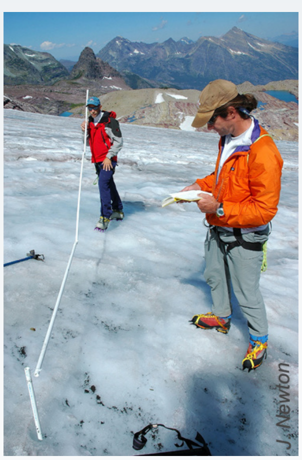
Retreat of Glaciers in Glacier National Park

In Glacier National Park (GNP), MT some effects of climate change are strikingly clear. Glacier recession is underway, and many glaciers have already disappeared. The retreat of these small alpine glaciers reflects changes in recent climate as glaciers respond to altered temperature and precipitation. It has been estimated that there were approximately 150 glaciers present in 1850, around the end of the Little Ice Age. Most glaciers were still present in 1910 when the park was established. In 2015, measurements of glacier area indicate that there were 26 remaining glaciers larger than 25 acres. There is evidence of worldwide glacial glacier recession and varied model projections suggest that certain studied GNP glaciers will disappear between 2030 to 2080. USGS scientists in Glacier National Park are incorporating standardized methods and emerging technologies to understand glacier-climate interactions to advance the understanding of alpine glaciers and to provide a scientific foundation for land managers.

WHAT IS A GLACIER? A glacier is a body of snow and ice that moves. Glacier movement is detected by the presence of crevasses, cracks that form in the ice as the glacier moves. Glaciers are dynamic – changing in response to temperature and precipitation. A glacier forms when winter snowfall exceeds summer melting. It retreats when melting outpaces accumulation of new snow. A commonly accepted guideline for glacier activity and movement is that a glacier must be 0 .1 km2 (100,000 m2), or about 25 acres in size. Below this size, the ice is generally stagnant and does not move, unless it is on a steep slope.



USGS and University of Montana scientists measuring melting rates on Sperry Glacier, GNP.

While the glaciers that carved GNP's majestic peaks were part of a glaciation that ended ~12,000 years ago, current glaciers are considered geologically new, having formed ~7,000 years ago. These glaciers grew substantially during the Little Ice Age (LIA) that began around 1400 A.D. and reached their maximum size at the end of the LIA around A.D. 1850. Their maximum sizes can be inferred from the mounds of rock and soil left behind by glaciers, known as moraines, which provide a scientific baseline for comparison to current glacial extent.

1911 Morton Elrod photo Courtesy of K. Ross Toole Archives, UM

2009 Lisa McKeon photo USGS

Jackson Glacier, Glacier National Park

WHY ARE THEY MELTING? Glaciers, by their dynamic nature, respond to climate variation and reveal the big picture of climate change. Unable to adapt, like living creatures, GNP's relatively small alpine glaciers are good indicators of climate, the long-term average of daily weather conditions. While occasional big winters or frigid weeks may occur, the glaciers of GNP, like most worldwide, are melting as long term average temperatures increase. Analysis of weather data from western Montana shows an increase in summer temperatures and a reduction in the winter snowpack that forms and maintains the glaciers. Since 1900 the mean annual temperature for GNP and the surrounding region has increased 1.33°C, which is 1.8 times the global mean increase. Spring and summer minimum temperatures have also increased, possibly influencing earlier melt during summer. Additionally, rain, rather than snow, has been the dominant form of increased annual precipitation in the past century. Despite variations in annual snowpack, glaciers have continued to shrink, indicating that the snowpack is not adequate to counteract the temperature changes.

WHAT ARE THE EFFECTS OF LOSING GLACIERS? The loss of glaciers in GNP will have significant consequences for park ecosystems as well as impacting landscape aesthetics valued by park visitors. While winters will still deposit snow in the mountains, this seasonal snow will not function the same as glacial ice since it melts early in the summer season. Glaciers act as a "bank" of water (stored as ice) whose continual melt helps regulate stream temperatures and maintains streamflow during late summer and drought periods when other sources are depleted. Without glacial melt water, summer water temperatures will increase and may cause the local extinction of temperature sensitive aquatic species, disrupting the basis of the aquatic food chain. Such changes in stream habitat may also have adverse effects for the threatened native bull trout (*Salvelinus confluentus*) and other keystone salmon species.

Glacier Area Summary

This table lists the area values of the 37 named glaciers of Glacier National Park, Montana, USA. Glacier area data determined by aerial photo analysis in conjunction with Portland State University.

Glaciers that are no longer active in Glacier National Park			
Glacier Name	**1966 Area (m^2)**	**2015 Area (m^2)**	**1966-2015 % change**
Baby Glacier	117,171.13	75,562.60	-35.51
Boulder Glacier	231,017.73	35,298.01	-84.72
Gem Glacier	29,140.12	22,156.68	-23.97
Harris Glacier	148,501.60	34,260.89	-76.93
Herbst Glacier	170,234.16	31,886.02	-81.27
Hudson Glacier	90,213.45	52,167.62	-42.17
Lupfer Glacier	126,375.83	73,274.68	-42.02
North Swiftcurrent Glacier	116,675.97	86,305.30	-26.03
Red Eagle	134,709.82	63,685.24	-52.72
Shepard Glacier	250,678.82	70,739.49	-71.78
Two Ocean Glacier	429,001.73	75,172.89	-82.48

- Perimeters of glacier margins were digitized from 1966 aerial photographs and 2015 satellite imagery taken in late summer when seasonal snow has melted to reveal the extent of the glacial ice.
- In 2015, twenty-six glaciers met the USGS size criteria to be considered "active" glaciers (ie sufficient area to sustain movement, defined as having an area exceeding 100,000 m2, about 25 acres). Ice masses smaller than this are generally stagnant and are no longer considered active glaciers.
- Retreat rates vary for each glacier based on: climate, aspect, elevation, ice flow, snow input from deposition, wind and avalanches, and the presence of a meltwater lake along a glacier's edge.
- The data for Glacier National Park's named glaciers are available at the USGS ScienceBase website. Additional information about the glacier research can be found at the USGS Northern Rocky Mountain Science Center website and the USGS Benchmark Glacier program website.

Glaciers that are active in Glacier National Park			
Glacier Name	**1966 Area (m^2)**	**2015 Area (m^2)**	**1966-2015 % change**
Agassiz Glacier	1,600,559.73	736,669.75	-53.97
Ahern Glacier	589,185.63	511,589.79	-13.17
Blackfoot Glacier	1,832,451.35	1,498,505.92	-18.22
Carter Glacier	355,743.44	224,773.89	-36.82
Chaney Glacier	563,819.03	334,484.90	-40.68
Dixon Glacier	291,142.05	125,831.13	-56.78
Grinnell Glacier	1,020,200.39	563,720.29	-44.74
Harrison Glacier	2,059,376.84	1,661,456.75	-19.32
Ipasha Glacier	328,608.60	194,738.75	-40.74
Jackson Glacier	1,280,508.24	756,864.10	-40.89
Kintla Glacier	1,309,016.20	877,726.05	-32.95
Logan Glacier	503,361.09	219,016.92	-56.49
Miche Wabun	204,468.79	103,616.92	-49.32
Old Sun Glacier	421,347.41	341,077.95	-19.05
Piegan Glacier	280,151.62	244,307.08	-12.79
Pumpelly Glacier	1,006,469.53	902,787.30	-10.30
Rainbow Glacier	1,430,411.36	1,053,376.03	-26.36
Salamander Glacier	229,028.19	176,108.77	-23.11
Sexton Glacier	400,493.53	298,681.73	-25.42
Siyeh Glacier	306,295.75	205,386.48	-32.95
Sperry Glacier	1,339,531.54	801,670.14	-40.15
Swiftcurrent Glacier	221,786.00	170,348.10	-23.19
Thunderbird Glacier	135,074.71	107,012.09	-20.78
Vulture Glacier	408,034.38	296,786.09	-27.26
Weasel Collar Glacier	558,088.21	499,734.76	-10.46
Whitecrow Glacier	242,488.01	103,824.86	-57.18

With nearly a century between photos, this pair of images reveals how Boulder Glacier has melted away. It is no longer considered a glacier because its area is less than 100,000 m^2. (1913, Alden photo; 2012, Jacks photo)

Fagre, D.B., McKeon, L.A., Dick, K.A., and Fountain, A.G., 2017, Glacier margin time series (1966, 1998, 2005, 2015) of the named glaciers of Glacier National Park, MT, USA: U.S. Geological Survey data release, https://dx.doi.org/10.5066/F7P26WB1.