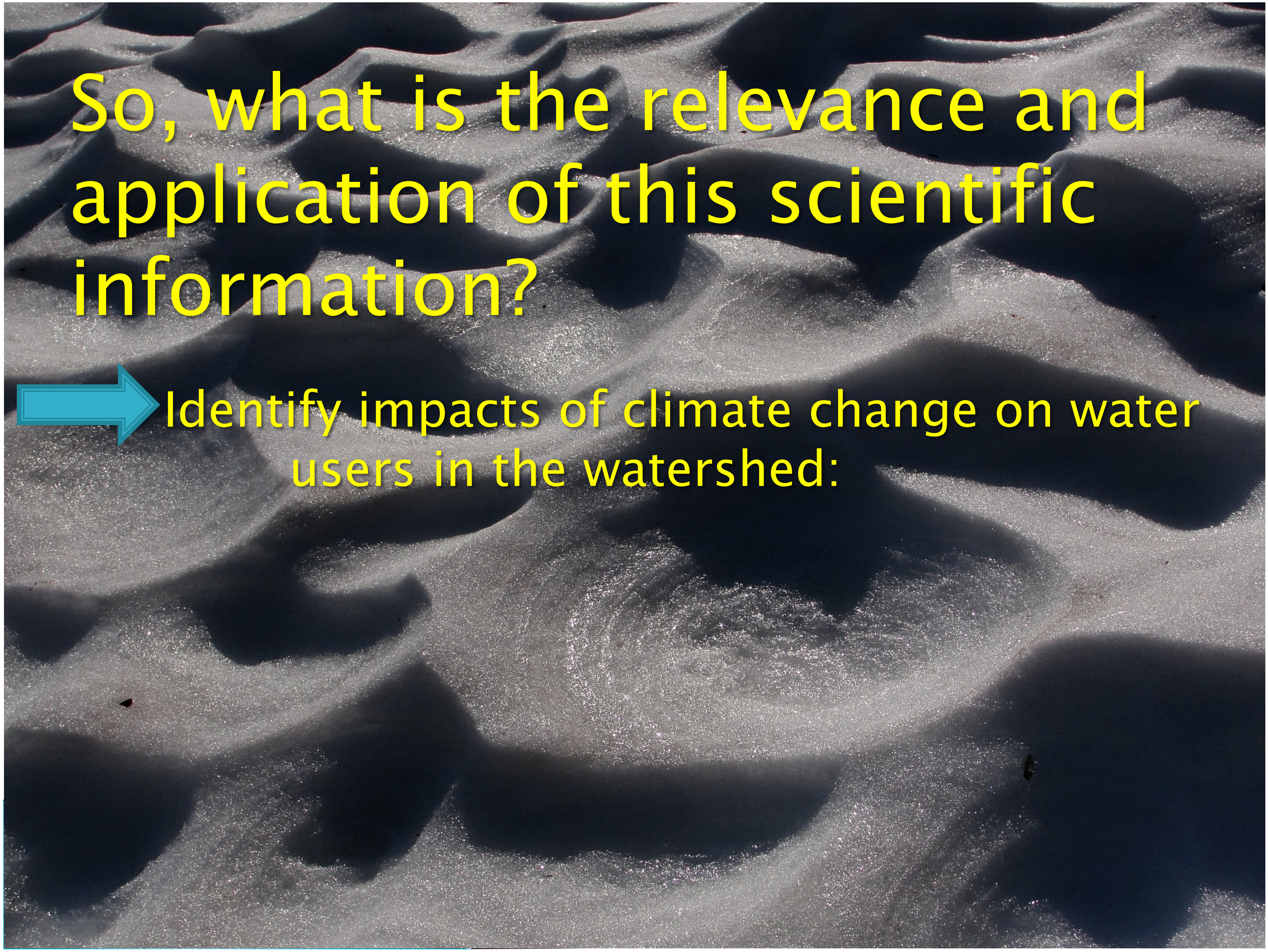


North Cascade Glacier Mass Balance follows global trend



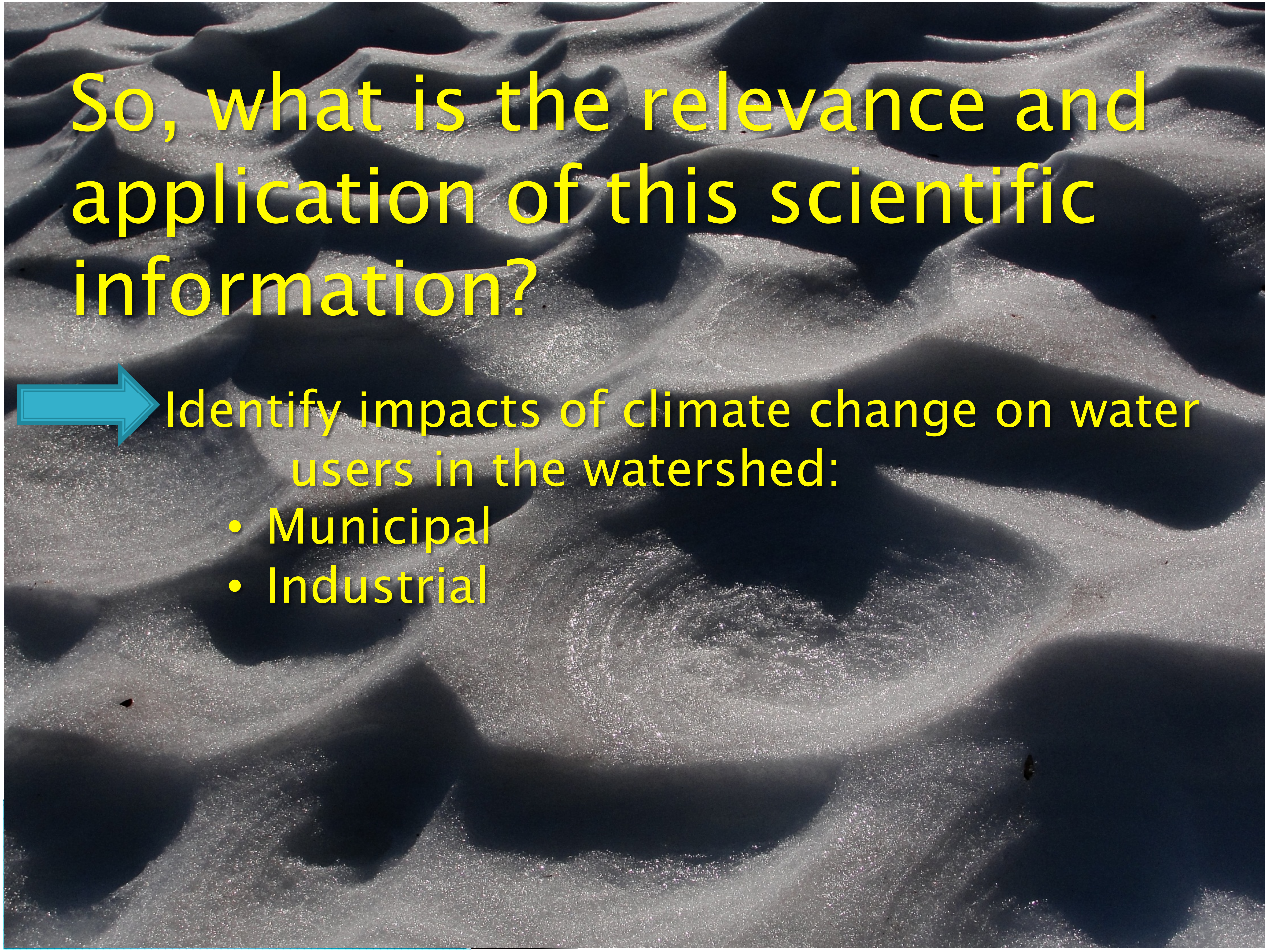
So, what is the relevance and application of this scientific information?




So, what is the relevance and application of this scientific information?
Identify impacts of climate change on water users in the watershed:

So, what is the relevance and application of this scientific information?

- Identify impacts of climate change on water users in the watershed:
  - Municipal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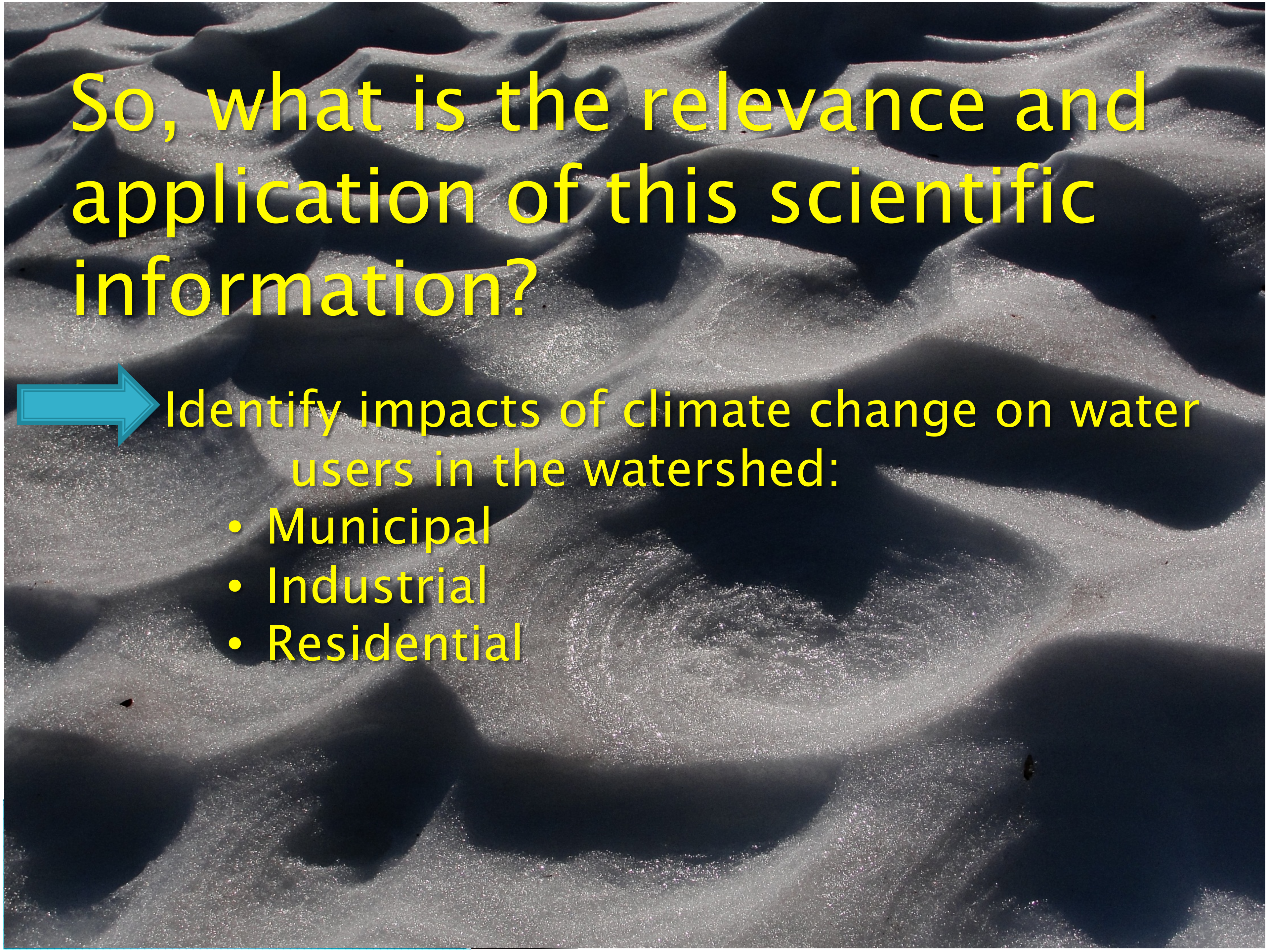
• Industrial


So, what is the relevance and application of this scientific information?
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• Municipal
• Industrial
• Residential

So, what is the relevance and application of this scientific information?

Identify impacts of climate change on water users in the watershed:

- Municipal
- Industrial
- Residential
- Agriculture

So, what is the relevance and application of this scientific information?

Identify impacts of climate change on water users in the watershed:

- Municipal
- Industrial
- Residential
- Agriculture
- Flood control

So, what is the relevance and application of this scientific information?

Identify impacts of climate change on water users in the watershed:

- Municipal
- Industrial
- Residential
- Agriculture
- Flood control
- Fish

So, what is the relevance and application of this scientific information?

Identify impacts of climate change on water users in the watershed:

- Fish
  - salmon recovery.
  - sustainable harvestable quantities.
  - restoration planning.

Tribe's climate change project also includes contracted services:

- UW –
  - Develop data inputs for the glacier module incorporated into the DHSVM.

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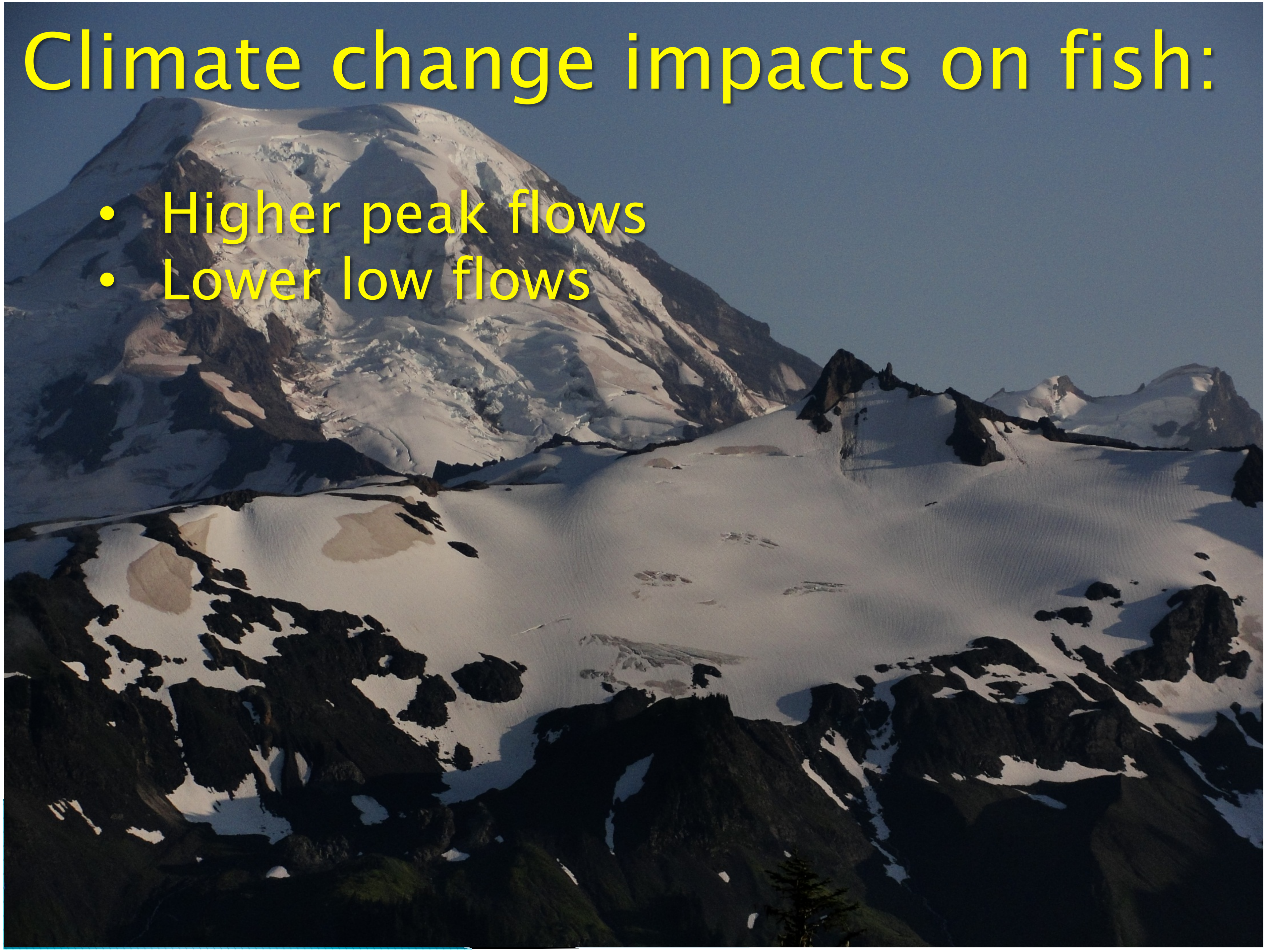
- WWU –
  - Update DHSVM for current climate change scenarios and down-scaling.
  - Evaluate glacier ablation in a dynamic manner.
  - Predict changes in Nooksack River hydrology in response to various climate change scenarios.

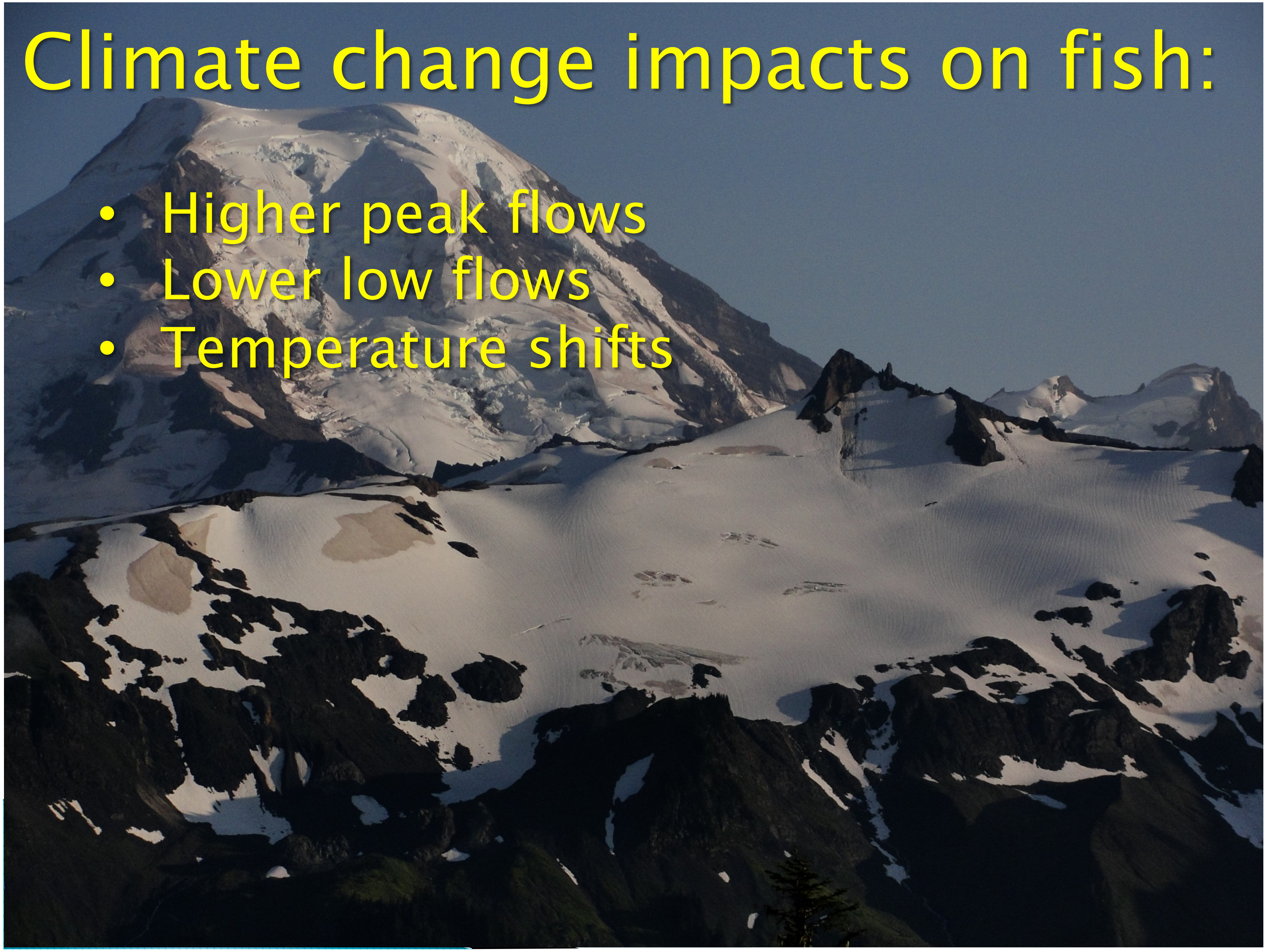
Climate change impacts on fish:


Climate change impacts on fish:
• Higher peak flows

Climate change impacts on fish:

- Higher peak flows
- Lower low flows

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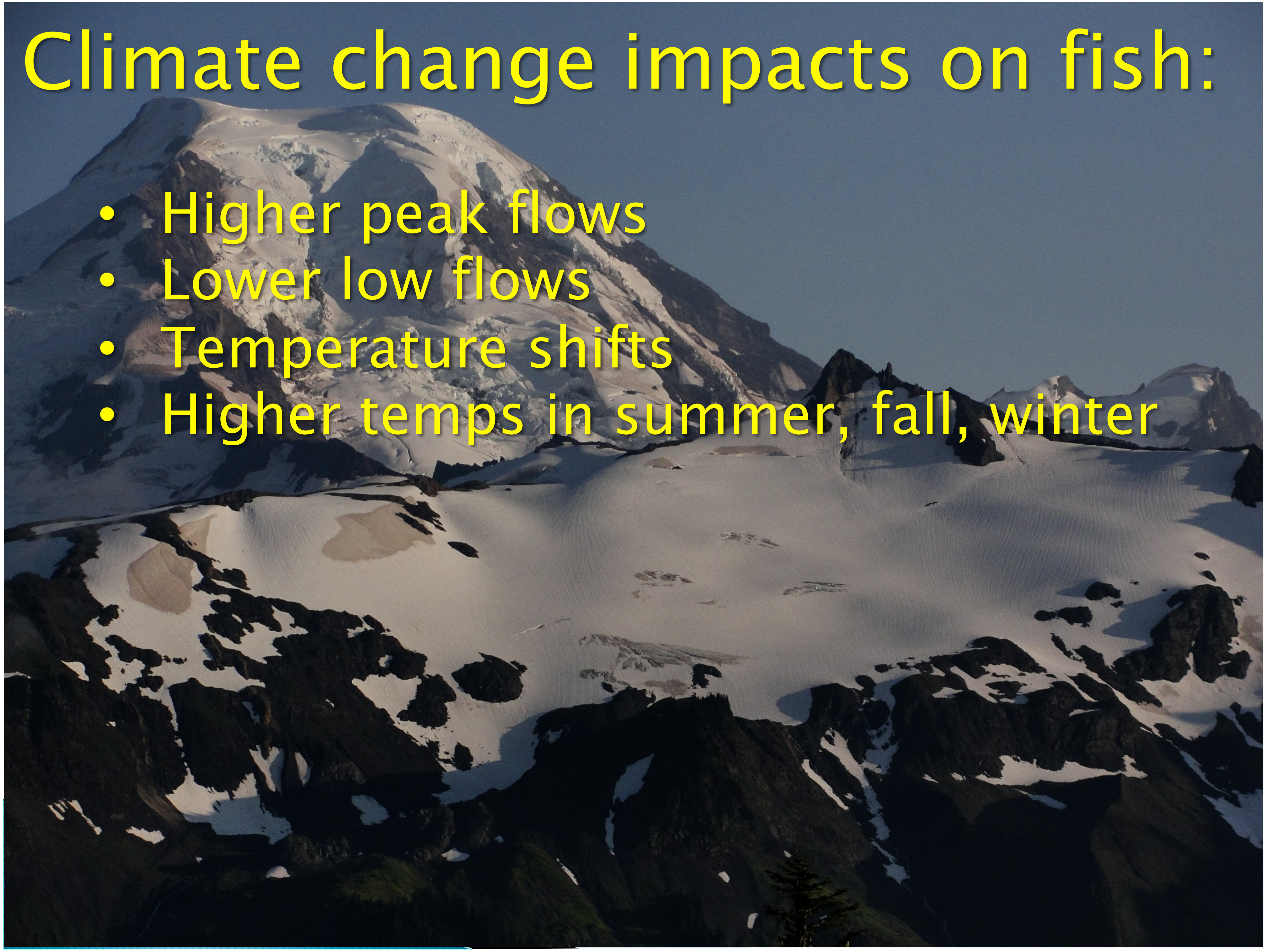
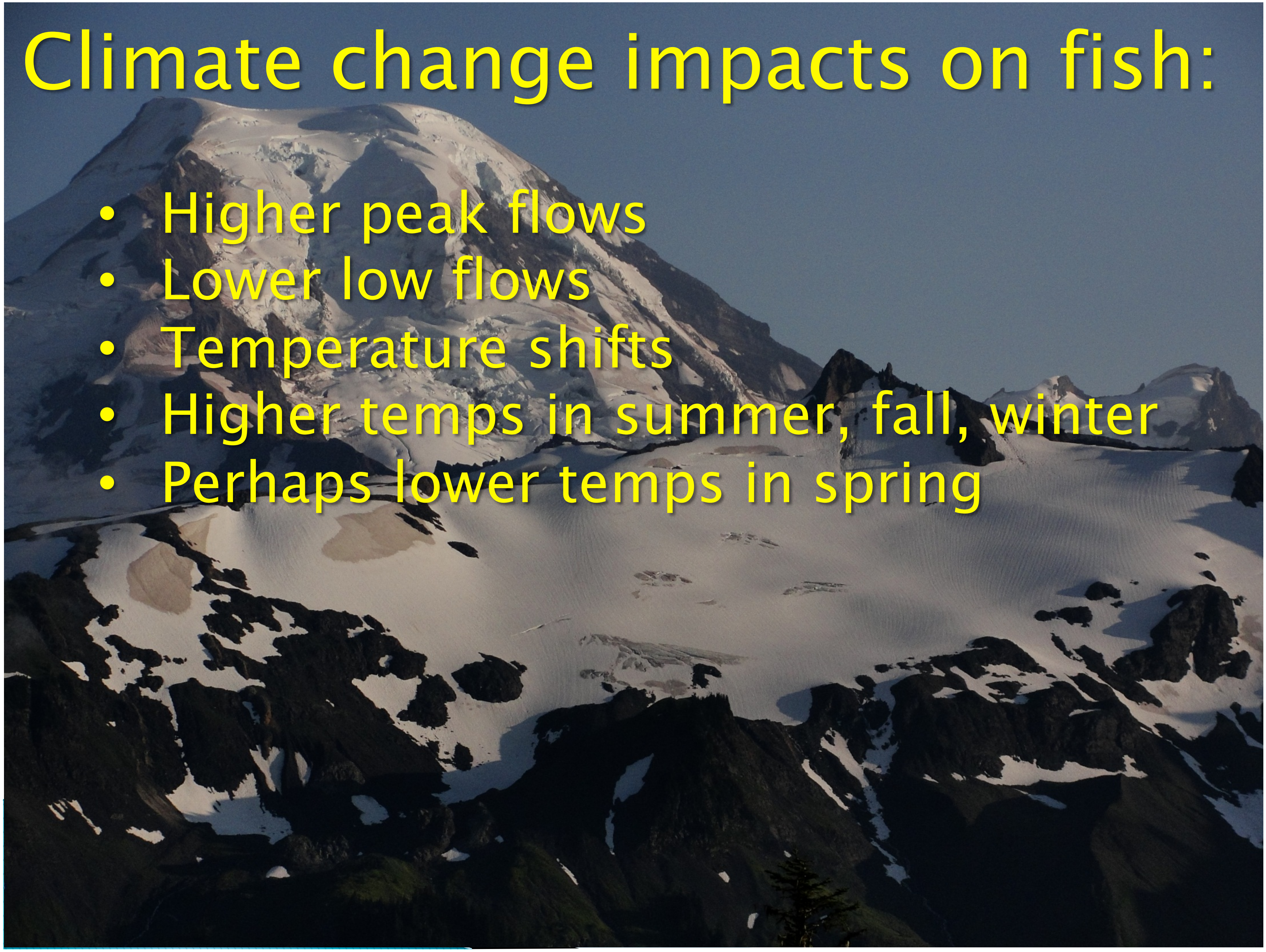
• Temperature shifts


Climate change impacts on fish:
• Higher peak flows
• Lower low flows
• Temperature shifts
• Higher temps in summer, fall, winter



Climate change impacts on fish:

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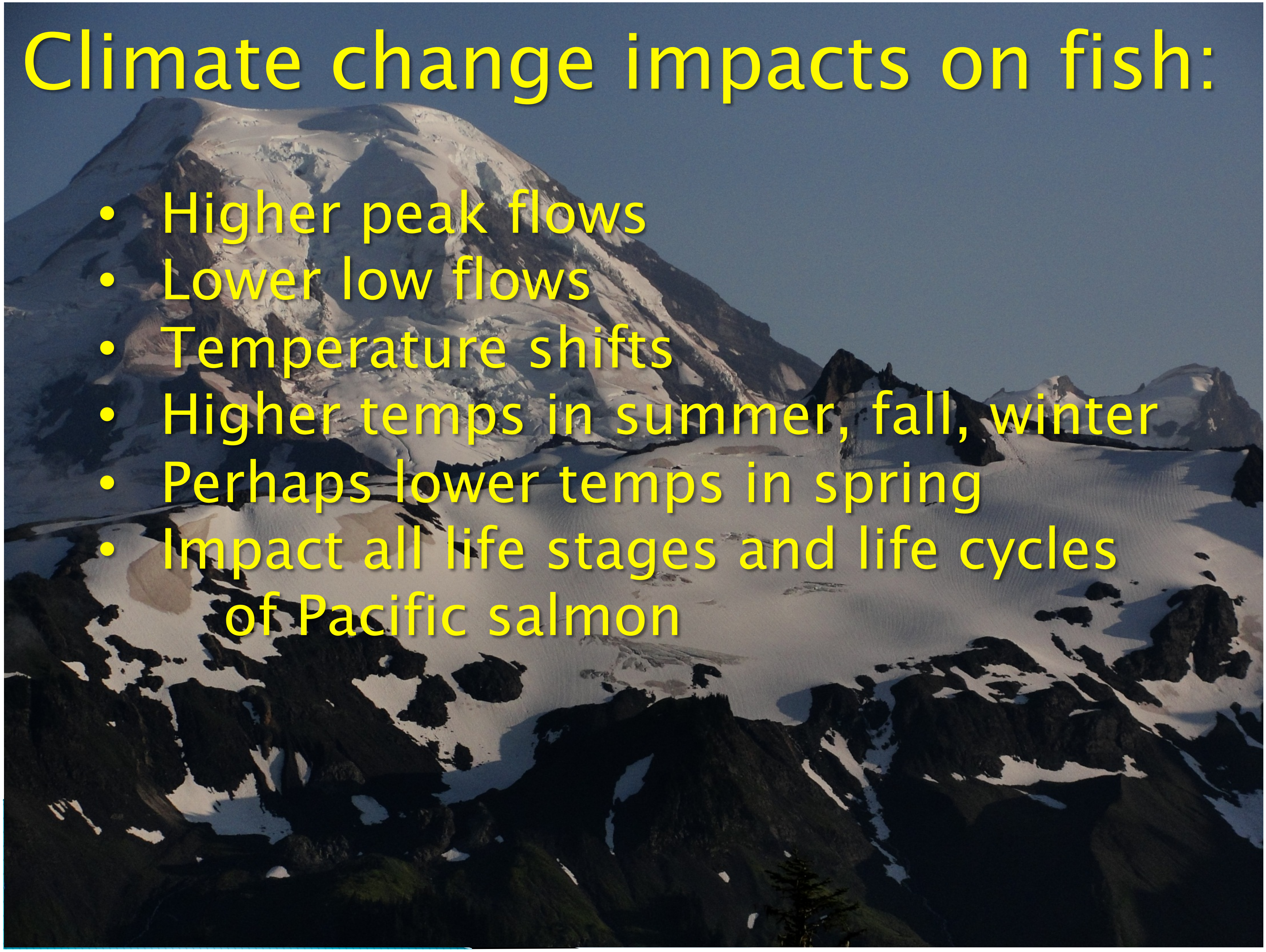
Climate change impacts on fish:
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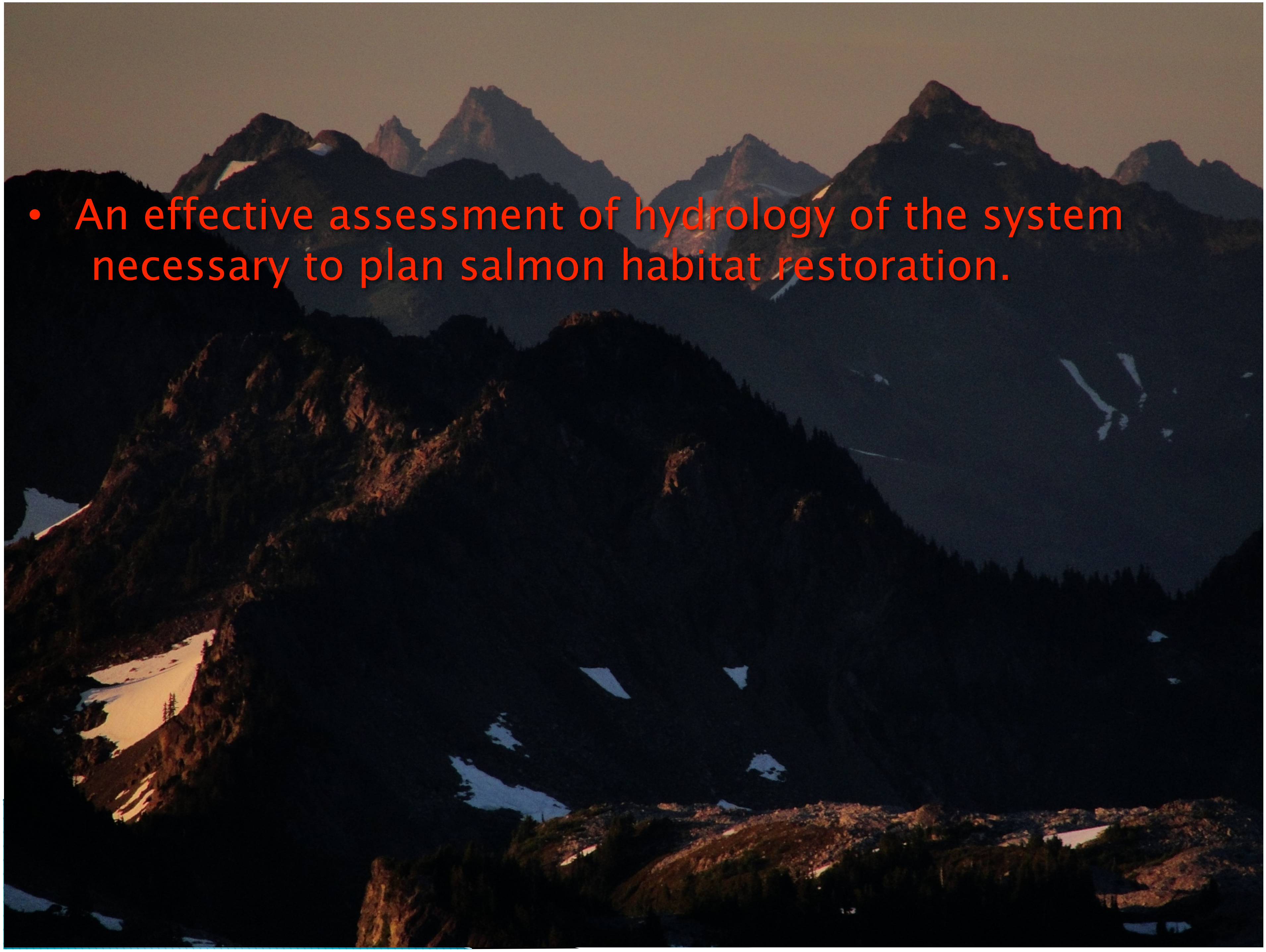
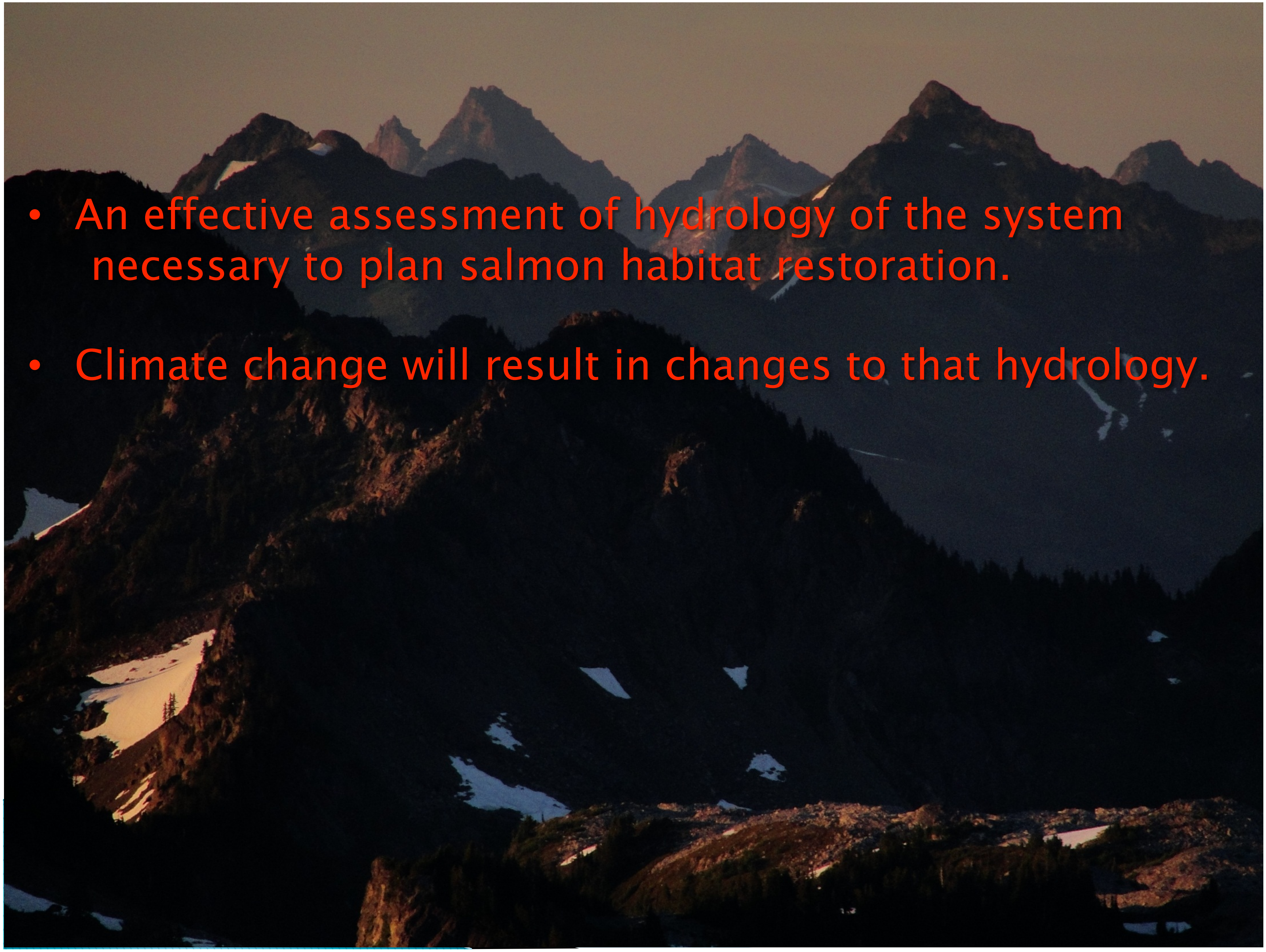
• Lower low flows
• Temperature shifts
• Higher temps in summer, fall, winter
• Perhaps lower temps in spring
• Impact all life stages and life cycles of Pacific salmon


What does this mean for salmon recovery and habitat restoration?



- An effective assessment of hydrology of the system necessary to plan salmon habitat restoration.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- Climate change will result in changes to that hydrology.
- An effective restoration program needs to be modified in order to address the altered hydrology.


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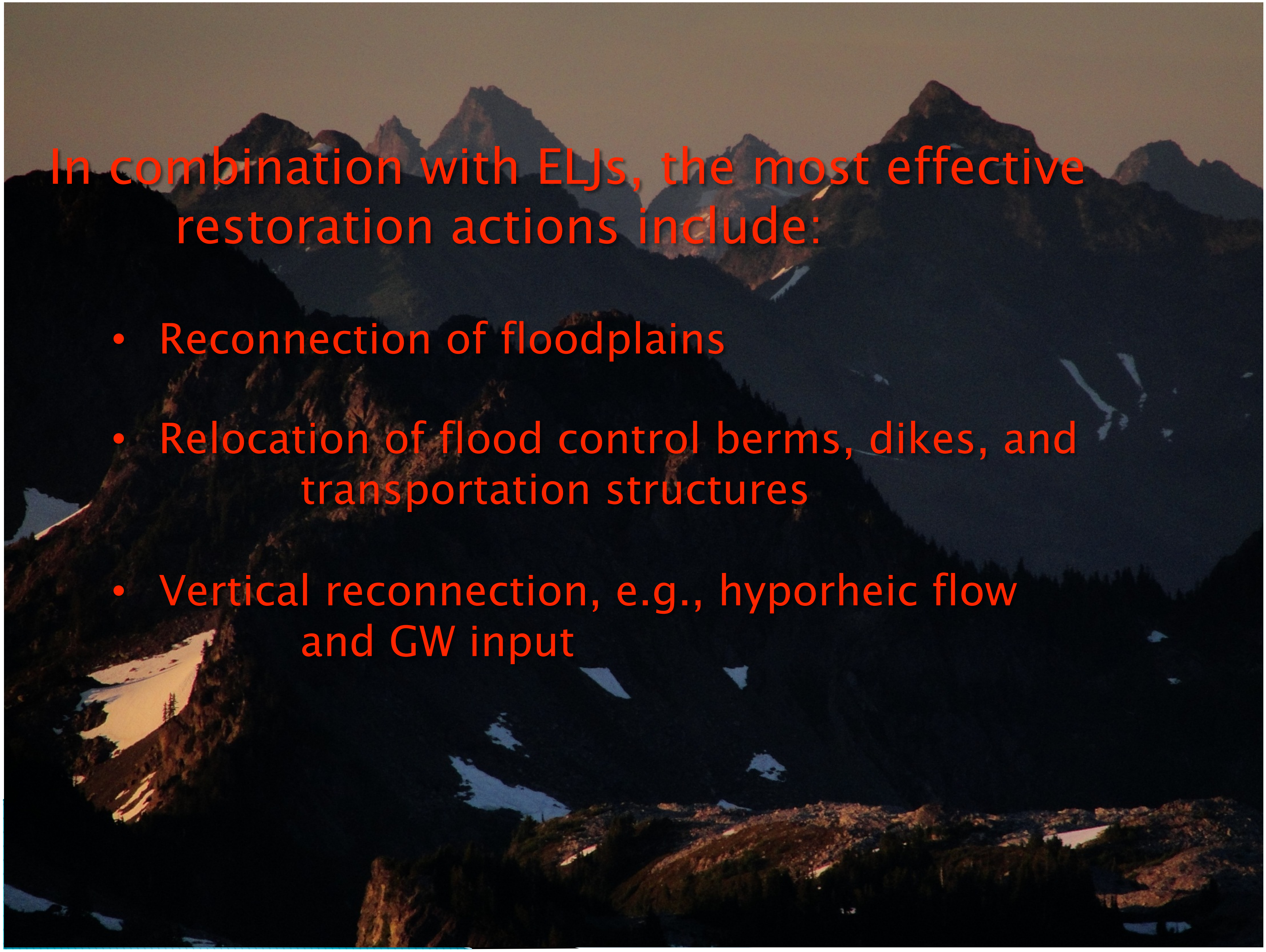

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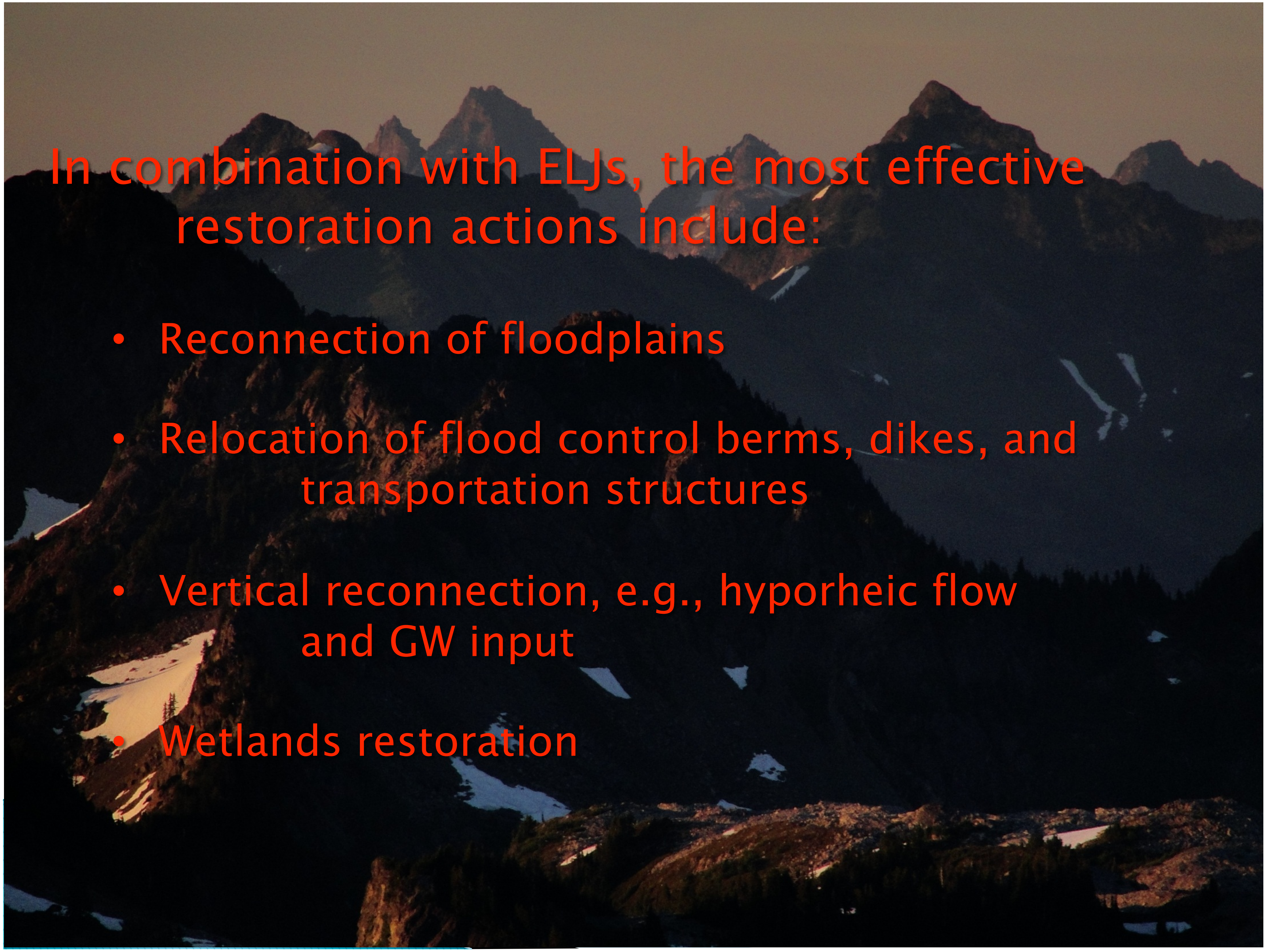
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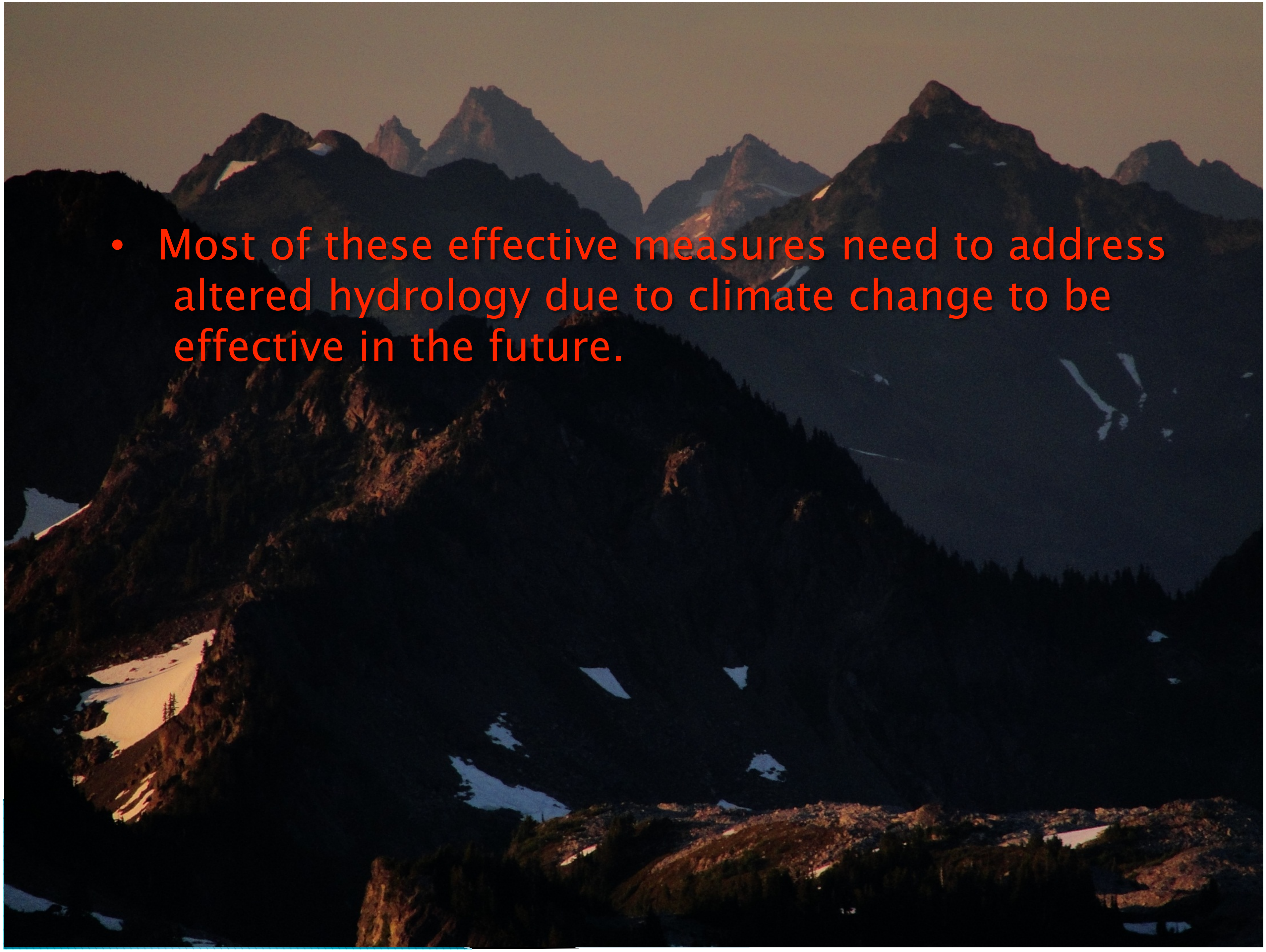
- Riparian planting



- Most of these effective measures need to address altered hydrology due to climate change to be effective in the future.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- Take substantial time to be effective e.g., riparian plantings.

Closing remarks:

- Get started ***NOW*** with assessing likely climate change impacts and implementing adaptation measures, including restoration, that are effective in the face of climate change.


Thank you!