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ScienceDirect
Global and Planetary Change 56 (2007) 23–56
GLOBAL AND PLANETARY CHANGE
www.elsevier.com/locate/gloplacha

Late nineteenth to early twenty-first century behavior of Alaskan glaciers as indicators of changing regional climate

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Received 30 August 2005; accepted 21 July 2006
Available online 2 October 2006

Abstract

Alaska's climate is changing and one of the most significant indications of this change has been the late 19th to early 21st century behavior of Alaskan glaciers. Weather station temperature data document that air temperatures throughout Alaska have been increasing for many decades. Since the mid-20th century, the average change is an increase of ~ 2.0 °C. In order to determine the magnitude and pattern of response of glaciers to this regional climate change, a comprehensive analysis was made of the recent behavior of hundreds of glaciers located in the eleven Alaskan mountain ranges and three island areas that currently support glaciers. Data analyzed included maps, historical observations, thousands of ground-and-aerial photographs and satellite images, and vegetation proxy data. Results were synthesized to determine changes in length and area of individual glaciers. Alaskan ground photography dates from 1883, aerial photography dates from 1926, and satellite photography and imagery dates from the early 1960s. Unfortunately, very few Alaskan glaciers have any mass balance observations.

In most areas analyzed, every glacier that descends below an elevation of ~ 1500 m is currently thinning and/or retreating. Many glaciers have an uninterrupted history of continuous post-Little-Ice-Age retreat that spans more than 250 years. Others are characterized by multiple late 19th to early 21st century fluctuations. Today, retreating and/or thinning glaciers represent more than 98% of the glaciers examined. However, in the Coast Mountains, St. Elias Mountains, Chugach Mountains, and the Aleutian Range more than a dozen glaciers are currently advancing and thickening. Many currently advancing glaciers are or were formerly tidewater glaciers. Some of these glaciers have been expanding for more than two centuries. This presentation documents the post-Little-Ice-Age behavior and variability of the response of many Alaskan glaciers to changing regional climate.

Keywords: Alaska; glaciers; climate change; temperature; advance; retreat

1. Introduction

1.1. Alaskan glaciers

Glaciers cover about 75,000 km^2 of Alaska (Fig. 1). Recent estimates range from 73,800 km^2 (Post and Mayo, 1971) to 74,700 km^2 (Post and Meier, 1980), to 75,110 km^2 (Molnia, 1982). This represents about 5% of Alaska's land area and includes glaciers on 11 mountain ranges (Coast Mountains, Saint Elias Mountains, Chugach Mountains, Kenai Mountains, Aleutian Range, Wrangell Mountains, Talkeetna Mountains, Alaska Range, Ahklun and Wood River Mountains, Kigluaik Mountains, and Brooks Range), one large island (Kodiak Island), one island archipelago (Alexander Archipelago), and one island chain (Aleutian Islands). Glaciers in Alaska extend from as far southeast

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0921-8181/$ - see front matter © 2006 Published by Elsevier B.V.
doi:10.1016/j.gloplacha.2006.07.011

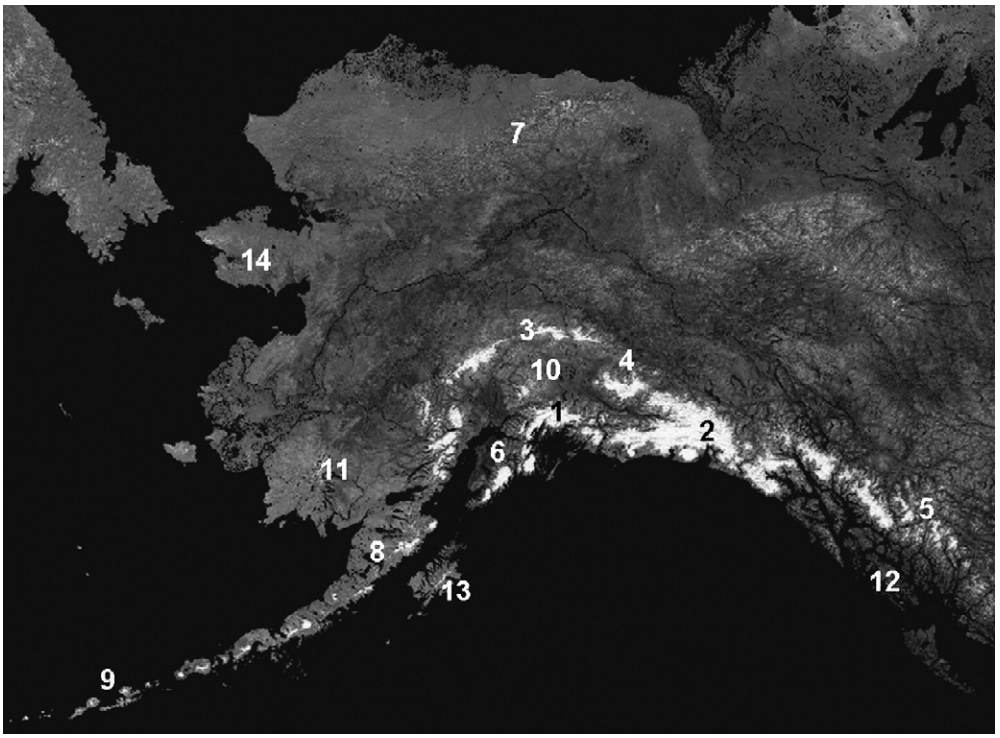

Fig. 1. AVHRR image map showing the location of the 14 glacierized areas of Alaska. Current glacier cover for each region, based on data presented in Molnia (in press), is: 1) Chugach Mountains — ~ 21,320 km^2; 2) Saint Elias Mountains — ~ 14,300 km^2; 3) Alaska Range — ~ 14,000 km^2; 4) Wrangell Mountains — ~ 5300 km^2; 5) Coast Mountains — ~ 7280 km^2; 6) Kenai Mountains — ~ 4810 km^2; 7) Brooks Range — <1000 km^2; 8) Aleutian Range — ~ 2000 km^2; 9) Aleutian Islands — ~ 2000 km^2; 10) Talkeetna Mountains — ~ 1000 km^2; 11) Ahklun–Wood River Mountains — ~ 60 km^2; 12) Alexander Archipelago — <100 km^2; 13) Kodiak Island — <50 km^2; and 14) Kigluaik Mountains — <1 km^2. AVHRR base figure by Michael Fleming is modified from Molnia, 2000.

as N55°19′ and W130°05′, about 100 km east of Ketchikan; to as far southwest as Kiska Island at N52°05′ and E177°35′ in the Aleutian Islands; to as far north as N69°20′ and W143°45′ in the Brooks Range. The number of glaciers is unknown, having never been systematically counted, but probably exceeds 100,000. Most are small, upland cirque glaciers. Approximately 2000 are valley glaciers. Of these valley glaciers, ~ 60 (<0.1% by number) are tidewater glaciers (Viens, 1995). Hence, by number, >99.9% of Alaska's glaciers are land-based or terrestrial. By area, tidewater glaciers occupy ~ 27,000 km^2, or ~ 1/3 of the glacier-covered area of Alaska.

Alaskan glaciers range in elevation from above 6000 m to below sea level. Most are unnamed. Fewer than 700 glaciers have been officially named by the U.S. Board on Geographic Names. Nearly all of these named glaciers and about 1000 additional unnamed glaciers descend below an elevation of ~ 1500 m.

During the Little Ice Age (LIA), the total glacier-covered area and the number of mountain ranges and islands with glacier cover were significantly larger than present (Molnia, in press). Since then, as has been the case in all of Earth's temperate glacier-covered areas, there has been a significant decrease in glacier length, area, and thickness. However, the timing, magnitude, and complexity of this "post-LIA" glacier change in each of Alaska's 14 glacier-bearing areas have been different. To understand these complexities, a detailed assessment of each of Alaska's glacier-bearing regions was prepared as part of the USGS' comprehensive *Satellite Image Atlas of the Glaciers of the World* series (Molnia, in press). Key findings from this *Atlas* assessment are synthesized and succinctly presented here specifically to define the late 19th to early 21st century behavior of Alaskan glaciers in response to a documented changing regional climate which is characterized by temperature increases at all monitoring stations throughout Alaska. As the details presented here show, although there is a significant thinning of lower-elevation glaciers and retreat of glacier termini, the current behavior of Alaska's glaciers varies significantly from area to area, varies significantly with elevation, and is extremely dynamic.