Glaciers in Glacier National Park

Identification

1. Description

This regional feature examines how the surface area of the 37 named glaciers in Glacier National Park in Montana has changed since 1966. Establishing rates of glacier retreat, using the decreasing extent of glacial surface area, is key to understanding the Glacier National Park ecosystem and future state of resources. Changes in glaciers have implications for ecosystems, animals, and people who depend on glacier-fed streamflow. Glaciers are part of Glacier National Park's appeal, and their retreat is of great interest to park visitors and the American public. The region relies on Glacier National Park to draw tourism and drive the local economy. Glaciers are important as an indicator of climate change because physical changes in glaciers—whether they are growing or shrinking, advancing, or receding—provide visible evidence of changes in temperature and precipitation.

Components of this feature include:

- Total surface area of glaciers in Glacier National Park at four points in time, starting in 1966 (Figure 1).
- A map of the park's glacier surface areas and how they have changed since 1966 (Figure 2).

2. Revision History

April 2021: Feature published.

Data Sources

3. Data Sources

This data set was originally published by the U.S. Geographic Survey's (USGS's) Northern Rocky Mountain Science Center (NRMSC) (Fagre et al., 2017).

4. Data Availability

Figure 1. Total Glacier Surface Area in Glacier National Park, 1966–2015

EPA obtained the total surface area values for the 37 named glaciers at four discrete points in time (1966, 1998, 2005, and 2015) in PDF form from USGS staff (Dan Fagre). This data set is also publicly available on the USGS website at: www.usgs.gov/data-tools/area-named-glaciers-glacier-national-park-gnp-and-flathead-national-forest-fnf-including.

Figure 2. Change in Glacier Surface Area in Glacier National Park, 1966–2015

The geographic information system (GIS) files defining glacier footprints (surface extent) at the same four points in time (1966, 1998, 2005, and 2015) are available on the USGS NRMSC website at: www.sciencebase.gov/catalog/item/58af7022e4b01ccd54f9f542?community=Northern+Rocky+Mountain+Science+Center. More detailed metadata are also available on this page. These GIS files were used without modification to create Figure 2.

Methodology

5. Data Collection

This feature provides information on the change in total surface area of the 37 named glaciers in Glacier National Park listed in Table TD-1. USGS selected these glaciers because they are "named" features that have been tracked over time. The list includes all of the park's current "active" glaciers—a designation that USGS assigns to glaciers that were larger than 100,000 square meters (or about 25 acres in size), a commonly accepted guideline for glacier activity and movement, during the most recent year of measurement. Glaciers below this threshold are classified as "inactive," where the ice is generally stagnant unless it is on a steep slope. This feature includes 26 glaciers that were classified as "active" and 11 classified as "inactive" as of 2015. The 26 active glaciers account for 95 percent of the total glacial area covered by this study as of 2015, and they account for 83 percent of the total change in glacial area between 1966 and 2015.

Table TD-1. Glaciers Included in This Feature

Name	Status	Name	Status	Name	Status
Agassiz Glacier	Active	Hudson Glacier	Inactive	Salamander Glacier	Active
Ahern Glacier	Active	Ipasha Glacier	Active	Sexton Glacier	Active
Baby Glacier	Inactive	Jackson Glacier	Active	Shepard Glacier	Inactive
Blackfoot Glacier	Active	Kintla Glacier	Active	Siyeh Glacier	Active
Boulder Glacier	Inactive	Logan Glacier	Active	Sperry Glacier	Active
Carter Glacier	Active	Lupfer Glacier	Inactive	Swiftcurrent Glacier	Active
Chaney Glacier	Active	Miche Wabun Glacier	Active	Thunderbird Glacier	Active
Dixon Glacier	Active	North Swiftcurrent Glacier	Inactive	Two Ocean Glacier	Inactive
Gem Glacier	Inactive	Old Sun Glacier	Active	Vulture Glacier	Active
Grinnell Glacier	Active	Piegan Glacier	Active	Weasel Collar Glacier	Active
Harris Glacier	Inactive	Pumpelly Glacier	Active	Whitecrow Glacier	Active
Harrison Glacier	Active	Rainbow Glacier	Active		
Herbst Glacier	Inactive	Red Eagle Glacier	Inactive		

The USGS study also included two glaciers located southwest of the Glacier National Park boundary in Flathead National Forest: Grant Glacier and Stanton Glacier. These two glaciers are not included in this feature, which focuses on Glacier National Park.

Data have been collected using an assortment of methods. The timing and frequency of re-measurement by these methods has varied over time, and the technologies available for measurement have evolved. For this comparison, USGS selected four points in time—1966, 1998, 2005, and 2015—that had consistent contemporary data for all the glaciers on the list. The 1966 footprints were derived primarily from USGS topographic maps. The 1998 footprints were derived from aerial imagery. The 2005 glacier footprints were derived from National Agriculture Imagery Program (NAIP) aerial imagery. The 2015 glacier footprints were derived from WorldView satellite imagery. More information about the methodologies used for each timepoint are available on the USGS NRMSC website at: www.sciencebase.gov/catalog/item/58af7022e4b01ccd54f9f542?community=Northern+Rocky+Mountain+Science+Center.

6. Derivation

USGS staff used tablets to digitize glacier outlines from the source maps and images described in Section 5, then calculated the total area of each glacier polygon using GIS software. EPA converted the units from square meters to square miles and summed the areas across all 37 glaciers to create the aggregate time series graph in Figure 1. EPA mapped the individual glacier footprints in Figure 2, using color to distinguish the time steps in the static version of the map. Glacier margins are shown layered on top of each other, with the 2015 margins on top and the 1966 margins on the bottom, as all of the glaciers generally decreased in size between 1966 and 2015. A web version of Figure 2 allows users to zoom and pan the map to see more detail.

7. Quality Assurance and Quality Control

Quality assurance and quality control involved review by several scientists familiar with these glaciers. Specific steps depend on the data source in use at each point in time. To enable maximum comparability between time points, the determination of what constituted the "main body" of glaciers was made in accordance with established USGS criteria, and some disconnected patches were eliminated in the interest of maintaining consistency over time. The following steps were taken for specific points in time:

- For 1966 observations, which were digitized from USGS topographic maps, digitizers noticed that some glacier margins in the maps were overly generalized compared with contemporary USGS aerial imagery. The original cartographers might have used a more generalized outline for the glaciers without concern for small-scale ice features, even when they were evident in the photographs. In cases where a glacier perimeter seemed overly generalized, USGS revised the perimeter based on aerial imagery. Specific details about margin revisions are detailed in the GIS attribute files for those glaciers.

- The 1998 observations involved a review of 2001 digitization efforts after new, higher-resolution imagery from the period became available in 2015. In several cases, the higher-resolution 2015 imagery revealed features (such as debris-covered ice) that the 1998 image analysis had deemed bedrock, and thus the glacier margins had to be reevaluated.

- For 2005 observations, glacier margins were digitized from aerial imagery. Supplemental data from oblique USGS images (captured at a 45-degree angle rather than a bird's eye view) and Google Earth satellite imagery, as well as local knowledge, were used to determine glacier margins with maximum accuracy.

- Glacier margins for 2015 were digitized in a similar fashion to 2005, but with a combination of Google Earth imagery, other satellite imagery, and oblique images.

Analysis

8. Comparability Over Time and Space

Within each of the four measurement periods, consistent methods were applied to all glaciers in the inventory. Methods differed between measurement periods as technologies have evolved, but as described in Section 7, USGS made efforts to revise glacier area estimates based on the best available maps and images for each point in time, so as to standardize the approach to the extent possible.

9. Data Limitations

Factors that may impact the confidence, application, or conclusions drawn from this feature are as follows:

1. Seasonal snow sometimes obscured the visibility of glacier margins in the aerial and satellite imagery used as a data source for this feature. USGS excluded seasonal snow when it was identified, however.

2. Unlike EPA's Glaciers indicator, this feature only characterizes the surface area of glaciers, not their change in volume or mass balance. Consistent ice depth and surface altitude data are not available for most of the glaciers in this feature, so ice volume or volume change cannot be directly calculated. Although larger footprint glaciers will typically have more volume, the relationship between area and volume varies over time and from one glacier to another. For example, several of the smaller glaciers in Glacier National Park formed in areas with limited space for expansion, so as they grew, they tended to grow thicker instead of growing larger in area. Now that they are losing ice, these small glaciers are losing thickness more rapidly than they are losing surface area. Thus, a relatively small change in footprint could belie a larger change in total volume.

3. Changes in glacier size will not necessarily track linearly with changes in temperature, as the relationship to temperature can be complex. For some glaciers, continued warming temperatures begin to have less influence on glacier size once the (now smaller) glaciers retreat to the upper confines of a basin, where there is more shade to slow melting, more frequent snow avalanches that add mass to the glacier, and wind deposition of snow from other areas. Topography, wind drift, and other factors play a role in glacier size from year to year.

4. The 37 glaciers included in this data set include all of Glacier National Park's large, named glaciers, but they do not represent a comprehensive accounting of all glaciers or permanent ice features in the park.

5. These glaciers are not necessarily representative of glaciers in other regions that may have different climatic or topographic conditions. However, the observations of glacier decline in this feature are consistent with observations of glacier decline throughout the western United States (Fountain et al., 2017).

10. Sources of Uncertainty

Glacier area measurements have inherent uncertainties, because glaciers move and grow in three dimensions, but glacier margins are measured in two dimensions. Uncertainties in this data set have been identified and minimized, though not explicitly quantified.

11. Sources of Variability

Glacier area can reflect year-to-year variations in temperature, precipitation, and other factors. The period of record is longer than the period of key multi-year climate oscillations such as the Pacific Decadal Oscillation and El Niño–Southern Oscillation, meaning the patterns over time shown in Figures 1 and 2 are not simply the product of decadal-scale climate oscillations.

12. Statistical/Trend Analysis

This feature does not report on the slope or average rate of change in either figure, nor does it calculate the statistical significance of these trends or provide confidence bounds. This is primarily due to the limited, discrete temporal nature of these data.

References

Fagre, D.B., L.A. McKeon, K.A. Dick, and A.G. Fountain. 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. doi:10.5066/F7P26WB1

Fountain, A.G., B. Glenn, and H.J. Basagic IV. 2017. The geography of glaciers and perennial snowfields in the American West. Arct. Antarct. Alp. Res. 49(3):391–410. doi:10.1657/AAAR0017-003