Understanding Climate Impacts on the Rate and Extent of Glacier Loss in the Olympic Mountains

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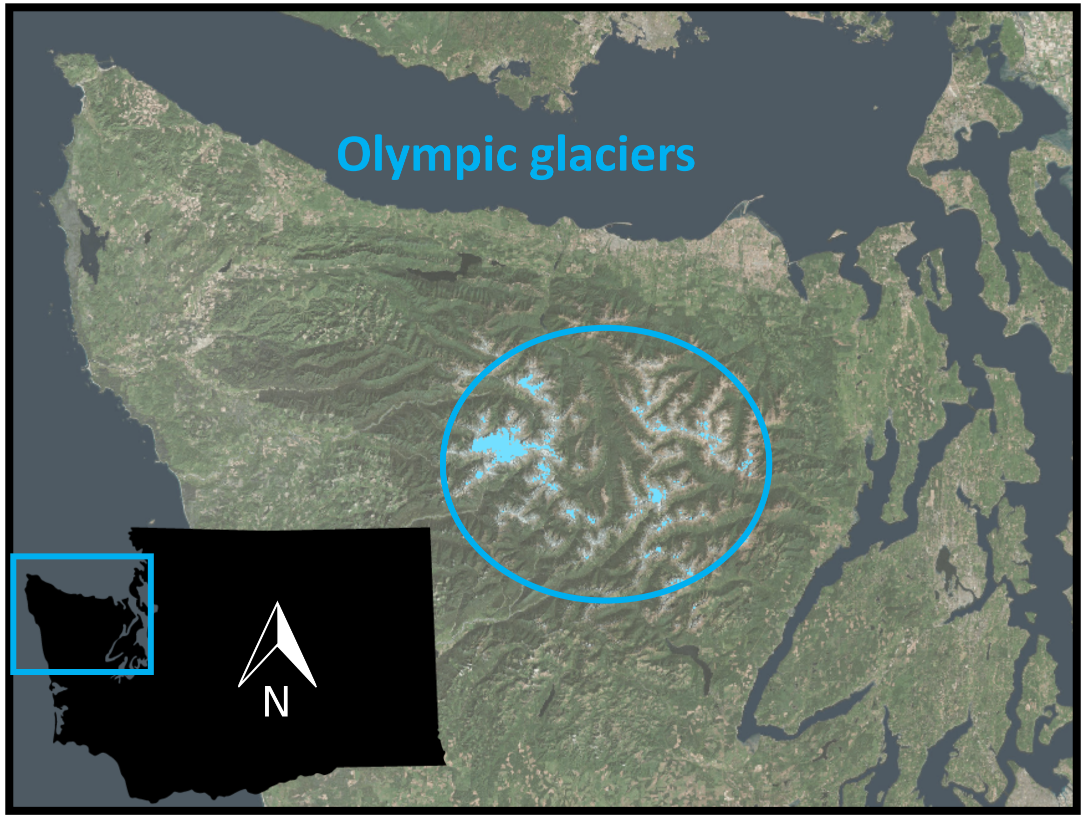
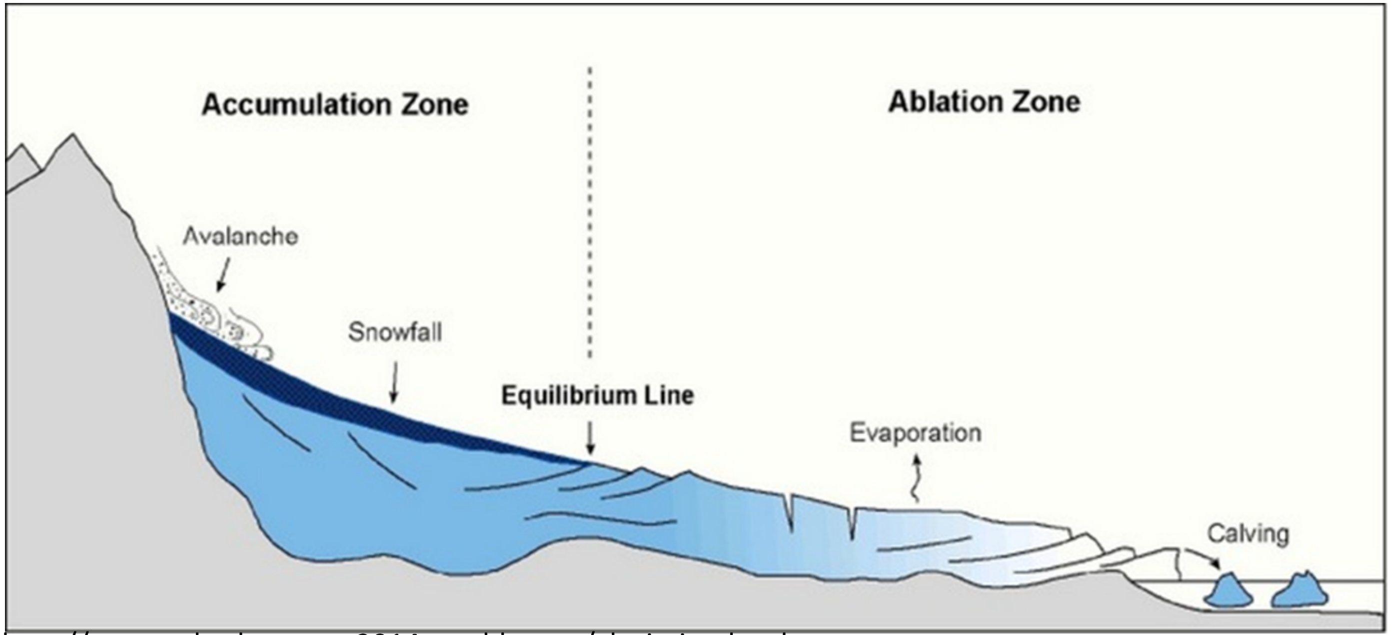
The Olympic Glaciers and Glaciology:

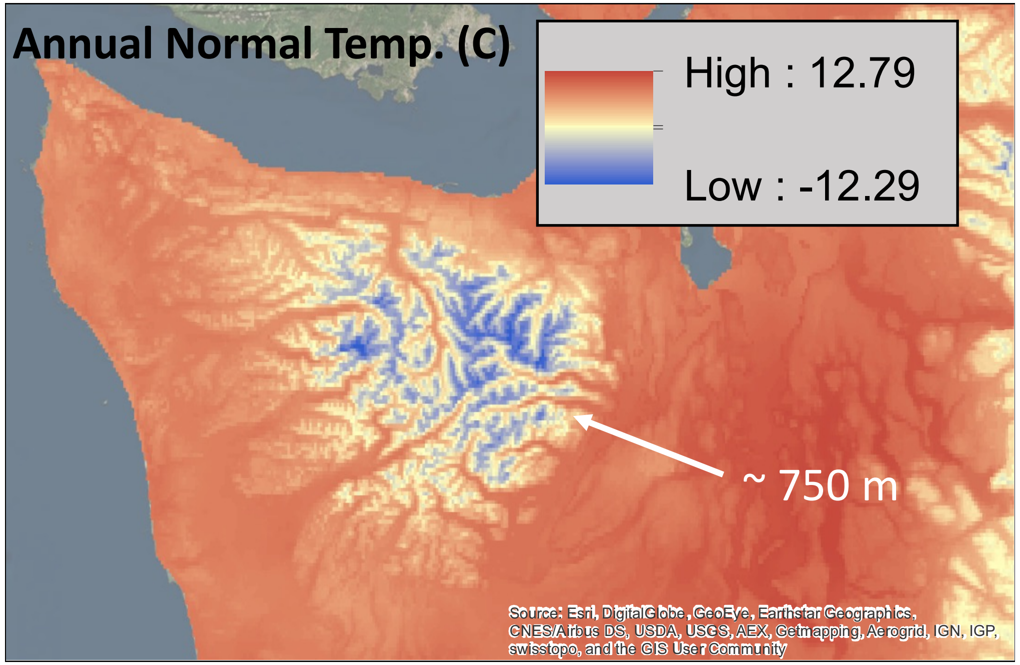


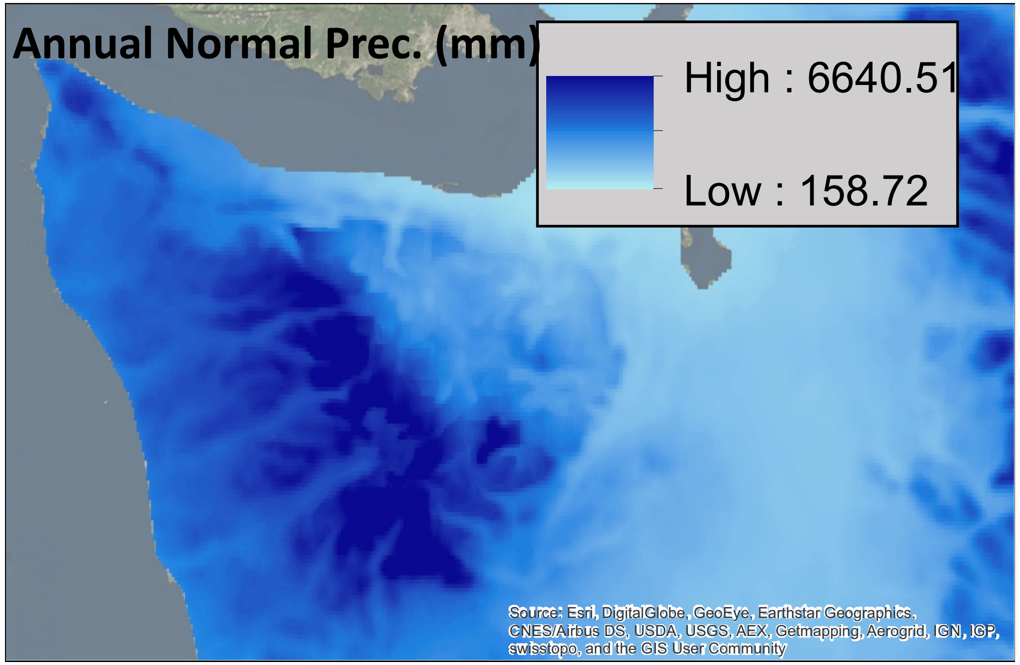


http://geographyclassroom2014.weebly.com/glaciation.html

Terms and definitions:

- **Ablation** = removal of ice by melting or evaporation.
- **Equilibrium Line Altitude (ELA)** = non-static point at which mass-balance is equal.
- **Perennial snow/ice** = snow or ice that lasts for multiple years. Typically does not exhibit flow.





Olympic Climate:

- Maritime climate with prominent rainshadow and cold air shielding by Northern Rockies and Cascade mountain ranges.
- 80% of annual precipitation occurs October – March with less than 5% in July – August.
- Temperate conditions, dominant precipitation, thin depths, and small areas cause Olympic glaciers to be highly dynamic.
- Warm and dense snowpack with snowpack formation near 0° C.

Effects from climate change:

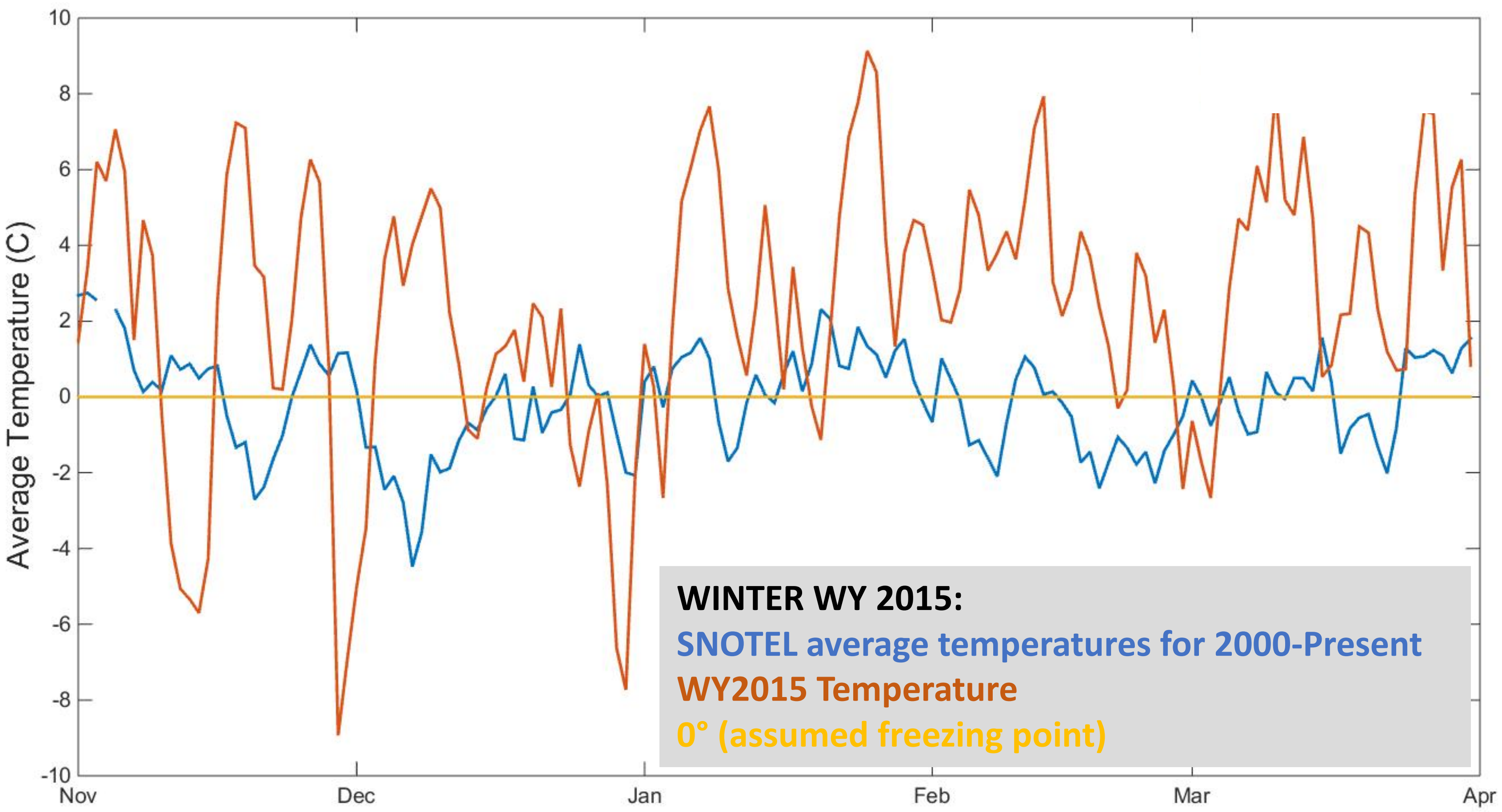
- While typically noted for seasonal-term water availability and variance control, future climate concerns are with respect to long-term.
- Region with one of the highest percentages of “at-risk” snow.
- Projected 1.2°C increase by 2040 and 2.8°C increase by 2080
- Documented 3° C increase on Blue Glacier surface from 1948.

Rising snow-line → Reduction in snow covered area (SCA)

Earlier snow-free date → Glaciers exposed (snow-free) for longer period → Increased glacier melt →

WY2015 Climate

- Winter of WY2015 was 2° C warmer than usual in the Olympic Mountains.
- Summer of WY2015 was 2.6° C warmer than usual.
- Although warmer than usual, precipitation was typical.



WY2015 Climate

- Resulted in the Lowest snowpack ever recorded.
- Streams showed prominent evidence of glacier melt as early as June

Peak snow WY2015

Peak snow WY2016

Mt. Anderson

Average June 1st

2015 June 1st

Previous reports

PRESENT DISTRIBUTION OF GLACIERS

Inventory of Glaciers

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Journal of Glaciology, Vol. 61, No. 225, 2015 doi: 10.3189/2015JoG14J138

Glacier status and contribution to streamflow in the Olympic Mountains, Washington, USA

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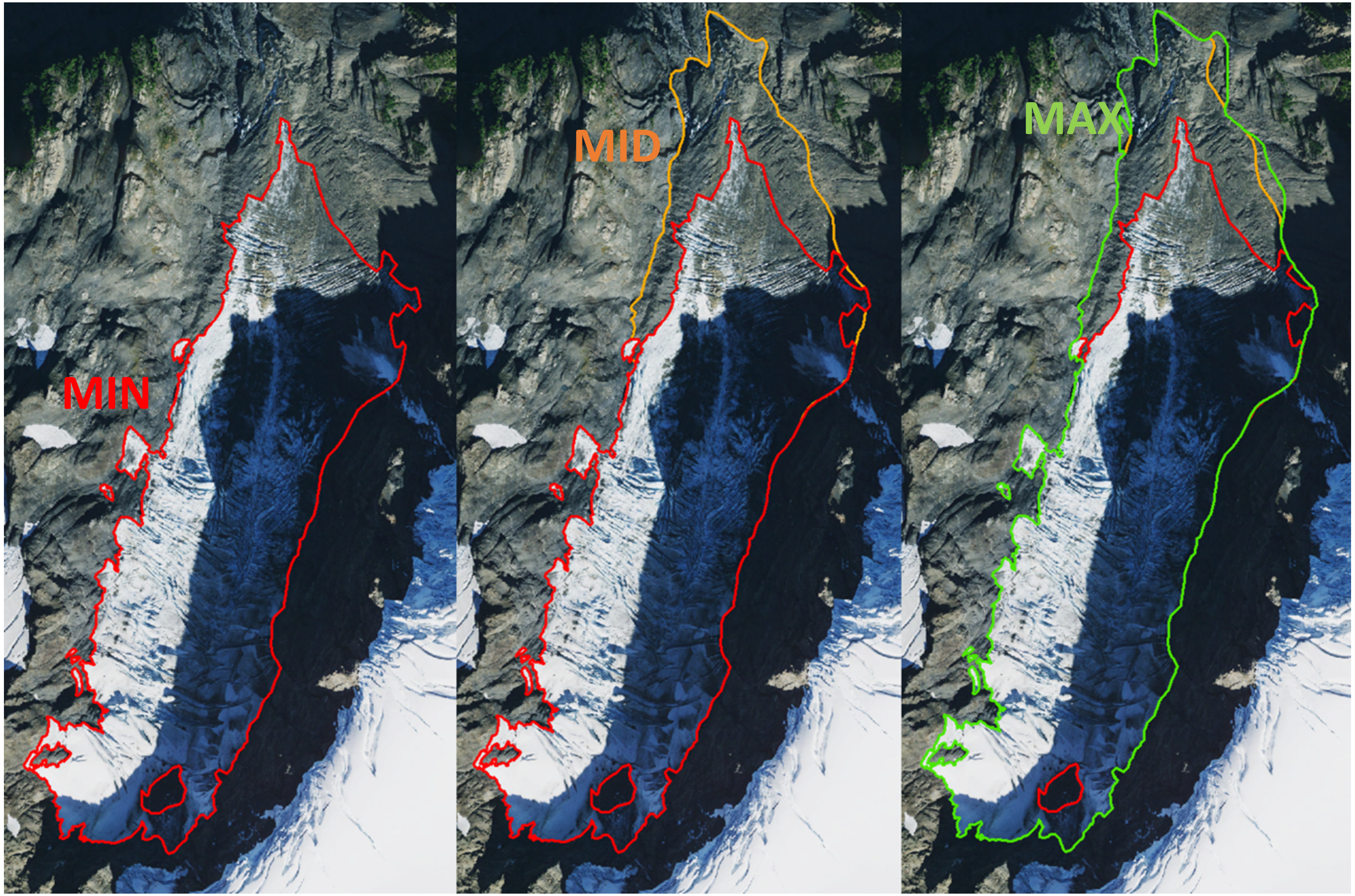
ABSTRACT. The Olympic Peninsula, Washington, USA, currently holds 184 alpine glaciers larger than $0.01\,km^2$ and their combined area is $30.2 \pm 0.95\,km^2$. Only four glaciers are $>1\,km^2$ and 120 of the others are $<0.1\,km^2$. This represents a loss of 82 glaciers and a 34% decrease in combined area since 1980, with the most pronounced losses occurring on south-facing aspects and in the more arid northeastern part of the range. Annual rate of loss in glacier area for seven of the largest glaciers accelerated from $0.26\,km^2\,a^{-1}$ (1900–80) to $0.54\,km^2\,a^{-1}$ (1980–2009). Thinning rates on four of the largest glaciers averaged nearly $1\,m\,a^{-1}$ from 1987 to 2010, resulting in estimated volume losses of 17–24%. Combined glacial snow, firn and ice melt in the Hoh watershed is in the range $63–79 \pm 7 \times 10^6\,m^3$, or 9–15% of total May–September streamflow. In the critical August–September period, the glacial fraction of total basin runoff increases to 18–30%, with one-third of the water directly from glacial ice (i.e. not snow and firn). Glaciers in the Elwha basin produce $12–15 \pm 1.3 \times 10^6\,m^3$ (2.5–4.0%), while those in the Dungeness basin contribute $2.5–3.1 \pm 0.28 \times 10^6\,m^3$ (3.0–3.8%).

Provided opportune chance to repeat glacier surveys performed in 1986 and 2009:

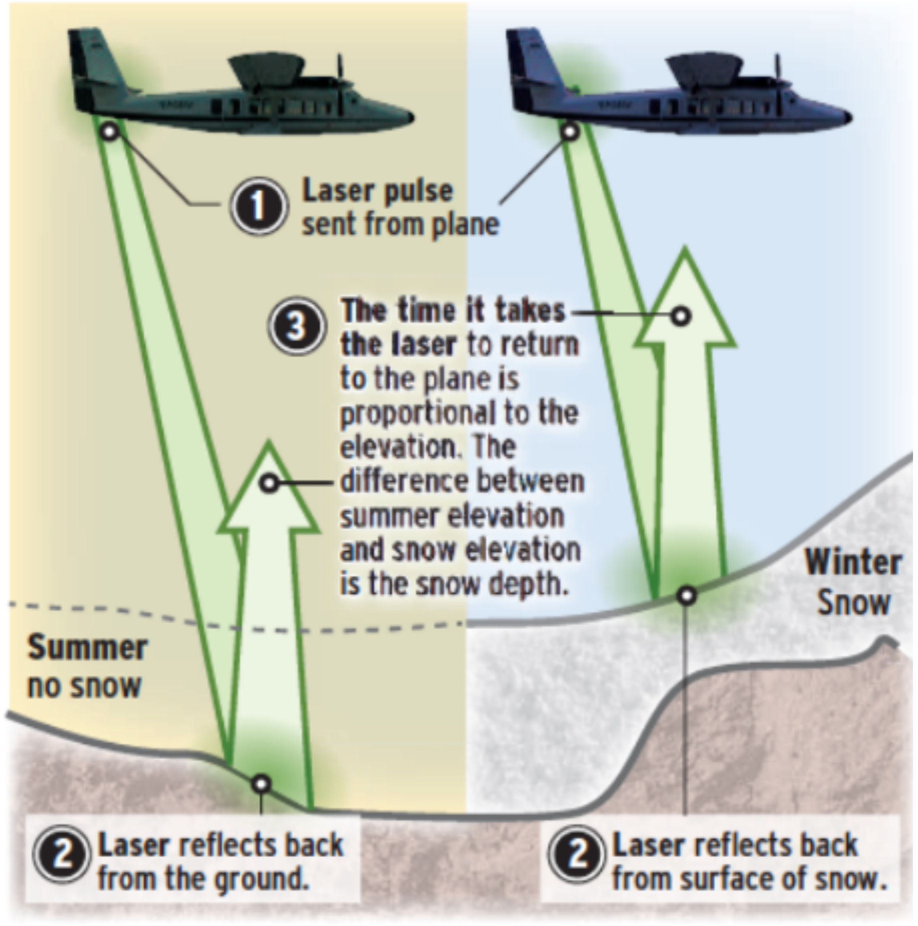
- Climate conditions representative of future projections.
- Collection of LiDAR, and imagery from NAIP and WorldView.
- Minimal levels of snow on glaciated surfaces.

Glacier delineations

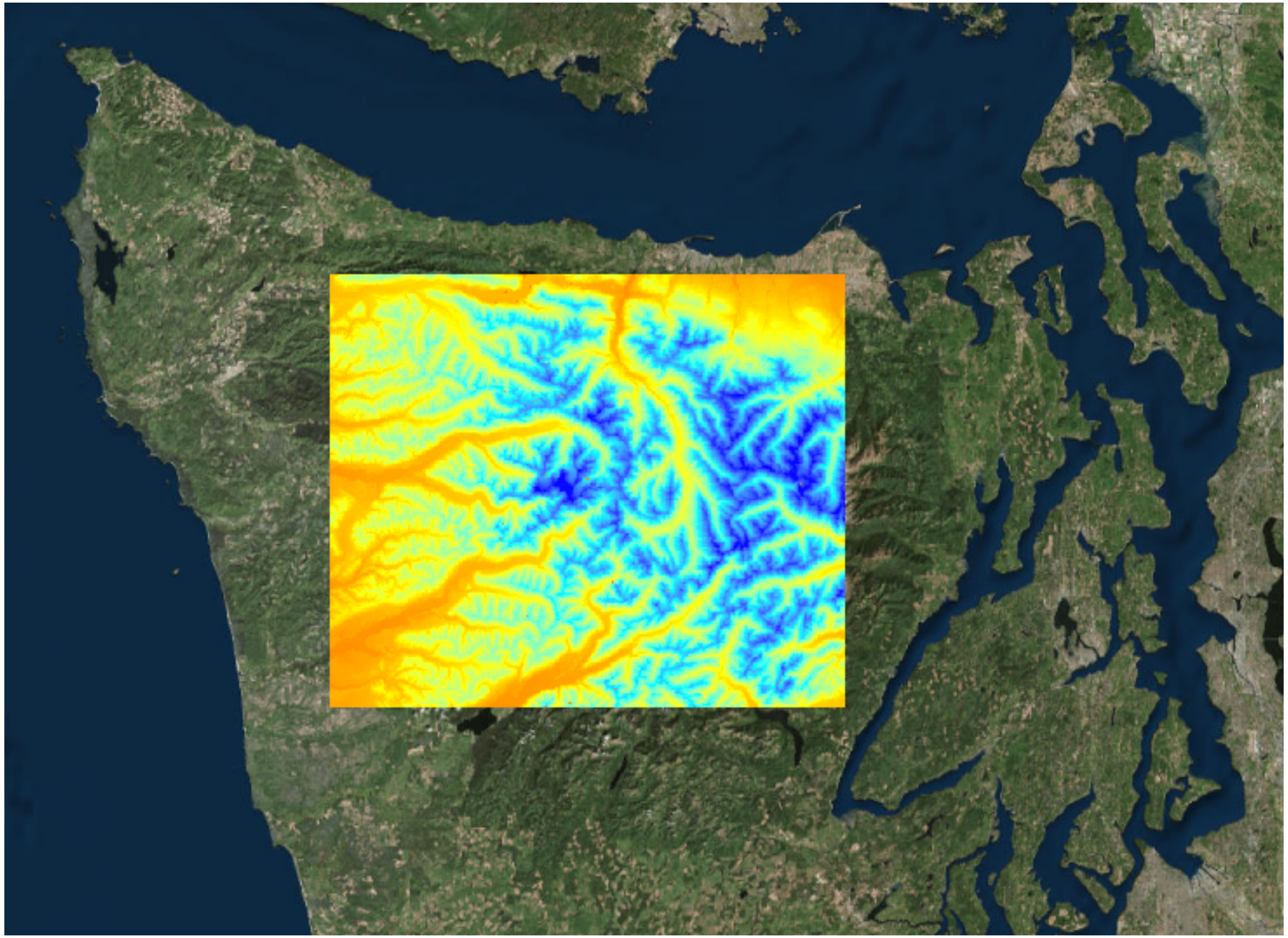


- 2015 NAIP imagery + ASO LiDAR and WorldView stereo-derived elevation
- Difference between products define uncertainty
- Loss of 36 glaciers and 18% reduction in total surface area since 2009
  - Glaciers larger than $.01\text{km}^2$
- 1900-1980 recession rate doubled in 1980-2009 and quadrupled in 2009-present

LiDAR

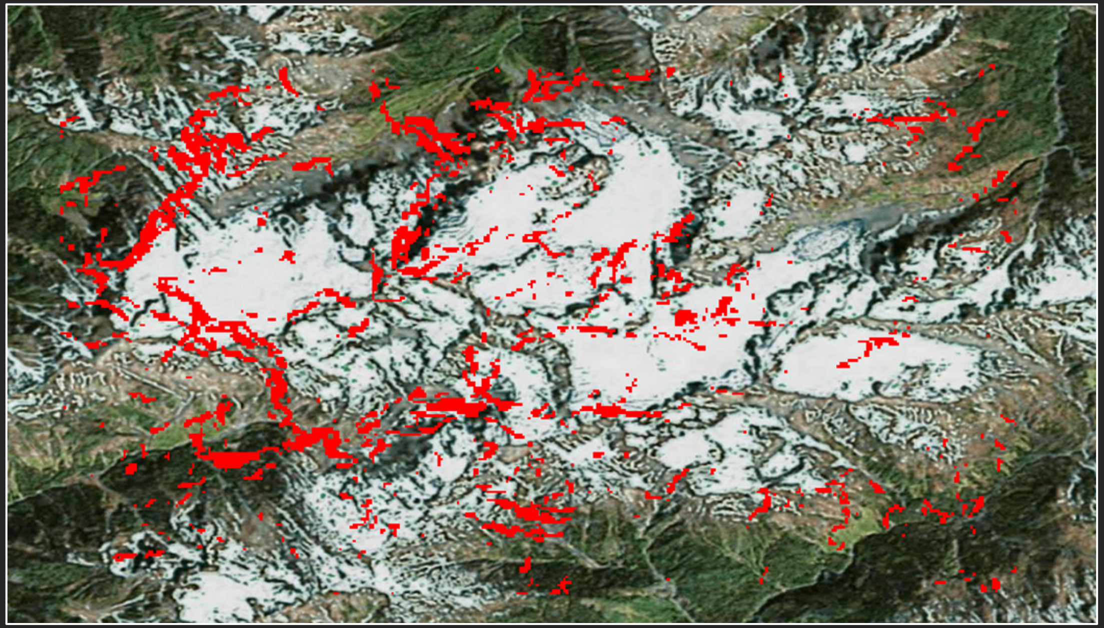


Sources: Thomas Painter, Frank Gehrke, Optech Inc.



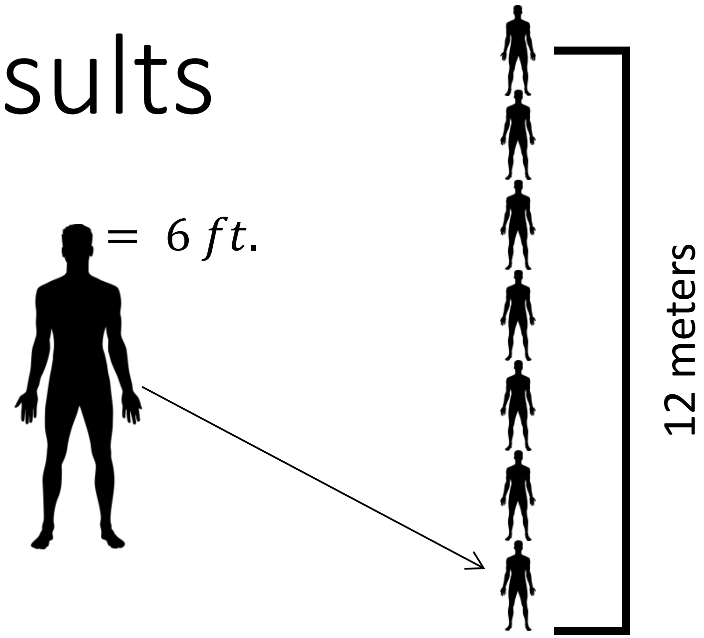
Mass-balance methodology

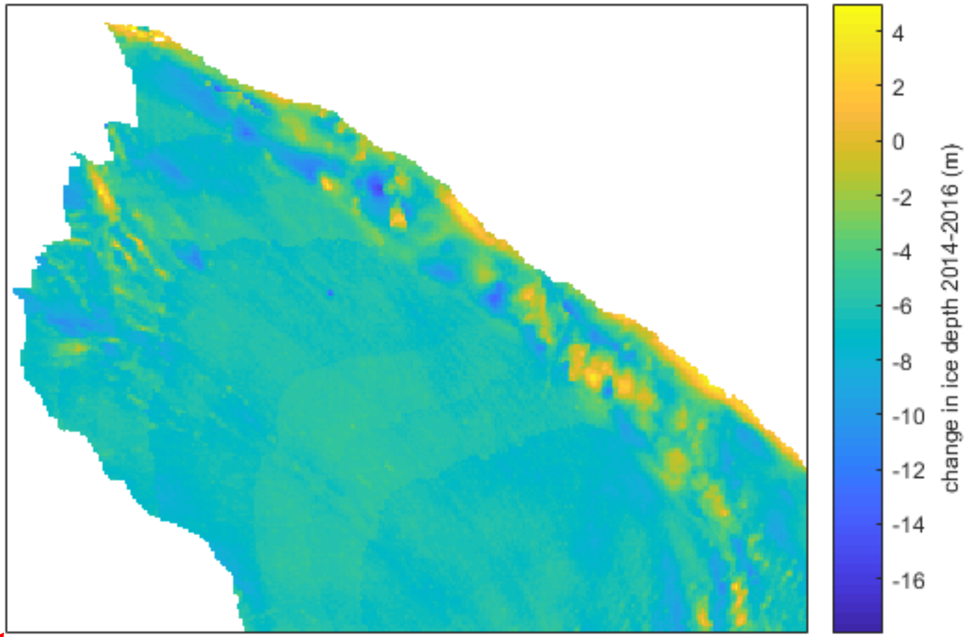
- Due to wide coverage, used LiDAR
- Developed algorithm that corrected for snow levels
- Modeled wind deposition, avalanching, and preferential deposition.

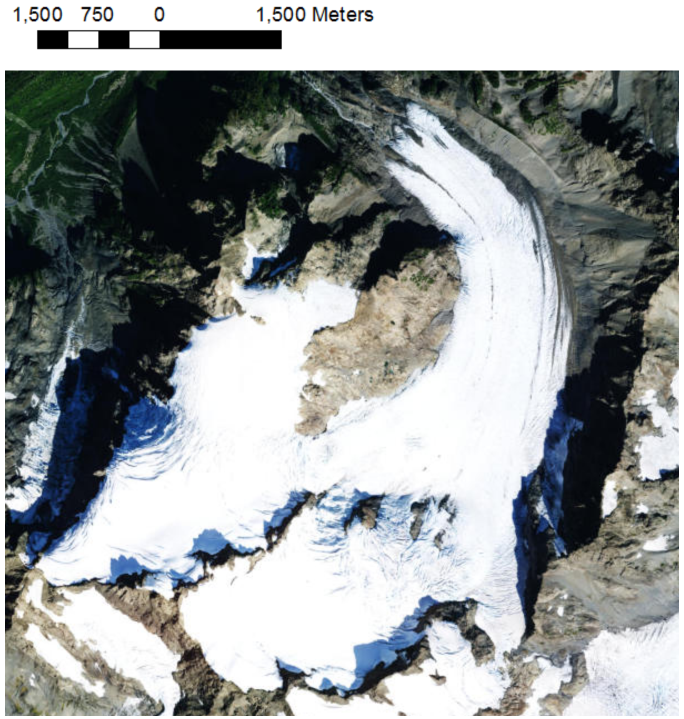


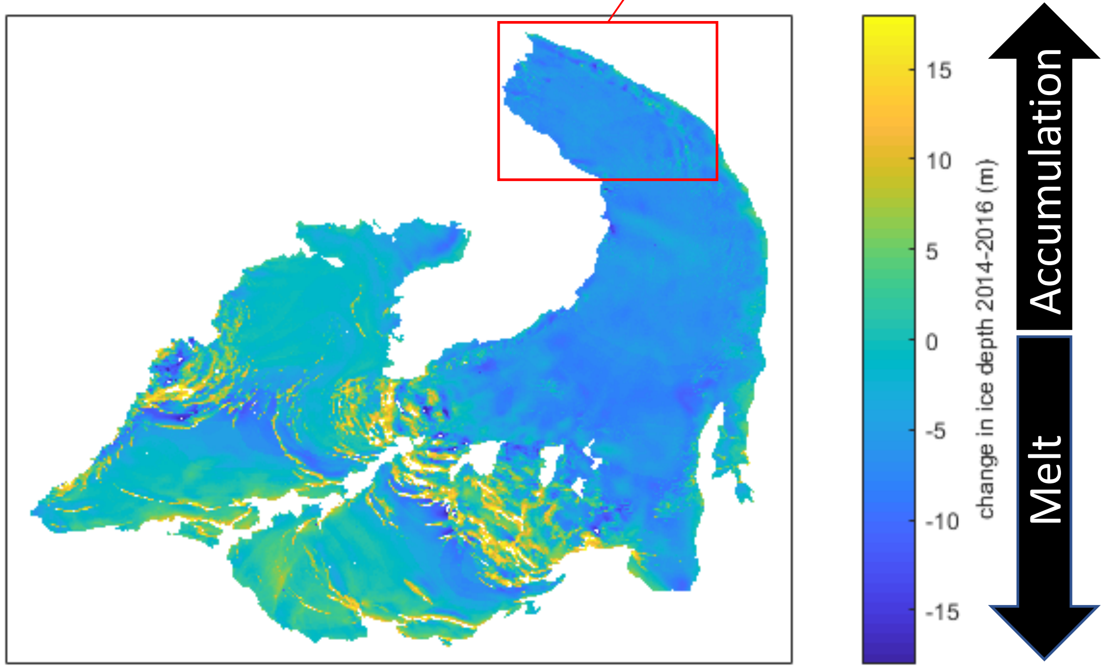
Mass-balance results

Melt season in WY2015…





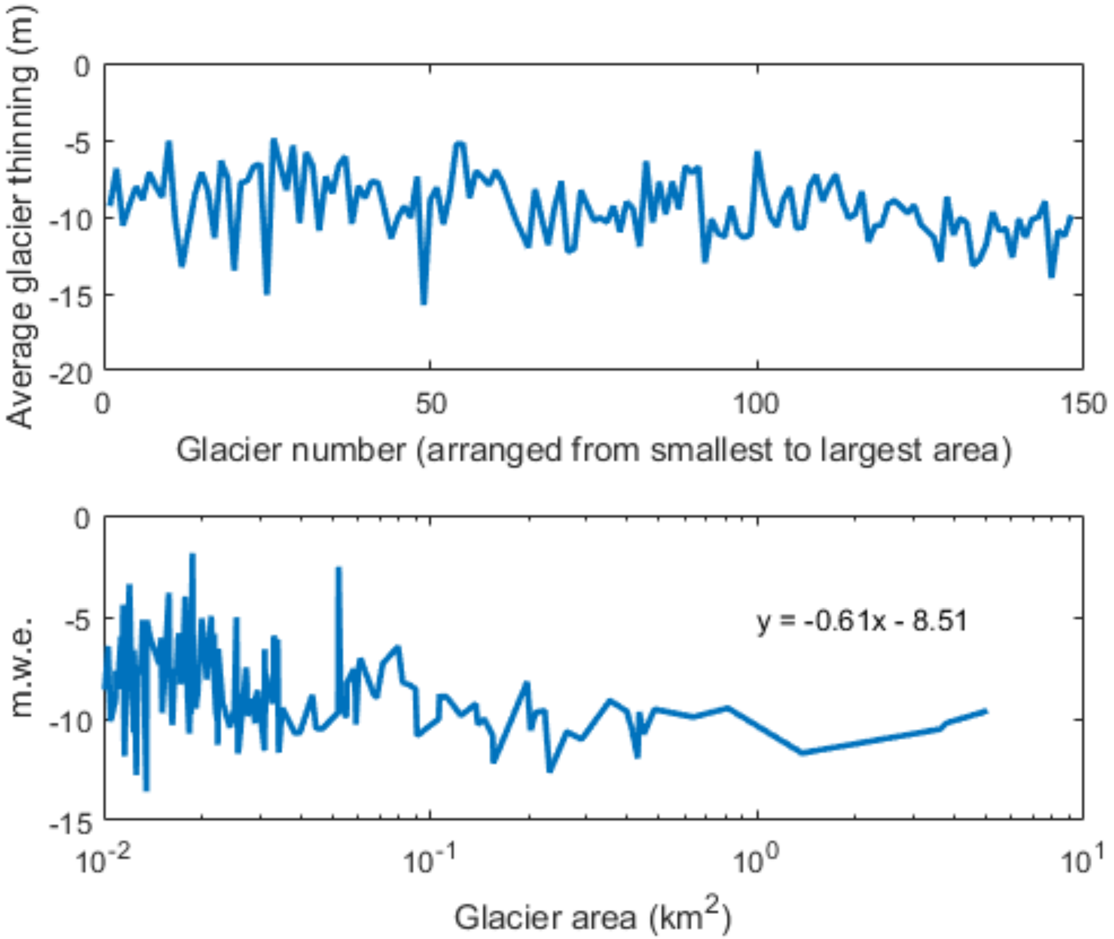




Total mass-balance

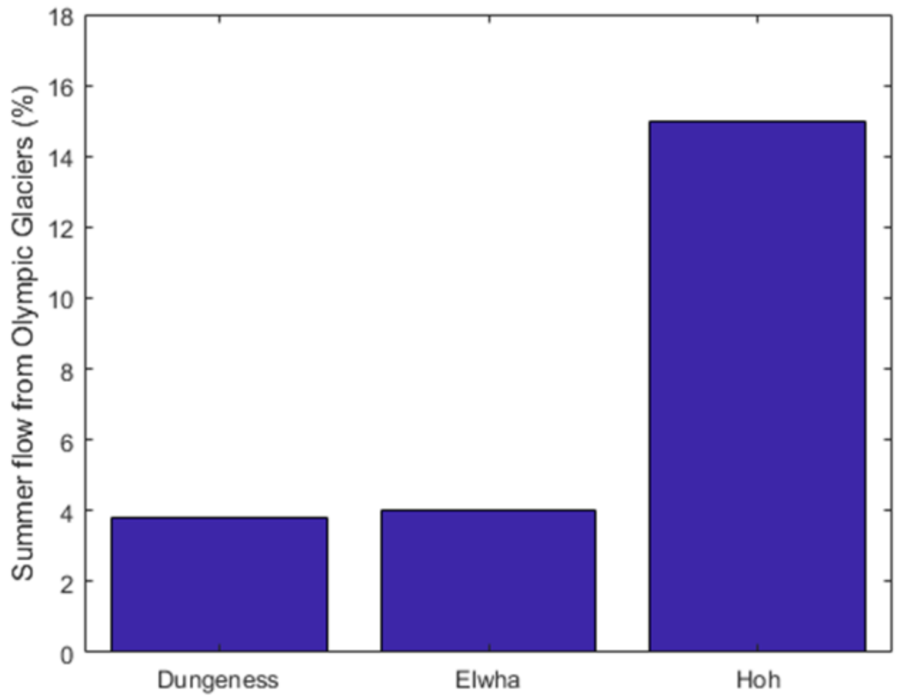
For all glaciers larger than .01 square kilometers:

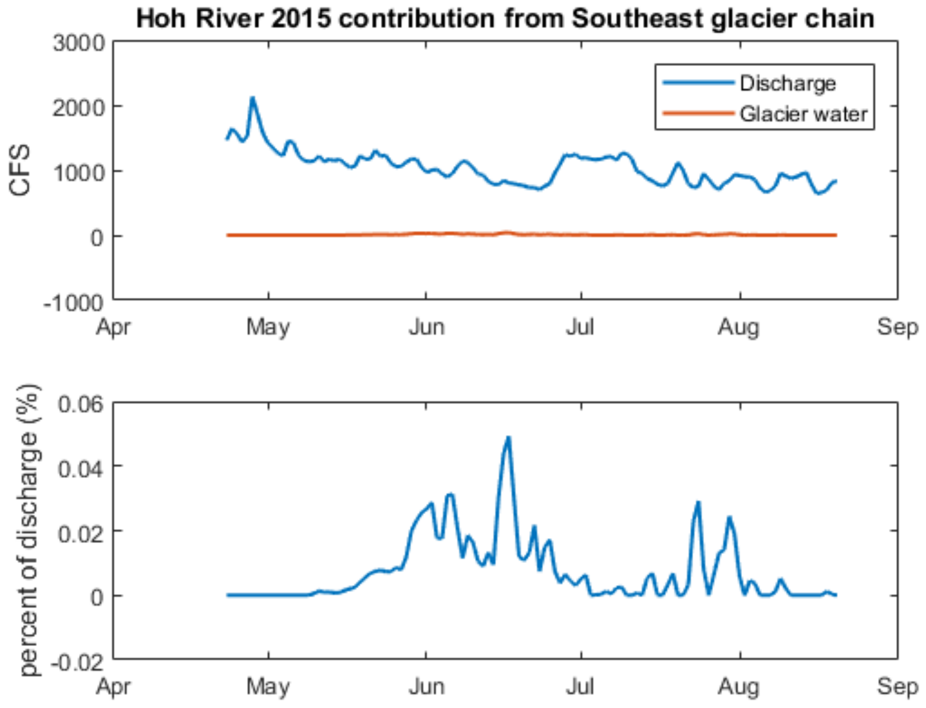
- Loss of over 35 million cubic meters of water from 9/2014 to 3/2016
- 9.93 m.w.e.
- 130,000+ Olympic-sized swimming pools
- Loss-rate seen on South Cascade glacier over ten years from 1984 to 1994.
- Fairly steady amounts of loss across the entire peninsula representing widespread loss of snow cover.



Stream contribution:

- Use of degree-index model (commonly used) as well as two Physical models that explicitly account for glaciers (DHSVM and SnowModel)
- Determine timing and amount of water runoff
- Define the complexity necessary to quantify glacier water resources in Pacific Northwest watersheds

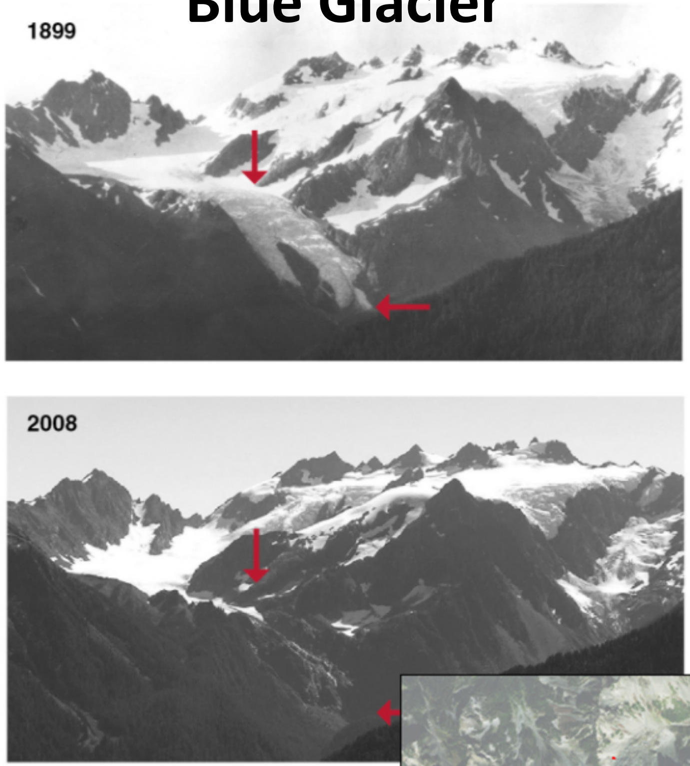


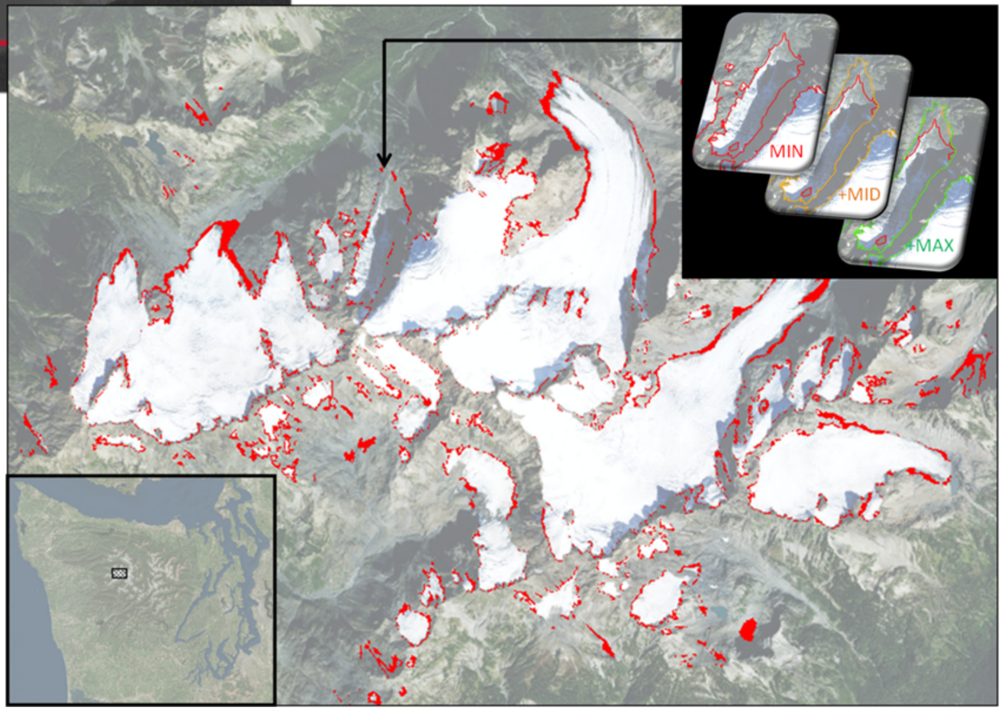


Takeaways

- Disappearance of glaciers = Disappearance of important sources of late-summer water
- Alternative effects
  - Altered glacier water timing
  - Increased variance in stream temperature
  - Geomorphology
- Given future climate change scenarios, only glaciers on Mt. Olympus are expected to survive into 22nd century.
- Complete depletion of glacier water resources in multiple watersheds.

Blue Glacier





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