The Timing of Deglaciation in Alaska Since the Last Glacial Maximum

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Abstract

Glaciers globally have been in retreat since the Last Glacial Maximum, and the timing of deglaciation in Alaska has not yet been fully understood. Surface exposure studies have been done in Alaska to understand the history of the glaciation. It was expected that glaciers at lower latitudes would have deglaciated first. Surface exposure ages from previous studies throughout the state were spatially compared to determine the timing of deglaciation. Results show higher latitude regions of Alaska deglaciating ~20 ka, and lower regions ~17 ka with fluctuations of advancing and retreat in the southern regions. Glaciers in Alaska were likely responding to changes in atmospheric circulation due to other continental ice sheets receding. The timing of deglaciation in Alaska was different throughout the state with each region deglaciating at different times.

Introduction

- The Last Glacial Maximum (LGM) occurred approximately **20,000 years ago** which is the most recent time of maximum glacial extent (Briner et al., 2017). Ice sheets in North America included the Laurentide and Cordilleran ice sheets. Since the LGM, glaciers globally have been in retreat which leaves behind landforms and glacial material that can act as a record to determine the glaciation history (Booth, 1987).
- Important interstadials/stadials for glaciers include the Older Dryas (14.5-14.1 ka), Bolling-Allerod (14.1-12.9 ka), Younger Dryas (12.9-11.7 ka). (Fig. 3)
- The LGM is important to study because we can use it to determine how glaciers responded to climate forcing before industrialization affected our climate (Larsen et al., 2007).
- By studying the LGM, predictions about glacier response to climate change can be made for the future of existing glaciers. This is especially important for communities that rely on glaciers for hydroelectric power, fishing industries and marine ecosystems.
- Previous studies in Alaska (Briner et al., 2017) include work that studied how the buildup of CO_2 is related to glacial retreat (Fig.1). Briner found that glaciers in Alaska are at about 40% of their LGM lengths. Southeast Alaska is a region that is poorly understood by glaciologists as post glacial sea level rise has covered much of the evidence of the glaciation record (Briner et al., 2017).
- Surface exposure dating studies have been done in Alaska to provide dates of deglaciation throughout the area. Surface exposure dating works by cosmic rays forming nuclides such as beryllium-10 in the rocks on the surface. By quantifying the amount of nuclides in the rock, an age of when the rock was exposed from underneath the glacier can be determined. Unusually high ages for an area can be due to the sample collecting nuclides before being covered by the glacier, known as inheritance (Balco et al., 2008).

Field Area:

- Alaska is an important region to study glaciers due to the high number of glaciers present-day. Elevations in Alaska range from 6,190 meters to sea level and latitudes range from 54° to 71°. There are many mountain ranges in Alaska which span the large latitudinal range, making it a prime location to spatially study glaciers. Locations for this study include the Brooks Range, Alaska Range, Ahklun Mountains, and Juneau Icefield. (Fig. 1)

Research Question

What is the timing of the deglaciation across Alaska since the Last Glacial Maximum?

Methods

Collection:

- Created a database in Google Sheets of surface exposure samples previously done in studies from Briner et al., (2017) and Juneau Icefield Research Program (2012, 2018).
- Database consisted of 120 samples from ten individual studies. Attributes included are location, landform type (terminal moraine, recessional moraine, erratics, bedrock) (Fig.2), elevation, calculated surface-exposure age and error. Locations were color coded by region, which include Alaska Range, Ahklun Mountains, Brooks Range, and Juneau Icefield. All data taken from Briner et al., (2017) and Juneau Icefield Research Program (2012, 2018).

Synthesis:

- To account for different ages in a location, the data were sorted by region and by age to group together similar ages to determine similarities or outliers.
- Ages were averaged in two ways, a total average and a LGM average using ages from 22-12 ka. (Table 1)
- Mapped sample site locations using Google Earth to spatially compare surface-exposure ages.
- Patterns of glacial change were tested using the database to sort samples by various attributes such as latitude, age, and elevation.

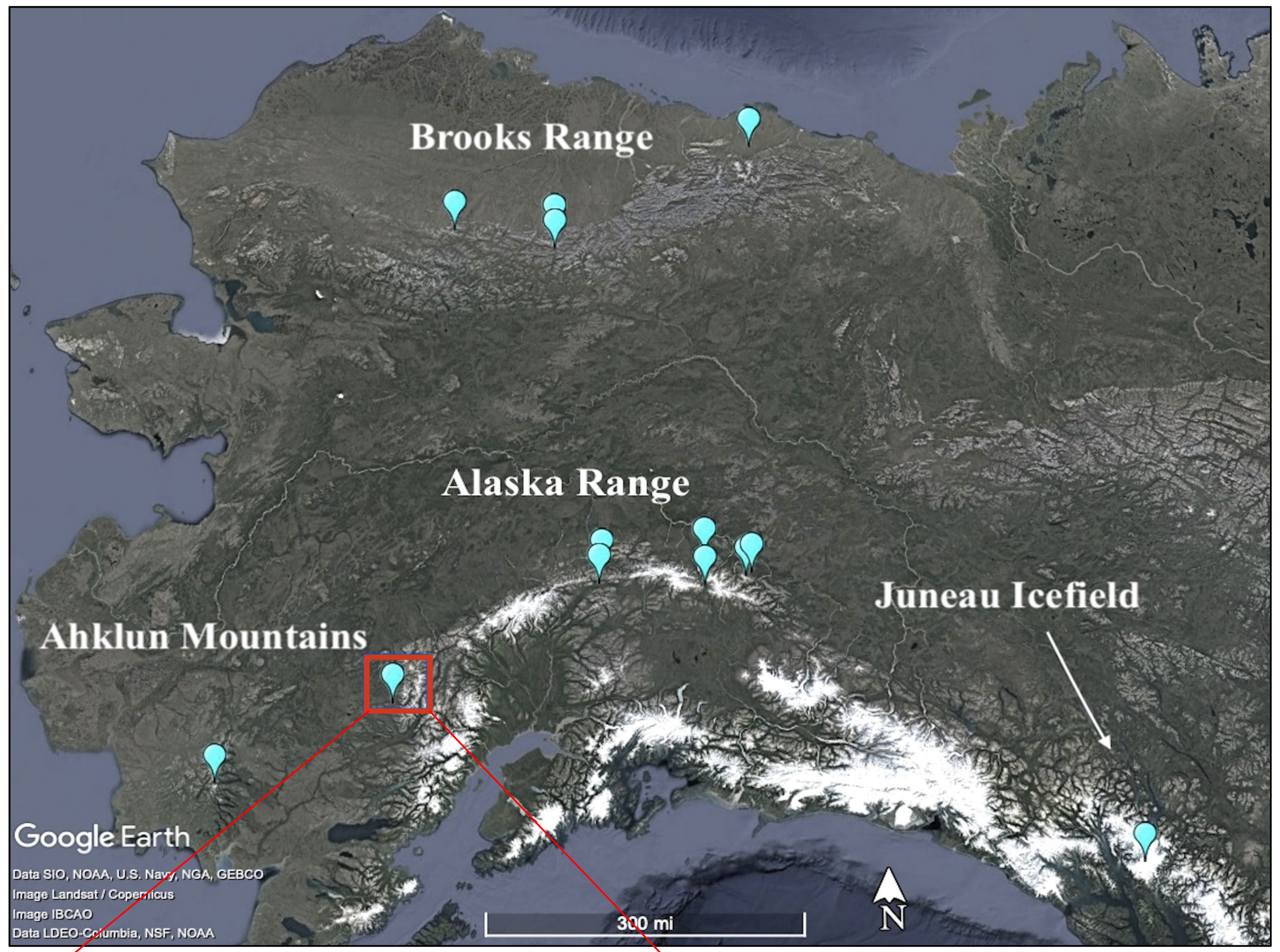


Figure 1: (above) Study locations from the Alaska Range, Brooks Range, Ahklun Mountains, and Juneau Icefield. Box represents location of figure 2. (Briner et al., 2017)

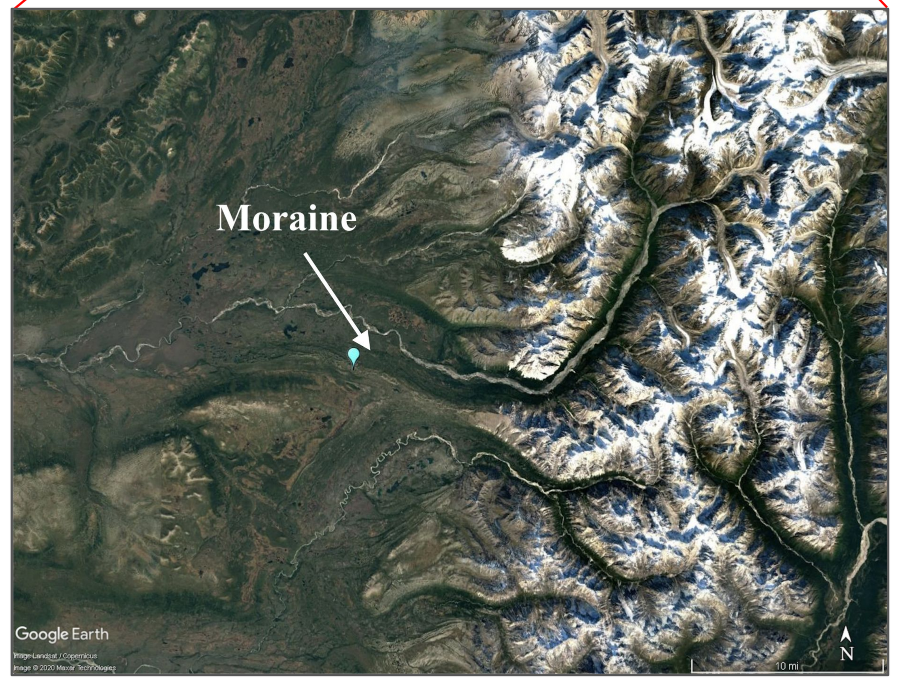
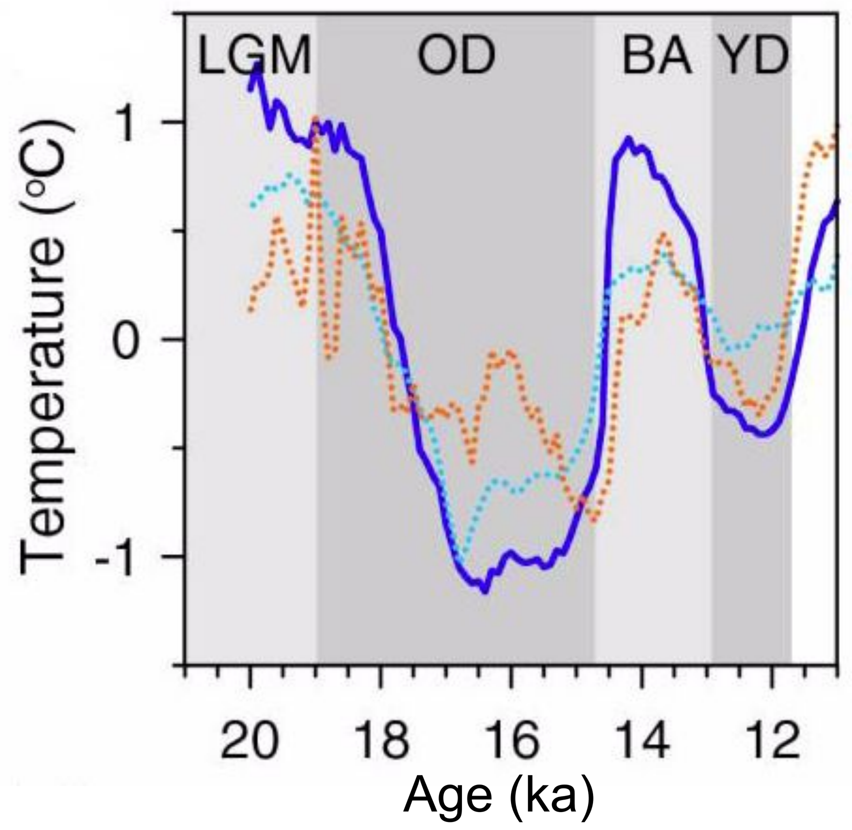


Figure 2: (left) Glacial moraine on the Alaska Range, at the Lime Hills Region. (Briner et al., 2005)

Figure 3: (right) Global temperature data for the Last Glacial Maximum from Clark et al., (2012). Solid blue line represents temperature based on all surface sea temperatures. Various time periods are shaded, Last Glacial Maximum (LGM), Older Dryas (OD), Bolling-Allerod (BA), Younger Dryas (YD).

Older Dryas (OD)	14.5-14.1 ka	Short cold period
Bolling-Allerod (BA)	14.1-12.9 ka	Warming event
Younger Dryas (YD)	12.9-11.7 ka	Cold period



Results

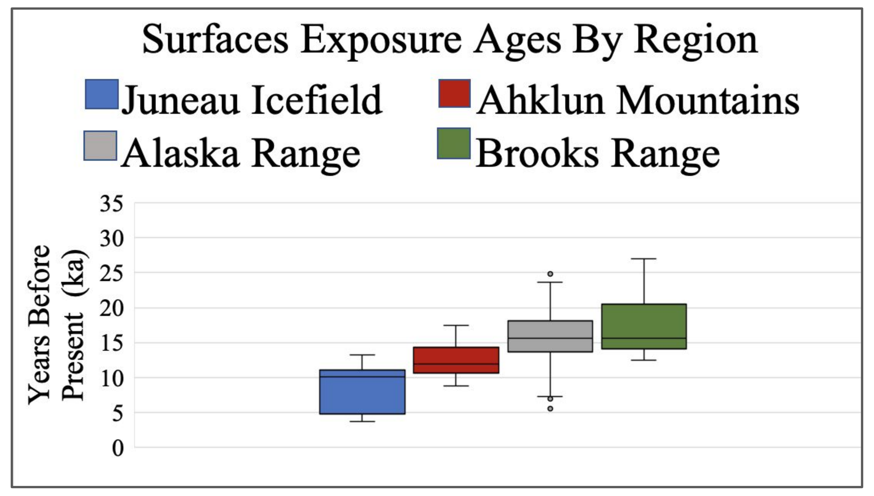


Figure 4: Surface Exposure ages for the four main regions, increasing in latitude from left to right.

Table 1: Results of dataset by region, listed is average age, youngest age, oldest age, and average sample elevation per region.

	Brooks Range	Alaska Range	Ahklun Mountains	Juneau Icefield
LGM Average Surface Exposure age (ka)	16.6	16.2	14.1	12.1
Total Average Surface Exposure Age (ka)	18.9	14.7	12.3	8.9
Oldest Surface Exposure Age (ka)	56.7	67.2	17.5	13.2
Youngest Surface Exposure Age (ka)	12.5	5.5	8.8	3.7

- Oldest age in the dataset is prior to the LGM at 67.2 ka found at 679 meters in a terminal moraine in the Alaska Range.
- Youngest age in the dataset is after the LGM at 3.7 ka found at 1300 meters in bedrock in the Juneau Icefield.
- Generally younger ages at lower latitude and older ages at higher latitude. (Fig. 4)
- Most commonly occuring age is 14.6 ka.

- Brooks Range
  - Retreat period between ~21-17 ka.
  - Glacial standstill ~17-15 ka.
  - Continued retreat ~15 ka.
- Alaska Range
  - Maximum glacial extent ~24 ka.
  - Readvance ~21-17 ka.
  - Retreat occurred ~16-14 ka.
- Ahklun Mountains
  - Retreat ~13 ka.

Discussion

- It is expected that glaciers at lower latitudes deglaciated before higher latitude regions. The opposite is seen in this study with the Brooks Range deglaciating before the other lower regions. This likely occurred due to a change in atmospheric circulation from the Laurentide Ice Sheet which is thought to have caused warming in the Yukon and northern Alaska (Balascio et al., 2005; Hughes et al., 2005).
- The oldest age in the dataset of 67.2 ka in the Alaska Range is likely due to nuclide inheritance.
- The Alaska Range deglaciation occurred during the Bolling-Allerod (BA) warm period (Fig. 3). There was melting of Northern Hemisphere ice sheets going into the warm BA period, this is seen in ice proxies for Greenland sea ice retreat. It is possible that the melting of large continental ice masses promoted the warming of the BA. This could explain the most commonly occuring age of 14.6 (Obase et al., 2019).
- Possible ice advance in the Alaska Range ~21-17 ka found in carbon-14 sediment cores (Werner et al., 1993). This could be seen in the data with many ages on terminal moraines dating ~18-17 ka.
- Glaciers in Southeast Alaska are currently experiencing deglaciation seen with the Taku Glacier recent change from advance to retreat, highly impacting communities near sea level (McNeil et al., 2019).
- There is still a lack of information regarding the LGM in Alaska in regards to the timing of glacier advance and retreat (Briner et al., 2017).

Conclusion

- The deglaciation of Alaska began in the Brooks Range, with the Alaska Range and Ahklun Mountains following, and Southeast Alaska currently deglaciating.
- Glaciers in the Brooks Range receded before lower latitude regions, a total latitudinal difference of 11°, confirming glaciers at different latitudes respond differently to changes in climate. This occurred due to a change in atmospheric circulation causing warming in northern Alaska.
- Most recent glacier recession is seen in the southeast in the Juneau Icefield, confirming that glaciers at sea level are strongly impacted by changes in climate.
- To better determine the timing of deglaciation throughout Alaska, more surface exposure studies should be done with more samples in more locations.

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