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How is land ice changing in the Arctic, and what is the influence on sea level?

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ARCTIC ANSWERS

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How is land ice changing in the Arctic, and what is the influence on sea level?

THE ISSUE. Land ice includes mountain glaciers, small ice caps, and large ice sheets. Changes in Arctic land ice area and volume directly influence sea level rise both locally and globally. Understanding where land ice is being lost and how quickly it is disappearing is key to projecting the rates of sea level rise around the globe.

WHY IT MATTERS. Globally, land ice is shrinking due to a rapidly warming climate. The pace of land ice loss is projected to increase as warming of both the air and ocean increases, causing the pace of sea level rise to accelerate. Mountain glaciers and small ice caps are a major contributor to sea level rise now (Figure 1, top), and have the potential to raise sea level further by nearly 50 cm. But as mountain glaciers disappear, their contribution will diminish as less ice is left to melt. The Greenland Ice Sheet, containing a much larger volume of ice, will contribute greater amounts to sea level rise by the end of the century. Antarctica's gigantic ice sheet will play a large but less predictable role. Antarctica has the greatest potential impact on future sea level change, because it contains by far the largest volume of ice on Earth.

Increasing rates of sea level rise have major consequences for coastal infrastructure and the environment. In particular, costs for insurance and for increased sea defenses near cities are a major potential impact of increased rates of sea level rise.

STATE OF KNOWLEDGE. Land ice in the Arctic consists of mountain glacier regions such as southeastern Alaska and small ice caps to large ice sheets such as the Greenland Ice Sheet.

The Arctic has warmed far faster than the global mean rate due to factors that amplify climate change, in the Arctic especially[1,3]. This accelerated warming will continue. As a result, ice in the Arctic is melting rapidly, leading to a disproportionate contribution to sea level. Examples of the changes that scientists have observed include as follows:

(1) Widespread retreat of glaciers across Alaska (see Figure 2), Canada and Greenland. Some glaciers have disappeared entirely.
(2) Increased surface melt on Arctic glaciers and ice caps, and on the Greenland Ice Sheet. Surface

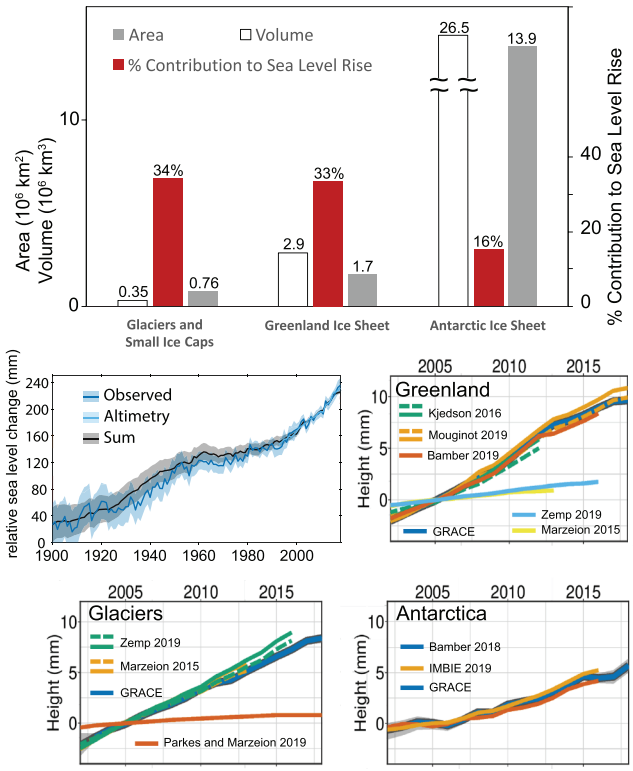

Figure 1. The recent contribution rate of glaciers and ice caps and the Greenland and Antarctic ice sheets to sea level rise (red), and ice area and volume in each (white and gray). Bottom: Observed sea level rise estimates from recent loss of land ice, including an estimate for all regions from a gravity-mapping satellite (GRACE). Estimates for glaciers include values for existing glaciers (dashed line) and glaciers plus recently-vanished glacier volumes (solid line); for the Greenland central ice sheet (dashed line) and the ice sheet plus peripheral glaciers (solid line). [graphics adapted from refs. 3 and 4. Also, see Knowledge Pyramid in Supplemental Material for additional references].

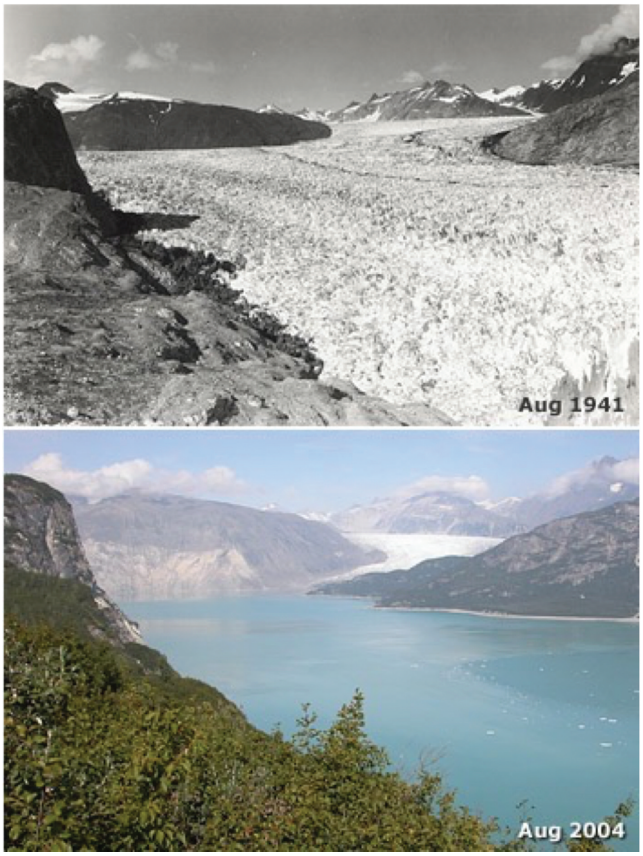

Figure 2. Dramatic retreat between 1941 and 2004 of the Muir Glacier in Glacier Bay National Park and Preserve, Alaska. This pattern of glacier retreat has now been observed across the world [NSIDC Photo Archive].

melting on Arctic land ice leads to meltwater runoff via streams, rivers, or directly into the ocean. In Greenland increased warming is also exposing older, darker ice, which absorbs heat more easily and accelerates melting.

(3) Faster ice motion in many Arctic glaciers, especially for glaciers that end in the ocean. Tidewater glaciers experience both rapid ocean-driven melting and dynamic calving at their fronts. Of these, the primary conveyors for ice from high interior ice regions to the ocean are the most important for land ice loss.[2,4,5,6]

WHERE THE RESEARCH IS HEADED. The science is clear that land ice loss will continue. However, estimates of sea level rise caused by land ice loss have larger uncertainties than other causes. Scientists are working to reduce these uncertainties by conducting focused research about glacier and ice sheet processes, particularly processes involving ice interaction with ocean and atmosphere. A primary goal is to use these observational studies to improve computer simulations and further constrain the range of sea level increase expected over the next few decades to centuries.

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Supplemental material

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