Documenting Glacier Change and Landscape Evolution: An Example of Providing Scientific Information to Support Decision Making and Outreach and Education

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ABSTRACT

This poster summarizes experiences in providing U.S. National Park Service (NPS) decision makers and outreach personnel with scientific information about the impacts of climate variability within specific NPS units. Glaciers are Earth's largest freshwater reservoir, a sensitive indicator of changing climate, and an important component of many subpolar ecosystems. They also annually attract hundreds of thousands of visitors to Glacier Bay National Park (GLBA), Kenai Fjords National Park (KEFJ), and more than a dozen other NPS units throughout the western United States. Therefore, NPS resource managers have a strong and immediate interest in understanding how their glacier resources and associated ecosystems have changed, are changing, and will change in response to climate variability. Consequently, unequivocal information that provides insights and answers into this response is critical for policymaking and decision making, and for adaptive management and planning.

For GLBA and KEFJ, NPS resource managers needed information that:

1) Assessed the post-Little-Ice-Age behavior of glaciers;
2) Developed easy-to-understand visual products to convey the results of these assessments;
3) Documented vegetative succession in newly ice-free areas; and
4) Provided information about past and present rates of change that could serve as a basis for predicting future changes.

One approach employed to respond to this need was photographic documentation of long-term change. Beginning in 2002, Park locations that had been photographed in the late-19th and early-20th centuries were revisited. Using historical photographs to identify the exact locations from which they were made, more than 175 sites have been examined. At each, fields of view shown in each historical photograph are duplicated. Then, differences between modern and historic images are quantitatively and qualitatively assessed. For GLBA, this results in a fiord by fiord history of glacier change and landscape evolution, and a visual documentation of more than a century of change. Resulting data are also used to produce GIS coverages for inclusion in a GLBA-wide management GIS. Additionally, visualizations are shared with NPS Interpretive Rangers who provide visitors with information about the Park's changing natural environment. A similar assessment is underway for KEFJ.

This cooperation with NPS resource managers and outreach personnel is an excellent example of how information developed through scientific research on climate variability and change is serving NPS customer needs on a number of levels, ranging from providing quantitative information to support resource managers in their decision making, to providing site-specific, unambiguous visual documentation to be shared with the public.

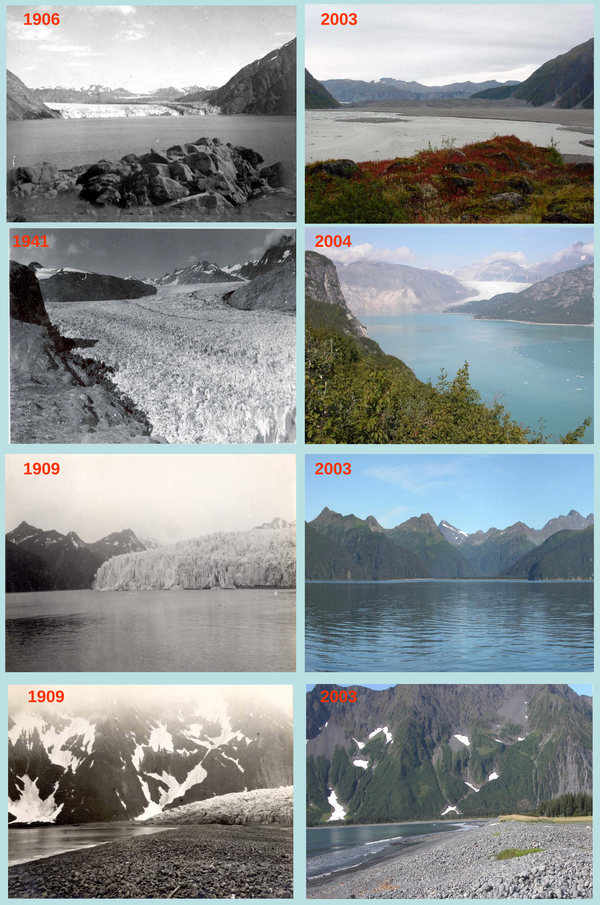
Assessing the Post-Little-Ice-Age Behavior of Glaciers

For GLBA, this study was conducted with Hal Pranger and Ron Karpilo of the USNPS Geological Resources Division; for KEFJ, with Doug Capra and Jim Pfeiffenberger of the KEFJ staff.

For each Park investigated, the first step in any assessment of historical glacier behavior is a comprehensive literature survey to determine the existence of previous investigations and to capture their results. For GLBA, which has been investigated by many expeditions since 1890, abundant information was found. For KEFJ, which has been virtually unstudied, very little was found. Text summaries, including bibliographies, describing regional glacier behavior and the details of each glacier previously investigated were prepared for each Park. These summaries were shared with Park resource managers and interpreters. Although well received, in every instance, additional visual products that clearly show evidence of, and the impact of changing climate were requested.

To respond to this request, more than 1,500 late-19th-century and early-20th-century, ground- and sea-surface-based photographs have been found that show landscape features in GLBA and KEFJ. (>1,400 of GLBA, <100 of KEFJ). More than half of these historical photographs depict glacier termini and related features. The earliest of these photographs predates 1885. Sources of these photographs include national archives, museums, publications, libraries, internet sites, antique dealers, and individuals. Nearly all of the historical photographs lack important elements of metadata, most significantly camera specifics, lens information, and film and exposure data. Not a single description of a historical photograph was accompanied by the geographic coordinates of the photo-point from which it was made. During the 2003 - 2005 field seasons, >175 locations from which historical photographs had been made were identified and revisited. For each site, date, time, latitude and longitude, elevation, and bearing to the center of each photographic target were determined with GPS receiver and compass.

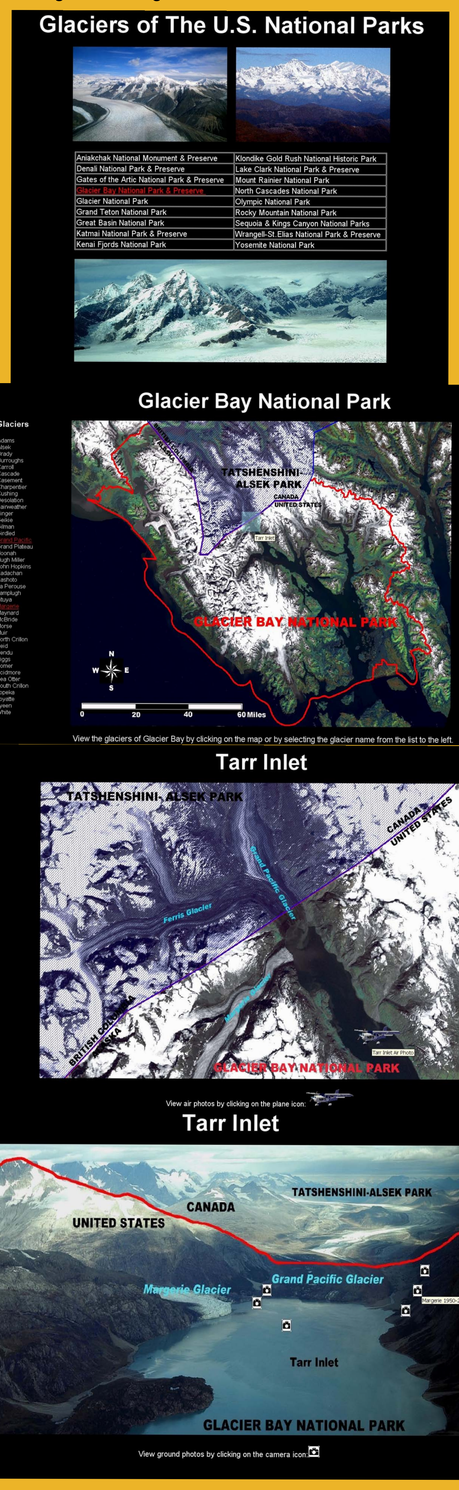
In the laboratory, new images and photographs were compared with corresponding historical photographs to determine differences, and to better understand rates, timing, and mechanics of landscape change and evolution. Particular emphasis was placed on understanding the response of specific glaciers to changing climate and environment.



Four modern and historic pairs of "repeat photography." A) Carroll Glacier (GLBA), B) Muir Glacier (GLBA), C) McCarty Glacier (KEFJ), and D) Pedersen Glacier (KEFJ). Each holds clues to local climate change.

Develop Easy-to-Understand Visual Products to Convey the Results of These Assessments

Our Goal is to develop simple, attractive, information-rich visual products that can be easily understood and modified so that they can be used for all glacier-hosting National Parks. We also wanted a suite of graphics, with accompanying text to provide decision- and policy-makers with clear descriptions of observed landscape evolution and glacier change.



Four sequential graphics that "zero-in" on more detailed information about NPS glaciers. The progression is from all glacier-hosting National Parks, to a specific Park (GLBA), to a specific part of a Park (Tarr Inlet), to a single glacier (Grand Pacific Glacier). Links provide access to text describing post-Little-Ice-Age behavior and historical photo pairs.

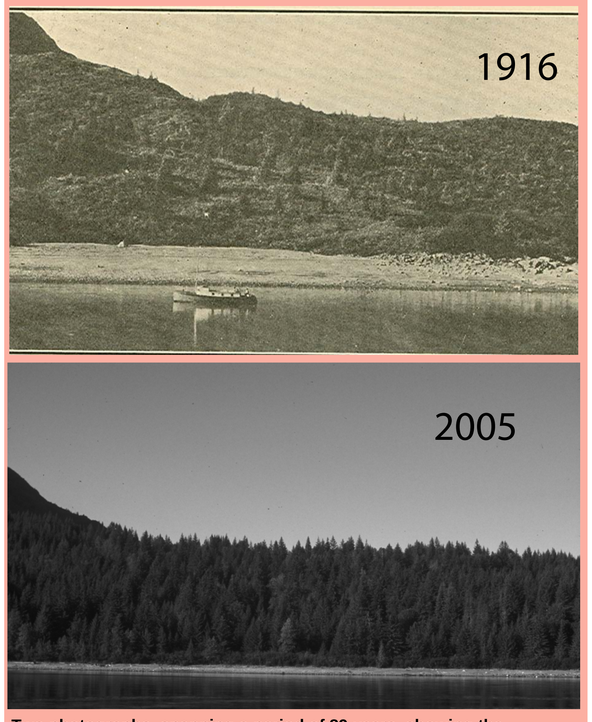
Document Vegetative Succession in Newly Ice-Free Areas

This study is being conducted with Sue Hazlett, a USGS biologist and University of Alaska Fairbanks graduate student.

The impact that changing climate has on vegetative succession is as important as its impact on glaciers. With warming, glaciers retreat, new land is exposed, and vegetative succession begins. With cooling, glaciers advance, forests are destroyed, and vegetated land is covered with ice. In GLBA, forest succession has been studied for almost 90 years. Beginning in 1916, William S. Cooper, one of the first botanists to explore Alaska, established the existence of a sequence beginning with pioneer species such as dryas, mosses, grasses and sedges, progressing to alder and willow thicket, and finally to spruce and hemlock forest.

Between 1916 and 1939, Cooper established 65 stations and described the vegetation throughout Glacier Bay. Since then, no systematic inventory of his sites had been made. With NPS funding, most of Cooper's sites were revisited during the summer of 2005. At each site, current species composition and density were noted and then compared with previous findings. Vegetation assemblages and trends were analyzed throughout the bay.

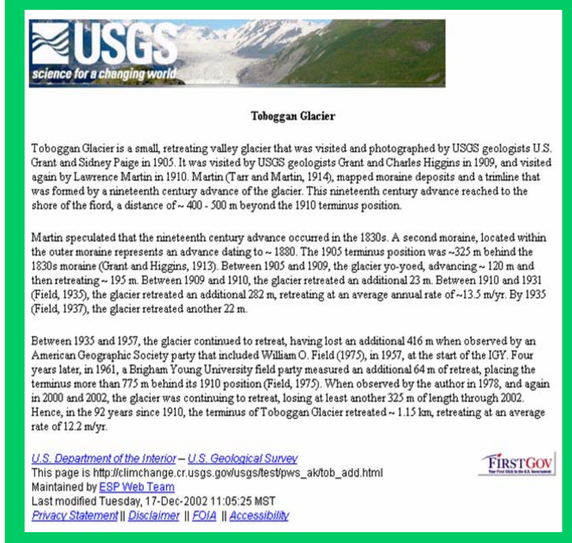
Preliminary results show that the landscape of Glacier Bay has changed dramatically from the time Cooper began his studies in 1916 to the present day. Although the lower bay was heavily forested when Cooper visited, it was primarily first-growth same-age trees. A spruce bark beetle infestation, a result of changing climate, has opened up many areas of the forest and secondary succession is now occurring that will eventually lead to an old-growth forest. The mid-bay has perhaps changed the most since Cooper's time, with areas that were populated with pioneer species or open alder and willow thickets now either covered with spruce or cottonwood trees reaching a height of 10 meters or greater. Some parts of the upper bay have also changed, with cottonwood trees dominating some areas, and dense alder thicket growing closer to the present-day position of the glaciers. Some inlets such as Johns Hopkins have changed little, probably due to colder temperatures and a short growing season in proximity to stable or advancing glaciers. This rate of plant succession has had far-reaching effects on human and animal habitation in the bay. Pioneer vegetation, and willow and alder thicket provided good habitat for small mammals and coastal brown bears. The spruce-hemlock forest is home to black bear and a variety of birds. Even the return of salmon was dependent upon bank stabilization and enough woody debris to create suitable spawning streams. Understanding variations in succession can aid management in predicting changes in forest composition under different climactic conditions.



Two photographs, spanning a period of 89 years, showing the vegetation change that has occurred at Cooper's Station 22 at Tlingit Point, GLBA.

Provide Information About Past and Present Rates of Change that Could Serve as a Basis for Predicting Future Changes

Several different approaches are being employed to present information about past and present rates of change. These include animations of individual glacier terminus variations, animated region-wide graphics, and static maps and fact sheets.



Toboggan Glacier

Toboggan Glacier is a small, retreating valley glacier that was visited and photographed by USGS geologists U.S. Grant and Sidney Paige in 1905. It was visited by USGS geologists Grant and Charles Higgins in 1909, and visited again by Lawrence Martin in 1910. Martin (Tarr and Martin, 1914), mapped moraine deposits and a trimline that was formed by a nineteenth century advance of the glacier. This nineteenth century advance reached to the shore of the fiord, a distance of ~ 400 - 500 m beyond the 1910 terminus position.

Martin speculated that the nineteenth century advance occurred in the 1830s. A second moraine, located within the outer moraine represents an advance dating to ~ 1880. The 1905 terminus position was ~325 m behind the 1830s moraine (Grant and Higgins, 1913). Between 1905 and 1909, the glacier yo-yoed, advancing ~ 120 m and then retreating ~ 195 m. Between 1909 and 1910, the glacier retreated an additional 23 m. Between 1910 and 1931 (Field, 1935), the glacier retreated an additional 282 m, retreating at an average annual rate of ~13.5 m/yr. By 1935 (Field, 1937), the glacier retreated another 22 m.

Between 1935 and 1957, the glacier continued to retreat, having lost an additional 416 m when observed by an American Geographic Society party that included William O. Field (1975), in 1957, at the start of the IGY. Four years later, in 1961, a Brigham Young University field party measured an additional 64 m of retreat, placing the terminus more than 775 m behind its 1910 position (Field, 1975). When observed by the author in 1978, and again in 2000 and 2002, the glacier was continuing to retreat, losing at least another 325 m of length through 2002. Hence, in the 92 years since 1910, the terminus of Toboggan Glacier retreated ~ 1.15 km, retreating at an average rate of 12.2 m/yr.

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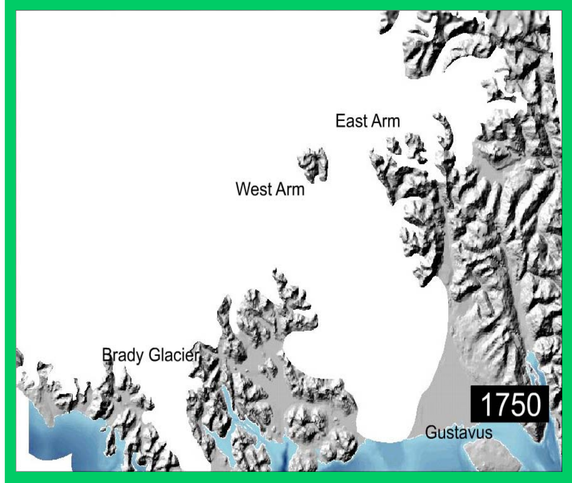

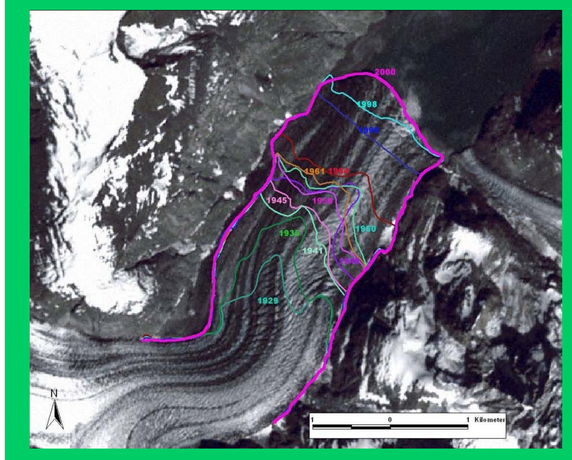

Johns Hopkins Glacier terminus position locations 1929-2000