Glaciers

This indicator examines the balance between snow accumulation and melting in glaciers, and it describes how glaciers in the United States and around the world have changed over time.

Background

A glacier is a large mass of snow and ice that has accumulated over many years and is present year-round. In the United States, glaciers can be found in the Rocky Mountains, the Sierra Nevada, the Cascades, and throughout Alaska. A glacier flows naturally like a river, only much more slowly. At higher elevations, glaciers accumulate snow, which eventually becomes compressed into ice. At lower elevations, the "river" of ice naturally loses mass because of melting and ice breaking off and floating away (iceberg calving) if the glacier ends in a lake or the ocean. When melting and calving are exactly balanced by new snow accumulation, a glacier is in equilibrium and its mass will neither increase nor decrease.

In many areas, glaciers provide communities and ecosystems with a reliable source of streamflow and drinking water, particularly in times of extended drought and late in the summer, when seasonal snowpack has melted away. Freshwater runoff from glaciers also influences ocean ecosystems. 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. If glaciers lose more ice than they can accumulate through new snowfall, they ultimately add more water to the oceans, leading to a rise in sea level (see the Sea Level indicator). The same kinds of changes occur on a much larger scale within the giant ice sheets that cover Greenland and Antarctica, potentially leading to even bigger implications for sea level. Small glaciers tend to respond more quickly to climate change than the giant ice sheets. Altogether, the world's small glaciers are adding roughly the same amount of water to the oceans per year as the ice sheets of Greenland and Antarctica. During the last two decades, they added more water overall to the oceans than the ice sheets did.[1]

About the Indicator

This indicator is based on long-term monitoring data collected at selected glaciers around the world. Scientists collect detailed measurements to determine glacier mass balance, which is the net gain or loss of snow and ice over the course of the year. A negative mass balance indicates that a glacier has lost ice or snow. If cumulative mass balance becomes more negative over time, it means glaciers are losing mass more quickly than they can accumulate new snow.

Figure 1 shows trends in mass balance for a set of 37 reference glaciers around the world that have been measured consistently since the 1970s, including a few that have been measured since the 1940s. Data from these reference glaciers have been averaged together to depict changes over time. Figure 2 shows trends for three "benchmark" glaciers: South Cascade Glacier in Washington state, Wolverine Glacier near Alaska's southern coast, and Gulkana Glacier in Alaska's interior. These three glaciers were chosen

because they have been studied extensively by the U.S. Geological Survey for many years and because they are thought to be representative of other glaciers nearby.

This indicator describes the change in glacier mass balance, which is measured as the average change in thickness across the surface of a glacier. The change in ice or snow has been converted to the equivalent amount of liquid water.

Photographs of McCall Glacier, Alaska, 1958 and 2003

Sources: Post, 1958;[2] Nolan, 2003[3]

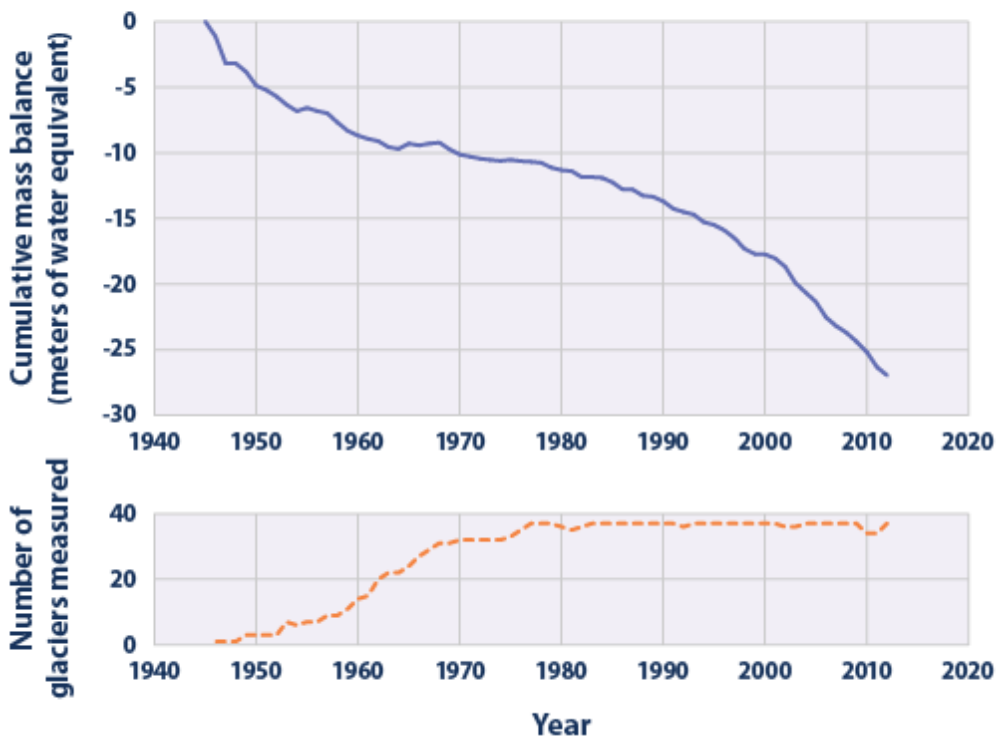
Key Points

- On average, glaciers worldwide have been losing mass since at least the 1970s (see Figure 1), which in turn has contributed to observed changes in sea level (see the Sea Level indicator). A longer measurement record from a smaller number of glaciers suggests that they have been shrinking since the 1940s. The rate at which glaciers are losing mass appears to have accelerated over roughly the last decade.

- All three U.S. benchmark glaciers have shown an overall decline in mass balance since the 1950s and 1960s and an accelerated rate of decline in recent years (see Figure 2). Year-to-year trends vary, with some glaciers gaining mass in certain years (for example, Wolverine Glacier during the 1980s). However, most of the measurements indicate a loss of glacier mass over time.

- Trends for the three benchmark glaciers are consistent with the retreat of glaciers observed throughout the western United States, Alaska, and other parts of the world.[4] Observations of glaciers losing mass are also consistent with warming trends in U.S. and global temperatures during this time period (see the U.S. and Global Temperature indicator).

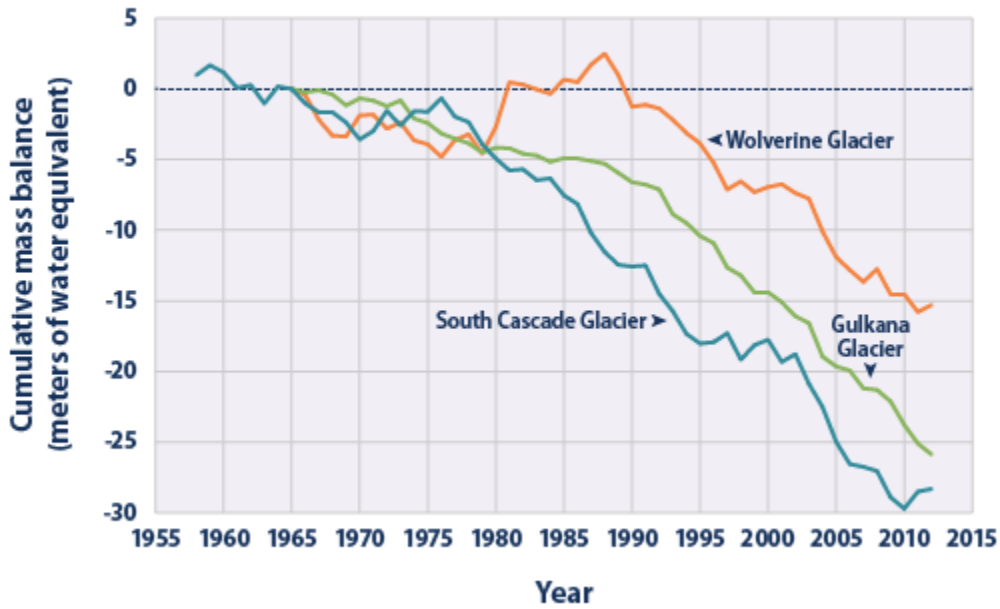
Figure 1. Average Cumulative Mass Balance of "Reference" Glaciers Worldwide, 1945–2012



This figure shows the cumulative change in mass balance of a set of "reference" glaciers worldwide beginning in 1945. The line on the graph represents the average of all the glaciers that were measured. Negative values indicate a net loss of ice and snow compared with the base year of 1945. For consistency, measurements are in meters of water equivalent, which represent changes in the average thickness of a glacier. The small chart below shows how many glaciers were measured in each year. Some glacier measurements have not yet been finalized for the last few years, hence the smaller number of sites.

Data sources: WGMS, 2013,[5] 2014[6]

Figure 2. Cumulative Mass Balance of Three U.S. Glaciers, 1958–2012



This figure shows the cumulative mass balance of the three U.S. Geological Survey "benchmark" glaciers since measurements began in the 1950s or 1960s. For each glacier, the mass balance is set at zero for the base year of 1965. Negative values indicate a net loss of ice and snow compared with the base year. For consistency, measurements are in meters of water equivalent, which represent changes in the average thickness of a glacier.

Data sources: O'Neel and Sass, 2013;[7] USGS, 2014[8]

Indicator Notes

The relationship between climate change and glacier mass balance is complex, and the observed changes at specific reference or benchmark glaciers might reflect a combination of global and local variations in temperature and precipitation. Individual glaciers also vary in their structure, flow, and

response to climate. Slightly different measurement and analysis methods have been used at different glaciers, but overall trends appear to be similar.

Long-term measurements are available for only a relatively small percentage of the world's glaciers. This indicator does not include the Greenland and Antarctic ice sheets, although two decades of satellite data suggest that these ice sheets are also experiencing a net loss of ice.[9] Continued satellite data collection will allow scientists to evaluate long-term trends in the future.

Data Sources

The World Glacier Monitoring Service compiled data for Figure 1, based on measurements collected by a variety of organizations around the world. The U.S. Geological Survey Benchmark Glacier Program provided the data for Figure 2. These data, as well as periodic reports and measurements of the benchmark glaciers, are available on the program's website at: http://ak.water.usgs.gov/glaciology.

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[1] IPCC (Intergovernmental Panel on Climate Change). 2013. Climate change 2013: The physical science basis. Working Group I contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. www.ipcc.ch/report/ar5/wg1.

[2] Post, A. 1958. McCall Glacier. Glacier photograph collection. Boulder, Colorado: National Snow and Ice Data Center/World Data Center for Glaciology. http://nsidc.org/data/g00472.html.

[3] Nolan, M. 2003. McCall Glacier. Glacier photograph collection. Boulder, Colorado: National Snow and Ice Data Center/World Data Center for Glaciology. http://nsidc.org/data/g00472.html.

[4] IPCC (Intergovernmental Panel on Climate Change). 2013. Climate change 2013: The physical science basis. Working Group I contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. www.ipcc.ch/report/ar5/wg1.

[5] WGMS (World Glacier Monitoring Service). 2013. Glacier mass balance bulletin no. 12 (2010–2011). Zemp, M., S.U. Nussbaumer, K. Naegeli, I. Gärtner-Roer, F. Paul, M. Hoelzle, and W. Haeberli (eds.). ICSU (WDS)/IUGG (IACS)/UNEP/UNESCO/WMO. Zurich, Switzerland: World Glacier Monitoring Service. www.wgms.ch/mbb/mbb12/wgms_2013_gmbb12.pdf.

[6] WGMS (World Glacier Monitoring Service). 2014. Preliminary glacier mass balance data 2011/2012. www.wgms.ch/mbb/sum12.html.

[7] O'Neel, S.R., and L.C. Sass. 2013. 2013 update to: Van Beusekom, A.E., S.R. O'Neel, R.S. March, L.C. Sass, and L.H. Cox. 2010. Re-analysis of Alaskan benchmark glacier mass-balance data using the index method. U.S. Geological Survey Scientific Investigations Report 2010–5247. http://pubs.usgs.gov/sir/2010/5247.

[8] USGS (U.S. Geological Survey). 2014. Water resources of Alaska—glacier and snow program, benchmark glaciers. Accessed April 2014. http://ak.water.usgs.gov/glaciology.

[9] Melillo, J.M., T.C. Richmond, and G.W. Yohe (eds.). 2014. Climate change impacts in the United States: The third National Climate Assessment. U.S. Global Change Research Program. http://nca2014.globalchange.gov.