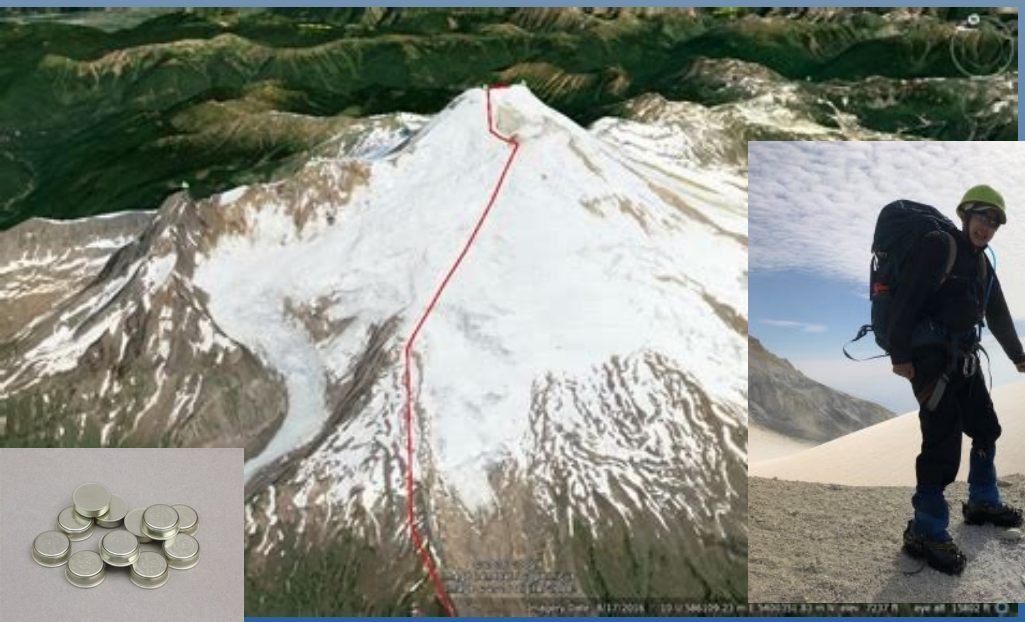
Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

Michael Town — GFI, Bjerknes Centre for Climate Research
michael.town@uib.no — Bergen, Norway

Chip Mehring — Lakeside School, Seattle, WA
Logan Searl
Devin Parry



NWRA
April 2022
Seattle, WA

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Outline

Land acknowledgement

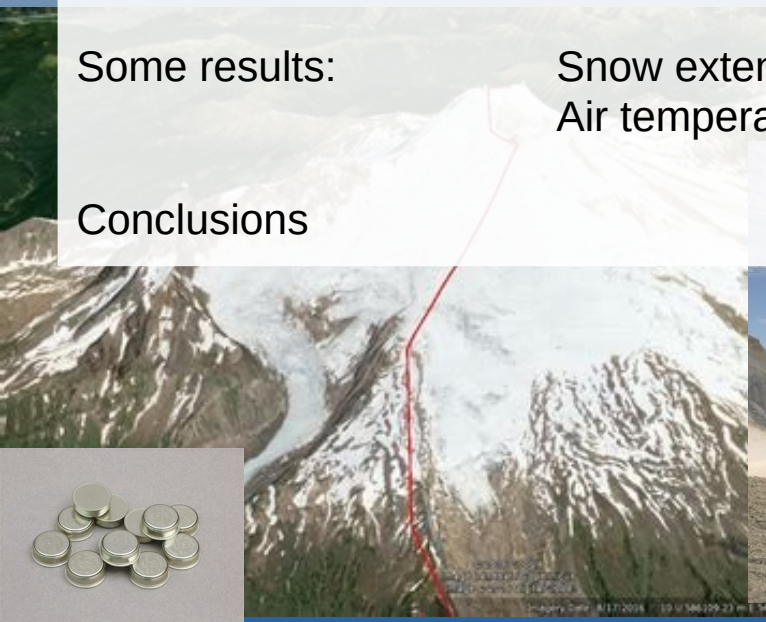
Other acknowledgements

The problem(s): glacier/snowpack vulnerability in PNW
geoscience education

A monitoring program: Mt. Baker Climate Project

Some results: Snow extent
Air temperature time series

Conclusions



BJERKNES CENTRE for Climate Research

LAKESIDE SCHOOL

NWSA
16 March 2022
Cal Poly
Humboldt, CA

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BJERKNES CENTRE
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LAKESIDE
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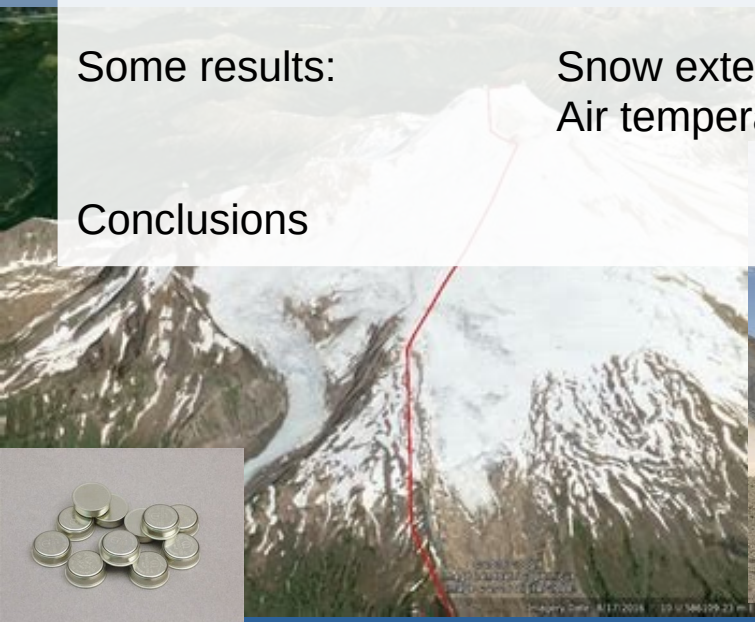

NWSA
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Land Acknowledgement

As we gather, we respectfully acknowledge that we learn, live, reflect, teach, and observe on the ancestral homelands of Tribes, Bands, and First Nations, including Coast Salish, Lower Skagit, and Upper Skagit.

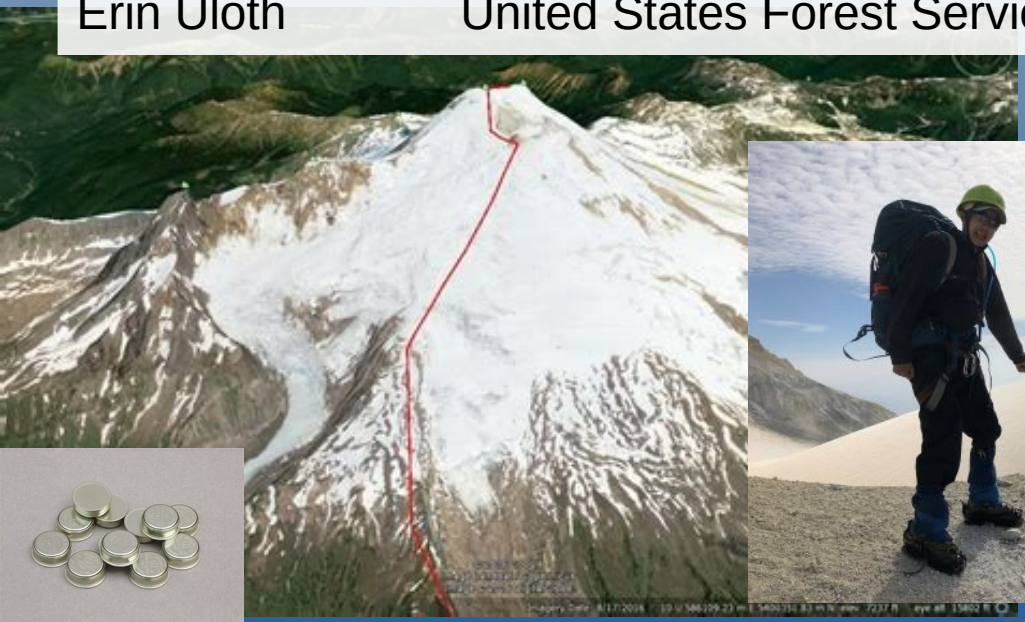
We would like to express respect and gratitude for our Indigenous neighbors for their care and protection of our shared lands and waterways and celebrate the resilience and strength that Indigenous peoples have shown and continue to show.

To acknowledge this land is to critically reflect on a history that includes disease, displacement, violence, and loss of land, and to recognize our place in that history.
We offer this acknowledgement as an important step in honoring the relationship with land we share, and a call towards further learning and action.

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

Other Acknowledgements

Jennifer Mapes	Lakeside School
Kat Yorks	Lakeside School
Greta Block	Lakeside School
Many other staff	Lakeside School
Robert Hahn	Northwest Avalanche Center
Erin Uloth	United States Forest Service



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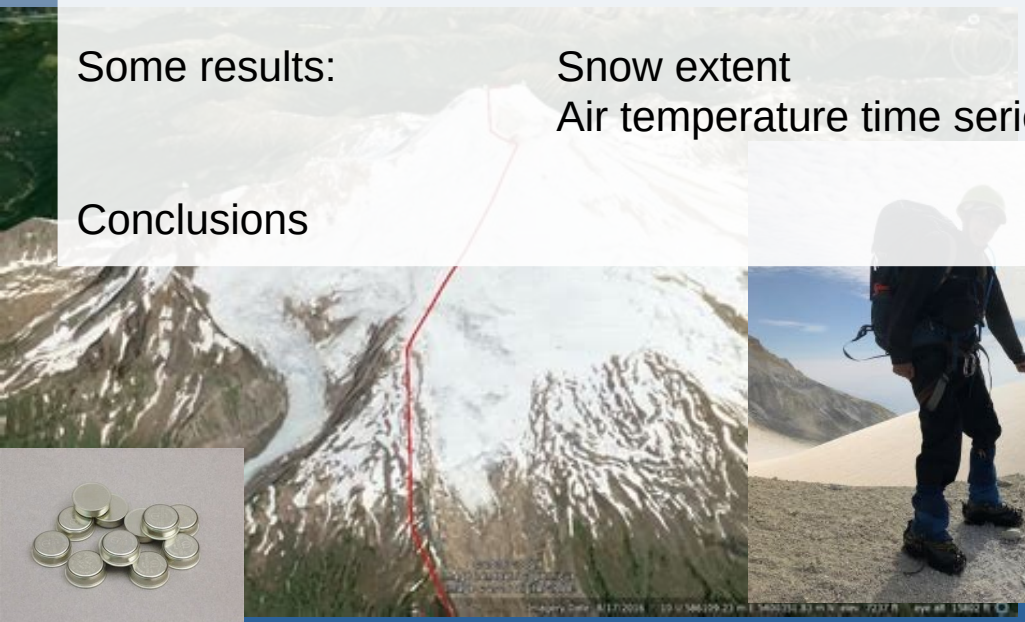

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The problem(s):

Locations like Mt. Baker experiencing 2x the warming of the USA.

PNW snowpack is very likely in decline

Many glaciers in the PNW in retreat impacting regional water resources

Mt. Baker then is a large reservoir of snow with an *inadequate* temperature sensor network.

Gonzalez et al 2018 Environ. Res. Lett. 13 104001

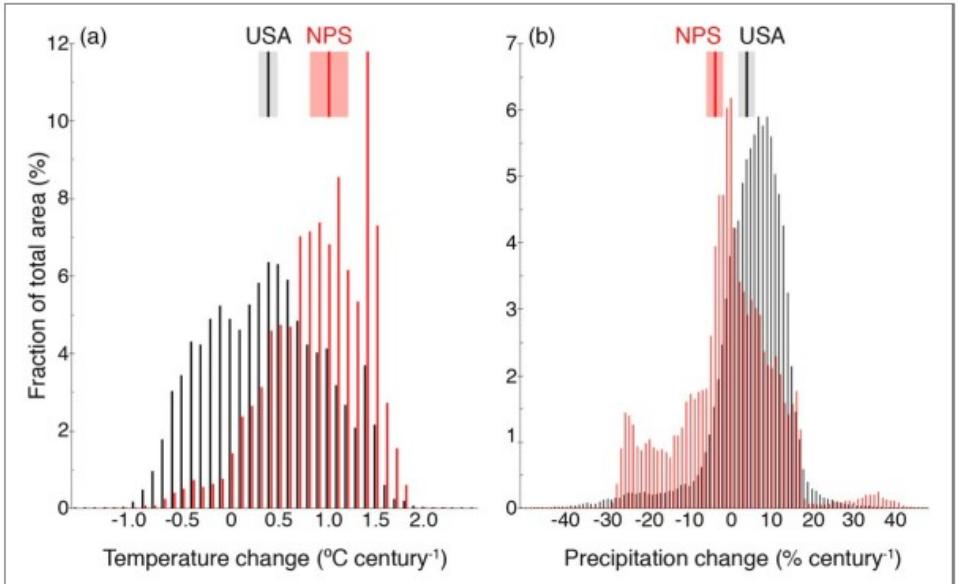

Figure 1. Historical climate change, 1895–2010. Fractions (%) of the US national park area (NPS) and the US (USA) experiencing changes in (a) mean annual temperature (°C century^{-1}) and (b) annual precipitation (% century^{-1}) (relative to 1895–2010 average precipitation). Mean (dark bar) and standard error (shaded rectangle) are indicated for each area as a whole.

Table 1. Climate changes across the US and US national park area. Historical trends and standard errors from linear regression, after correction for temporal autocorrelation. Historical period for areas outside the contiguous states is 1901–2009, the period of available spatial data. Historical precipitation trends relative to average of entire period. Projected changes and standard deviations for the difference between the periods 1971–2000 and 2071–2100, from ensembles of all general circulation model output available for IPCC (2013).

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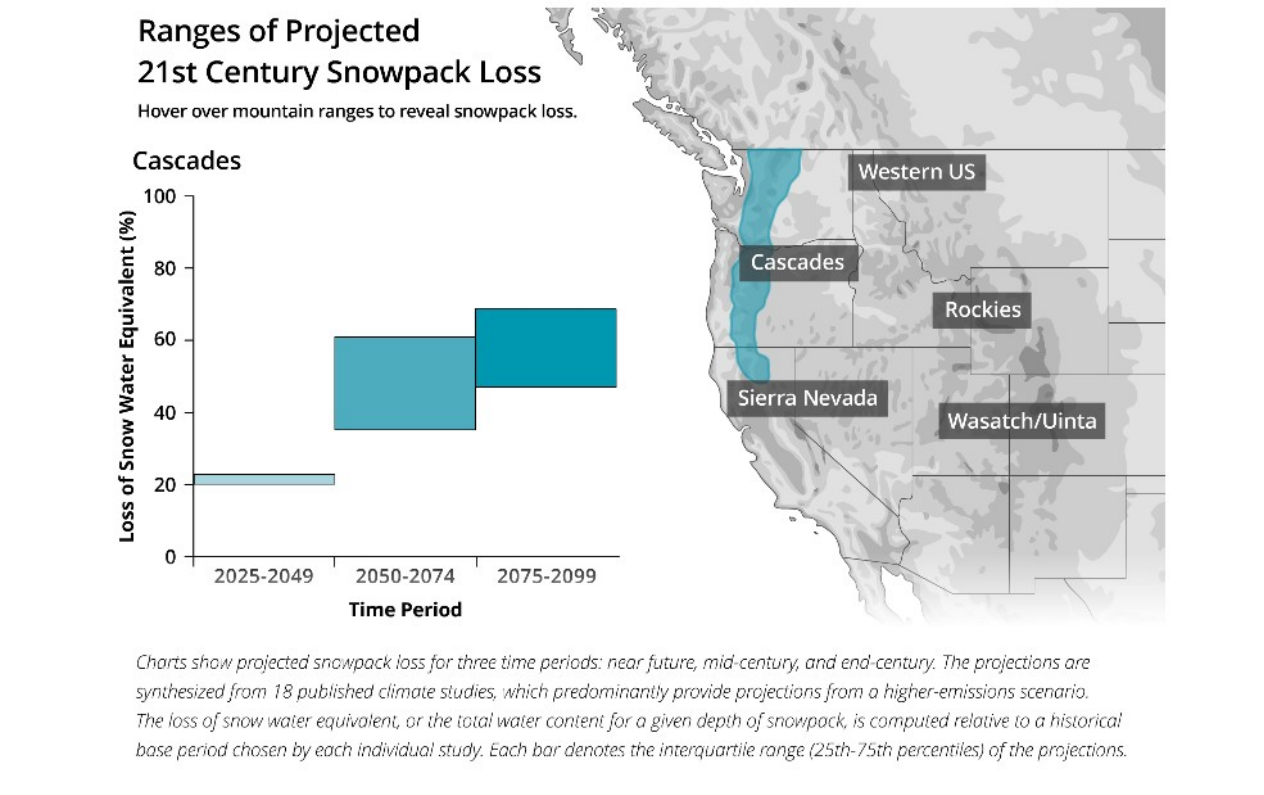
Siirila-Woodburn et al. Nat Rev Earth Environ 2, 800–819 (2021). https://doi.org/10.1038/s43017-021-00219-y



Charts show projected snowpack loss for three time periods: near future, mid-century, and end-century. The projections are synthesized from 18 published climate studies, which predominantly provide projections from a higher-emissions scenario. The loss of snow water equivalent, or the total water content for a given depth of snowpack, is computed relative to a historical base period chosen by each individual study. Each bar denotes the interquartile range (25th-75th percentiles) of the projections.

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Frans, C., et al. (2018). WRR, 54,6202–6225. https://doi.org/10.1029/2017WR021764

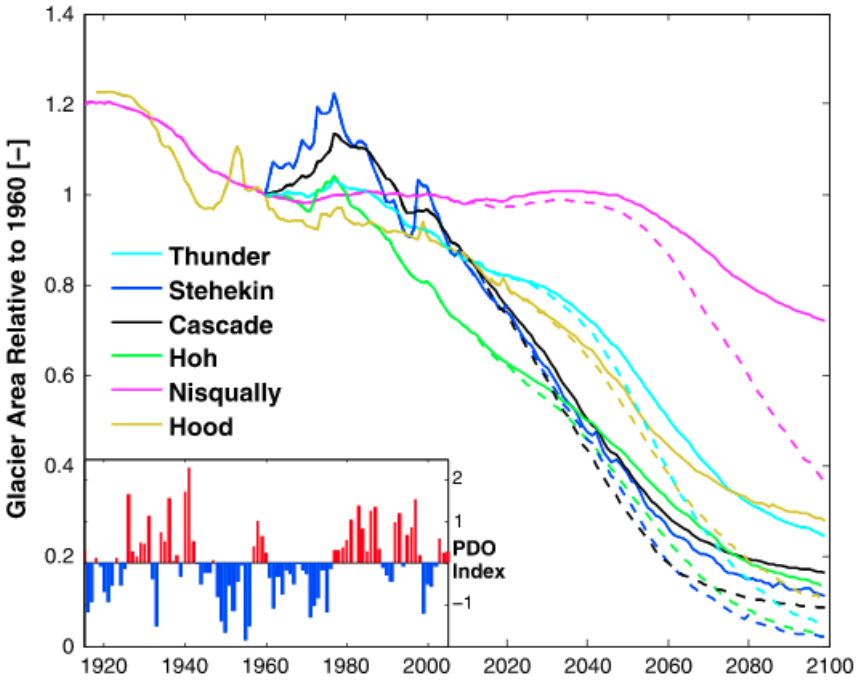

Figure 7. Modeled glacier area relative to the glacier area of 1960 for the modeled river basins. The solid lines represent the historical and ensemble mean of the Representative Concentration Pathway (RCP) 4.5 emission scenario, and the dashed lines represent the ensemble mean of RCP8.5. A time series of the Pacific Decadal Oscillation (PDO) index for the period 1915–2005 is provided on the inset.

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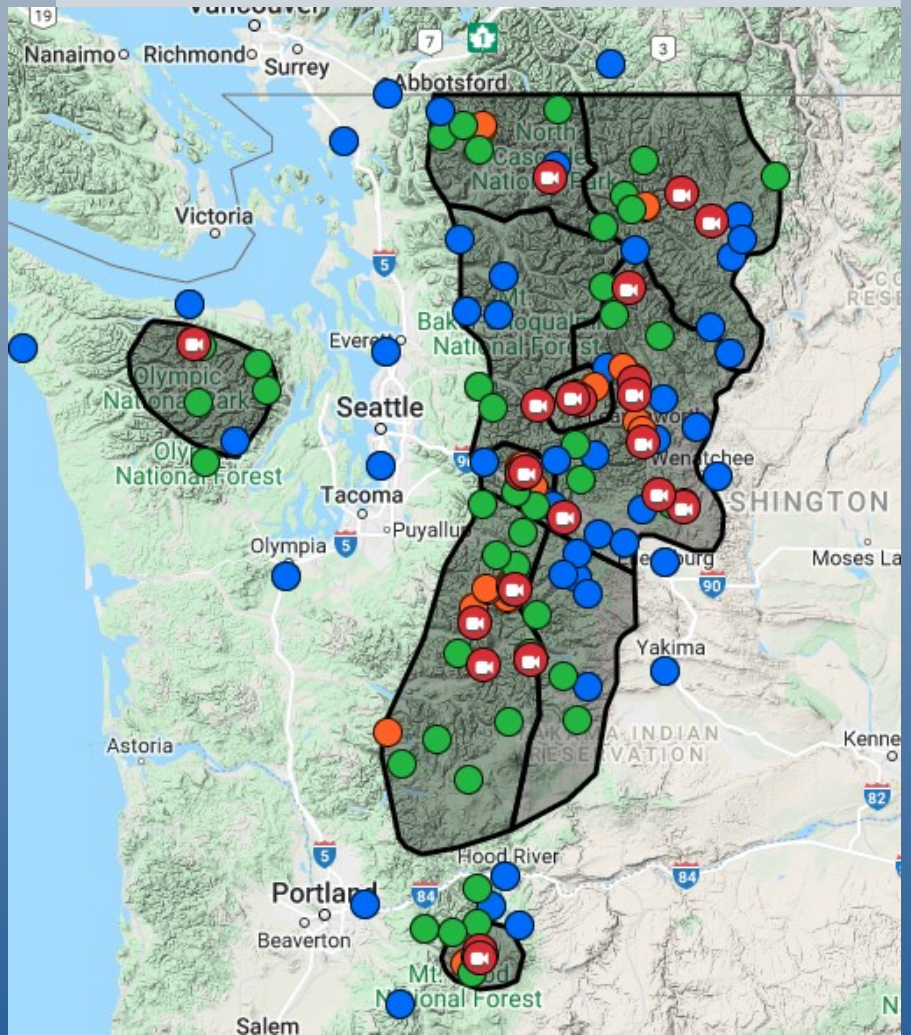
https://nwac.us/weatherdata/map/



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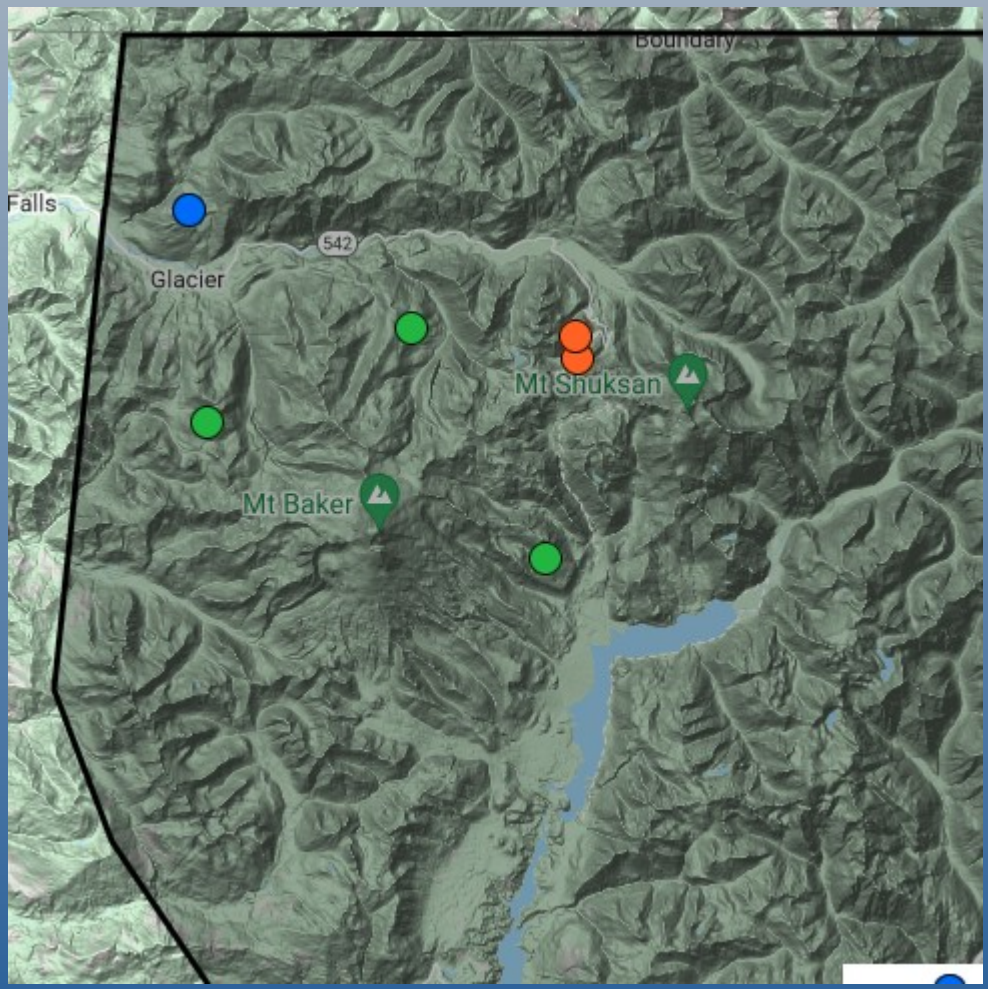

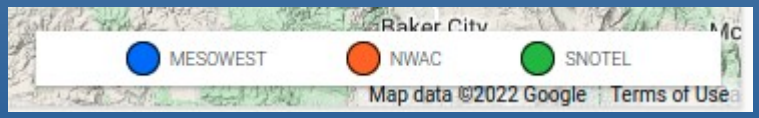

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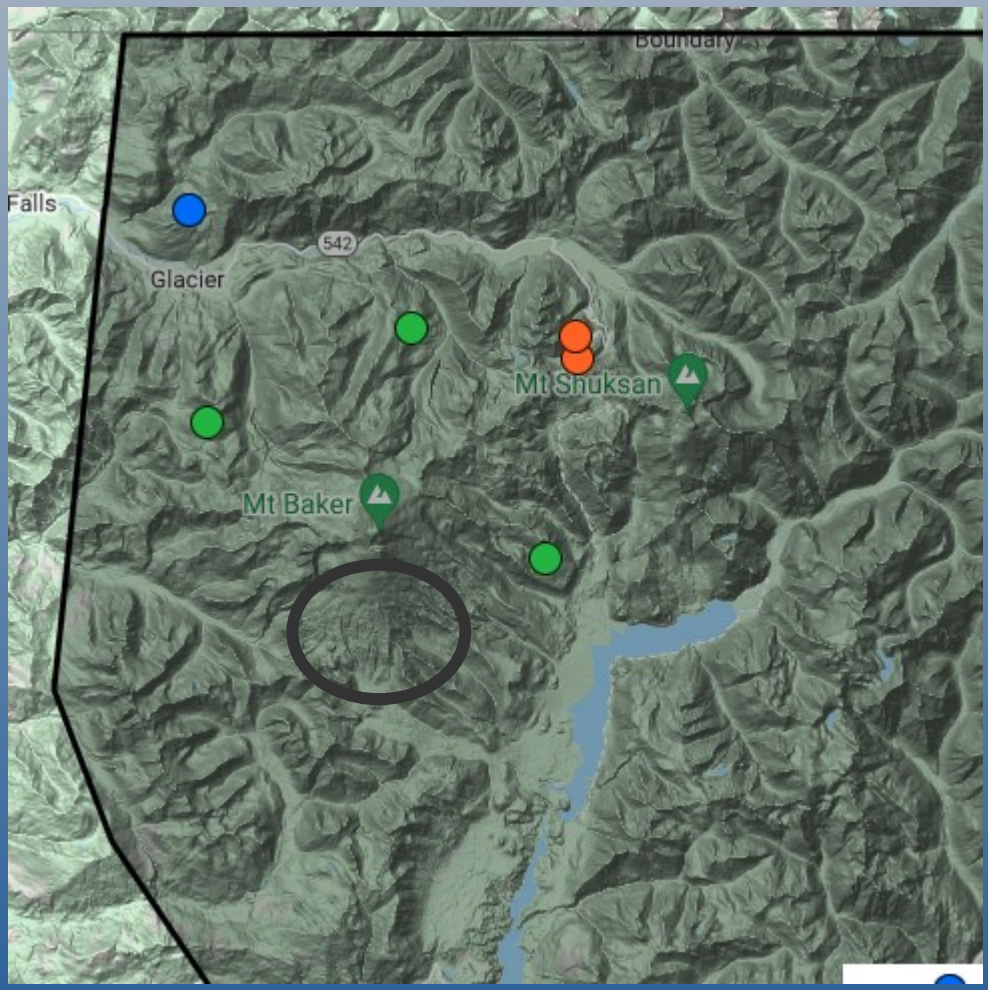

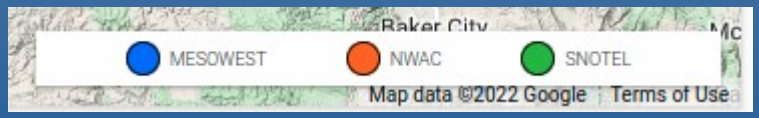

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

The problem(s):

There is a lack of diversity in geoscience

Many students winnow their ideas of careers in high school or before

Students are not often exposed to real Geoscience (or similar ‘applied’ careers) in high school

All students should have access to ideas and tools related to geoscience and data science

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Bernard and Cooperdock,
Nature Geoscience, 2018.

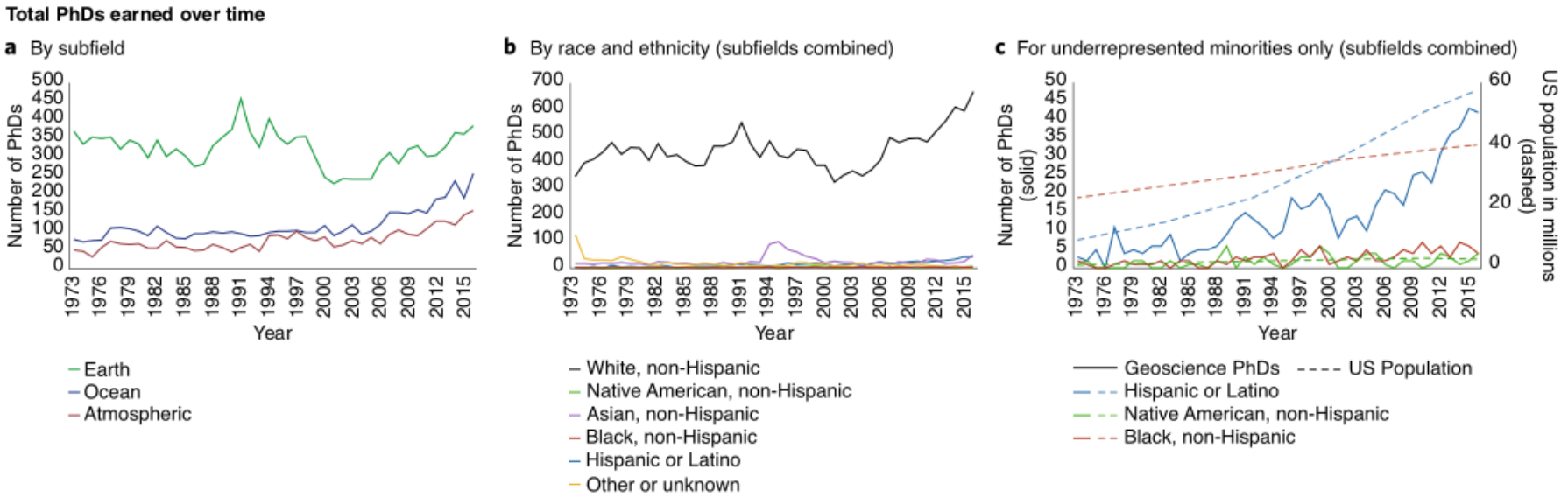

Fig. 1 | PhDs earned by US citizens and permanent residents between 1973 and 2016. a, The total number of PhDs for all races, ethnicities and genders combined have fluctuated around 350 for the earth sciences, but have taken an upward turn from a stable base level in the last decade or so for ocean and atmospheric sciences. **b**, The largest race/ethnicity category by far is the White non-Hispanic PhD group. **c**, Focusing on what the NSF considers to be underrepresented minorities (that is, excluding White non-Hispanics and Asian non-Hispanics), and comparing with the increasing share of these groups in the US population (measured by decadal census and 2016 estimate), it becomes clear that gains in Hispanic or Latino PhDs largely reflect an increase in the relevant population in the US, and that there are no gains in PhDs earned among the other underrepresented groups. Data in **a**–**c** run from 1973 to 2016.

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Career choices are multifaceted decisions

Family
Community
Faith
Opportunities
Self-identity

e.g. Ferry (2006)
https://archives.joe.org/joe/2006june/rb7.php

Parents, peers, and schools are influential
Messersmith et al.
(J Adolesc Res. 2008 Mar; 23(2): 206–227.)

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Process of Career development
career exploration, commitment, and reconsideration

Porfeli and Lee (2012)

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Most geoscience is taught at 8th grade level (in USA)

In WA we have 9th grade IPS

These curricula do not usually refect what geoscience is like as a profession

https://www.k12.wa.us/student-success/resources-subject-area/science/science-k%E2%80%9312-learning-standards

https://serc.carleton.edu/teacherprep/issues/current.html

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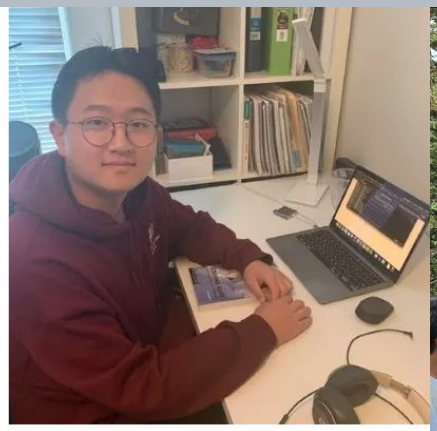

A mountain is a pile of rocks

JUL 26 2021

by Sol P.

This was it. I was given past student’s work on th
Research Forecasting (WRF) model. The SNOW

LSRI: Hand-me-down data

JUL 20 2020

by Zelia E. ’21

LSRI: Determining snow depth from autonomous temperature sensor arrays on Mount Baker

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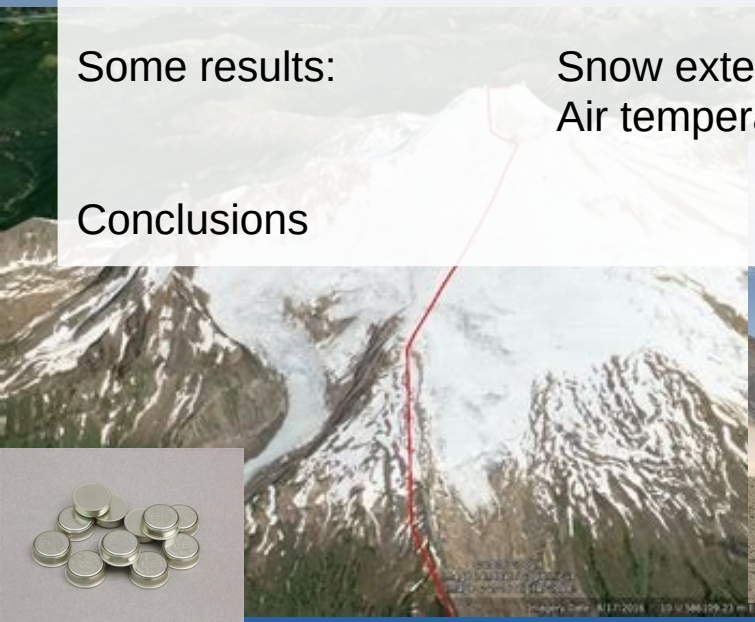

BJERKNES CENTRE for Climate Research

LAKESIDE SCHOOL

NIKOLA TESLA STEM HIGH SCHOOL

NWSA
16 March 2022
Cal Poly
Humboldt, CA

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The monitoring program:

Mt. Baker Climate Project (MBCP)

Annual outdoor trip provides stable and safe logistics for weather/climate monitoring

Student engagement at each point in monitoring program provides window into science process

Robust, accurate temperature sensors can be leveraged to tell more than simply temperature.

Deployed from Jul 2018 - Present

This man is a climate record.

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

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Mt. Baker Climate Project

Goal:
Deploy *and retrieve* 16 small temperature sensors along Easton Glacier Mt. Baker ascent route to provide educational climate data for Lakeside school.

Details:
Sensor type: iButton Thermochron in water-proof housing

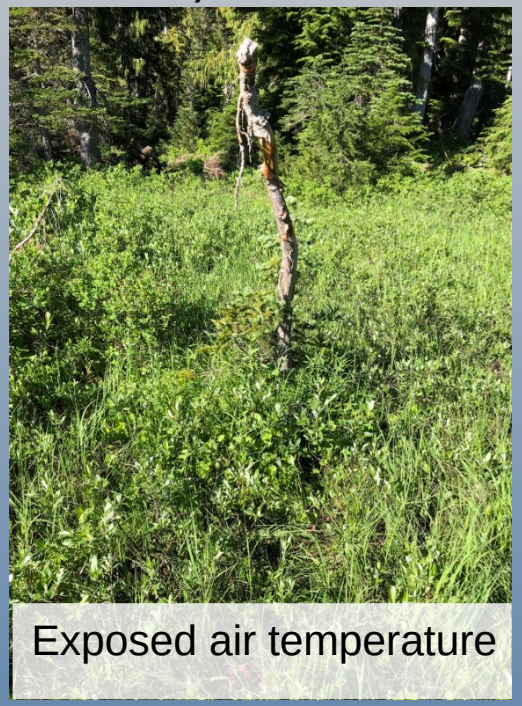
Record: Sensor location description and image.

Three sensors will be deployed at *The Portal, The Crater, and The Summit*

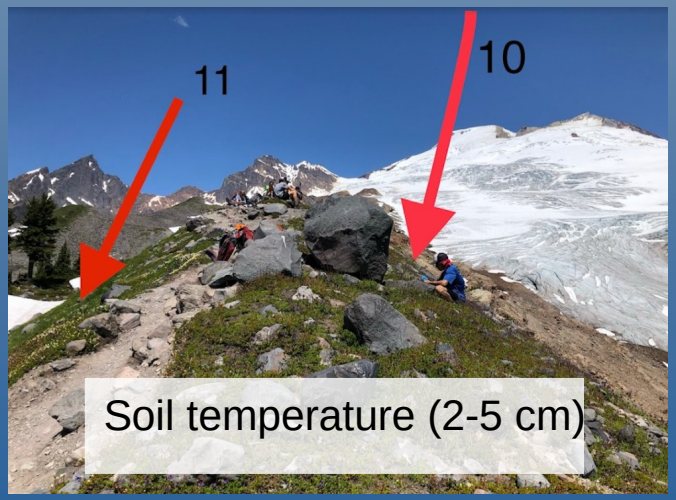
The purple sensor will be retrieved on descent

Buried sensors should not be buried near tree wells. (2-5 cm)

'**Shaded**' temperature sensors should not receive direct sunlight. '**Exposed**' sensors should receive direct sunlight. (2-3 m high)


Exposed air temperature


Shaded air temperature



Soil temperature (2-5 cm)

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

Mt. Baker Climate Project

Lundquist and Lott (2008)
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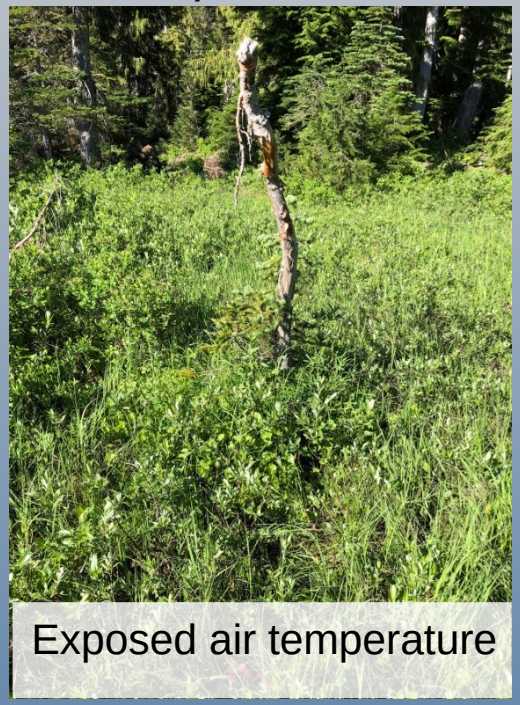
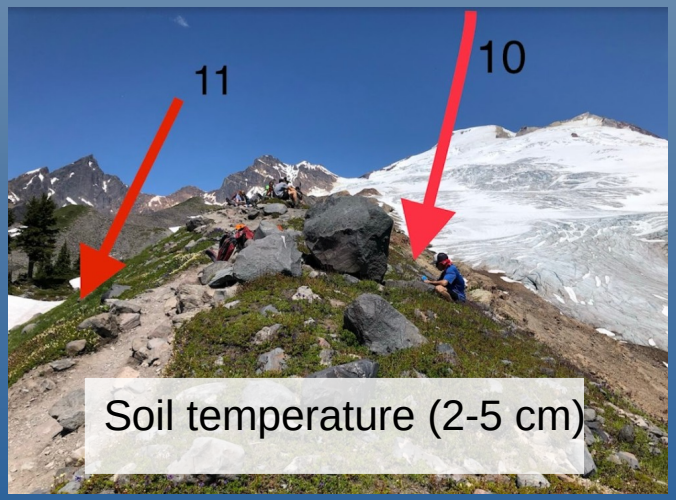

Exposed air temperature


Shaded air temperature



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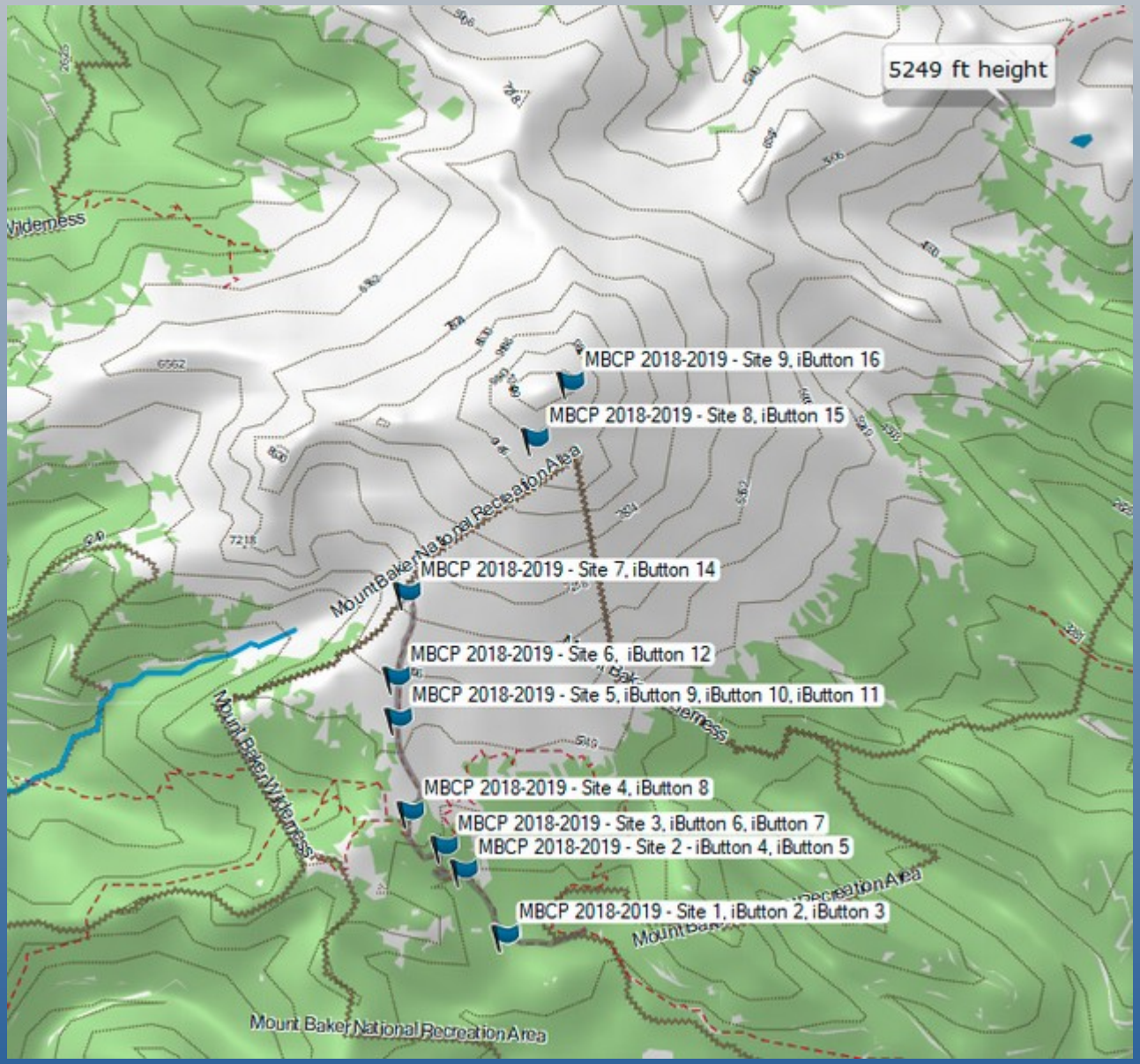

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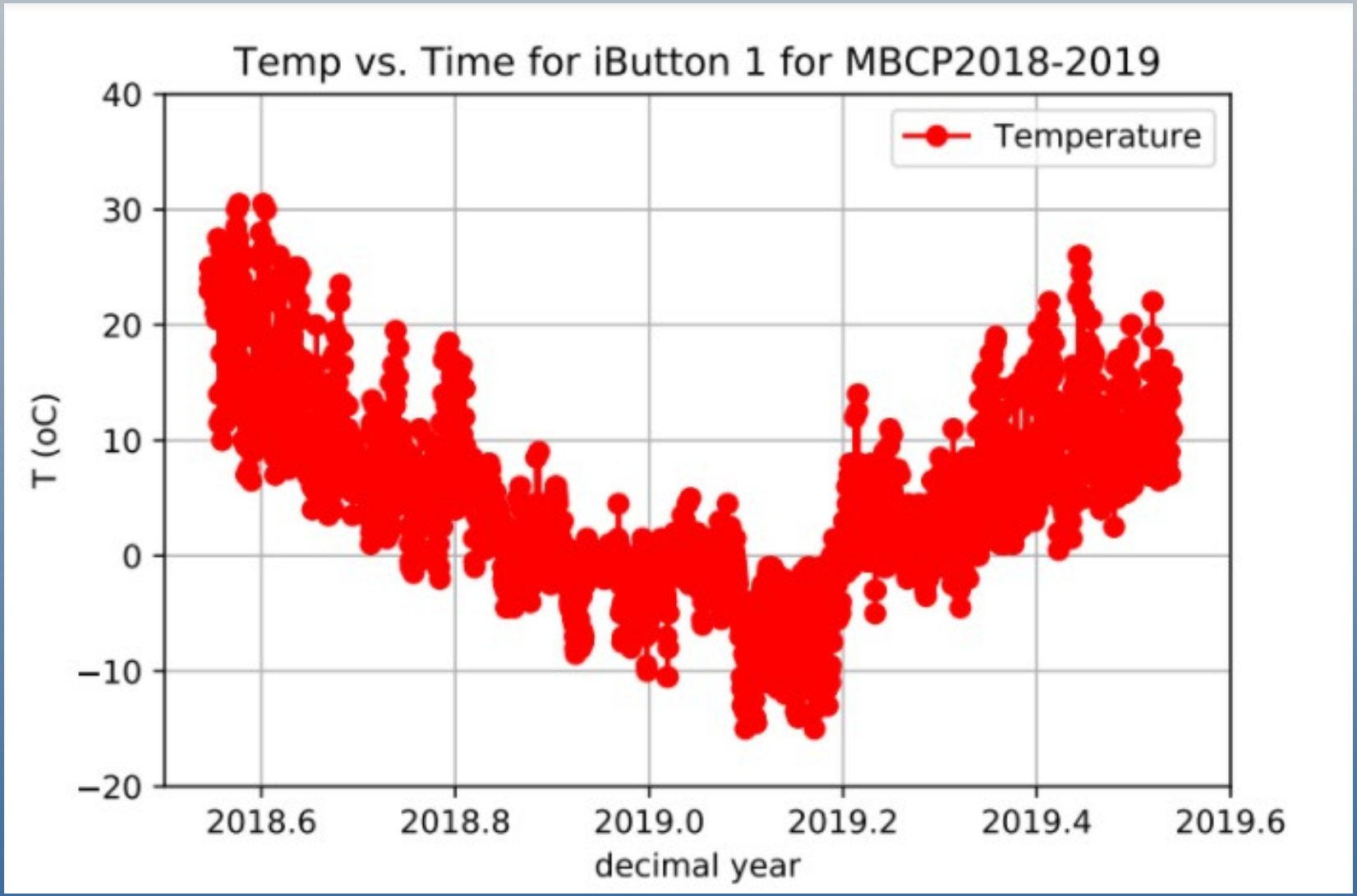

IButtons (+/- 0.5 C, 4.25 hourly measurements, max 2048 measurements)

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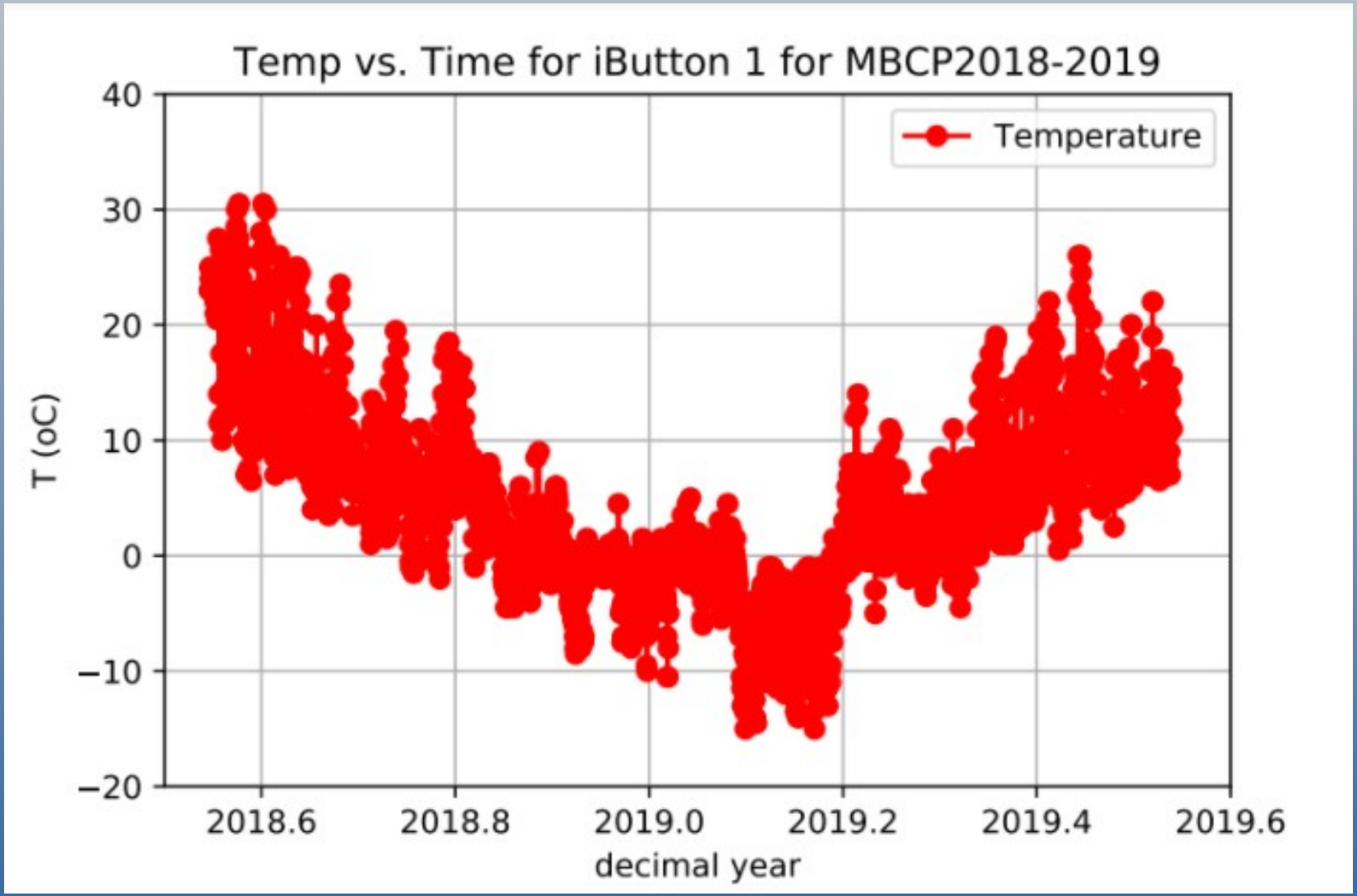

Schriebers Meadow (1030 m), shaded air temperature

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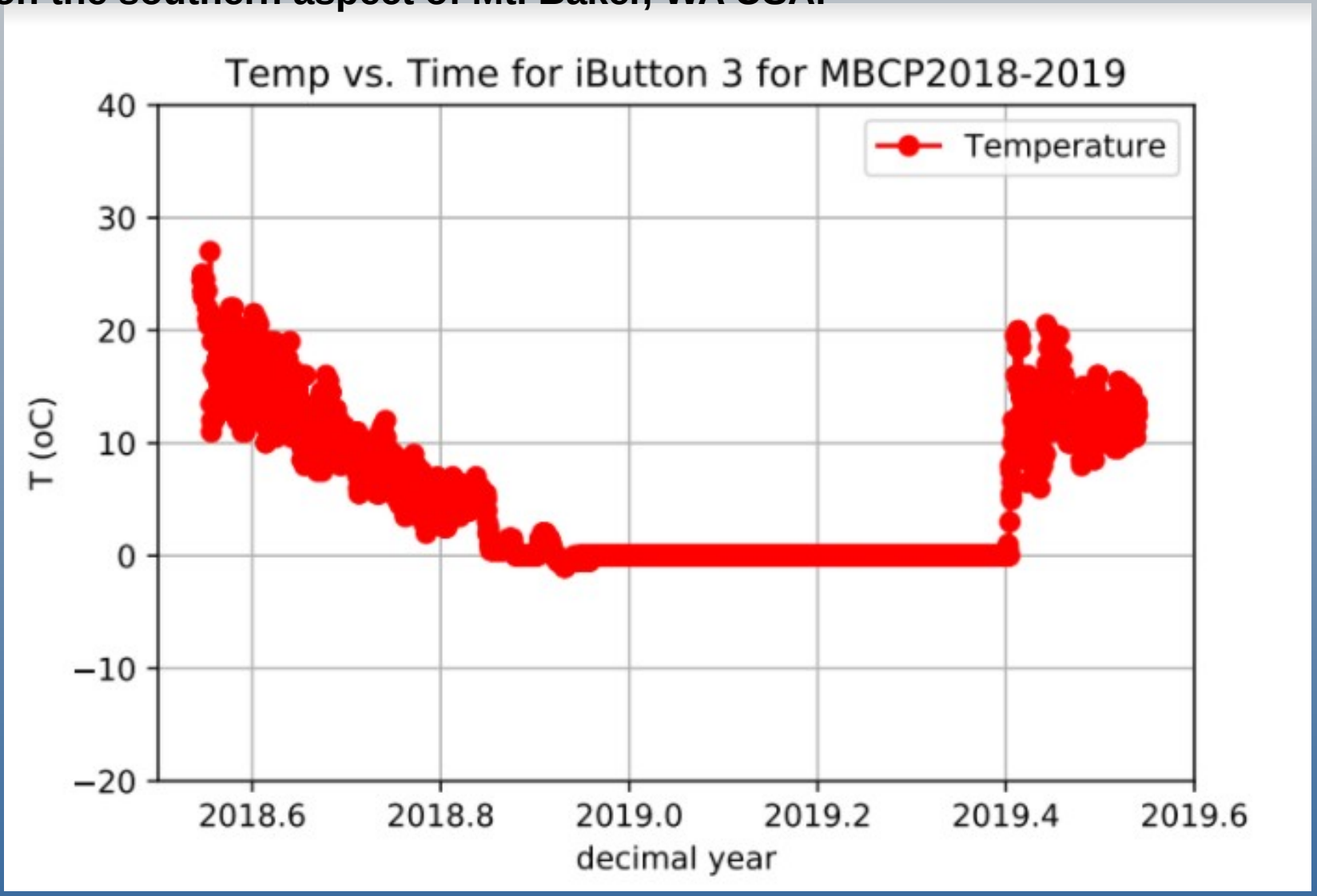

Schriebers Meadow (1030 m), buried (soil) temperature

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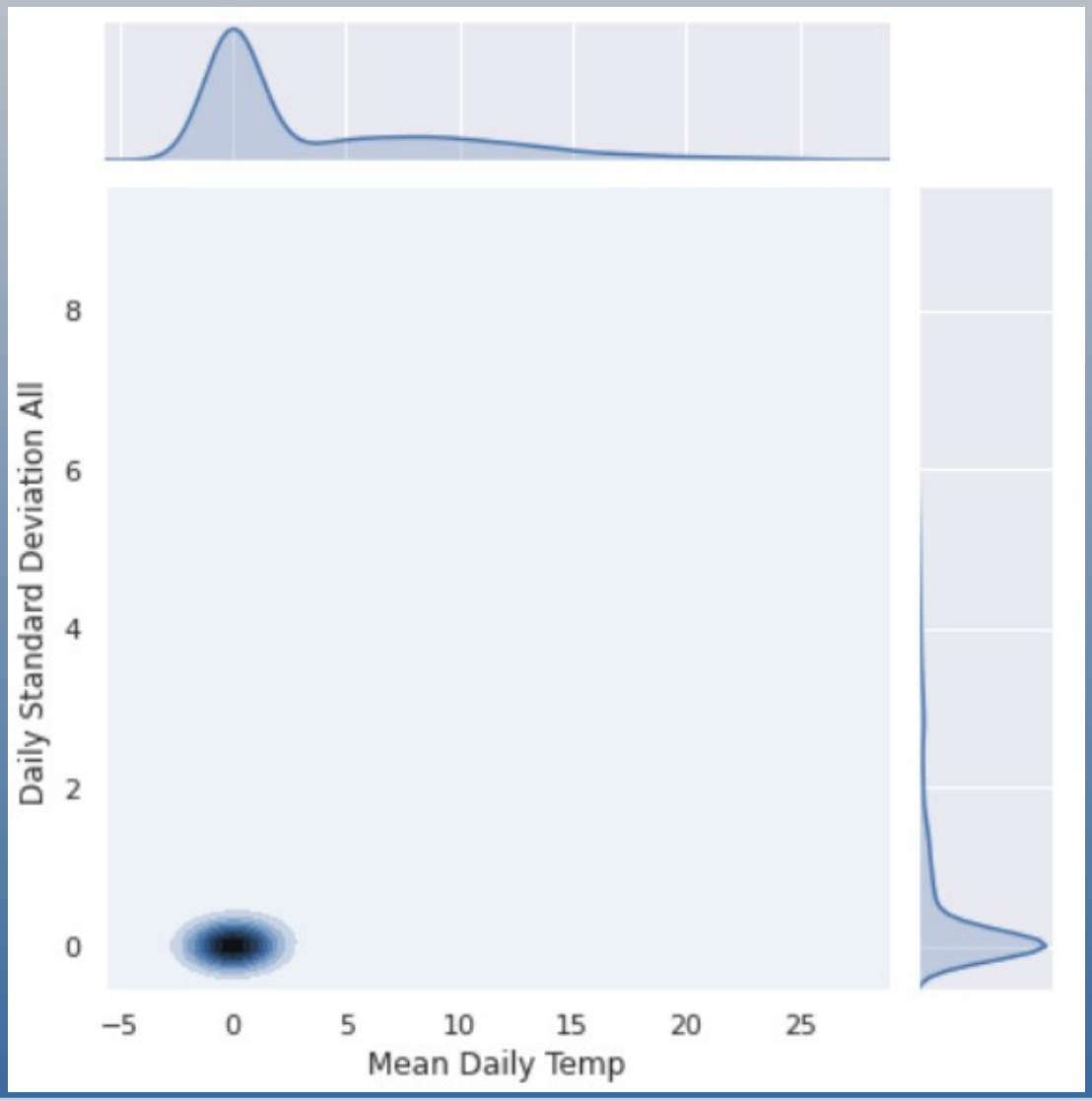

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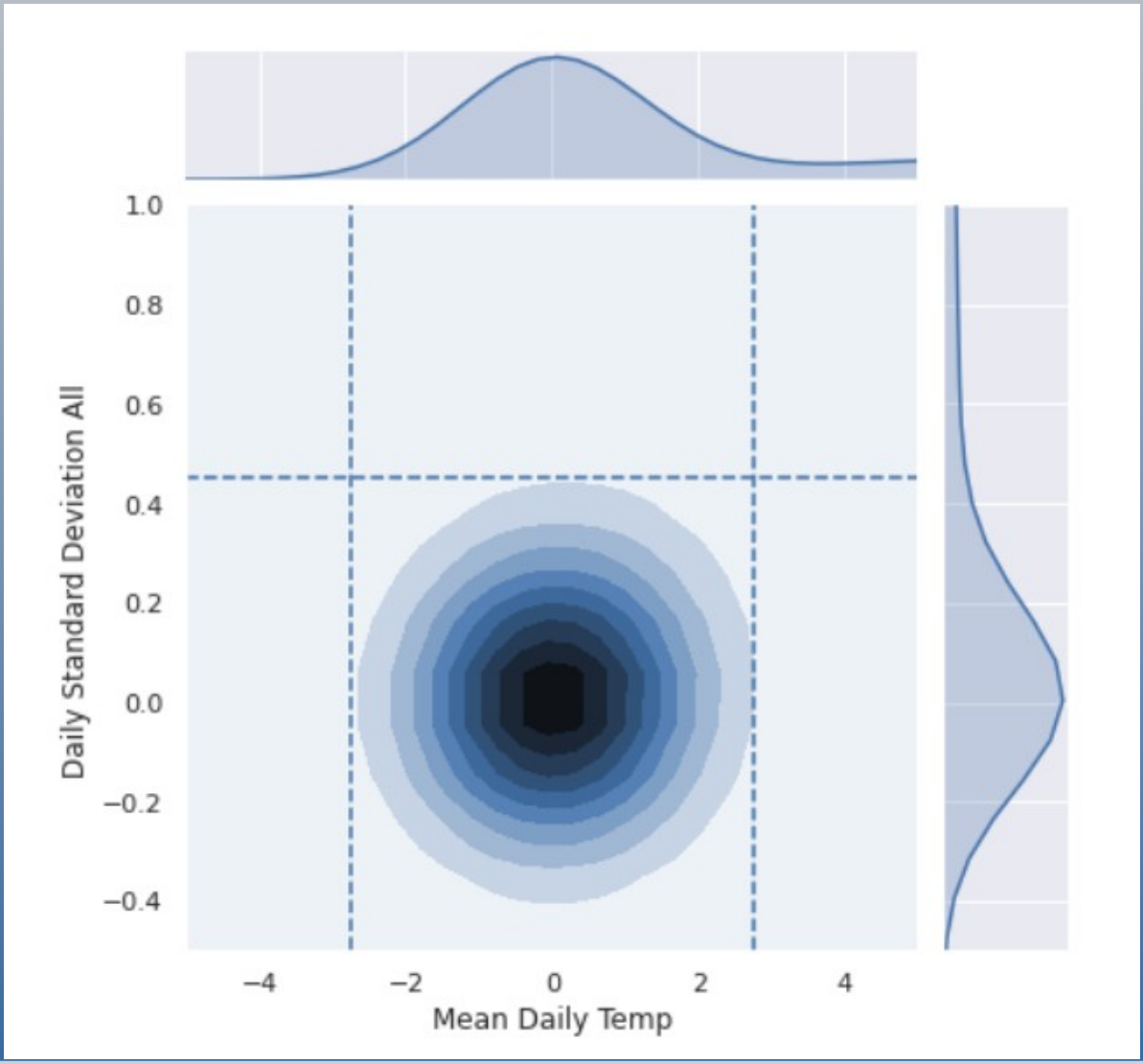

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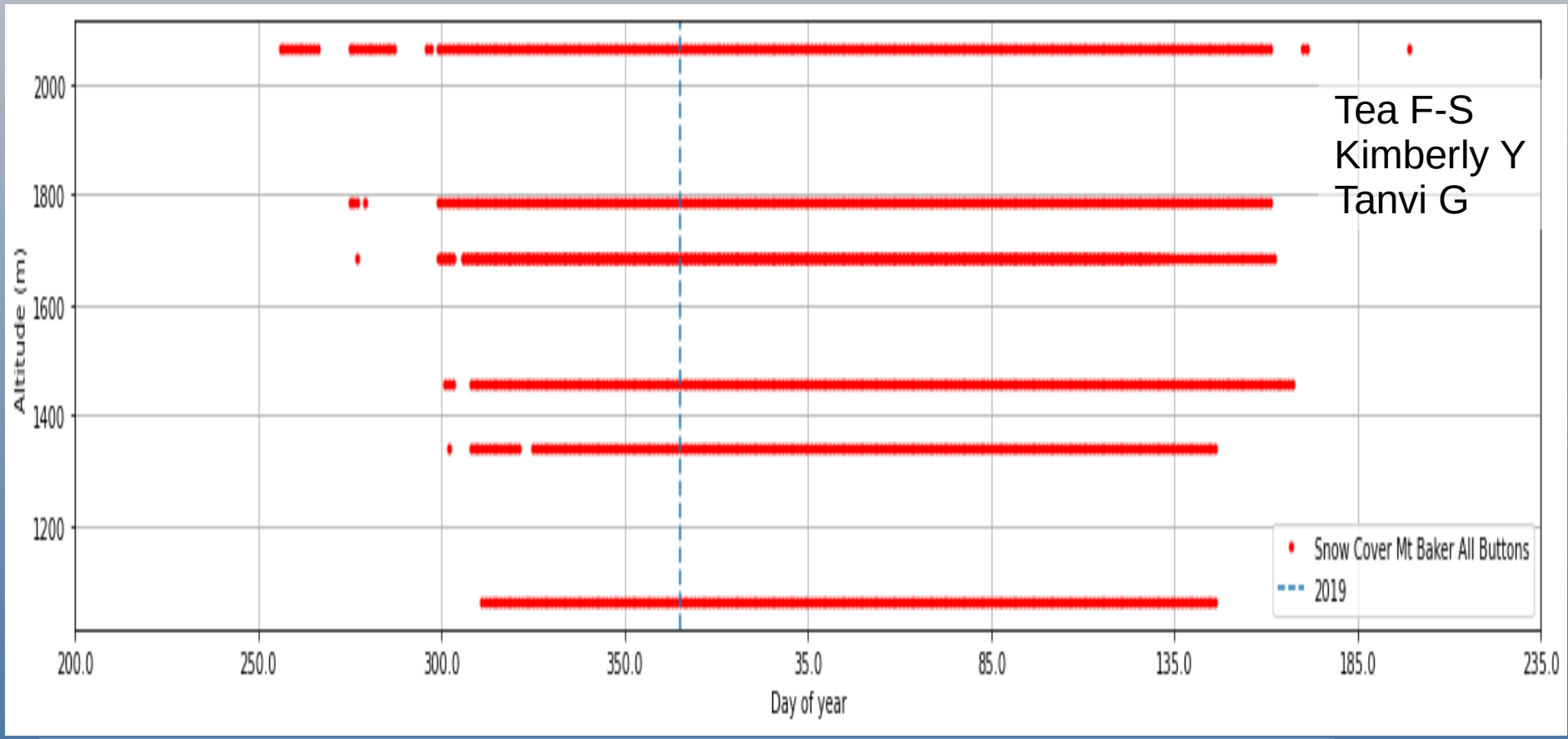

Lundquist and Lott (2008)
Demonstrated that **buried** *iButton* temperatures can give **snow cover**.

Kimberly Y applied this work to iButton data from our campus, and Tanvi G. applied this work the Mt. Baker data set (2018-2019).

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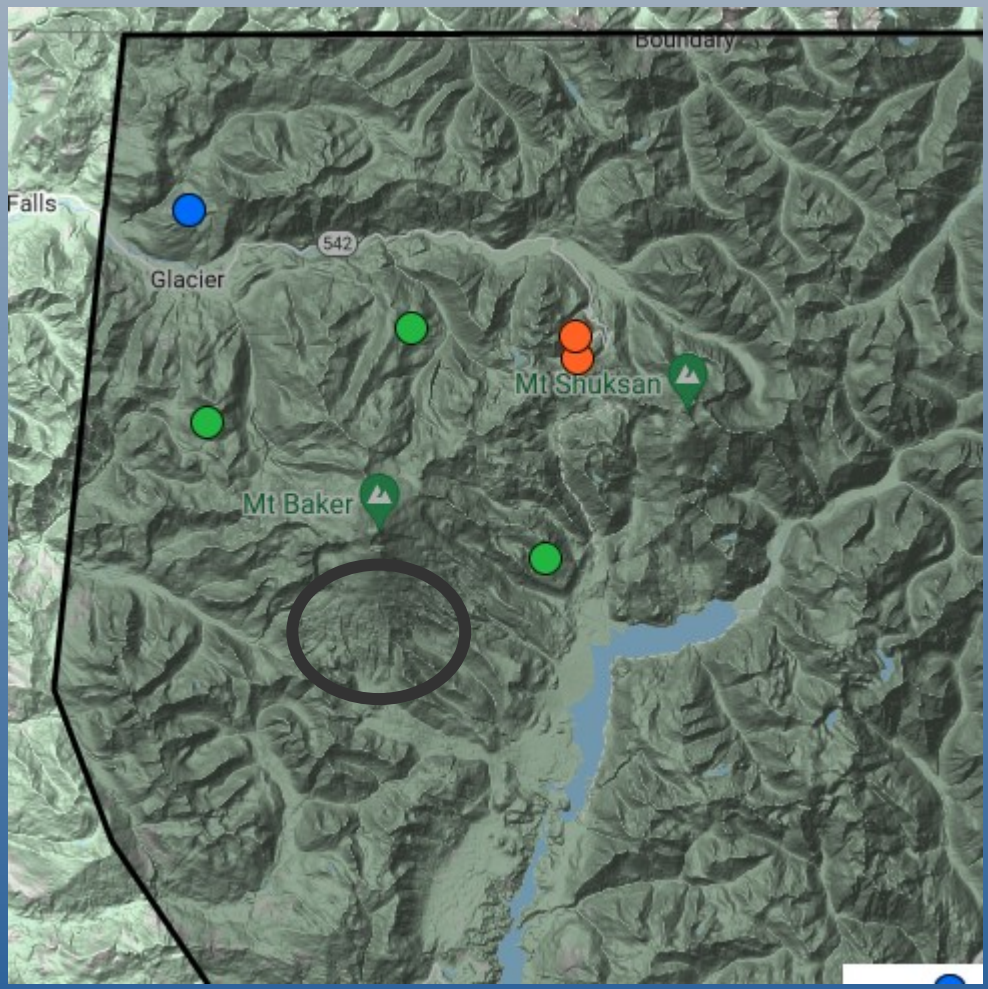
Extending the time series

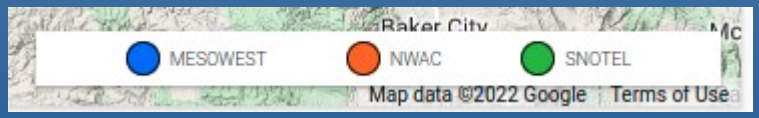
We have Tair data from **Jul 2018 – Jul 2021**

We use neighboring data sets (Tair, precip) from Mt. Baker Ski Resort (Sep 2014 - present) to extend our time series.

Use multiple linear regressions and compositing to do so.

https://nwac.us/weatherdata/map/





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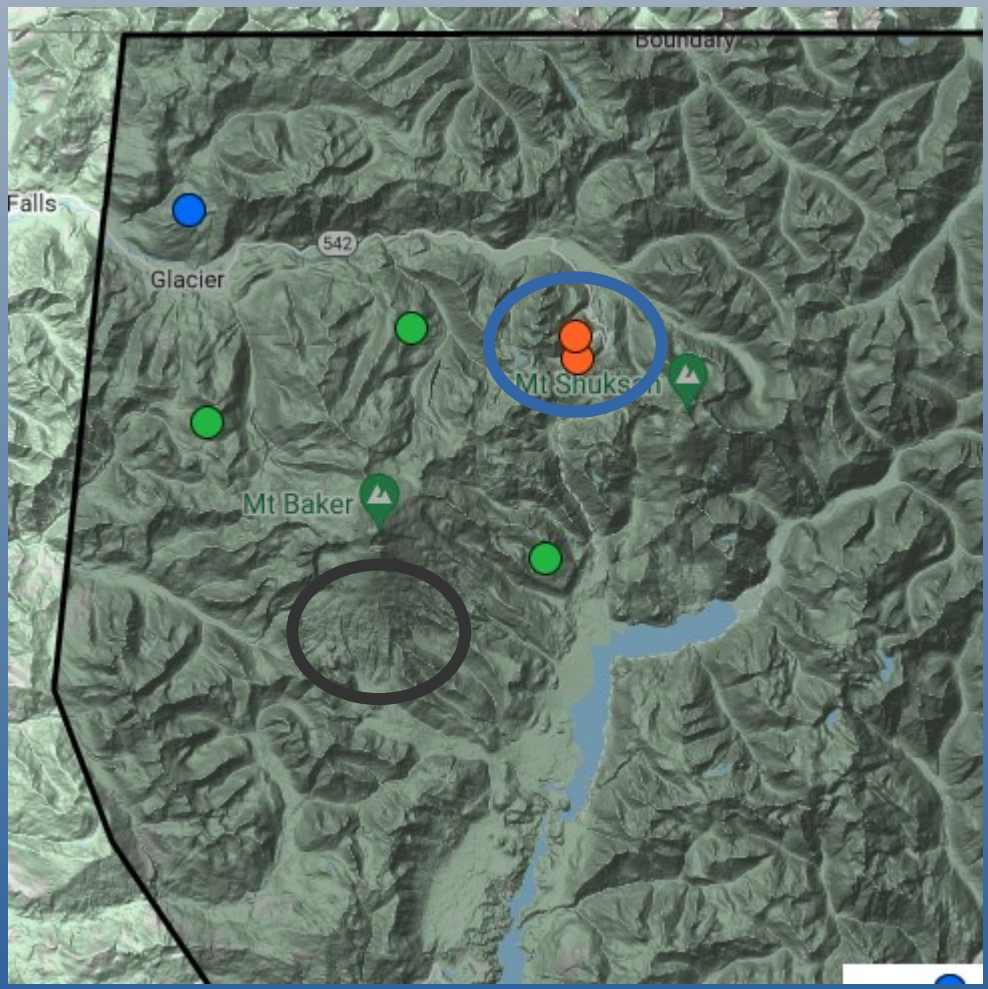
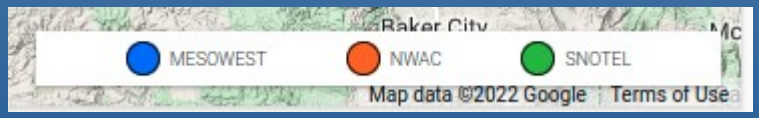
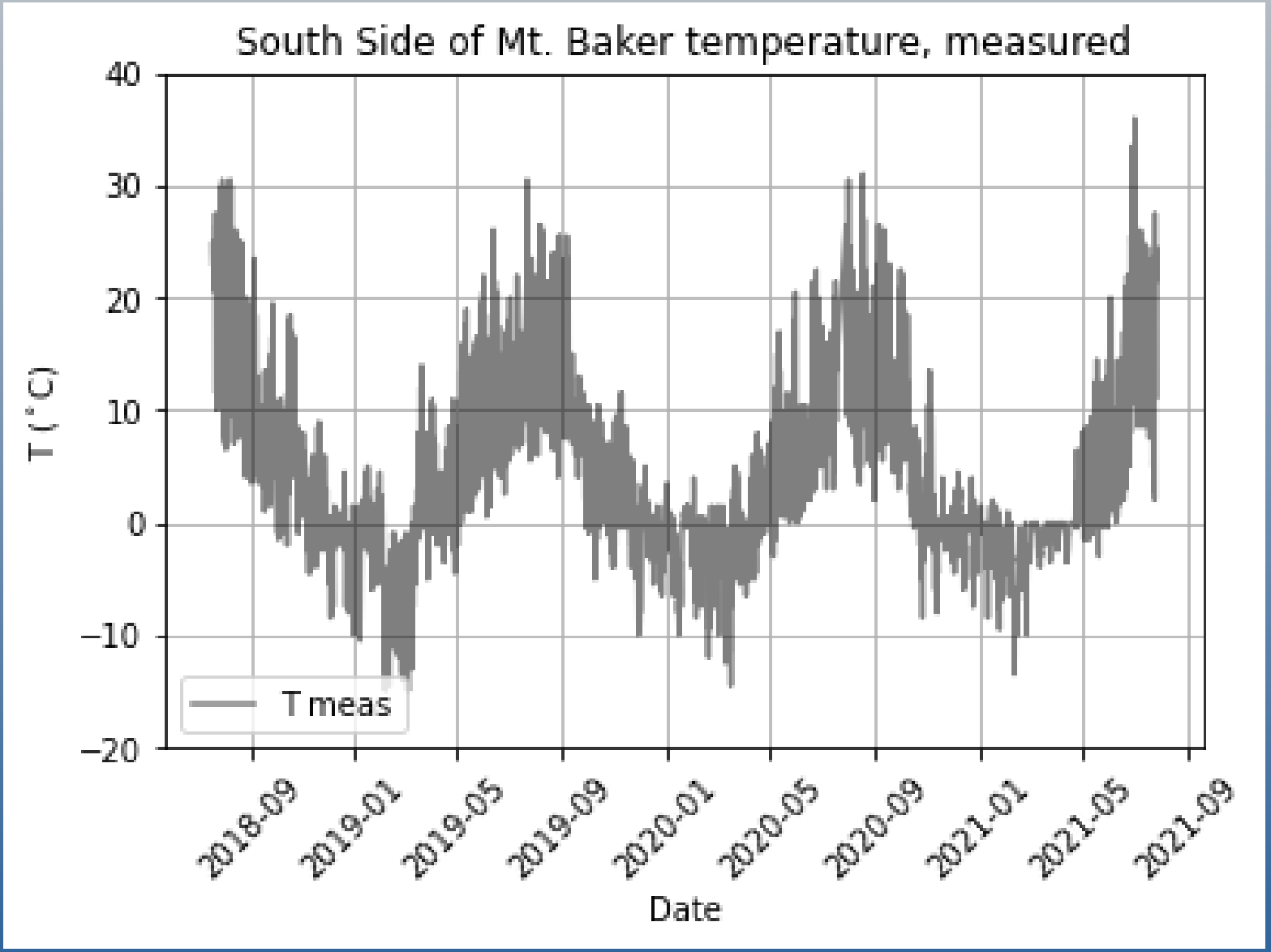




Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.



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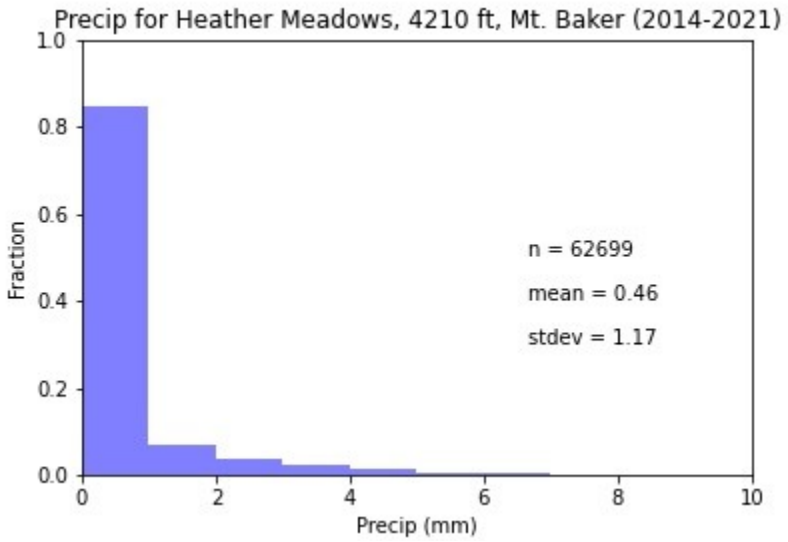

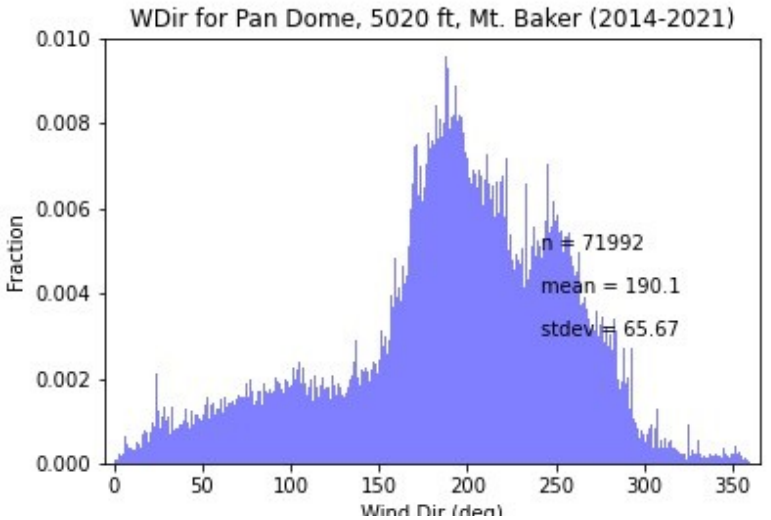

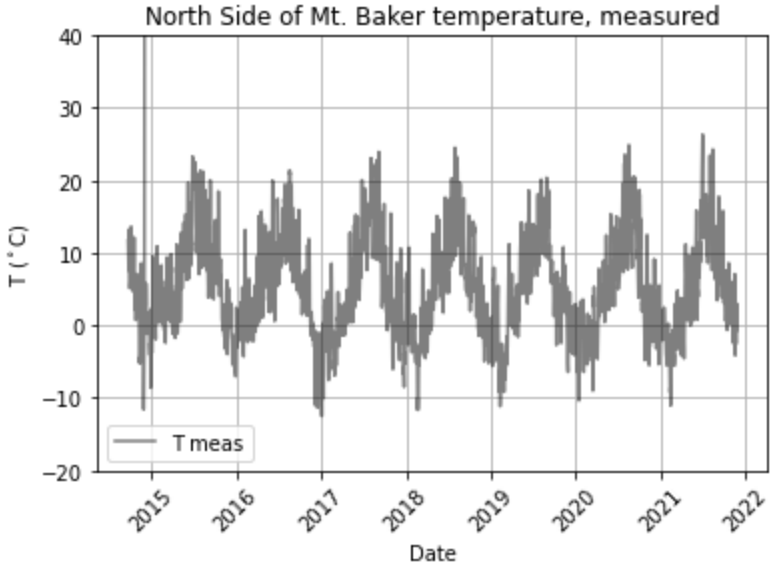

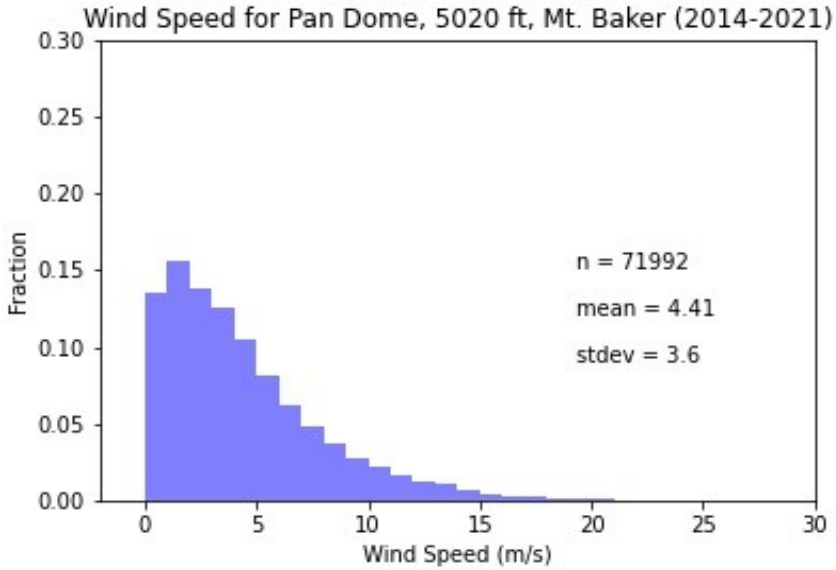

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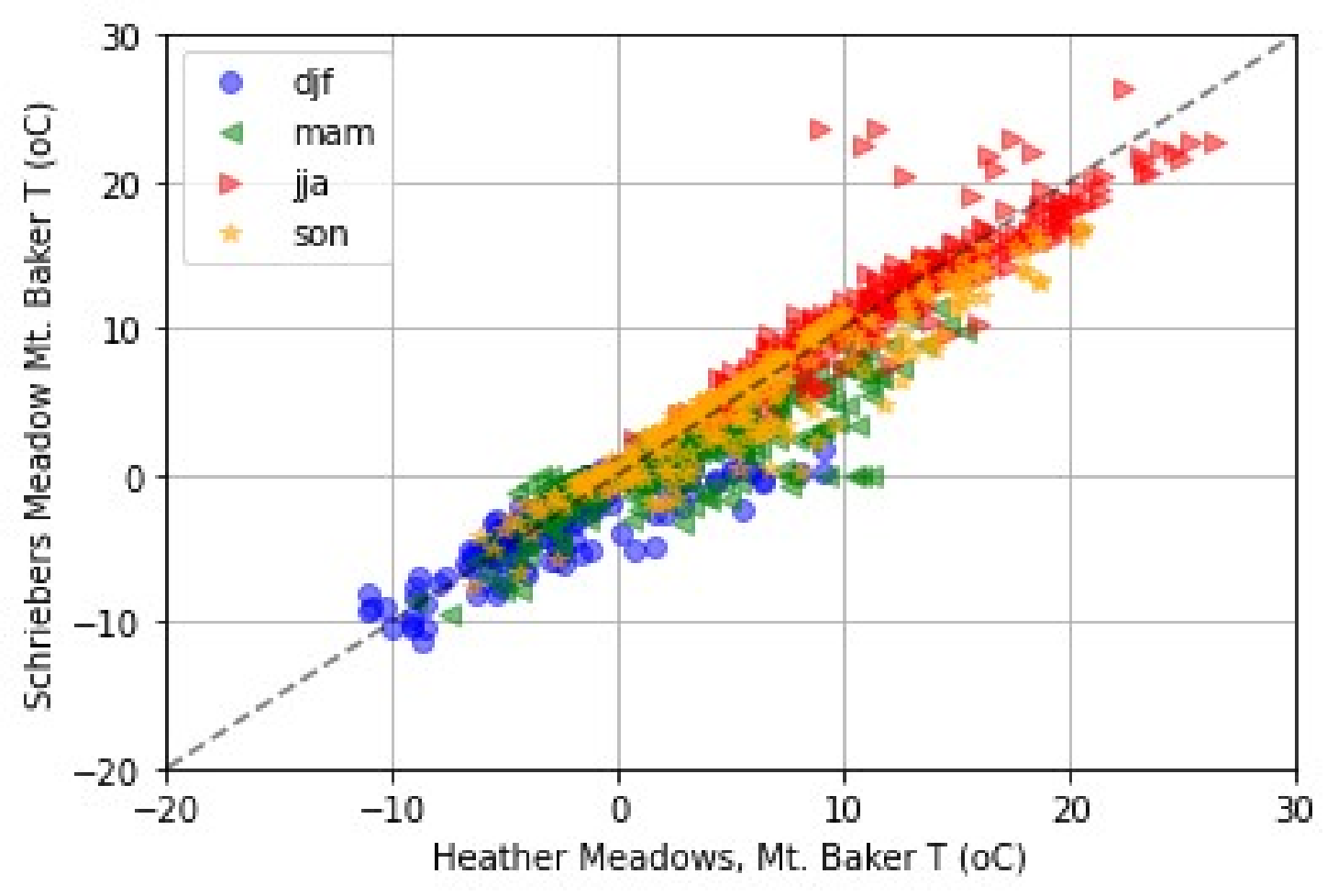
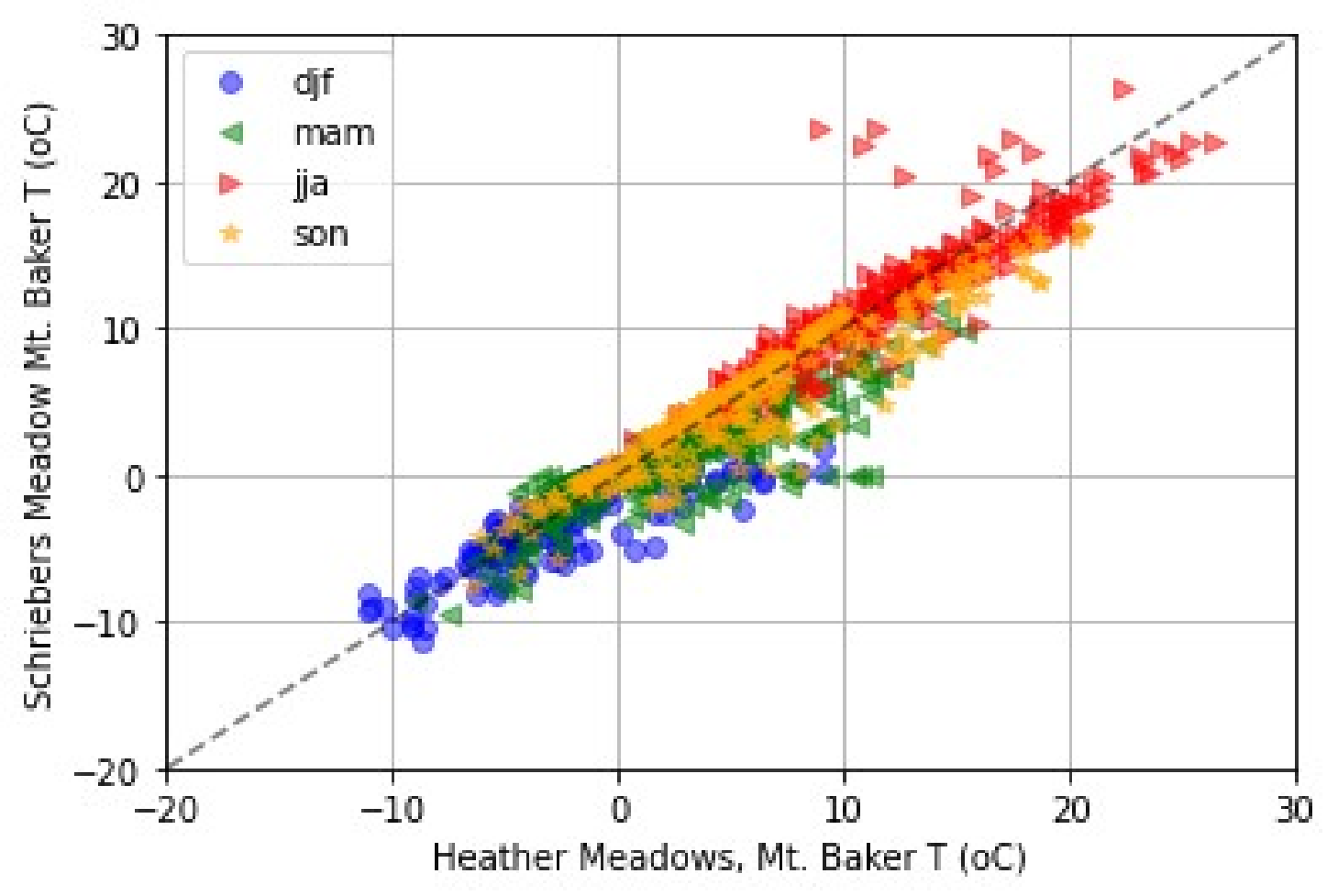


Regression of air temperature from north side of Mt. Baker,
R2 = 0.78, elevation = 1300 m, composited by season here (also precip rate)

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

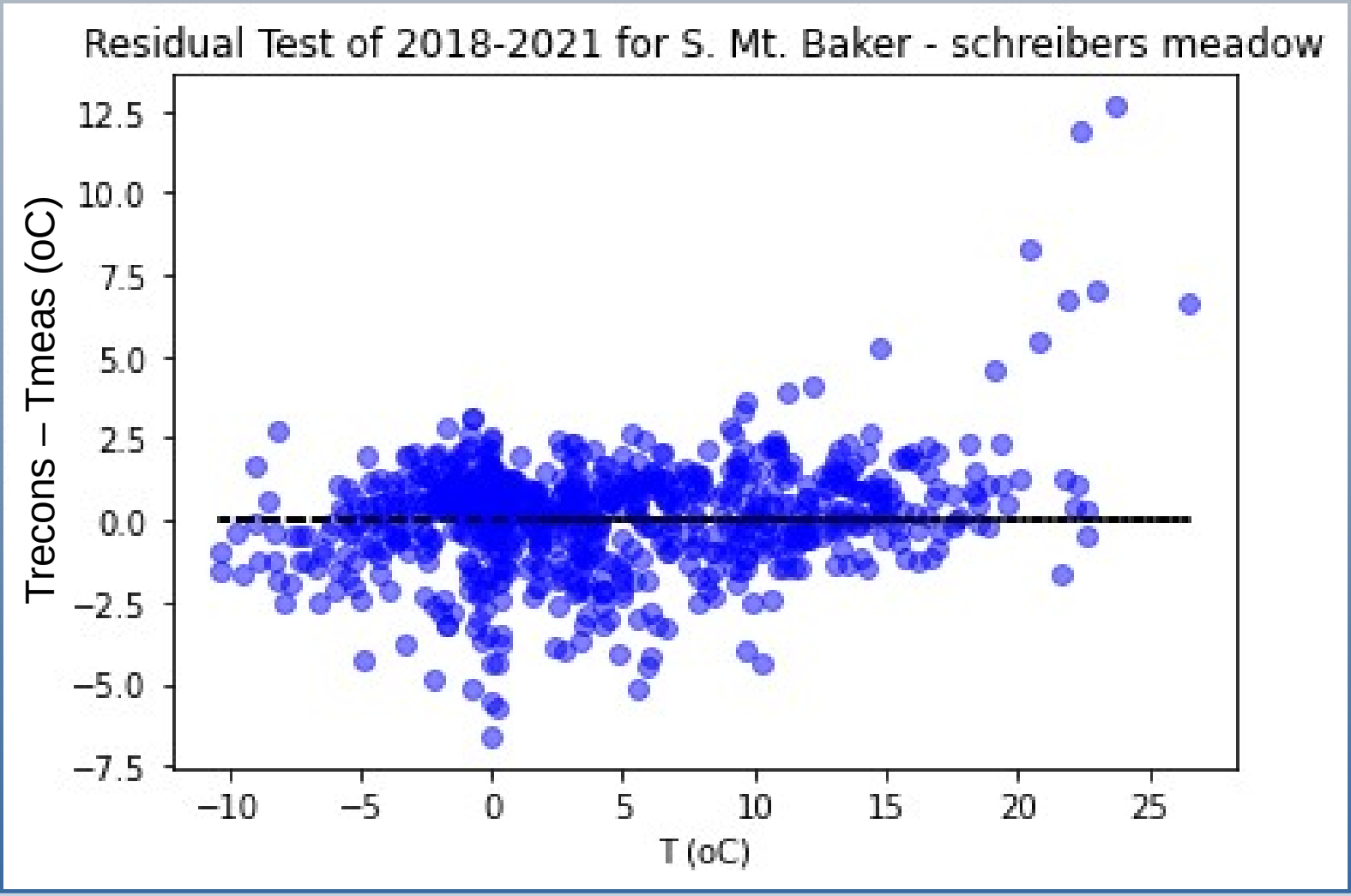


Precip class
heavy rain
(> 7.5 mm/hr)
moderate rain
(2.5-7.5 mm/hr)
light rain
(1-2.5 mm/hr)
drizzle
(0-1 mm/hr)
no rain
(0 mm/hr)

Ws/wdir
No skill in improving the regression

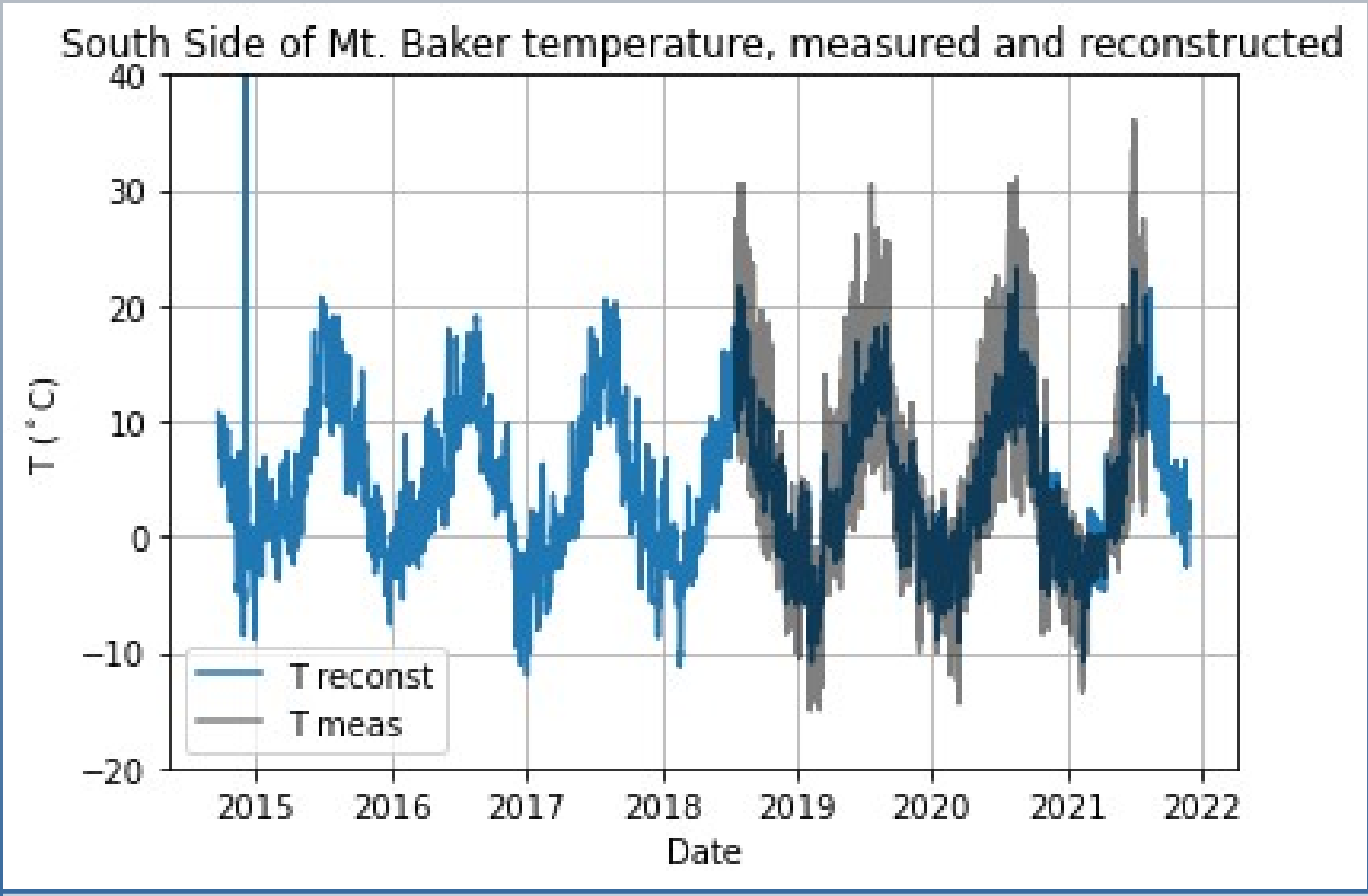
Regression of air temperature from north side of Mt. Baker,
R2 = 0.933, elevation = 1300 m, composited by season here (also precip rate)

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.



Residual test shows minimal pattern between main feature variable and result

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.



Temperature reconstructed using ML model of air temperature and precip rate from north side of Mt. Baker. Extended time series by ~4 years.

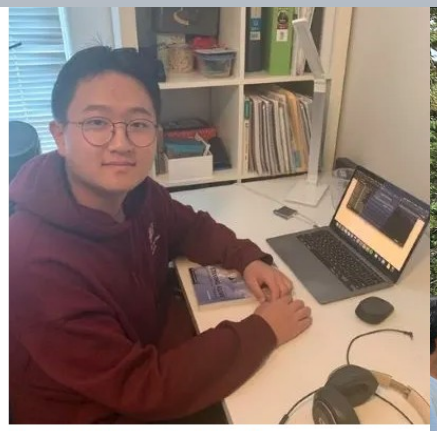
Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

Conclusions (education):

A stable environmental measurement program (MBCP) developed in collaboration with an outdoor program

Measurement program is symbiotic with ‘regular season’ and summer time education programs.

This is a potentially viable model for other geoscience goals.



A mountain is a pile of rocks

JUL 26 2021

by Sol P.

This was it. I was given past student’s work on th
Research Forecasting (WRF) model. The SNOW

LSRI: Hand-me-down data

JUL 20 2020

by Zelia E. ’21

LSRI: Determining snow depth from autonomous temperature sensor arrays on Mount Baker

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

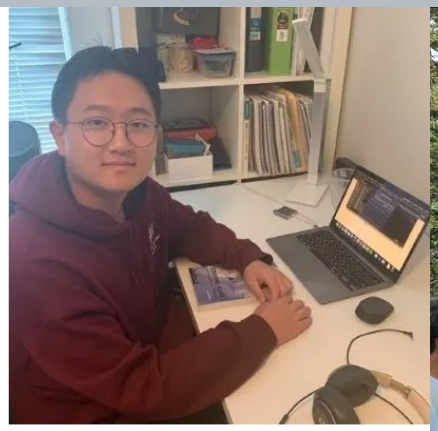
Conclusions (science):

In 2018-2019, the southern side of Mt. Baker seemed to melt out all at once.

There is a strong correlation of mean daily temperature across Mt. Baker.

Multiple linear regressions with temperature, season, and precip (but not wind speed/dir) yield an extended temperature time series for Schriebers Meadow (2018-2021 → 2014-2022)

Extended time series loses some variability information.



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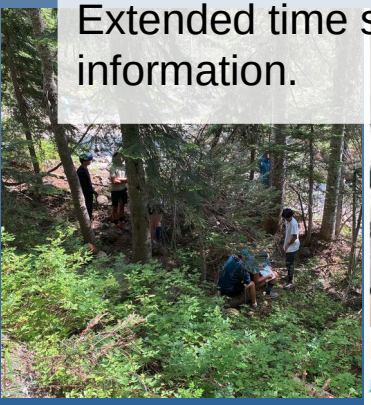

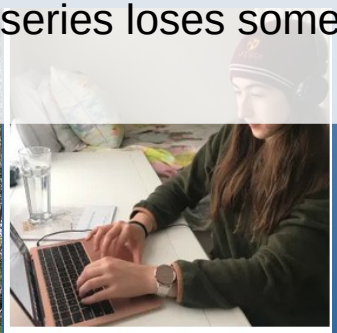

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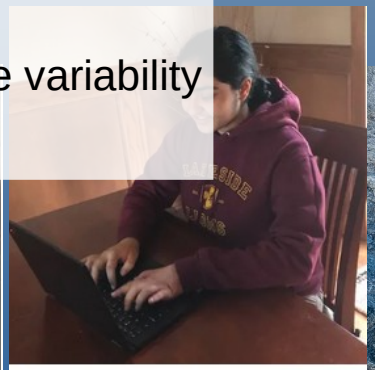

LSRI: Determining snow depth from autonomous temperature sensor arrays on Mount Baker

Air temperature and snow extent from iButton temperature measurements on the southern aspect of Mt. Baker, WA USA.

Future work:

MBCP data collection

Retrieve sensors from the crater rim and summit.
Collect on snow height from Schrieber's Meadow

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- Snow extent as a function of altitude
- Lapse rate
- Insolation
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Model evaluation (WRF/ERA5, WRF-forced-SNOWPACK)
Comparison to other field sensors (e.g. fiber optic cables from Lipovsky group at UW)

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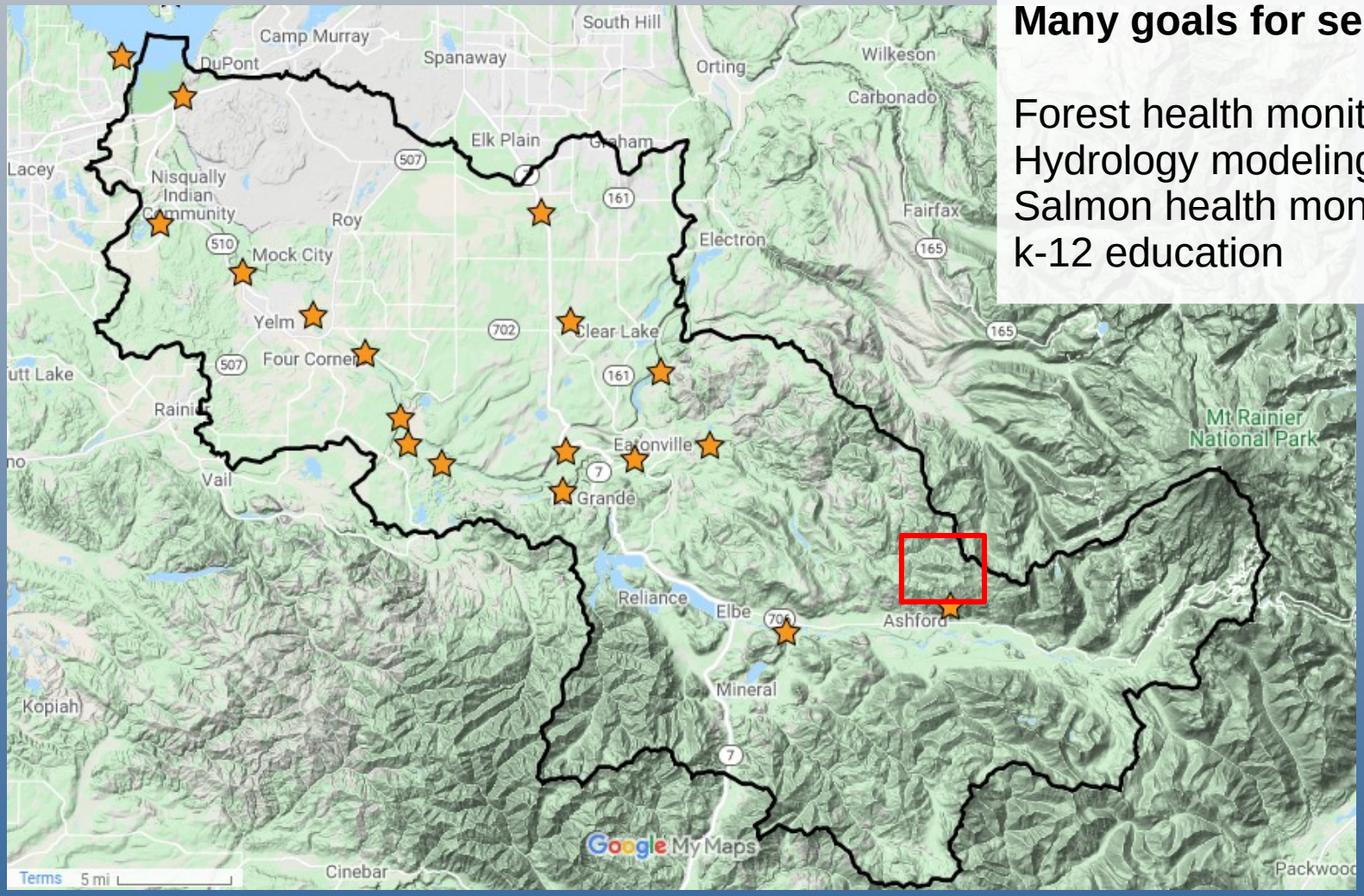
Other ways forward

Extend model to the Nisqually Community Forest

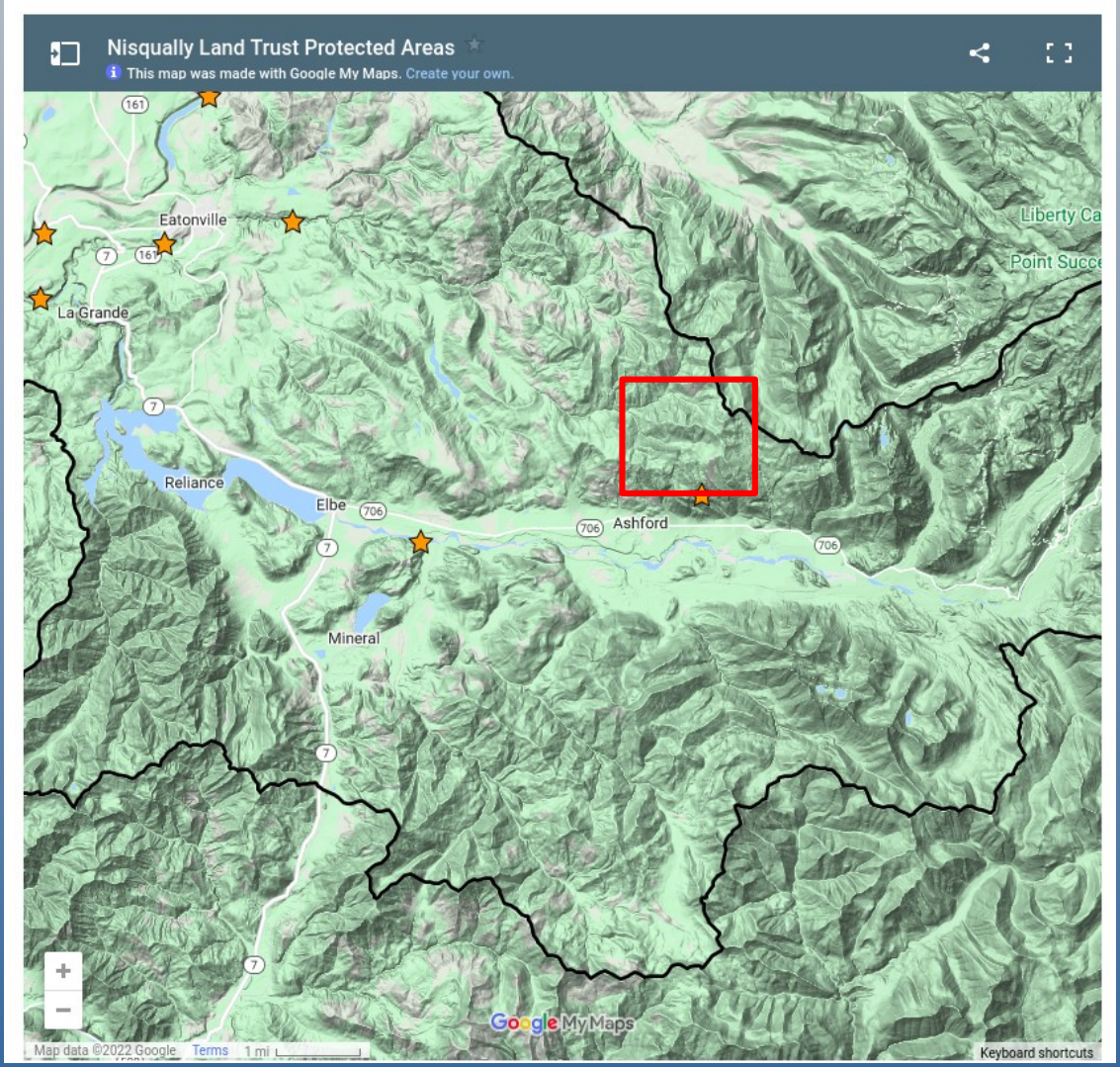
Proposed sensor array deployment locations in the Nisqually Community Forest



Many goals for sensors

Forest health monitoring
Hydrology modeling
Salmon health monitoring
k-12 education

Proposed sensor array deployment locations in the Nisqually Community Forest



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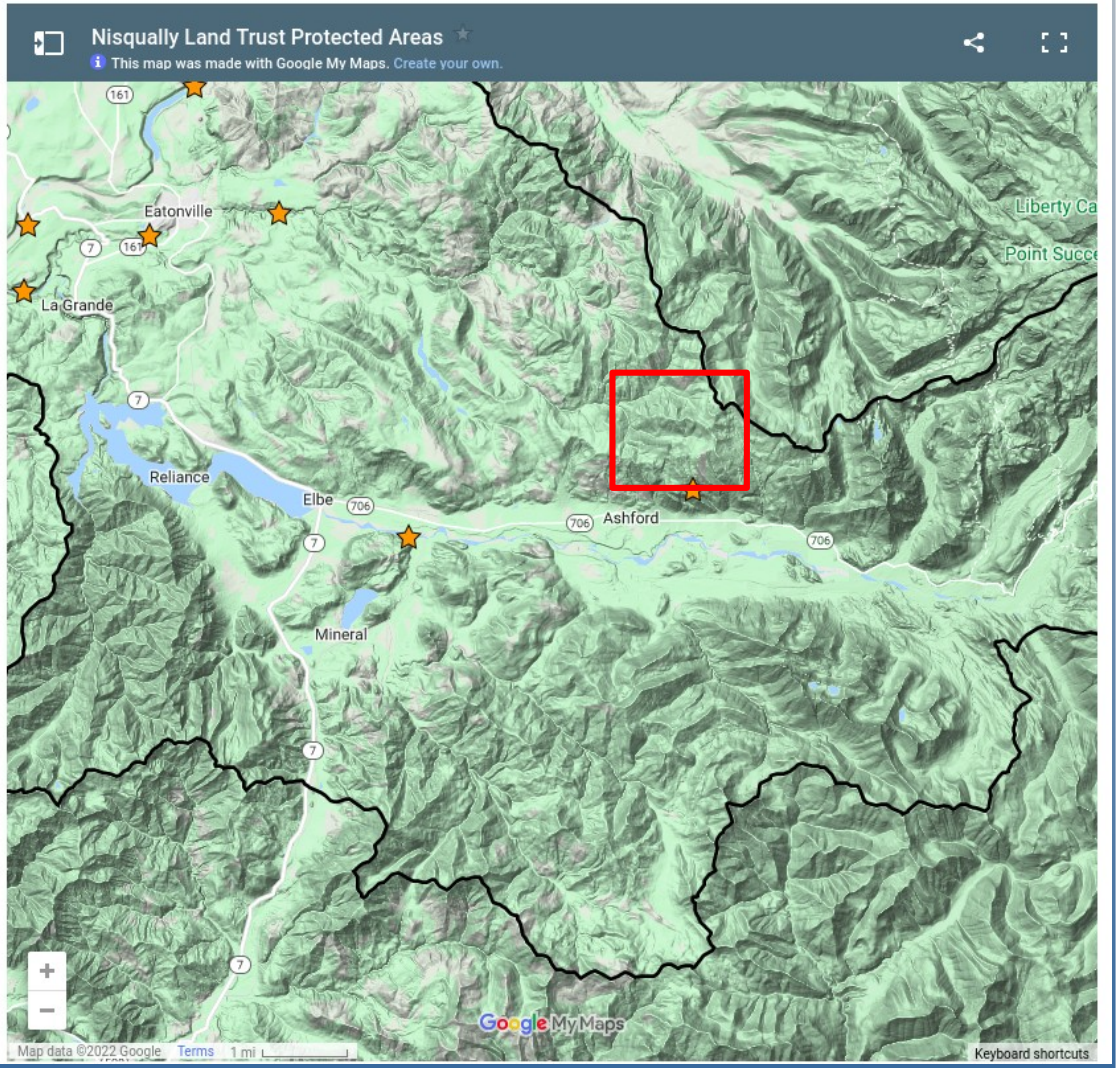


Propose to access area
just north of Ashford (red box)

Potentially install at 15 sites

1 snow gap array
- 9 sensors along a post

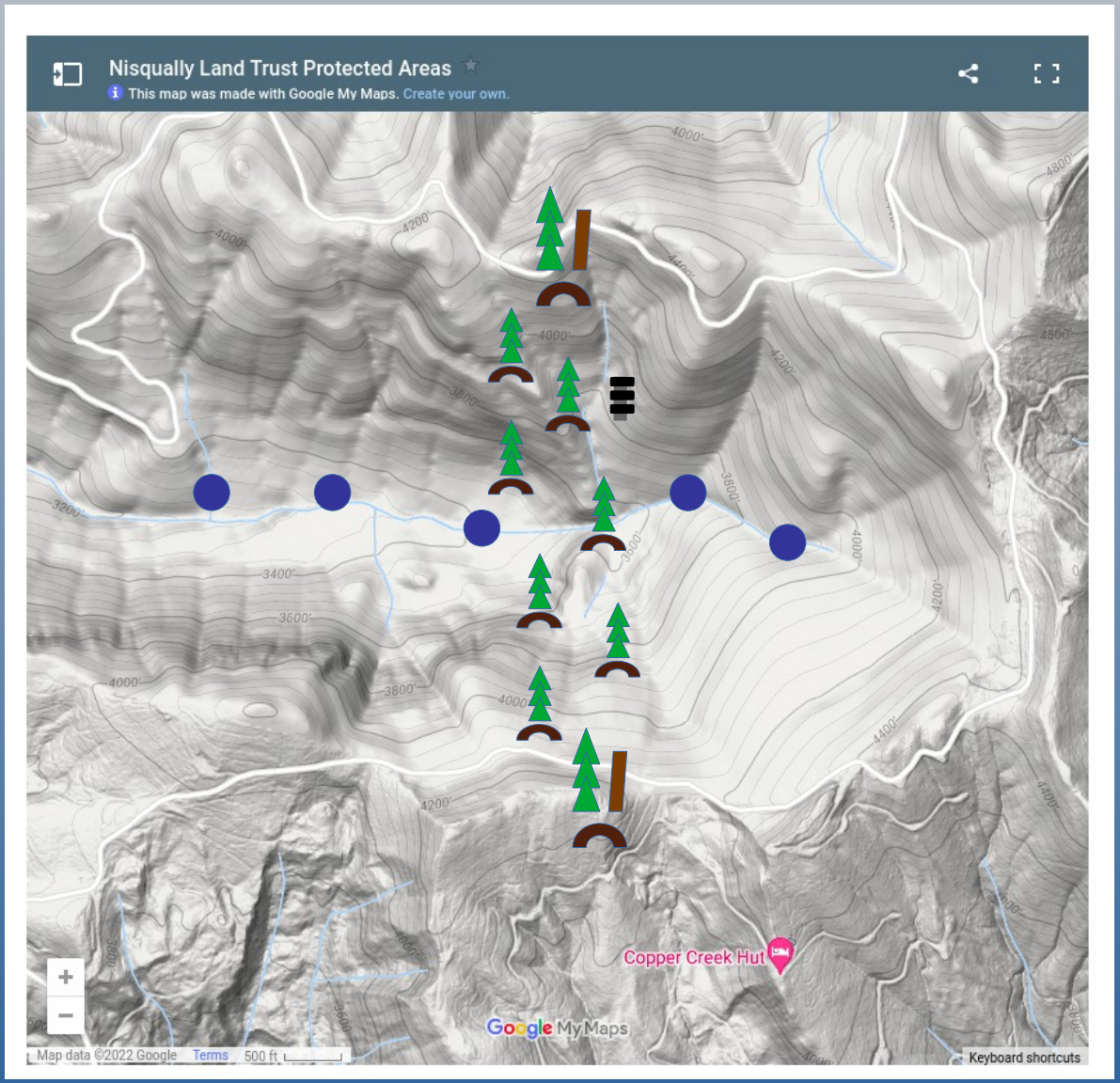
2 ‘ridge’ arrays
- 4 sensors/each
- 2 exposed, 1 shaded, 1 buried

7 ‘slope’ arrays
- 2 sensors/each
- 1 shaded, 1 buried

5 ‘submerged’ arrays
- 1 sensor/each
- submerged in waterway

36 sensors total

Proposed sensor array deployment locations in the Nisqually Community Forest



Snow gap sensors

Shaded sensor

Exposed sensor

Buried sensor

Submerged sensor

1 snow gap array
(9 sensors)

2 ‘ridge’ arrays
(4 sensors/each)

7 ‘slope’ arrays
(2 sensors/each)

5 ‘submerged’ arrays
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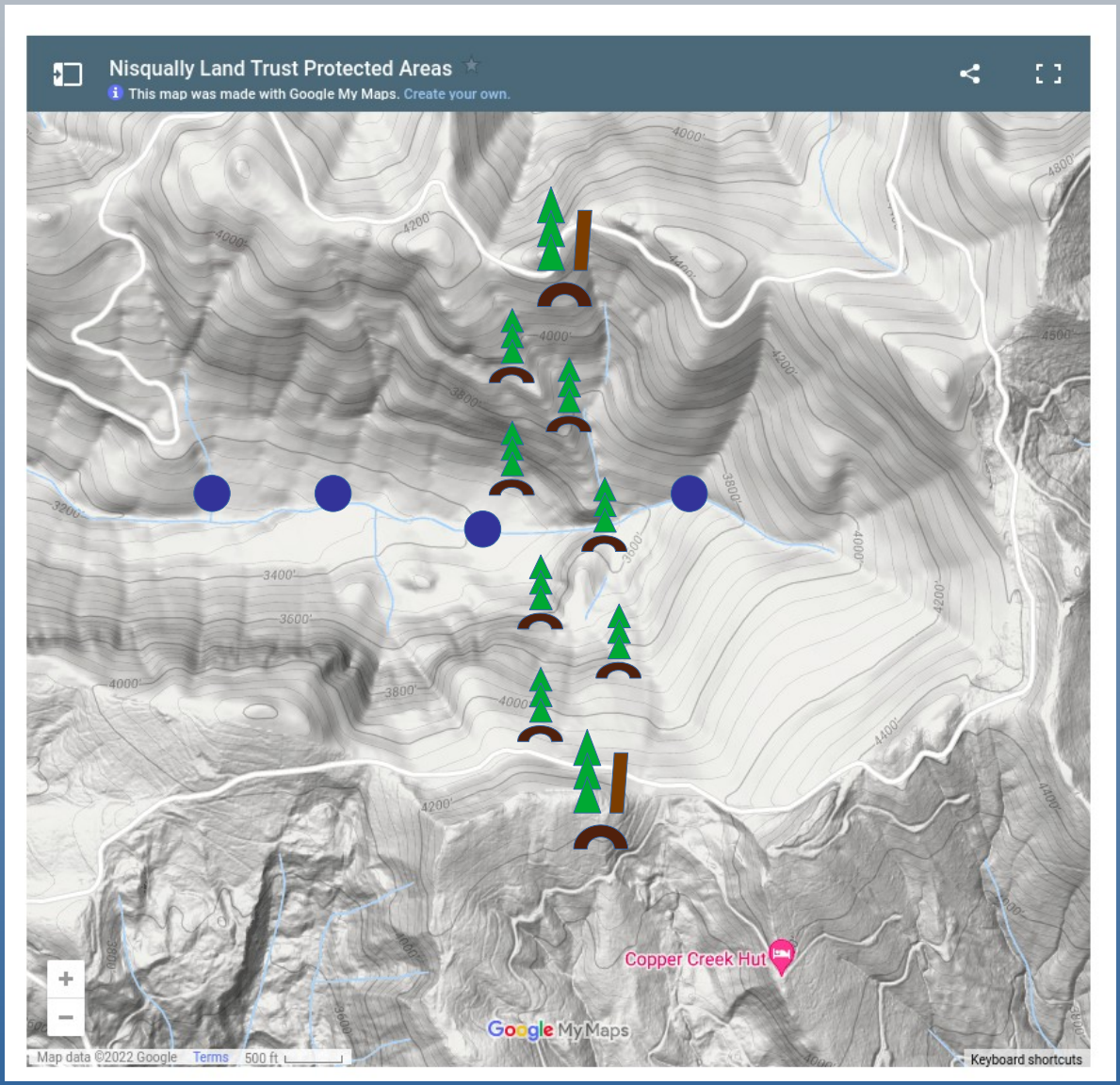
36 sensors total

Proposed sensor array deployment locations in the Nisqually Community Forest



Shaded sensor

Exposed sensor

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Many goals for sensors

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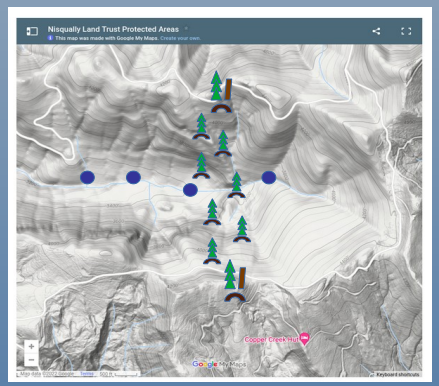
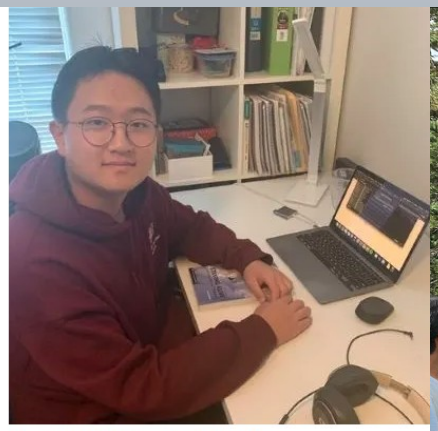
Questions?
Criticisms?
Ideas?
Partnerships?





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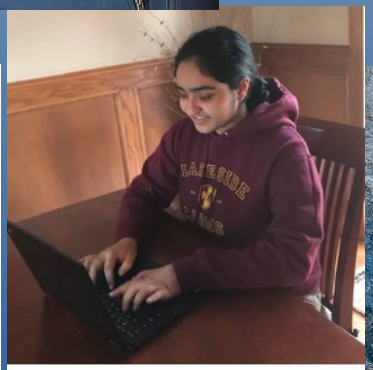

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