Recent Climatic Change and Increased Glacierization in the Eastern Canadian Arctic

THE climatic warming trend since the 1880s (refs. 1–5), which seems to have been global in extent and was manifested by an upward trend in mean annual (and particularly mean winter) temperatures, seems to have given way since the 1940s to a cooling trend[6], which is most marked in higher latitudes (> 60° N, refs. 7 and 8). Here we report recent field work on Baffin Island, eastern Canadian Arctic, and an analysis of the available climatic data for that area which provides further information.

We calculated seasonal running means of temperature and precipitation for all major weather stations on Baffin Island (Fig. 1). For the period 1960 to 1969 a marked decrease, by as much as 2.1° C, in the mean temperature of the ablation season (June to August) is apparent; but the accumulation season (September to May) shows an equally marked increase in temperature, by as much as 2.0° C. This pattern holds for all but two of the stations on Baffin Island (Table 1). The two exceptions are a result of local conditions at each site (Cape Dyer and Frobisher Bay).

An equally striking trend is seen for the seasonal precipitation totals over the same ten year period. Winter precipitation shows marked increases throughout Baffin Island, but summer records show more station to station variability (Table 1). In view of the extremely important influence of local topographic factors on precipitation in the area, the consistency of the trends over such a large area, where total precipitation amounts vary widely, is surprisingly good.

Using a catalogue of synoptic pressure pattern types for Baffin Island[9], we examined airflow characteristics for the months of July and August. From 1961–1965 to 1966–1970 there was a 29% increase in the number of days on which airflow with an easterly (particularly a north-easterly) component affected the region and a concurrent decrease in the number of days on which airflow with a westerly (particularly a south-westerly) component affected the region. The increased frequency of cool air being advected into the area from the east and north-east has apparently resulted in lower summer temperatures. A synoptic classification catalogue for all of the winter months is not yet available but it seems likely that

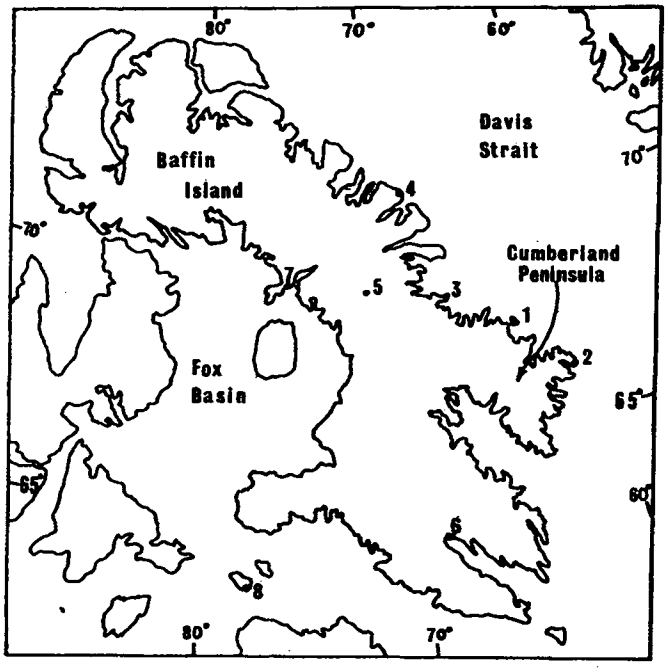

Fig. 1 Location of field area and meteorological stations discussed in text. Numbers refer to stations in Table 1.

Table 1 Net Changes in Seasonal Mean Temperatures and Seasonal Precipitation Totals, 1960–1969, derived from Linear Regressions

Station	Latitude	Longitude	Elevation (m)	Ablation season (J, J, A) Temperature change (° C)	Precip. (cm/we)	Change* %	Accumulation season (Sept.–May) Temperature change (° C)	Precip. (cm/we)	Change %
1. Broughton Is.	67° 33′	64° 03′	581	−0.9	−0.2	−3.4	+0.7	+12.6	+51.7
2. Cape Dyer	66° 35′	61° 37′	376	−2.0	−6.9	−49.7	−0.4	+11.8	+21.8
3. Cape Hooper	68° 26′	66° 47′	401	−0.5	+5.8	+82.5	+0.4	+23.4	+127.4
4. Clyde	70° 27′	68° 33′	3	−2.1	−0.2	−2.2	+1.6	+2.2	+16.6
5. Dewar Lakes	68° 39′	71° 10′	518	−1.4	+0.2	+1.9	+0.9	+2.5	+23.3
6. Frobisher Bay	63° 45′	68° 33′	21	+0.03	−0.2	−1.3	+1.2	−2.6	−10.0
7. Longstaff Bluff	68° 57′	76° 18′	162	−2.1	−2.1	−24.9	+0.7	+0.7	+5.9
8. Nottingham Is.	63° 07′	77° 56′	16	−1.7	+3.7	+54.4	+2.0	+5.8	+32.9
			Average	−1.3	+0.5	+7.2	+0.9	+7.1	+33.7

* Values are for net precipitation changes, 1960–1969, as a percentage of the mean 1960–1969.

the observed warming during these months is related to a higher frequency of days on which relatively warm, moist southerly air entered the region.

Short term climatic changes are manifested visually, by field evidence, only in sensitive regions. On Baffin Island, permanent snowbanks, incipient glaciers and the duration of ice cover on small lakes respond essentially concurrently with climate. Field observations (1969 to 1971) of these features in the northern Cumberland Peninsula (Fig. 1) and comparisons with aerial photographs taken late in the ablation seasons of 1949 and 1960 support the climatological evidence for a climatic deterioration.

Aerial photograph comparisons show that snowbanks generally decreased in area between 1949 and 1960, whereas all observed snowbanks increased markedly during the past decade. The actual increases are variable; permanent snowbanks now exist in many areas that were free from snow in 1960 and many of the smaller (< 10 m diameter) snowbanks have more than doubled in size, whereas larger (> 50 m diameter) snowbanks have changed less noticeably. In one instance, snowbanks now occupying an area free from snow in 1960 are encroaching on 25 mm diameter thalli of the lichen species *Alectoria minuscula*. A growth curve developed for this species, relating thallus diameter to substrate age, indicates a seasonally snow-free substrate for the previous 40 ± 10 yr (ref. 10). This suggests that the present distribution of snow cover, resulting from climatic deterioration over the past decade, is at least as extensive as that of 40 yr ago. In contrast to snowbank growth, glacier termini had receded between 1949 and 1960 and continued active recession through 1971 because of their much longer response time to climate.

Another, less frequently observed result of climatic change is the formation of incipient glaciers. In 1970 two cirques, which were snow-free in 1960, were noted as being occupied by glacierets or large snowbanks. Also, a number of small lakes (< 1 km²) free from ice in 1960 have been observed to remain ice covered throughout the ablation season in recent years, and on many of these lakes ice has accumulated for several years. On all lakes observed, the percentage of ice-cover at the end of the ablation season was equal to or greater than ice-cover in 1960.

Williams *et al.*[11] have demonstrated the glaciological sensitivity of Baffin Island to climatic fluctuations. For an area north of the Barnes Ice Cap, Ives[12] has shown that although 2% of the area is now glacierized, in the recent past (< 330 ± 75 yr (ref. 13)) 70% of the area was glacierized. The present glaciation limit for the area lies 0 to 300 m above the land surface[14]. Using an observed mean lapse rate for the area of 0.5° C/100 m based on radiosonde data (R. S. Bradley, unpublished), a mean summer cooling of 1.5° C, augmented by increased snowfall, seems sufficient to lower the glaciation limit below a significant portion of the land surface. An increase in the number and size of thin ice caps on the plateau region, and accompanying increases in the mean albedo of the island during the ablation season, would give positive feedback and further reinforce the climatic trends already in progress.

Namias[15] suggests that a new climatic regime over the North Pacific and North America began "abruptly in the late summer and fall of 1961", as a result of warmer water replacing cold surface water in the central northern Pacific Ocean. This oceanic temperature anomaly has had the effect of amplifying the standing long wave pressure pattern in the Northern Hemisphere. Baffin Island is situated in a critical position with regard to the mean position of the upper air trough over eastern North America and slight changes in the position of the trough may significantly affect the climate of the region. So it is possible that the recent climatic fluctuation which has occurred in Baffin Island since the late 1950s is related to atmospheric teleconnexions[16] resulting from the inception of a new climatic regime which in turn can be related to large scale seasonal ocean–atmosphere interactions in the Pacific.

It is clear that the apparent cooling trend since the 1940s is not observed at present in this area. During the past decade mean annual temperatures on Baffin Island have been increasing, but the net effect on the landscape is an apparent move towards more glacial conditions. This contradicts assertions[17,18] that a decrease in mean annual temperature is a prerequisite for increased glaciation of an area.

Finally, one may speculate on the glaciological implications of a continuation of this trend towards more accumulation of snow and ice on the land. According to Namias[19] "there seems to be no strong reason why repetitive conditions such as those described cannot lead to climatic fluctuations of a much longer time scale than a decade". Should the present circulation regime be maintained for, say, another ten years, then dramatic changes in the pattern of accumulation in the area can be expected following the lag response to a lowering of the glaciation limit.

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