GLACIER

# Withdrawal of Alaskan Glaciers

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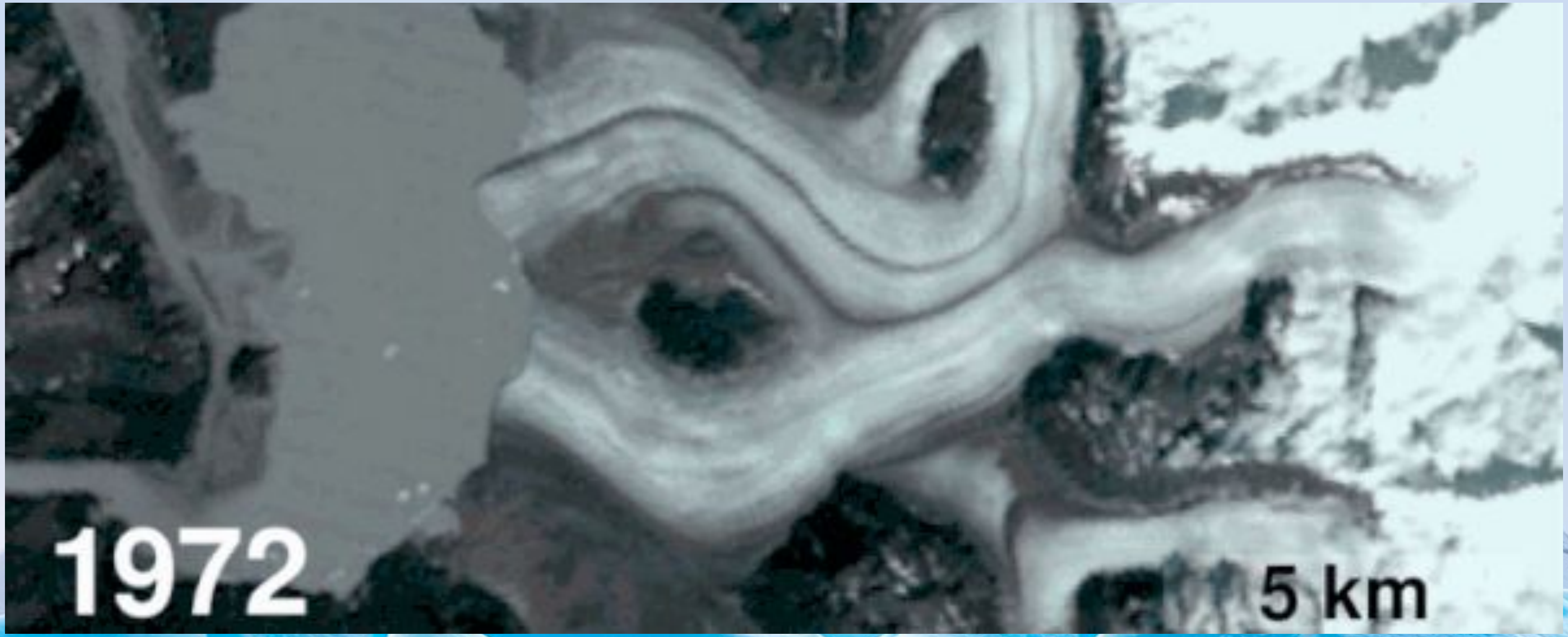
# Intro – Background

This project aims to provide input for evaluating areas climate change mitigation measures would be needed. Specifically, analyzing the ablation of glaciers in Alaska and the rate at which they deteriorate and the factors that contribute.



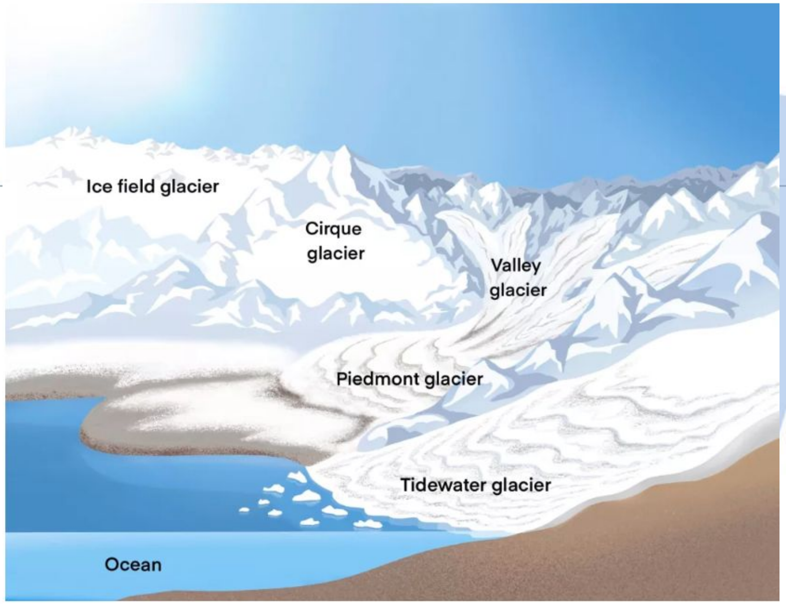

Alsek Glacier, Alaska

1972 - 2019 (NASA's Goddard Space Flight Center/Mark Fahnestock/University of Alaska Fairbanks)

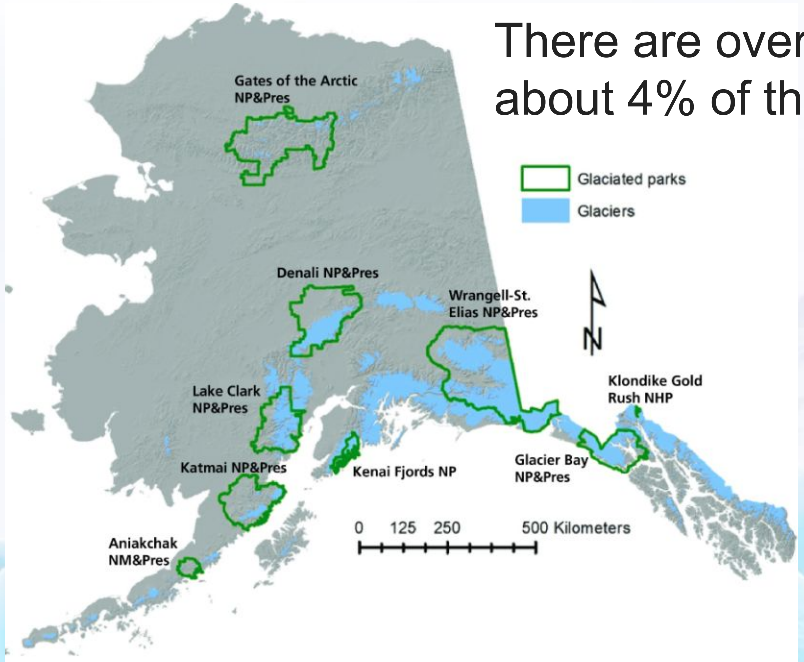
# Science of glaciers

Glaciers are formed by centuries of snow accumulation. As the snow compacts, air is squeezed out and glacial ice forms. These “rivers of ice” slowly flow downslope. Geographic location, temperature, and precipitation are the primary components of how glaciers form and why they change. To form, the temperature needs to be cold enough that snow accumulates without melting. Glaciers around the world were generally much larger during the last ice age, a period that peaked about 23,000 years ago and ended more than 10,000 years ago. Since the end of the Little Ice Age (about 1300-1850 CE), glaciers have retreated to roughly their current locations.

Types of glaciers




*This graphic shows some different types of glaciers. — Credit: PeakVisor*




There are over 19,400 glaciers in Alaska covering approximately 23,000 square miles, or about 4% of the state’s total land area.

The effects of climate change are felt more in high-latitude regions like Alaska than in most other regions of the world. Over a 50-year interval—between the 1950s and early 2000s—glaciers within Alaska national parks shrank by 8%. From 1985 to 2020, glacier-covered area in Alaska decreased by 13%, indicating that the rate of glacier loss accelerated in recent decades. Climate change is not the only thing that contributes to the speed of ablation.

Natural Resource Condition Assessment Program Inventory & Monitoring Division. (2023, April 12). *Alaska’s Shrinking Glaciers*. National Park Service .

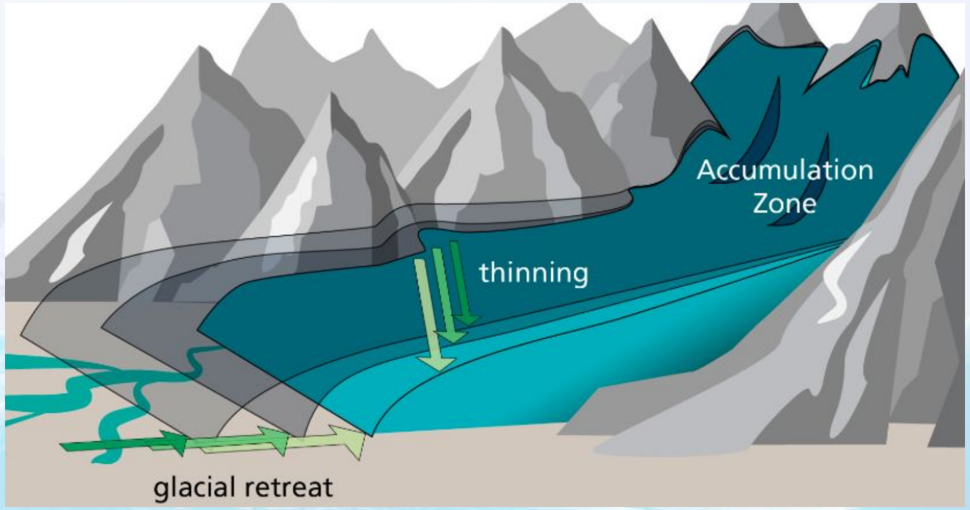
# What causes glacier ablation

Ablation is the term used in reference to the loss of ice and snow from a glacier through processes like melting, sublimation, calving (breaking off of ice chunks), and wind transportation; essentially, when a glacier loses more ice than it gains through snowfall, it is considered to be deteriorating.

*Icebergs float from the calving Mendenhall glacier, which originates in Alaska's Coast Range. The glacier velocity dataset reveals that about 40 percent (approximately 20 cubic km) of ice lost annually in Alaska is due to calving alone, mostly from a few coastal glaciers. © UAF*

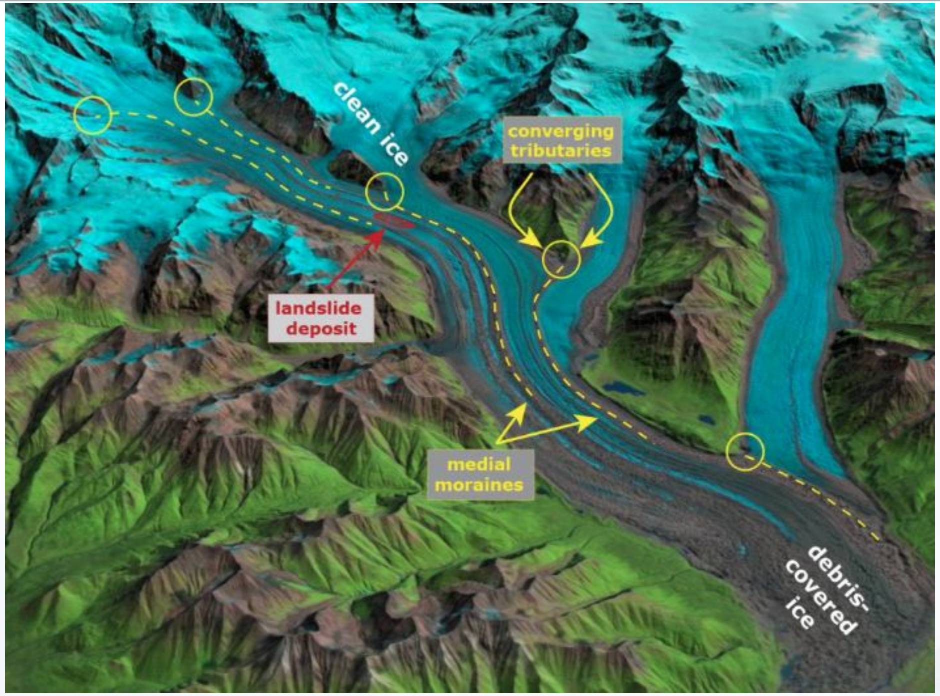
**Calving:** When large chunks of ice break off from the end of a glacier, forming icebergs.
**Retreat:** When the edge of a glacier moves backwards due to melting or calving, indicating a loss of glacial mass.

**Downwasting:** term referring to the vertical loss of ice from a glacier due to melting.
**Accumulation zone:** The higher part of a glacier where snowfall accumulates.
**Ablation zone:** The lower part of a glacier where melting and ice loss occur.



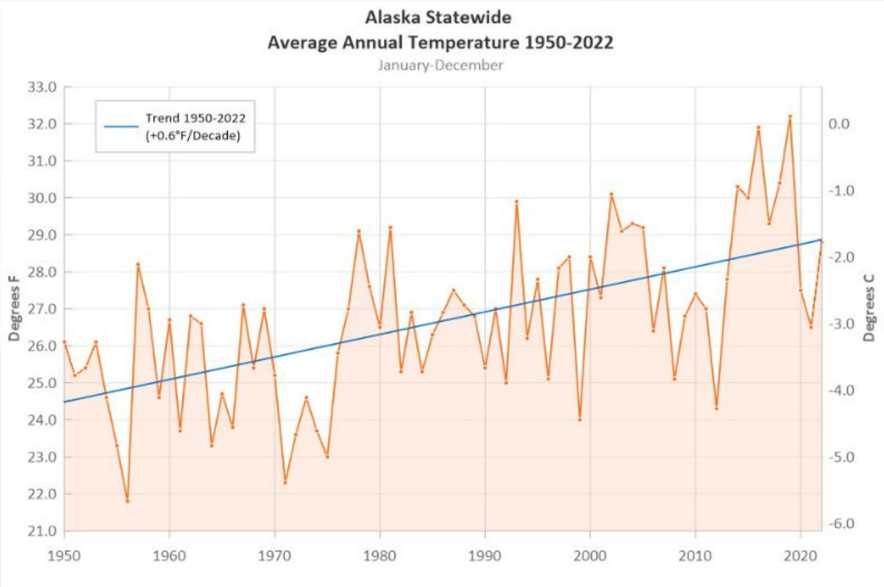

Burgess et al. (2013). *Glacier Speed*. Alaska Satellite Facility. https://asf.alaska.edu/datasets/daac/glacier-speed/

# Temperatures and Debris Impacts Glacier Change



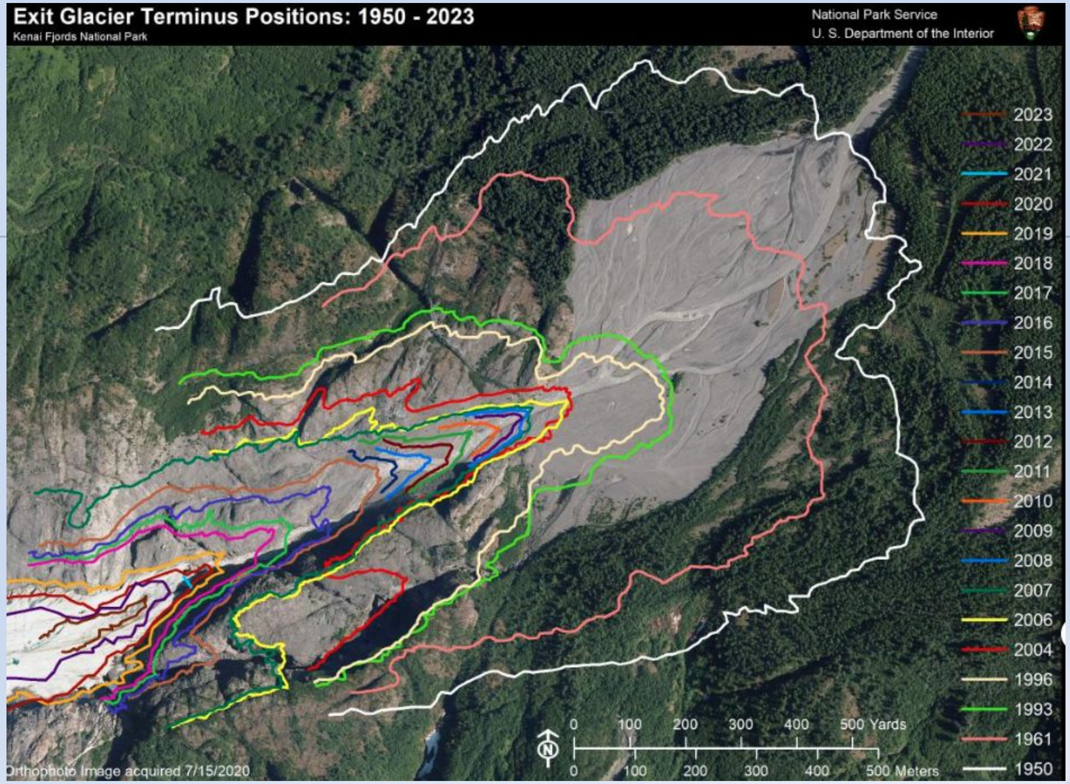

Glaciers erode and transport huge amounts of rocky debris as they grind their way through mountain slopes. Lateral moraines are crested piles of glacially transported rock and debris deposited along the glacier edges as it flows. Medial moraines form where two glaciers flow together. They consist of rock that has fallen from the mountain walls onto the glacier or exposed rock entrained into the ice.

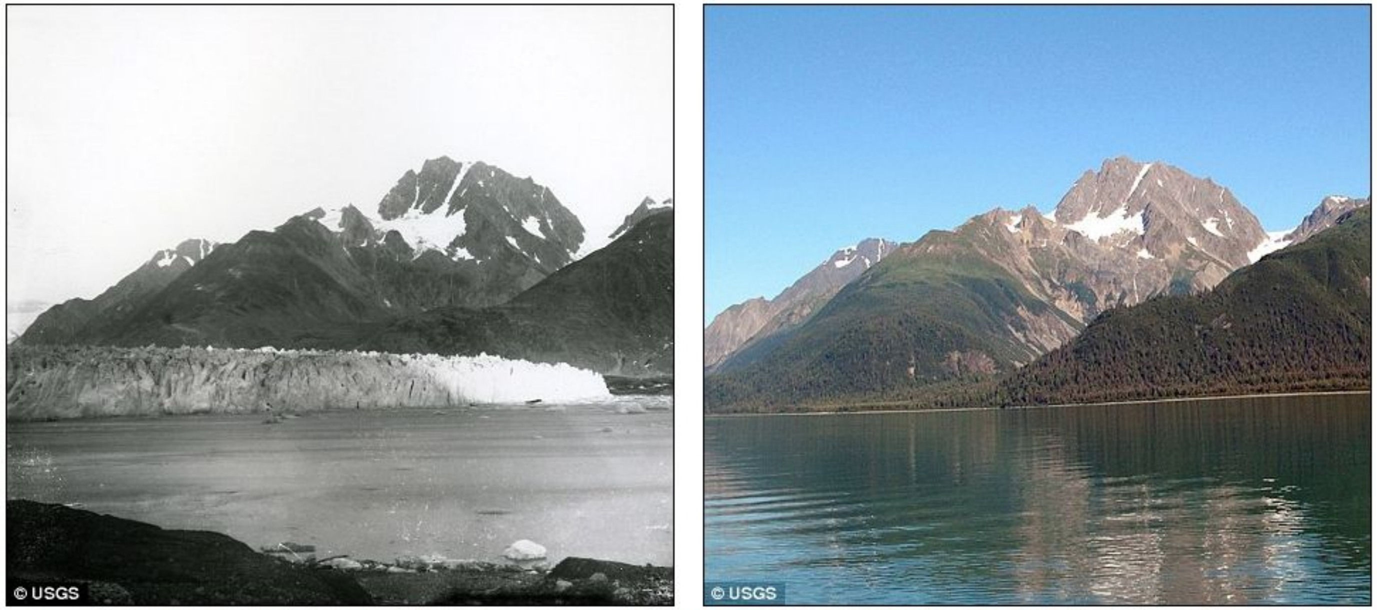
Supraglacial debris is all the rock, soil, volcanic material, and any other material on the top of a glacier. Most of the debris comes from medial moraines, rockfall, avalanches, and years of dust deposited on the surface. Supraglacial debris has increased across the glaciers in southern Alaska by 64% between 1985 and 2020, an area of over 1,000 square miles.



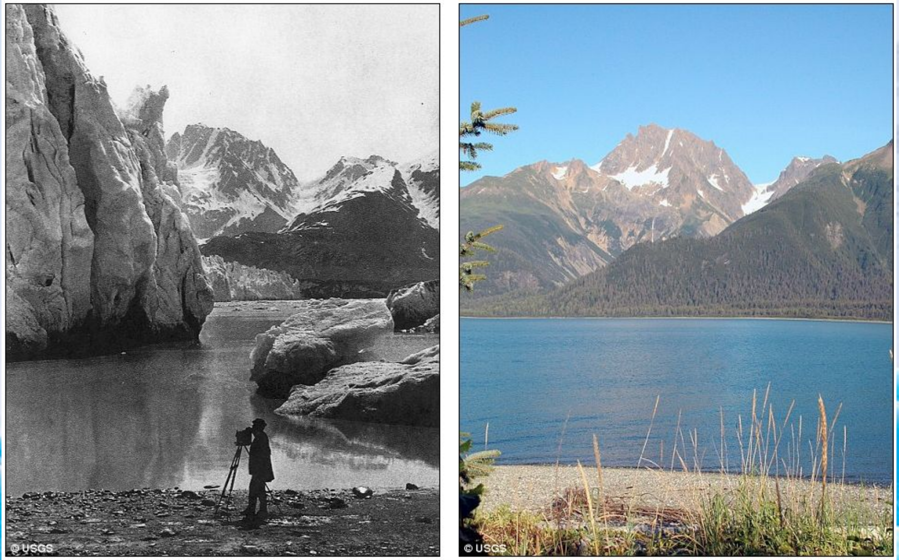

Alaska's statewide average annual temperature has been increasing by 0.6°F/decade since 1950.

Darkening of the glacier surface with very thin layers of debris, volcanic ash, dust, and algae increases glacier melt rates by increasing absorption of solar radiation. Thin layers of supraglacial debris warm the glacier surface, melting the ice, and make snow accumulation on top more difficult. In contrast, thicker layers of supraglacial debris, as little as an inch, can insulate underlying glacier ice from solar radiation and slow the melt rate.

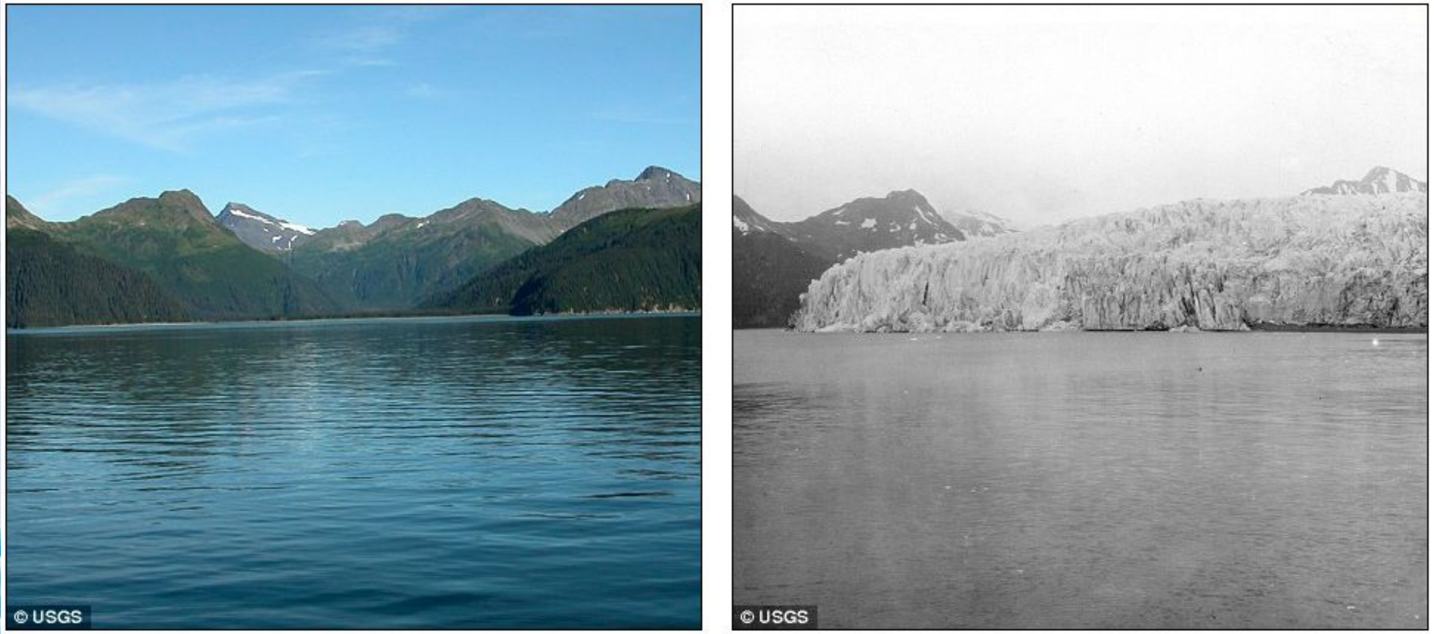



Muir Glacier: A dramatic reduction in glacial ice can be shown from 1899 (left) to 2003 (right)




Muir: A vast amount of glacial ice present in the 1890's (left) has simply vanished by 2005 (right)

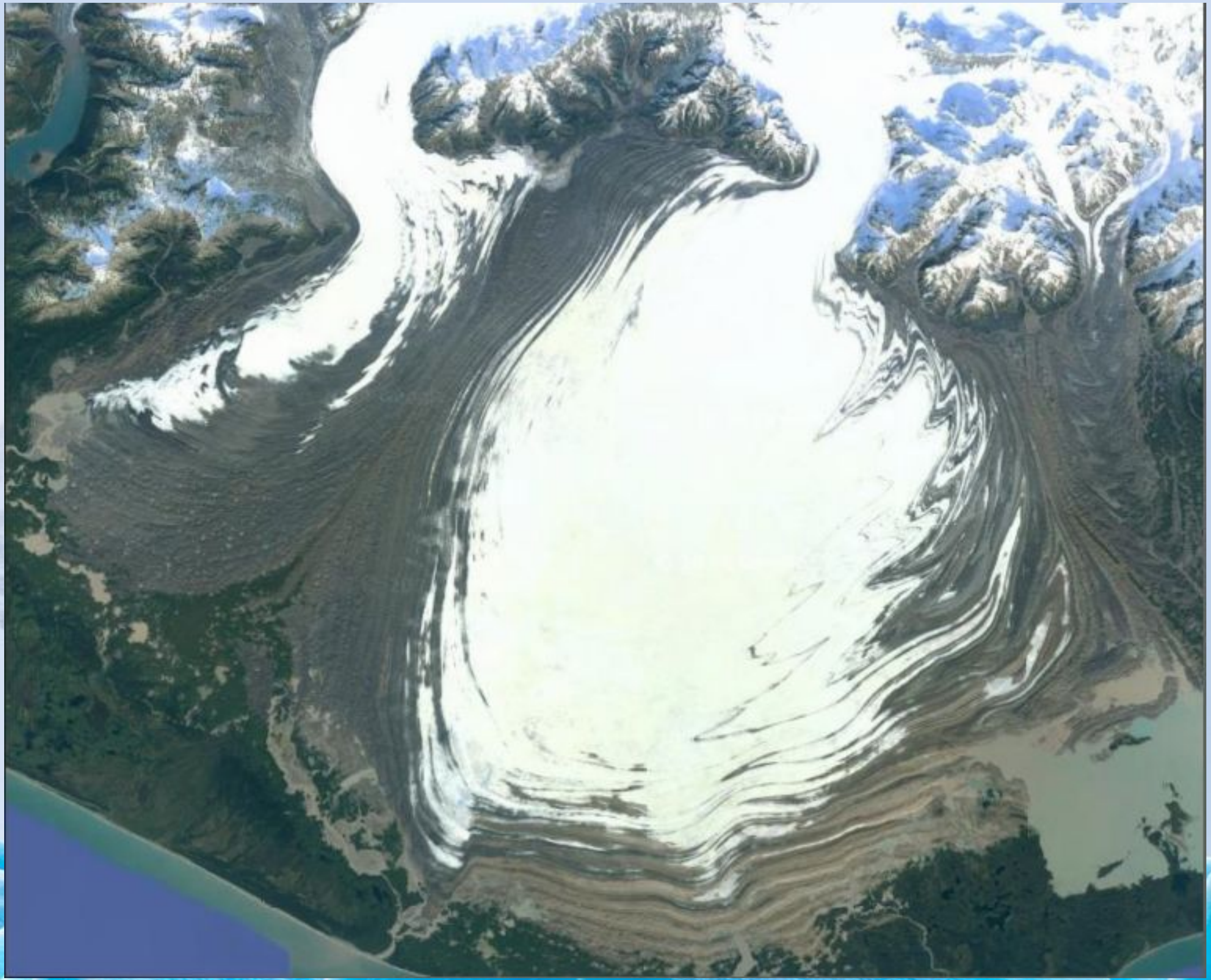



Now you see them, then you don't: The McCarty glacier has completely retreated by 2004 (left), but completely obscured these mountains in 1909 (right)

# Visit to NSIDC

- Bruce Raup & Mark Serreze
- GLIMS & QGIS
- Future of Machine Learning

Bruce Raup, Manager, Global Land Ice Measurements from Space (GLIMS) and our very own Adam Raffel
Met in Boulder, CO on 12/23/2024



# Data Collection

National Snow and Ice Data Center
a part of CIRES at the University of Colorado Boulder

```
import pandas as pd
csv_file_path = 'AK_1985_to_2000_overall_glacier_covered_area.csv'
df = pd.read_csv(csv_file_path)
print(df.head())
         RGIId        GLIMSId  BgnDate  EndDate   CenLon  CenLat  \
0  RGI60-01.00002  G213332E63404N  20090703 -9999999 -146.668  63.404
1  RGI60-01.00003  G213920E63376N  20090703 -9999999 -146.080  63.376
2  RGI60-01.00004  G213880E63381N  20090703 -9999999 -146.120  63.381
3  RGI60-01.00005  G212943E63551N  20090703 -9999999 -147.057  63.551
4  RGI60-01.00006  G213756E63571N  20090703 -9999999 -146.244  63.571

   O1Region  O2Region    Area  Zmin  ...   Lmax  Status  Connect  Form  \
0         1         2   0.558  1713  ...   1197       0        0     0
1         1         2   1.685  1609  ...   2106       0        0     0
2         1         2   3.681  1273  ...   4175       0        0     0
3         1         2   2.573  1494  ...   2981       0        0     0
4         1         2  10.470  1201  ...  10518       0        0     0

   TermType  Surging  Linkages  Name  GN_area  GN_comp_ye
0         0        9         9   NaN   0.5922        2000
1         0        9         9   NaN   1.8045        2000
2         0        9         9   NaN   3.6765        2000
3         0        9         9   NaN   2.6064        2000
4         0        9         9   NaN   7.7220        2000

[5 rows x 24 columns]
```

```
raw_df.shape
```

```
(287327, 24)
```

Data Storage
- Hosted in pgAdmin

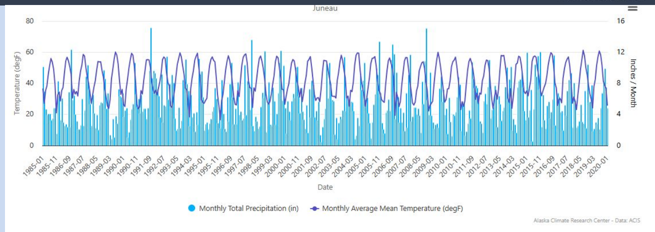
Datasize issues
- Git LFS

Glacial Data
- "Glacier Covered Area for the State of Alaska, 1985–2020" (Dataset ID: G10040) dataset created by the National Snow and Ice Data Center (NSIDC)
- 287k by 24
- Paired to 8

Box-Whisker plots
- Area, Height, Length
- High number of outliers; required normalization

Alaska Climate Research Center
*The Alaska State Climate Center*

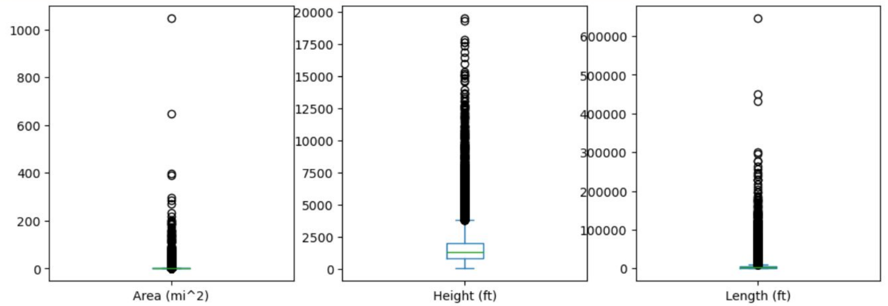
UNIVERSITY OF ALASKA FAIRBANKS



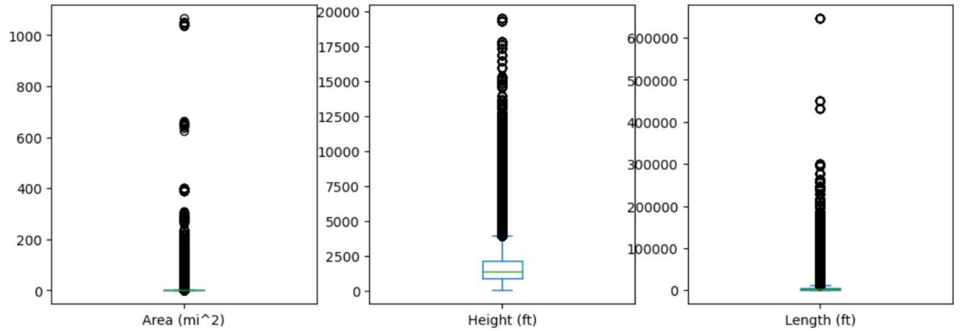

| Date | Monthly Total Precipitation (in) | Monthly Average Mean Temperature (degF) |
|---|---|---|
| 1985-01 | 10.13 | 36.37 |
| 1985-02 | 7 | 27.05 |
| 1985-03 | 4.67 | 35.31 |

Weather Data
- ERA5 Reanalysis
  - ECCodes
  - Filesize
- Open Weather Map API
  - Current Weather Only
- Alaska climate research center (ACRC) of the Alaska State Climate Center at the University of Alaska Fairbanks

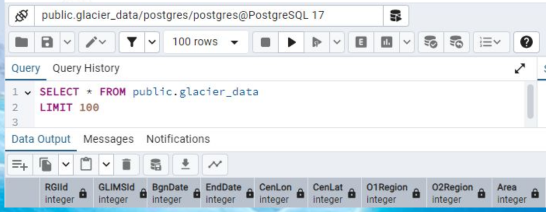
```
[24]: grouped_box = glaciers.groupby(glaciers["Id"]).mean()
      grouped_box_p = grouped_box[["Area (mi^2)", "Height (ft)","Length (ft)"]]
      grouped_box_p.plot.box(subplots=True, layout=(1, 3), figsize=(12, 4))
      plt.show()
```




```
[21]: box_p = glaciers[["Area (mi^2)", "Height (ft)","Length (ft)"]]
      box_p.plot.box(subplots=True, layout=(1, 3), figsize=(12, 4))
      plt.show()
```

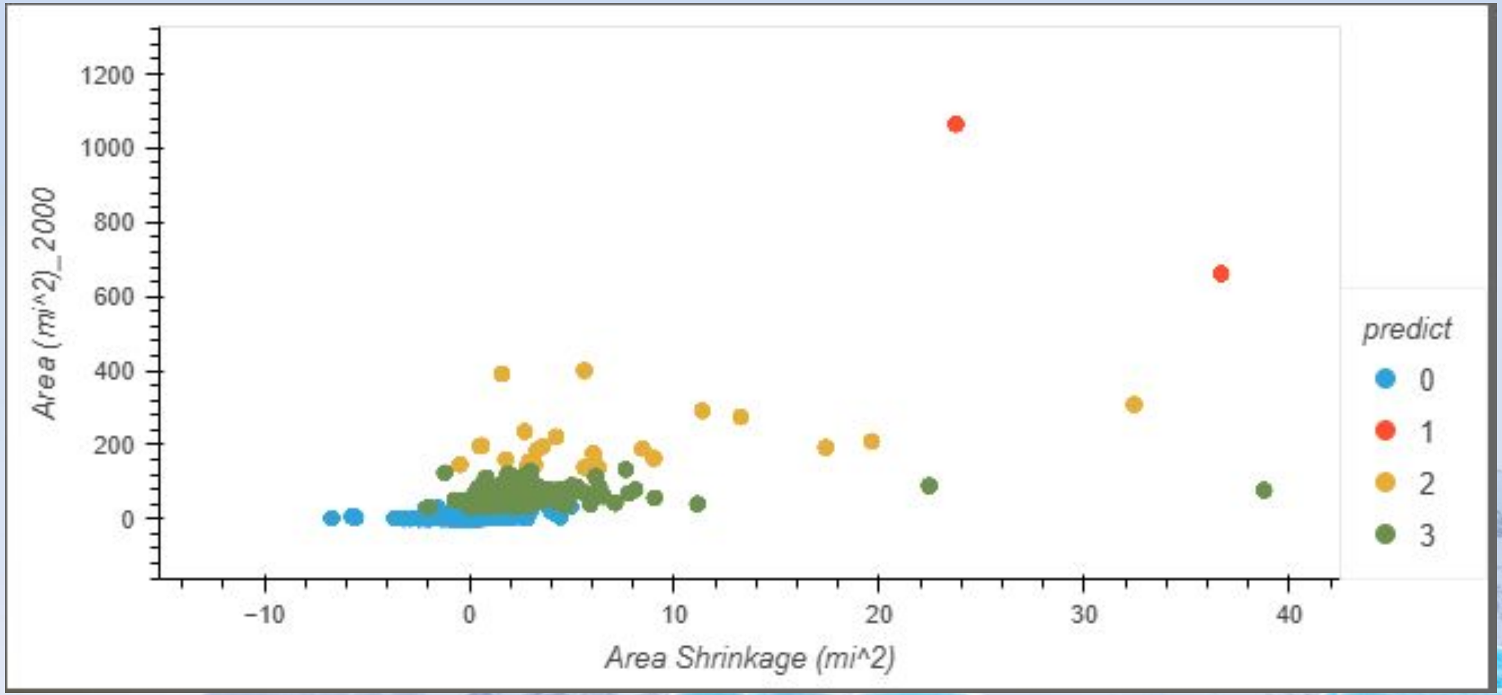



pgAdmin
Management Tools for PostgreSQL



# Building AI model - Unsupervised ML

```
Total Glaciers that Shrunk between 1985 and 2020: 11652.
Total Glaciers that Didnt Shrink between 1985 and 2020: 2134.
Total Percentage of Glaciers that Shrunk between 1985 and 2020: 84.521%.
```




- Original data was a 35-year period by 2 year increments
- Led to waxing & waning values (inconsistent data)
- Comparing just the initial (1985) and final (2020) area sizes of the data sets led to more interesting results - **84% of glaciers shrunk**
- Most UML categorizing led to horizontal streaks; local temperature, precipitation, and snowfall does not appear to have a major impact on area shrinking compared to global values
- **Graph -** Shrinkage does correlate to initial area, but due to the horizontality of the data, it is clearly not the sole reason

# Building AI model - Supervised ML

```
--- --- ---    -    --- --- ---    -    --- --- ---
Confusion Matrix
```

| | Predicted 0 | Predicted 1 |
|---|---|---|
| **Actual 0** | 278 | 256 |
| **Actual 1** | 0 | 2913 |

```
--- --- ---    -    --- --- ---    -    --- --- ---
Accuracy Score: 0.9257325210327821
--- --- ---    -    --- --- ---    -    --- --- ---
Classification Report
              precision    recall  f1-score   support

       False       1.00      0.52      0.68       534
        True       0.92      1.00      0.96      2913

    accuracy                           0.93      3447
   macro avg       0.96      0.76      0.82      3447
weighted avg       0.93      0.93      0.92      3447

--- --- ---    -    --- --- ---    -    --- --- ---
```

First Model:

- 92% Accuracy
- 100% Recall for shrinking glaciers
- Only 52% Recall for non-shrinking glaciers
- This may mean that it is easier to predict a glacier shrinking but when it doesn't shrink there is not a clear answer (likely because these are anomalous)

Optimizing:

- This means the model is overfitting to the "shrinking" class
- Balanced Class Weights

Final Model:

- Accuracy loss less than 1%
- Non-Shrinking Recall increased from 0.52 to 0.99, meaning fewer False Negatives
- F1-Score for the Non-Shrinking class has increased from 0.68 to 0.79, indicating a better balance between precision and recall.
- Shrinking class performance remains very strong

```
--- --- ---    -    --- --- ---    -    --- --- ---
Confusion Matrix
```

| | Predicted 0 | Predicted 1 |
|---|---|---|
| **Actual 0** | 530 | 4 |
| **Actual 1** | 278 | 2635 |

```
--- --- ---    -    --- --- ---    -    --- --- ---
Accuracy Score: 0.918189730200174
Accuracy Score Loss: 0.007542790832608115
--- --- ---    -    --- --- ---    -    --- --- ---
Classification Report
              precision    recall  f1-score   support

       False       0.66      0.99      0.79       534
        True       1.00      0.90      0.95      2913

    accuracy                           0.92      3447
   macro avg       0.83      0.95      0.87      3447
weighted avg       0.95      0.92      0.92      3447

--- --- ---    -    --- --- ---    -    --- --- ---
```

# GIS

- Shapefiles and their associated files with the following extensions
  **-shp:** Geometric data for the features (polygons)
  **-shx**: Index of the feature geometry
  **-dbf**: Attribute information
  **-prj**: Coordinate system and projection information

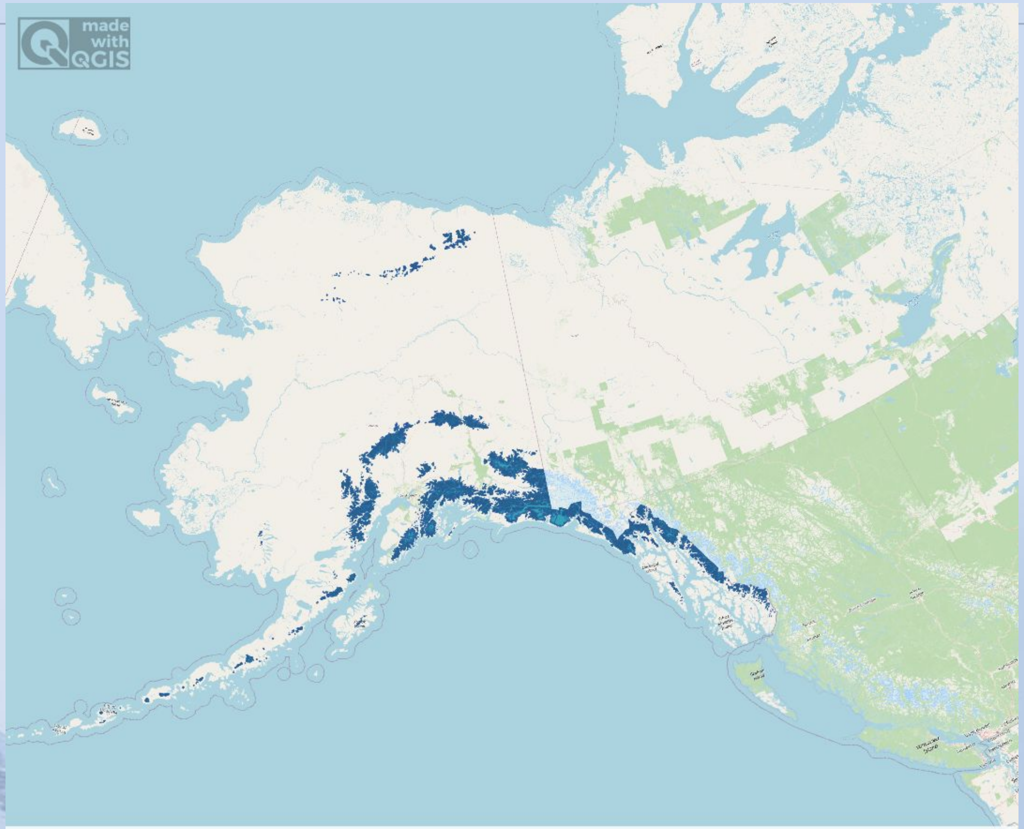
- Large file size (Github has file size limitations)
- **35 years** of data (1985 - 2020)
- **287327** rows / **18259** unique glacier ids (≈10% of the world's glaciers)
- Main **data source**: Satellite imagery from NASA's Terra Satellite - ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) :
  Data retrieval: **8 minutes of data per orbit** (sun-synchronous)

**Visualization Approach:**

- **Geopandas** : Uses libraries such as folium for interactivity
- **QGIS**: An open-source software for viewing, editing, printing

and analyzing geospatial data.

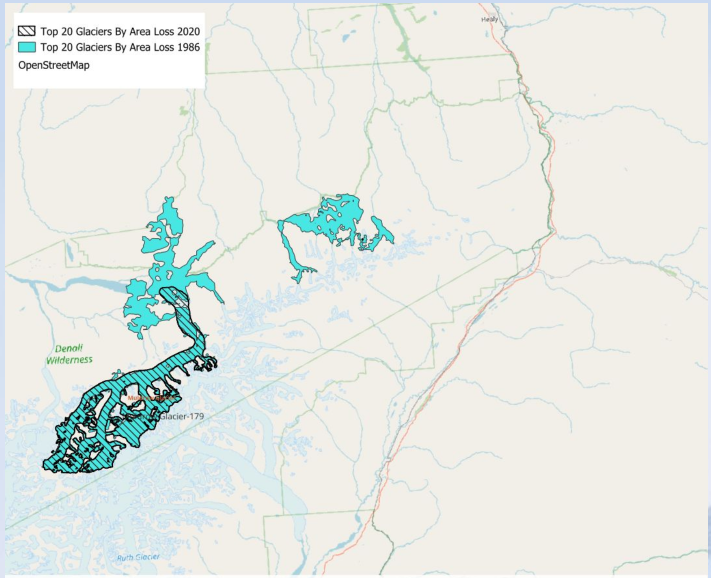
- **Plug-ins** for additional functionality
- Adds the data as **polygon layers**
- Uses **labels** to display values from the attribute table



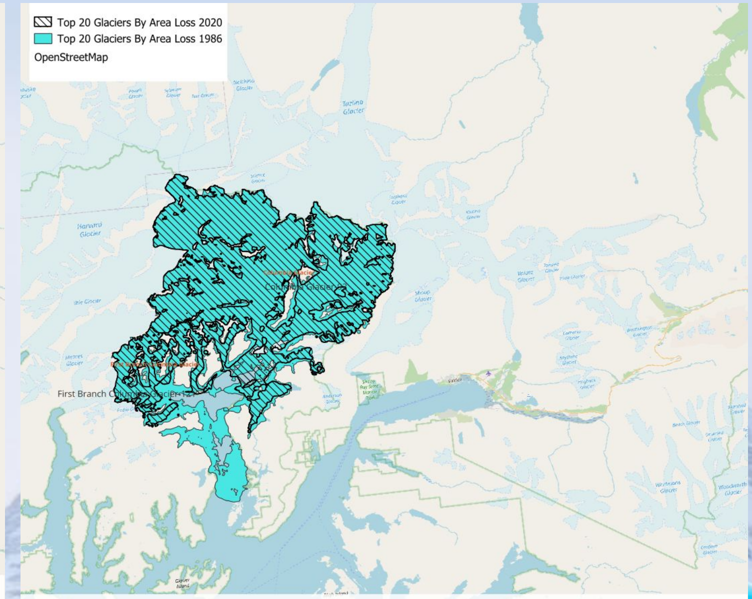

ALASKA GLACIERS 1985 - 2020

# Summary

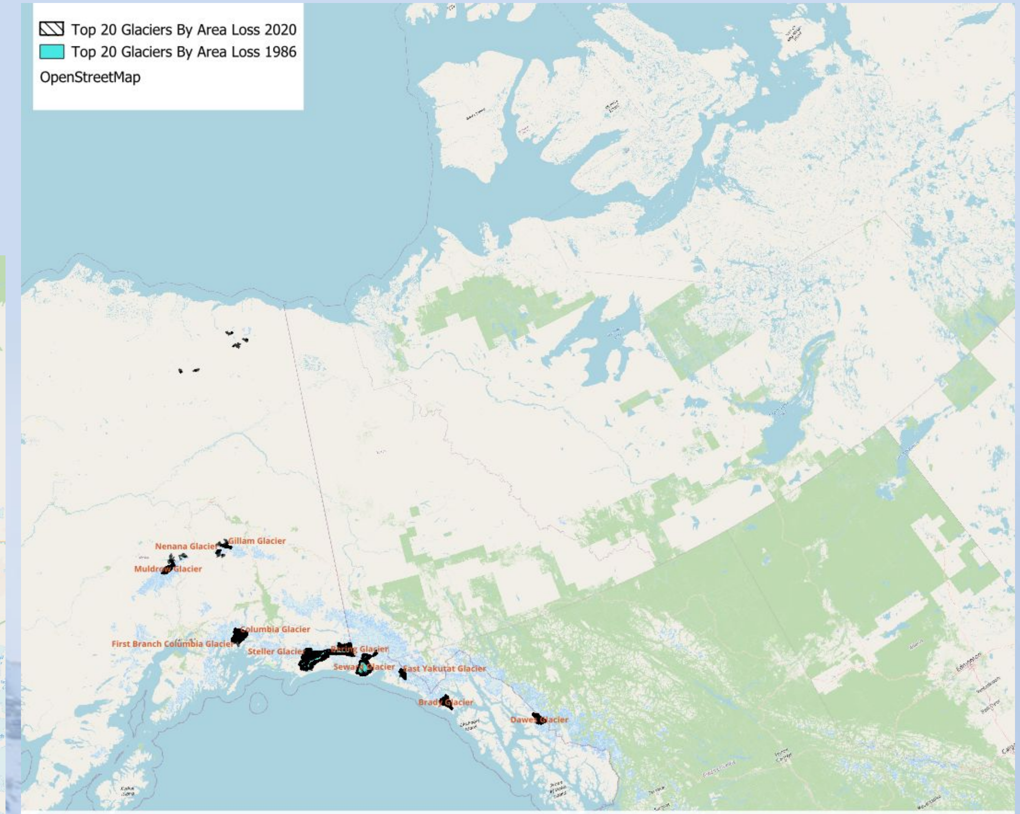
- *Total area change between 1985 and 2020: ≈**8500 km2 / 13%***
- ***84%** of the glaciers in the dataset shrank during the same period.*
- *Glacier covered areas in **1985** : **simple blue fill***
- *Glacier covered areas in **2020** : **line pattern fill***




TOP 20 GLACIERS BY AREA LOSS 1985 - 2020: MULDROW GLACIER




TOP 20 GLACIERS BY AREA LOSS 1985 - 2020: COLUMBIA GLACIER




TOP 20 GLACIERS BY AREA LOSS 1985 - 2020

# QUESTIONS?