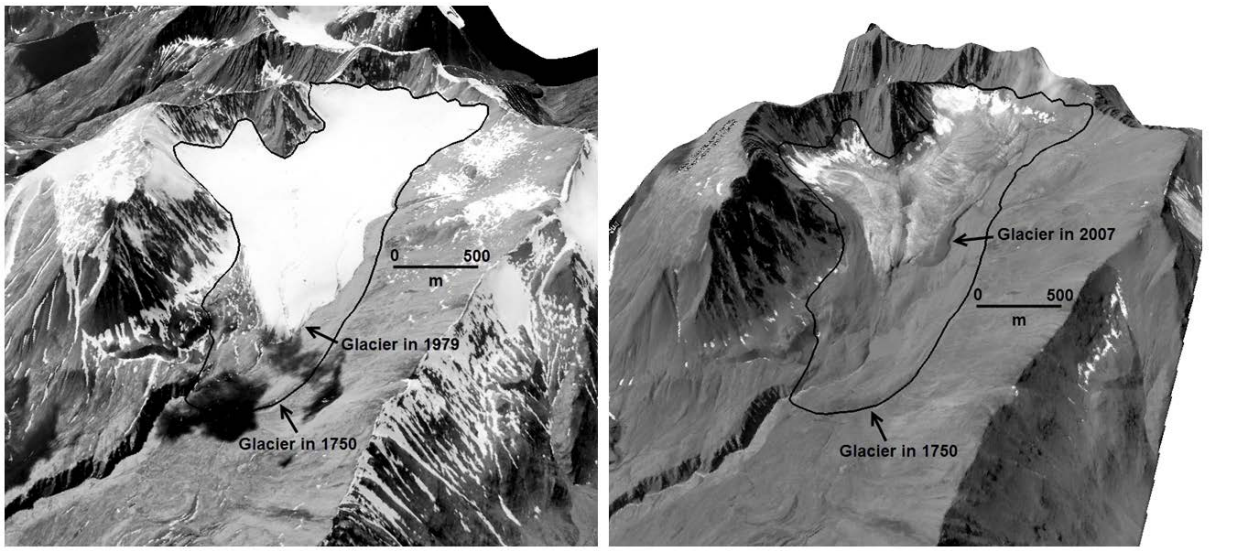
Glacier Retreat in the Brooks Range, Alaska

Glaciers have occupied north-facing cirques and valleys in the Brooks Range of northern Alaska for the past ~4,500 years (Ellis and Calkin, 1984). Buffalo Glacier, a large cirque glacier in the central Brooks Range, and Okpilak Glacier, a valley glacier in northeast Brooks Range, have well-preserved downslope moraines that were deposited by the glaciers during cold, cloudy, and/or snowy periods during the past 4,500 years (Figure 16-14). The last major advance was coincident with Europe's "Little Ice Age" and spanned 1410 to 1600. Glaciers across the central Brooks Range expanded and built large moraines over the ~200-year time interval. The glaciers stayed close to their Little Ice Age maximum extent until approximately 1640 to 1750, and then began to slowly retreat upslope as the climate became warmer, less cloudy, and/or less snowy (Ellis and Calkin, 1984). The age of glacial deposits is determined by measuring the size of slow-growing lichen species on stable boulders and dating buried organic material with the radiocarbon technique (Calkin and Ellis, 1980).

Figure 16-14 Location map of Buffalo and Okpilak Glaciers, Brooks Range, Alaska.

Buffalo Glacier

Buffalo Glacier is one of the largest cirque glaciers in the central Brooks Range. The ice formed in two coalescing cirques and flowed almost 3 km downhill during the Little Ice Age to cover an area of 2.4 km^2. The maximum Little Ice Age extent of Buffalo Glacier was mapped in the field by Ellis in 1979 (black outline in Figure 16-15). The glacier remained within 100 m of its maximum Little Ice Age extent until about 150 years ago (Calkin and Ellis, 1980, Figure 8).



A. 1979 aerial photograph of Buffalo Glacier looking west (Credit: USGS.

B. 2007 satellite image of Buffalo Glacier looking west. © DigitalGlobe 2007, and GoogleEarth

Figure 16-15 Perspective view of Buffalo Glacier with 1750, 1979, and 2007 margins. Courtesy GoogleEarth and © DigitalGlobe (2007).

In 1979, the USGS acquired overlapping, color IR aerial photographs of Buffalo Glacier. The 1979 aerial photographs were scanned, orthorectified, and draped on the USGS DEM of the area (Figure 16-15A). A 2007 high-resolution satellite image was integrated into a GIS to create the perspective views in Figure 16-15B.

Area and length were measured to determine the size of the glacier in 1750, 1979, and 2007 (Table 16-1). Length was determined along the centerline of the glacier, from the base of the exposed headwall to the toe of the downslope 1750 moraine (black outline on Figure 16-15) and the nose of the ice in the 1979 and 2007 images. The percent area and length were based on the Little Ice Age as 100% and more recent dimensions as a percentage of the Little Ice Age size (Table 16-1).

Table 16-1 Buffalo Glacier dimensions 1750 to 2007.

Date	Perimeter (m)	Area (m^2)	Area (Percent)	Length (m)	Length (Percent)
1750	8,184	2,422,902	100.0%	2,800	100.0%
1979	7,063	1,890,531	78.0%	2,250	80.4%
2007	5,843	1,202,403	49.6%	1,700	60.7%

Buffalo Glacier's rate of retreat has significantly accelerated between 1979 and 2007. Buffalo Glacier lost 22% of its area and 20% of its length in the two centuries between the Little Ice Age and 1979. During the 28-year period of 1979 to 2007, Buffalo Glacier lost another 28% of the area and 20% of length attained during the Little Ice Age. As of 2007, Buffalo Glacier is 50% smaller and 40% shorter than in the Little Ice Age. Figure 16-16 plots the three dates and areas of Buffalo Glacier in Table 16-1 to graphically display the glacier's retreat from its maximum expansion in the Little Ice Age. Rapid acceleration of glacier melting after 1979 is evident.

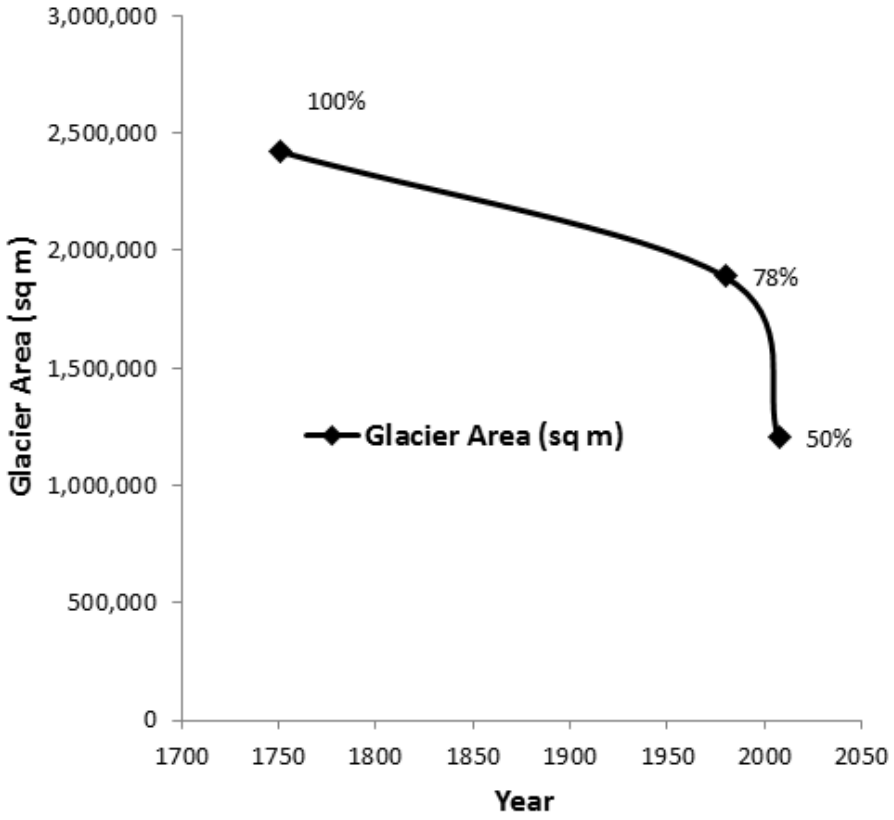
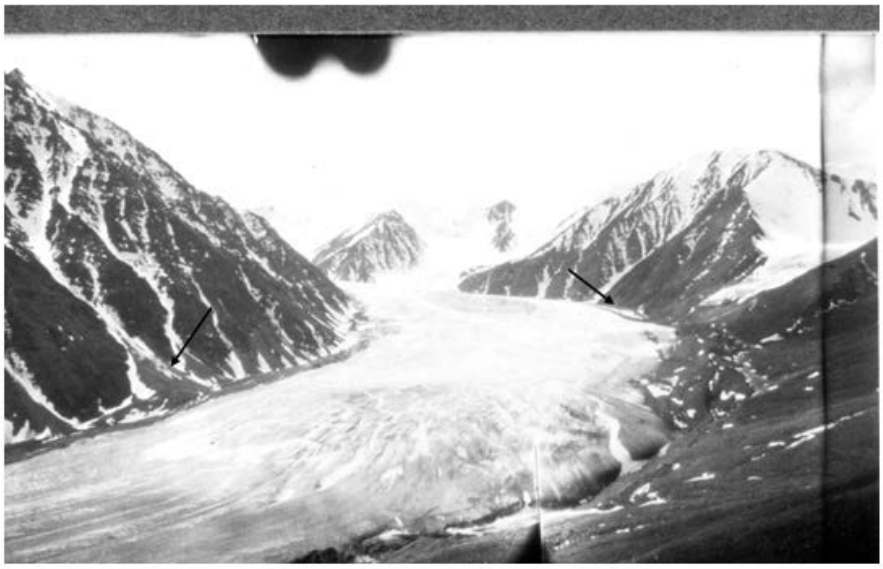


Figure 16-16 Buffalo Glacier area reduction from the Little Ice Age maximum to 2007.

Area and length dimensions are only two dimensional and as glaciers shrink in area and length they also decrease in the third dimension—topographic elevation. Geck and others (2013) used DEMs reconstructed from 1970 and 1973 USGS topographic maps and a 2001 interferometric SAR DEM to calculate volume and mass changes for 107 glaciers in the central Brooks Range. Over the period 1970 to 2001 approximately 0.5 m of ice thickness per year was lost from the surface of the glaciers in the central Brooks Range.

Okpilak Glacier

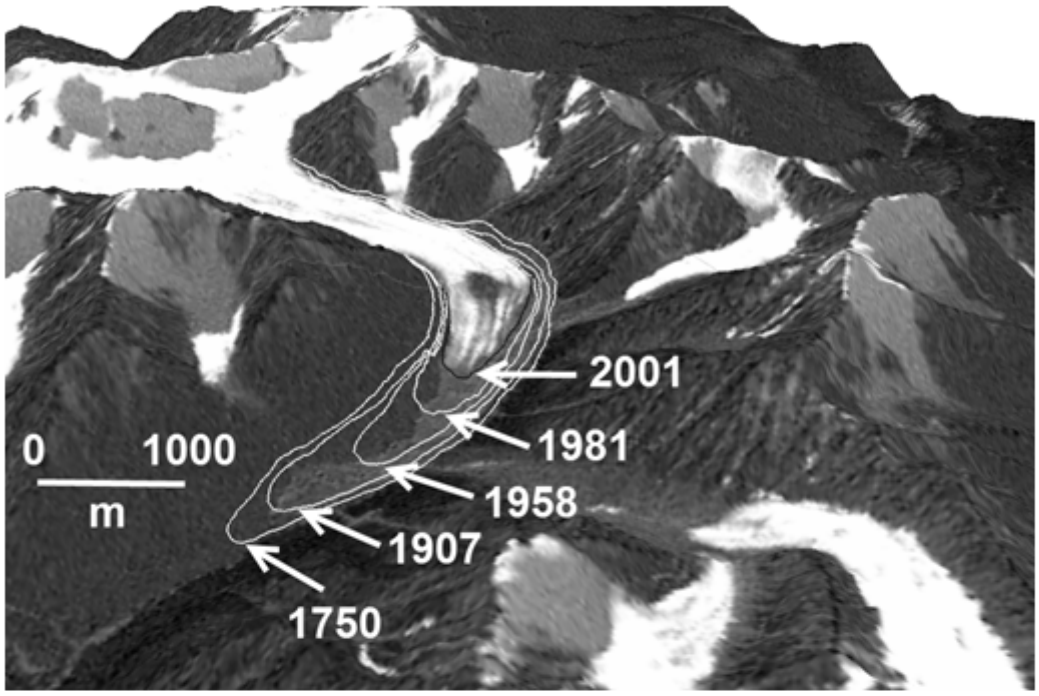
Okpilak Glacier is fed by ice accumulation in several cirques that coalesce downstream into a valley glacier that was approximately 10.5 km long during the Little Ice Age. Okpilik is one of the few glaciers in the Brooks Range that was photographed over a century ago. Leffingwell (1919) photographed the glacier in 1907. In 1981, Ellis reoccupied Leffingwell's camera position and photographed the retreating glacier (Figure 16-17). In 1958, Sable photographed and surveyed the glacier (Sable, 1961), and Nolan reoccupied Leffingwell's camera position in 1994, 2004, and 2007 (for Sable and Nolan's images, see Pelto, 2010). Landsat images of the glacier were acquired in 2001 and 2017. These satellite images were draped on a USGS DEM and displayed with a perspective view; the outlines of past margins of the glacier from 1750 to 2017 are shown (Figure 16-18).



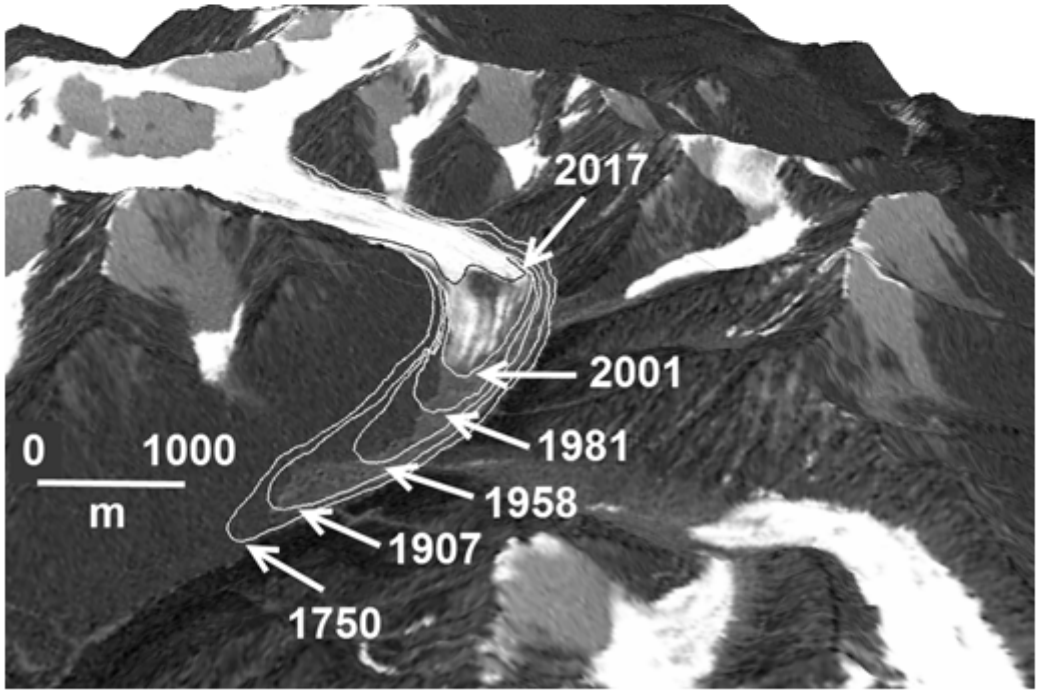
A. 1907 photograph of Okpilak Glacier looking WSW, northeast Brooks Range, Alaska
Credit: Leffingwell, 1919.

B. 1981 photograph of Okpilak Glacier looking WSW, northeast Brooks Range, Alaska
Credit: Ellis, unpublished, available at http://www.ellis-geospatial.com/brooksrange.html

Figure 16-17 1907 and 1981 ground photographs of Okpilak Glacier, Alaska. The black arrows point to the same feature in the 1907 and 1981 photographs.



A. 2001 Landsat 7 TM satellite image of Okpilak Glacier looking west. Credit: USGS.



B. 2017 Landsat 8 OLI satellite image of Okpilak Glacier looking west. Credit: USGS.

Figure 16-18 2001 and 2017 Landsat images of Okpilak Glacier with outlines of past ice margins labeled by year. Landsat courtesy USGS.

Table 16-2 quantifies the dimensions seen in Figures 16-17 and 16-18. The area for each date includes the upslope coalescing cirque glaciers and the downslope valley glacier while length was measured from the base of the headwall at the largest tributary to the toe of the downslope glacier. Okpilak retreated 3,400 m, or 32% of its total length, since the Little Ice Age. Between 1958 and 2017 (a span of 59 years), the glacier retreated 2,400 m, or an average of 40 m/yr. Glacier recession from the Little Ice Age to 2017 has reduced the glacier's area by approximately 36%.

Table 16-2 Okpilak Glacier dimensions 1750 to 2017.

Date	Area (m^2)	Area (Percent)	Length (m)	Length (Percent)
1750	14,869,116	100.0%	10,500	100.0%
1907	13,282,364	89.3%	10,000	95.2%
1958	12,517,372	84.2%	9,500	90.5%
1981	10,965,436	73.7%	8,800	83.8%
2001	9,776,233	65.7%	8,200	78.1%
2017	9,503,065	63.9%	7,100	67.6%

Figure 16-19 plots the Okpilak Glacier's length versus time. This plot displays the same dramatic acceleration of glacial shrinkage since the mid-1950s as was mapped at Buffalo Glacier 250 km to the southwest (see Figure 16-16). Rabus and Echelmeyer (1998) calculated the topographic elevation loss at Okpilak Glacier as 51 cm/yr between 1973 and 1993. They also determined a 420 m retreat during this 20 year interval for a rate of 21 m/yr. The impact of shrinking glaciers on downstream ecosystems (fish, birds, floodplains, and estuaries) in the Arctic National Wildlife Refuge, which spans across the east-central to northeastern Brooks Range and includes the eastern Alaska North Slope, is discussed by Nolan and others (2011).

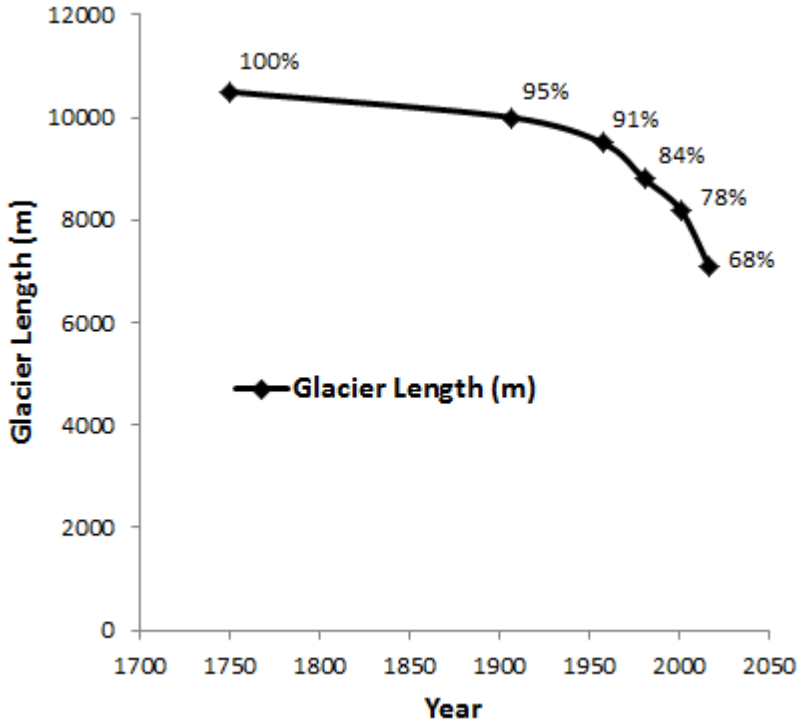


Figure 16-19 Okpilak Glacier length reduction from the Little Ice Age maximum to 2017.

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