Glacier Mass Changes and Their Effect on the Earth System (Sea Level)

By Mark B. Dyurgerov[1] and Mark F. Meier[1]

Glaciers are indicators of climate. They also have significant impacts on other globally important processes, such as sea-level rise, hydrology of mountain-fed rivers, fresh water inflow to the oceans, and even the shape and rotation of the Earth. Observational results about change in glacier mass (mass balance) collected since the mid-20th century in many mountain and subpolar regions on Earth present clear evidence that the volume of the Earth's glaciers is being reduced, with substantial reductions since the mid-1970s and even more rapid loss since the end of the 1980s. The total area of non-ice-sheet glaciers globally is newly estimated to be 763×10^3 square kilometers (km^2), somewhat larger than earlier estimates, because of more accurate information on isolated glaciers and on ice caps around the periphery of the Earth's two largest glaciers, the Greenland and the Antarctic ice sheets.

Glacier wastage (melting) causes sea level to rise. We now estimate that average wastage from nonpolar glaciers contributed 0.58 millimeter (mm) per annum for the period 1961 to 2005, but their contribution to sea-level rise increased to 0.98 mm per annum in the decade 1993 to 2005 (fig. 1). Non-ice-sheet glaciers (fig. 2) contribute fresh water to the oceans that accounts for about 1.0 mm per annum of sea-level rise, which may affect ocean circulation and ocean ecosystems. Data about the magnitude and rate of glacier wastage are critical to our ability to understand and therefore to predict the rate of sea-level change. This contribution from glaciers is likely to increase, not decrease, in the future. The accelerating rate of the rise in global sea level has important ramifications for human populations and associated infrastructure in low-lying coastal regions, such as deltas, and atolls in the Pacific Ocean (fig. 3). The reduction in volume of glacier ice can also uplift deglacierized land areas regionally.

Glacier mass-balance data (both annual and seasonal) can be used to infer climatic variables such as precipitation and temperature. Knowing the spatial distribution of these variables can assist in the analysis and modeling of climate change, especially important in high-mountain and high-latitude areas, where precipitation data are few and biased (there are fewer meteorological stations, and they are insufficiently distributed geographically).

The increase in air temperature is the major forcing for glacier change. Glacier response to recent climate warming shows a steepening of the gradient of mass balance with altitude. Increasing ablation of ice below the equilibrium line altitude (ELA) causes that steepening, as does, to a lesser extent, increasing accumulation of snow above that altitude. Observational results show increases of glacier mass turnover and of mass-balance sensitivity to air temperature; these changes are not predicted by existing climate/glacier models. As the 1980s drew to a close, sensitivity and turnover began (and continue) to show a remarkable decrease in variability.

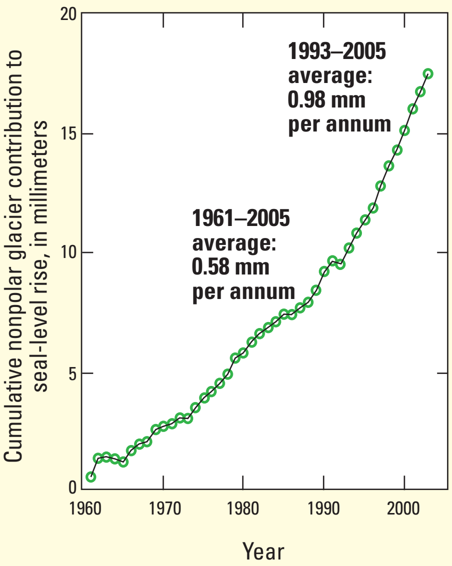

Figure 1. Rise in global sea level from meltwater from mountain glaciers and subpolar ice caps, 1961 to 2005. Although the average increase in global sea level was 0.58 mm per annum from 1961 to 2005, the rate of sea-level rise increased to 0.98 mm per annum from 1993 to 2005. Graph prepared by Mark Dyurgerov, University of Colorado, Institute of Arctic and Alpine Research, Boulder, Colorado.

Accelerated losses of glacier volume globally have affected the hydrologic cycle at many scales, from global to local. Precipitation over glacierized areas averages about 36 percent higher than that over nonglacierized areas. The glacier contribution to the fresh water inflow to the Arctic Ocean has been increasing.

[1] (Mark F. Meier, deceased—2012).
(Mark B. Dyurgerov, deceased—2009)

As a result of global climate warming, this increase will continue and will affect many aspects of the Arctic climate system. The glacier input to the Arctic basin is unique in that much of it flows directly to the ocean rather than to the several major rivers that glaciologists regularly measure. Increasing summer runoff to large Asian rivers and to high-elevation glacierized watersheds in both Americas is important for agriculture and for human needs, but this release of water from ice storage will diminish in the near future as the relatively small high-mountain glaciers shrink in volume and eventually disappear.

URL Addresses:

http://nsidc.org/sotc/glacier_balance.html

http://nsidc.org/glims/glaciermelt/

http://nsidc.org/sotc/sea_level.html

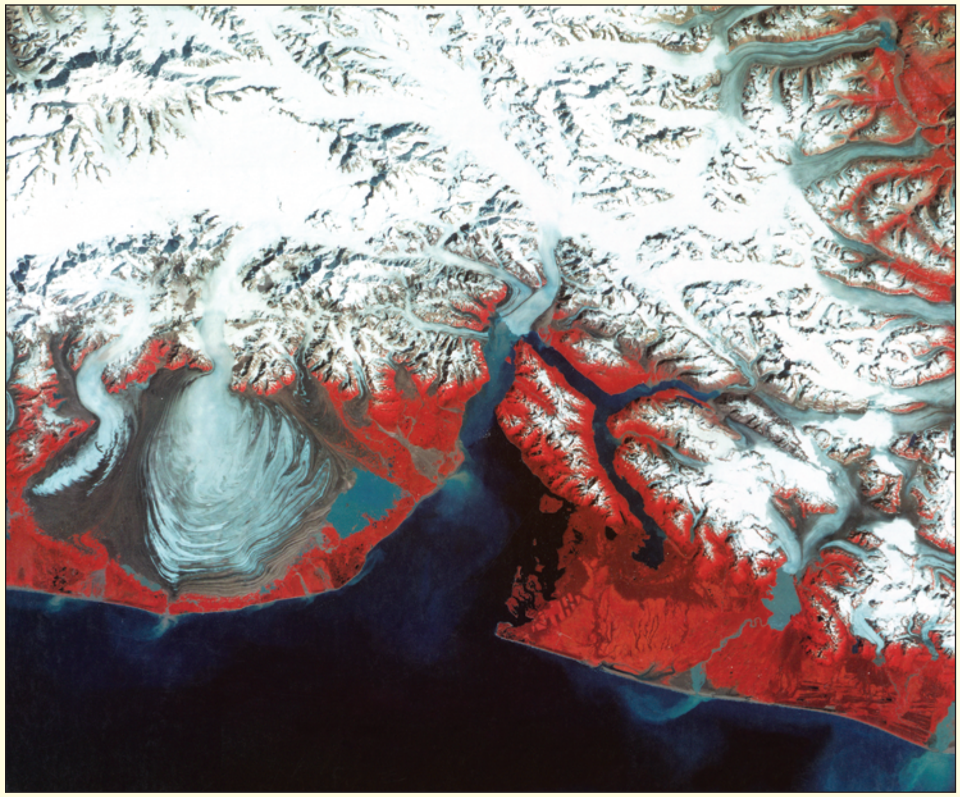

Figure 2. A Landsat 2 Multispectral Scanner false-color composite image of the Malaspina Glacier (piedmont outlet glacier), tidewater Hubbard Glacier, and other glaciers in the St. Elias Mountains, Alaska, 24 August 1979; see figure 144, p. K160, in Glaciers of Alaska (http://pubs.usgs.gov/pp/p1386k).

Contact information

Mark B. Dyurgerov, (Deceased—2009)

Mark F. Meier, (Deceased—2012)

Figure 3. Landsat image of four islands in the Society Islands of French Polynesia, about 200 kilometers northwest of Tahiti. Three of the islands are surrounded by fringing reefs with eroded extinct volcanoes within circumferential lagoons. Bora Bora is in the center. To its right is Taha'a and its neighbor to the south, Raiatea. Tupai, a small coral atoll, is in the upper left.