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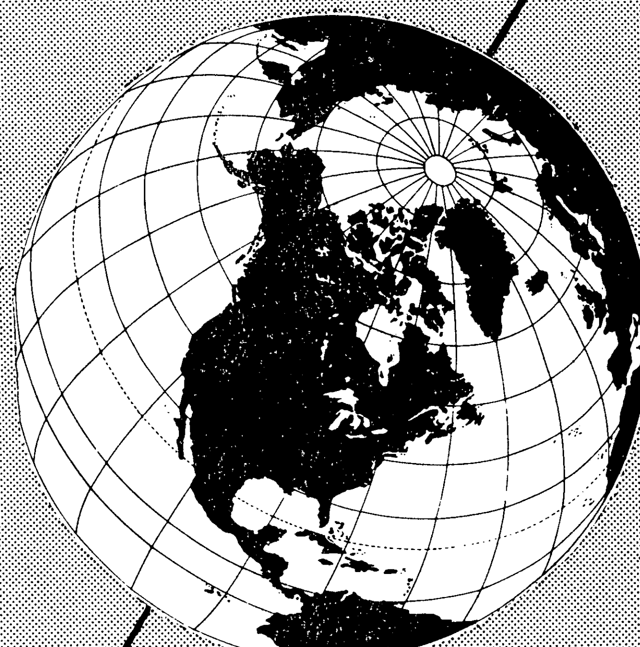
Research Report 22

DECEMBER, 1956

Precipitation Trends in Greenland during the Past 30 Years



SNOW, ICE AND PERMAFROST RESEARCH ESTABLISHMENT

Corps of Engineers, U. S. Army

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Precipitation Trends in Greenland during the Past 30 Years

by Marvin Diamond

SNOW ICE AND PERMAFROST RESEARCH ESTABLISHMENT

Corps of Engineers, U. S. Army

Wilmette, Illinois

PREFACE

This constitutes a progress report on a portion of SIPRE Project 22.5-1, Snow cover studies. The snow profile data used in this report were obtained at Site 2 on the Greenland Ice Cap by SIPRE personnel working on several projects under the direction of Dr. Henri Bader, Chief Scientist. The report is a product of studies on the climate of Greenland being undertaken by the Climatic and Environmental Research Branch under the direction of Dr. R. W. Gerdel, Branch Chief.

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SUMMARY

The record of annual precipitation as obtained from stratigraphic studies on snow profiles in the interior of Northern Greenland shows a decreasing precipitation trend since 1920 with the largest decrease occurring since 1932. A residual mass curve analysis of the data indicates that, in spite of large fluctuations in the accumulated precipitation, the decreasing trend may be considered valid over a period of several years.

PRECIPITATION TRENDS IN GREENLAND DURING THE PAST 30 YEARS

by

M. Diamond

INTRODUCTION

There is considerable evidence of a warming trend in the Arctic since the turn of the century and especially since 1920 (Willett, 1953). According to Ahlman (1953), the thickness of the ice formed annually in the North Polar Sea has diminished from an average of 365 cm at the time of Nansen's "Fram" expedition of 1893-96 to 218 cm during the drift of the Russian ice-breaker Sedov in 1937-40. The extent of drift ice in Arctic waters has also diminished considerably in the last few decades. Information available from the USSR in 1945 (Ahlman, 1953) showed that the area of drift ice in the Russian sector of the Arctic was reduced by no less than 1,000,000 km^2 between 1924 and 1944. The shipping season in West Spitsbergen lengthened from 3 months at the beginning of the century to about 7 months at the beginning of the 1940's. The mean annual temperature at Spitsbergen increased about 8C in the past 25 yr and the mean annual temperature at Upernavik, Greenland (72° N) increased 3.0C in the same period. No long-term temperature records are available for stations on the Greenland Ice Cap but, since a warming trend has been observed at stations along the coasts of Northern Greenland (Willett, 1953), it is possible that air temperatures at similar latitudes on the ice cap have also risen during the past 25 yr.

Since there has been no measurable change in incident solar radiation during the past 30 yr, the increase in air temperatures may be attributed to an increase in the transfer of heat from lower to higher latitudes, probably due to variations in atmospheric circulation. Winds blowing from lower to higher latitudes bring not only heat but also moisture. Hence one might expect that an increase in air temperature would be accompanied by an increase in precipitation, particularly on the Greenland Ice Cap where there would be effective cooling by lifting and by advection over the cold snow surface. An increase in annual precipitation in this area might result in increased snowfall in the winter season or increased rainfall in the summer with less snow during the shorter winter season.

The inaccuracies associated with measurements of the water equivalent of snowfall cast doubt upon any apparent trends in precipitation derived from records of stations in arctic areas where measurements are made by the usual methods. Measurement of the water equivalent of snowfall by means of a rain gage or by converting snow depth to inches of equivalent rainfall, using a conversion factor, has been shown to be greatly in error. In a study of precipitation at Point Barrow, Alaska, Black (1954) found that actual snowfall was two to four times that measured with a precipitation gage. In areas where snow is the predominant form of precipitation, it is customary to compute equivalent rainfall on the assumption that 10 in. of snow correspond to 1 in. of rain. Wilson (1955) has shown that during the winter at Burlington, Vermont, the density of newfallen snow varied from 0.02 to 0.17 g/cm^3 and the seasonal average of 295 storms was 0.08. In the Canadian Arctic Archipelago, Rae (1951) found that 4 to 5 in. of new snow were required to produce an equivalent inch of rain.

PRECIPITATION TRENDS FROM STRATIGRAPHIC STUDIES

It has been found that the difference in density between summer and winter snow permits estimation of the annual accumulation of snow from profile studies made at high elevations on the Greenland Ice Cap where little or no melting occurs.

It may be assumed that the annual accumulation on the flat surface characteristic of the interior Greenland Ice Cap has not been influenced by drifting. Over a year's time, the transport of snow into a given area is probably equal to the transport of snow out of the same area.

Snow-profile studies were made at the SIPRE test area at Site 2, 200 miles east of Thule, at an elevation of about 6800 ft. The annual precipitation (equivalent to annual accumulation) at this site was computed from stratigraphic studies on samples from deep pits and drill cores.

For the purpose of this report, October 1 was selected as the start of the precipitation year. The lower-density summer snow which aids in the stratigraphic identification of the annual layers in the snow profile is presumed to have been deposited before that date. All other annual precipitation records used in this report have been adjusted to conform to a precipitation year of 1 October to 30 September.

The record of annual precipitation at the Ice Cap site (Figure 1) indicates an apparent gradual decrease in precipitation between 1920 and 1954. A partial check on this pattern is provided by the record of measured precipitation at Upernavik, near 72° N on the west coast of Greenland (Figure 2), which indicates a downward trend in annual precipitation beginning about 1921. The annual precipitation in central Greenland between 1911 and 1931 also has been computed by Sorge (1935) from snow profile studies at the Eismitte station. This record (Figure 3) indicates that annual precipitation at this mid-Ice Cap station decreased between 1920 and 1931.

The changes in annual precipitation which have occurred on the ice cap over the last several decades is shown by a plot of the 5-yr moving means for both Site 2 and Eismitte (Figure 4). During the period 1922 to 1927 when there was a concurrent record for both stations, the 5-yr moving means show a trend toward increasing precipitation at both locations. There appears, however, to have been a downward trend in precipitation at Site 2 after 1931.

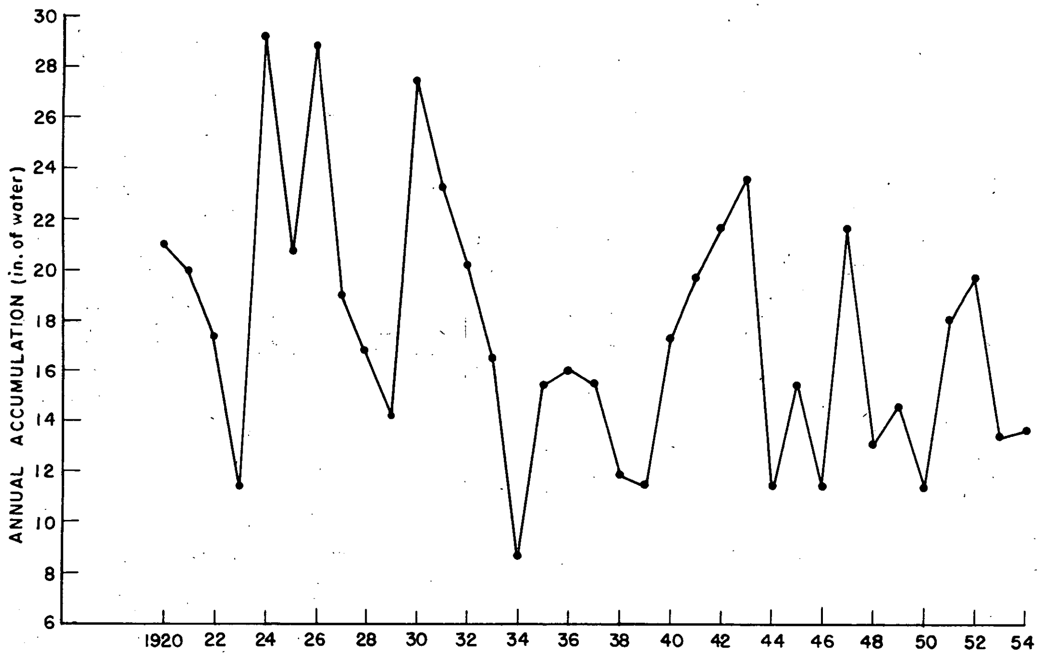

Figure 1. Annual accumulation of precipitation at Site 2, Greenland. Precipitation year, for all figures, is 1 October to 30 September.

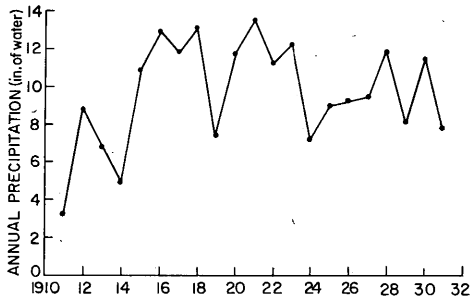

Figure 2. Annual precipitation at Upernavik, Greenland.

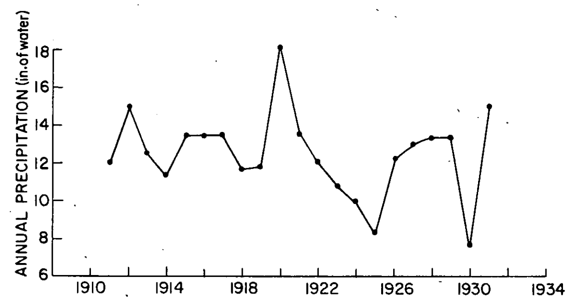

Figure 3. Accumulated annual precipitation, Eismitte, Greenland.

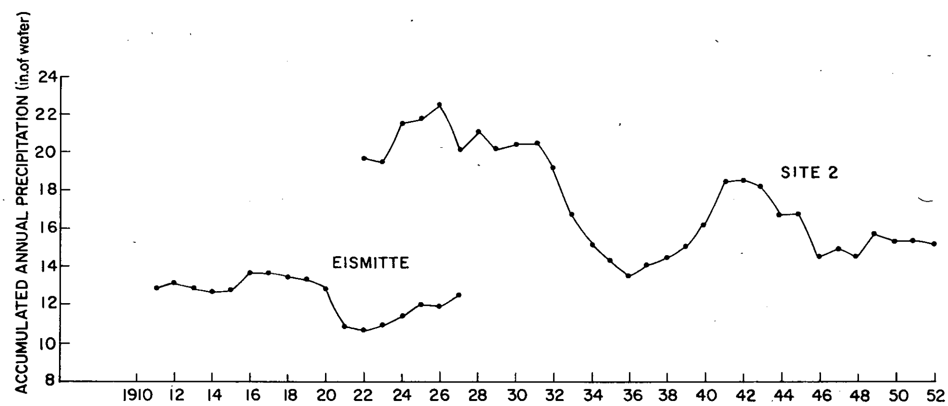

Figure 4. Five-year moving means for accumulated annual precipitation at Site 2 and Eismitte. Points are plotted on middle year of each 5-yr period.

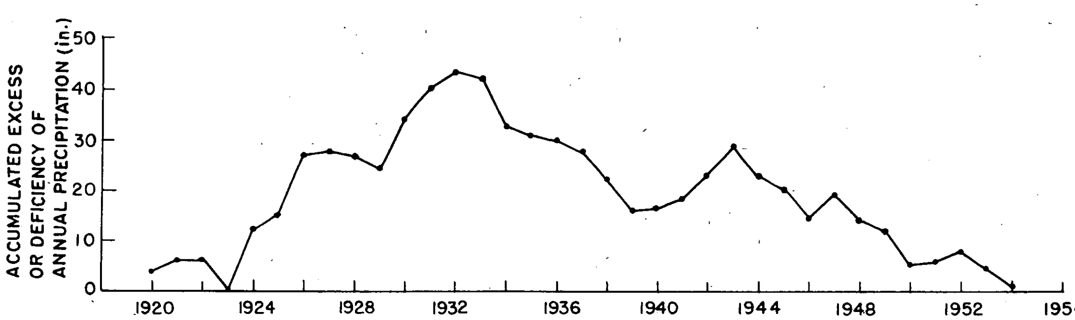

Figure 5. Residual mass curve for annual accumulated precipitation at Site 2, Greenland.

To determine whether the apparent decreasing trend in precipitation applies to the entire period from 1931 to 1952 or whether this apparent trend was the product of the marked precipitation deficiency which occurred during the few years centered around 1936, a residual mass curve for profile data from Site 2 was prepared (Fig. 5). The residual mass curve is a technique used to test the homogeneity of a record. It is essentially the progressive accumulation of departures from the arithmetic mean of a series of numbers taken in chronological order. In this process, the arithmetic average is subtracted from each number in the series and the residual values added progressively. The subtotals so obtained are plotted against time. A definite and progressive alteration in recorded phenomena is indicated by a change in slope of the portions of the curve covering the period of alteration. For long-term precipitation records, a change in slope of the curve may be caused by a climatic change or by a change in the conditions of observations. Relocation of a precipitation gage or the installation of a new gage of different type might influence the pattern of a residual mass curve. The stratigraphically determined precipitation record for the ice cap would not be subject to any artificial influence such as a change in gages or recording methods. Hence, the residual mass curve should provide a valid indication of the duration and extent of the precipitation trend over the years of record.

The residual mass curve for the Site 2 data indicates that the largest decrease in precipitation occurred after 1932. Prior to that time, annual precipitation was above the mean for the 1920-54 period. After 1932, the annual precipitation was below the 35-yr mean as shown by the falling limb of the residual mass curve after the 1932 peak. This curve indicates that the apparent increase in temperatures in Northern Greenland during the past 25 yr has been accompanied by a decrease in precipitation on the Ice Cap. The recent glacier retreat generally has been attributed to higher summer temperatures and an increase in the length of the ablation season. However, it appears that the decrease in precipitation on the Greenland Ice Cap may contribute also to the retreat of some of the Greenland glaciers.

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