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GRINNELL GLACIER STUDIES, A PROGRESS REPORT AS RELATED TO CLIMATE

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ABSTRACT

Efforts to obtain data affecting the behavior of Grinnell Glacier, Glacier National Park, are described. Some of the data so far observed, which include precipitation, temperature, runoff from the glacier basin, and actual surveys of the ice body, are tabulated. The possibility that observations to date point toward a renewal of glacier activity in the Northwest is developed. Recent trends toward cooler weather in the northwestern parts of Europe and North America, and wetter weather as well in the case of northwestern North America, are discussed.

1. INTRODUCTION

In an earlier report Dightman and Beatty [1] covered some of the background of the program for measurement and study of some of the glaciers in Glacier National Park. That report contained data through 1951, discussed findings from measurements, and compared observed climatic trends for a 57-year period with glacier behavior and with Willett's [2] tentative forecasts. At a time when many Pacific Northwest glaciers are beginning to show definite growth, as reported by Bengtson [3], Hubley [4], Harrison [5] and others, it is appropriate to report on the first seven years of observations of precipitation and runoff in connection with measurements and observations of the behavior of Grinnell Glacier, Glacier National Park.

While actual measurements of Grinnell Glacier were started by the National Park Service in 1932 at about the time the rate of recession during the first half of the current century was approaching its maximum, and there are photographs of this glacier several years before the turn of the century showing roughly its extent at that time, data on precipitation and runoff for the glacier basin are available only since 1949. The history of the project covered in the earlier report [1] will not be repeated here. The present report will be confined to bringing the earlier summary up to date, to comparing observations with later climate trends, and to discussing the purposes of the work.

2. DEVELOPMENT OF PROJECT SINCE 1950

A Weather Bureau Standpipe Seasonal Storage Precipitation Gage (now known as Grinnell Glacier No. 1), installed on August 27, 1949, about 2,000 feet north-northeast of the location of one of the fronts of the glacier at that time, produced its first seasonal total when the measurement made on July 20, 1950, showed a catch of 125.1 inches. The glacier, located in a cirque opening roughly to the north and northeast, has had its main terminus in recent years in a deep pool at the north end of the cirque, and glacier elevations on September 1, 1950, ran from 6,403 feet (melt pool) to around 7,300 feet at the southern (highest) end. The cirque is bounded on west and south by the Garden Wall, much of which runs between 8,000 and 9,000 ft. in elevation. While the glacier now flows mostly northward, old moraines indicate that at recent maximum size (around 1890) it had an eastward direction of movement at the terminus. Moraines indicate that the storage gage is located only about 100 feet from one earlier extension of the glacier.

This storage gage functioned well until the exceedingly heavy snows of the 1953–54 season resulted in lateral

TABLE 1.—*Precipitation measurements adjacent to Grinnell Glacier, 1950–1956*

Season ending (year and date)	Gage No. 1, Est. 8-27-49 Seasonal total precipitation (in.)	Gage No. 2, Est. 8-15-55 Seasonal total precipitation (in.)
1950—July 20	125.05 (11 mo.)	
1951—July 24	117.59	
1952—July 15	109.27	
1953—July 31	106.93	
1954—Aug. 5	138.20	
1955—Aug. 10	108.22	
1956—Aug. 7	100.11	152.83

TABLE 2.—*Temperature (°F.) at Grinnell Glacier (No. 1) 1951–52*

Year	Month	Average maximum	Average minimum	Average	Highest	Lowest
1951	Aug.*	58.5	39.2	48.9	82	29
1952	Aug.*	64.8	43.7	54.3	79	29

August mean temperatures at nearby stations compared with Grinnell No. 1

Year	Grinnell No. 1 (el. 6,238 ft.)	Summit (el. 5,213)	Babb, 6 NE (el. 4,300)	West Glacier (el. 3,154)	Polebridge (el. 3,690)
1951	48.9	53.2	55.1	60.1	57.0
1952	54.3	54.7	57.0	61.9	58.5

*August was the only complete temperature record month in both years. For period July 25–Sept. 10, 1951 highest temperature 82, lowest 26. For period July 9–Sept. 16, 1952 highest 82, lowest 29.

movement of the snow pack around the gage, damaging the drain assembly, and loosening the concrete foundation. This damage was repaired during the 1955 summer season, an additional 5-ft. section was added to the gage, a larger foundation was built, and the drain assembly was shielded to protect against future lateral movement of snow. At the same time a second gage (Grinnell Glacier No. 2) was installed about 3,000 feet south-southeast of No. 1; No. 2 has the same gage height (21.5 ft.) as No. 1. Windshields are not used on either, as experience during the first two seasons at No. 1 site showed that such shields could not withstand the severe winds in this area.

Establishment of the second gage was expected to show important differences in precipitation, and the first seasonal measurement seemed to verify that expectation (see table 1). Reasons for the larger catch at the new site are probably many, and interrelated in several ways, but it is not unreasonable to observe that since the second site is nearer to the upper end of the glacier, it could have been expected to be in an area of heavier precipitation. There is also some doubt as to the completeness of the No. 1 catch for the season.

During the 1951 and 1952 summer seasons a cotton region shelter, extreme thermometers, and a hygrothermograph were used at the No. 1 site, and a record of daily high and low temperatures was made during those summers only (the shelter was destroyed by porcupines before the 1953 season began). Some pertinent temperature notes appear in table 2. A continuous (throughout the year) temperature record was started by the U. S. Geological Survey in 1951 at the gaging station on Grinnell Creek about a mile from the glacier and about 1,400 feet lower than the melt pool, but little

TABLE 3.—*Runoff from Grinnell Glacier Basin (3.4 sq. mi.), 1950–56*

Water year ending September 30	Runoff in inches of precipitation	Runoff in percent of Grinnell No. 1 precipitation
1950	106.54	85
1951	104.98	89
1952	89.59	82
1953	97.16	91
1954	110.54	80
1955	94.29	87
1956	[a] 102.77	[b] 103

[a] Preliminary, subject to correction.
[b] Indicates that seasonal catch might not have been complete, due possibly to capping or icing of gage orifice. Runoff in 1956 water year was 67 percent of catch of 152.83 in gage No. 2.

work thereon has been done so far. It is interesting to note, in table 2, the differences in average temperature between Grinnell Glacier and nearby stations for the same months.

The U. S. Geological Survey has measured runoff from the glacier basin (3.4 sq. mi.) since 1949, and these data appear in table 3. While the glacier itself currently covers only about 270 acres, its area in 1900 was 600 acres, or just about a square mile. The gaging station on Grinnell Creek could not be located nearer the glacier because of impossible winter operating conditions that exist at other sites. The runoff records are of excellent quality, and reflect in at least some degree the behavior of the glacier. In late summer, for example, the glacier furnishes the larger part of Grinnell Creek's flow.

All these data, including precipitation and temperature observations by the Weather Bureau, temperature and runoff observations by the U. S. Geological Survey, and actual surveys and measurements by the National Park Service, will contribute much to our knowledge of climate and glacier relationships in the years to come—although it must be admitted that 6 or 7 years is certainly not a very long time in which to correlate glacial and climatic behavior, the implications of which correlations may extend into geological time. However, such data as have been accumulated so far already appear to have some significance, considering the well-documented growth of many western North American glaciers during recent years.

3. GLACIER ACTIVITY IN WESTERN UNITED STATES DURING RECENT YEARS

Bengtson [3], Hubley [4], and Harrison [5] have reported increased glacier activity over much of the western United States during recent years. Beatty and Johnson [6], in their annual reports of Glacier National Park glacier observations and measurements, have pointed out that the rapid recession noted during the 1930 and 1940 decades has halted, and since 1950 there has been some evidence of increased glacier activity. Spectacular growth of Coleman Glacier on Mount Baker in the Northern Cascades has been observed, and increased volume of others in this area has been reported. Activity of glaciers has increased as far south as the Central Sierras and as far east as the Northern Rockies. This change in general glacial behavior, covering at least several years over a large area, must

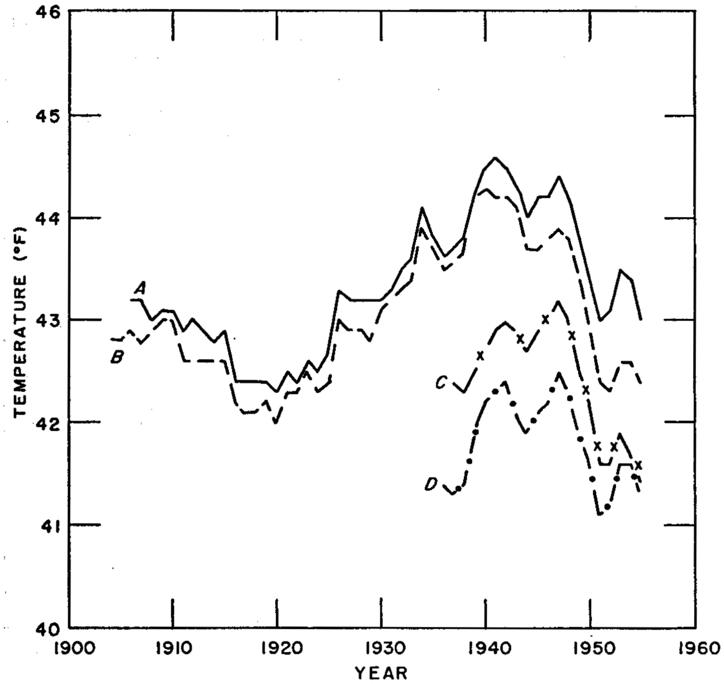

FIGURE 1.—Ten-year moving averages of annual mean temperature, for 10-year periods ending with plotted year, as follows: A. Kalispell (adjusted for change in location 1950), B. Areal average for Montana (weighted), C. West Glacier, and D. Fortine. All are reasonably near (under 60 miles away) to Grinnell Glacier, and reflect observed changes over the last several years.

have some climatic significance. Glaciers in a sense are integrators of climate for several years, i. e., it takes more than one year's weather to make an appreciable contribution to glacial growth or ablation. In this connection it is well to recall Ahlmann's [7] statement, "Glaciers have a tendency to establish time variations of their own that are more or less independent of climatic factors."

4. CLIMATE TRENDS IN THE AREA AROUND GLACIER NATIONAL PARK

In the earlier report [1] 10-year moving averages of average temperature and precipitation for the entire State of Montana were used to establish some short-range trends. In an effort to localize the application of these trends while bringing them up to date through 1955, several 10-year moving averages for single stations are shown in figures 1 and 2. Yearly total precipitation and average temperature data for Kalispell (from which curves A in figs. 1 and 2 were computed) are given in table 4 to enable the reader (1) to see the unsmoothed variations from year to year, and (2) to do his own smoothing by some other method that he may prefer. The similarity of the curves in figures 1 and 2 to the trends shown in [1] is apparent; and the marked agreement of the trends between stations and also between a single station (e. g., curve A) and the 146,000-sq. mi. state areal average (curve B) is noteworthy. They all confirm the observation that the weather around Glacier National Park has been markedly cooler and wetter since about 1946 than

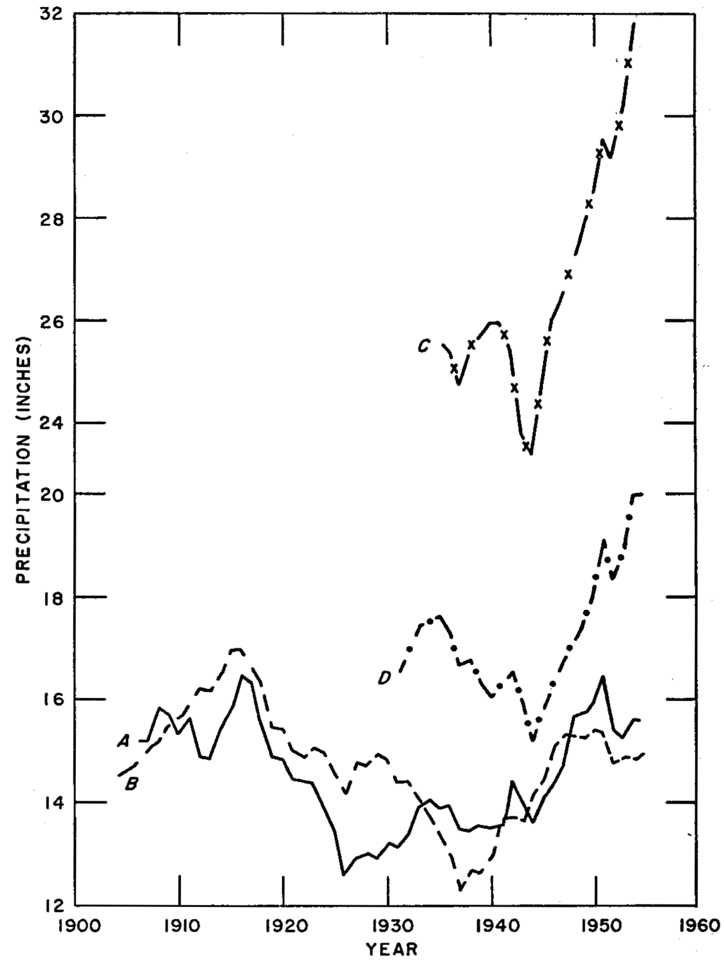

FIGURE 2.—Ten-year moving averages of total annual precipitation, for 10-year periods ending with plotted year, as follows: A. Kalispell (as adjusted), B. Areal average for Montana (weighted), C. West Glacier, and D. Fortine.

TABLE 4.—*Annual precipitation and annual average temperature for Kalispell (Curve A in figs. 1 and 2) 1897–1955. Station move in 1949 made adjustment of last 6 years necessary as new airport location is both wetter and cooler than the former city site. Adjustments were based on the record of a cooperative station located at the city site for two years after the move, and then relocated to the south edge of town*

Year	Total precipitation	Average temperature	Year	Total precipitation	Average temperature
1897	16.99	42.9	1927	18.61	42.0
1898	12.50	44.8	1928	11.94	43.3
1899	19.50	41.0	1929	10.39	41.6
1900	17.69	44.3	1930	15.85	43.2
1901	12.85	43.3	1931	12.31	44.8
1902	19.21	42.2	1932	13.43	43.2
1903	14.63	42.0	1933	18.12	44.3
1904	10.89	44.6	1934	13.74	47.6
1905	15.20	42.8	1935	11.47	42.1
1906	13.50	44.4	1936	14.05	43.1
1907	16.94	42.1	1937	13.80	42.4
1908	18 51	43.5	1938	11.94	45.0
1909	17.80	41.7	1939	11.79	45.4
1910	14.12	44.4	1940	15.06	46.1
1911	16.10	41.7	1941	13.53	45.7
1912	11.70	42.4	1942	20.81	43.0
1913	13.97	41.2	1943	14.17	42.1
1914	17.07	43.6	1944	10.42	44.4
1915	18.75	43.7	1945	15.96	44.4
1916	19.66	39.2	1946	16.10	43.9
1917	16.02	42.4	1947	18.73	44.1
1918	11.15	43.5	1948	20.91	42.4
1919	11.12	42.2	1949	12.48	42.0
1920	12.81	42.9	1950	16.63	41.3
1921	13.13	43.4	1951	20.47	40.8
1922	10.97	41.7	1952	8.79	43.5
1923	12.99	43.3	1953	12.31	45.7
1924	12.83	42.6	1954	14.50	42.7
1925	12.56	45.8	1955	15.83	40.2
1926	13.35	44.9			

during the period of rapid glacier ablation noted in the West for about 20 years after 1925.

Whether or not these observed trends are only a minor fluctuation in the larger Northern Hemisphere warming trend, touched upon by many authors, which is variously described as lasting from 100 to 200 years, we do know that there is a well-established short-range trend toward cooler weather in the Northwest. The general assumption that the warming trend continues unabated in all areas of the Northern Hemisphere (made most recently by Gilbert N. Plass [8]) probably requires qualification to recognize the observed changes. The conclusion that the changes are real is supported by our knowledge of glacier behavior in the affected area for the last 10 years.

It is generally agreed that there is geological evidence that periods of glacial advance and recession on varying scales have followed each other at intervals of several hundred or thousands of years through the Pleistocene Age, and an accompanying change in climate is a corollary of that knowledge. Ahlmann [9] said in 1948 that results of excavations in southernmost Greenland seemed to him to justify the conclusion that at no time since the year 1400 had the climate been so favorable as it had been since the 1920's. However, it seems reasonable to expect this long trend toward warmer climate to reverse itself eventually, if it has not already done so, as such trends already have reversed themselves several times within the last few thousand years. Ahlmann [7] in 1953 pointed out that the culmination of climate improvement had been reached in many places in the 1930 or 1940 decades, and a trend to colder climate had started in northwestern Europe. The important question, which probably will have to wait many years for an answer, is, "Is the trend actually reversing itself in northwestern Europe and in northwestern parts of the North American Continent?" The extent to which we can answer that question now seems to be that the warming trend has suffered at least a temporary interruption over sizable areas.

The periods with which we are working are extremely small on the scale of geological time. It will be many years, perhaps as many as 200 or 300, before our file of climatic information will contain data for a long enough period to permit reasonably full correlation between climate and glaciation. In the meantime, it appears that our knowledge of the history of climate can be increased by additional studies leading to a more complete picture of glacier activity during the last thousand years or so. Ahlmann [7] said "The relations between glaciers and climate are highly complicated and still far from clear. Until we have solved the problems of the existence and variation in size of glaciers, their structure, movement, and other features, we cannot fully utilize them as the climatological registers they really are."

SUMMARY

The work done so far on Grinnell Glacier is a start toward eventual accumulation of sufficient data for studies of the relationships between glacier and climate behavior in the Glacier National Park area of the United States. The almost seven years of data accumulated so far are a very small beginning—almost insignificant when considering the many years that appear involved in most major glacial cycles. Additional work can be done, however, in dating the several terminal moraines of Grinnell to establish more of a history of the activity of that glacier than is now known, and in defining the approach to building a file of climate-glacier data so that our successors a century or two in the future will have something with which to work.

It seems possible that the measurements of precipitation, runoff, and the glacier itself have been started at a turning point in the glacier's history. Whether it is a major reversal or a temporary interruption of a warming trend, only time will tell. In the meantime this cooperative project of studying Grinnell Glacier and accumulating data, participated in to date by the National Park Service, the U. S. Geological Survey, and the U. S. Weather Bureau, holds real hope for improving our ability to use glaciers as climatic indexes, and for increasing our understanding of climatic changes, of which glacier growth and ablation are only one result.

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