110-year record of Greenland shows ice loss accelerating

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Thousands of black-and-white aerial photographs of Greenland taken between 1978 and 1987 are helping scientists reconstruct a 110-year-long record of ice loss in this region.

A new study published in *Nature* yesterday that used the photographs found that the Greenland ice sheet lost about 9,000 gigatons of ice between 1900 and 2010 and that the rate has accelerated in recent years. The reduction in the ice mass has contributed to global average sea-level rise of 25 millimeters.

The results are consistent with other estimates, but this is the first time scientists have used actual observations from this far back in time rather than relying on model-generated estimates. "We have observation-based estimates that is new and super important," emphasized Kristian Kjellerup Kjeldsen, the lead author of the study at the Natural History Museum of Denmark.

Even the Intergovernmental Panel on Climate Change was missing these crucial data about Greenland's ice melt in its 2013 assessments of sea-level rise, which excluded the contribution of the ice sheets. The gap existed because of the lack of direct observations of Greenland, according to scientists.

"By processing the historical archive acquired by the Danish during the last century, they were able to provide an estimation of the ice sheet contribution to sea-level rise since 1900, which was critically missing in the last IPCC report," noted Jeremie Mouginot, a climate scientist at the University of California, Irvine.

Reliable records of this scope both in time and geographic area are difficult to obtain because the use of satellite imagery for climate research became popular only in the 1990s. "The effort to use the old photographs to learn how the margins of the ice sheet have changed is wonderful," said Richard Alley, a glaciologist at Pennsylvania State University.

"There have been many efforts over the years to photograph the edge of the ice sheet, for many purposes," he added. "This new effort is the most comprehensive and consistent that I know of to pull evidence together and produces useful and important results."

Looking back in time

The study -- the result of an international team led by climate researchers at the Natural History Museum of Denmark -- divided the studied time period into three phases, largely dictated by the availability of data: 1900 to 1983, 1983 to 2003, and 2003 to 2010.

The 1900 start date was chosen to mark the end of what is called as the Little Ice Age. There is some debate about when the "Little Ice Age" -- the last time when global average temperatures were falling -- ended, but it is well documented that glaciers started receding around that time as

a result of the relative warming of the planet. Regional variations notwithstanding, 1900 was a fair guess for when all of the Greenland ice sheet was in retreat, Kjeldsen said.

More than 3,500 images were recorded during aerial surveys by the National Survey and Cadastre of Denmark in the late 1970s and early '80s, captured with a camera that used film. These were very high-resolution images that were later digitized.

The 1983 time stamp for the start of the second phase was chosen because it was the midpoint of the period when the photographs were taken. The images from this period are not just a window into where the boundaries of glaciers were when the photographs were taken, but a measure of how far they had receded from their maximum expansion at the end of the Little Ice Age.

The photographs of the landscape allowed the researchers to visually capture the extent to which the boundaries of the glaciers had receded since the 1900s.

The line that demarcates the farthest reach of a glacier from areas that have not been overrun by a glacier is called the trim line. It can be distinguished by the difference in the vegetative cover on either side of the line. When glaciers advance, they erode and transform the landscape they pass over. When they retreat, they leave behind a freshly polished, pristine landscape that is markedly different from land that has not been buried under an ice sheet.

The movement of these large masses of ice also leaves distinct marks on the walls of valleys and in the form of deposits of glacial sediment. Much of the work of analyzing the photographs in the study was left to sophisticated software that is designed for the purpose of processing images and generating estimates.

Making 'better' future projections

Using the photographs, the researchers were able to not just map the historical boundaries of Greenland glaciers but also build models and determine how much ice was lost at the periphery of the ice sheet, where the maximum ice loss usually occurs.

Observing techniques have vastly improved with greater reliance on remote sensing data from satellites and aircraft that capture high-resolution images over large areas. For the last phase, from 2003 to 2010, the researchers relied on laser altimetry and radar altimetry to estimate the ice elevation and map the receding ice sheet.

One of the limitations of the work, Kjeldsen pointed out, was comparing rates of ice loss in time periods of different lengths. Their estimations show an average annual ice loss of about 75 gigatons for the first two phases -- an 80-year-long period and a 20-year one. The most recent data showed that an average of 186 gigatons of ice was lost during 2003-10, which is only a seven-year period.

However, experts noted that actual observations, despite their limitations, have great value not just to test model data but to improve forecasting. "The new work improves our understanding of history, allowing better model tests and allowing better assessment of how the ice responded to climate changes in the past," Alley said, "and this will help in making better and more-reliable projections for the future."