Recent Freezing Level Changes and Climatic Deterioration in the Canadian Arctic Archipelago

IT is well established that climatic fluctuations which are global or hemispheric in extent are most pronounced in high northern latitudes, particularly around the North Atlantic[1–4]. Recent evidence also suggests that certain sectors of the Arctic are extremely sensitive to small climatic shifts and as a result may undergo visible changes in the landscape[5–7]. Here I report on an analysis of upper air data for the Canadian Arctic archipelago which indicates that marked changes in freezing level heights have occurred during the past two decades as a result of changes in atmospheric circulation across the area.

Over most of the Canadian Arctic, surface temperatures rarely rise above 0° C from September to May. The freezing level (the 0° C isothermal surface) reaches a maximum elevation in July. A decrease in the elevation of the freezing level during summer months can therefore greatly decrease the area of snow and ice affected by melting.

Bradley and Miller[5] suggested that a significant climatic deterioration began on Baffin Island about 1960. The freezing level data indicate that the critical change probably occurred around 1962-1964. Table 1 shows average July freezing level elevations for two nine-year periods, 1955-1963 and 1964-1972, based on an analysis of daily records (no data available prior to 1955). July freezing levels have been much lower at all stations in the area during the past nine years. A similar pattern

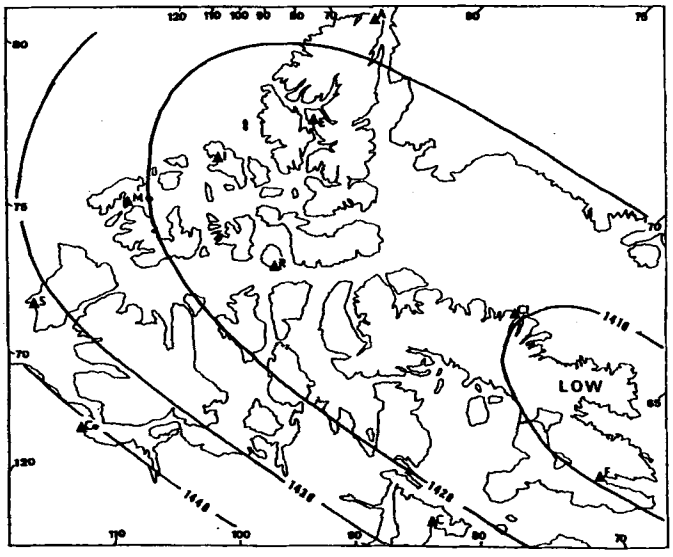

Fig. 1 Average height of the July 850 mbar surface, 1955–63, in geopotential metres (1 gpm ≃ 0.98 m). Letters refer to upper air stations mentioned in text. A=Alert; Cl=Clyde; C=Coral Harbour; Co=Coppermine; E=Eureka; F=Frobisher Bay; I=Isachsen; M=Mould Bay; R=Resolute; S=Sachs Harbour

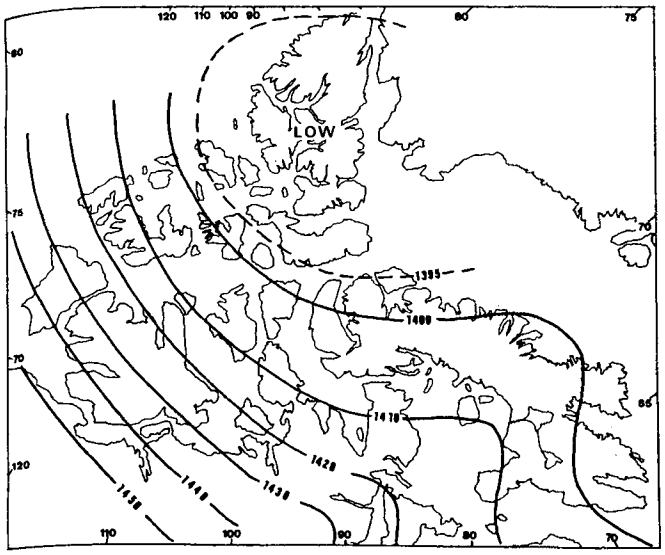

Fig. 2 Average height of the July 850 mbar surface, 1964–72, in geopotential metres.

1961 as a result of anomalously warm ocean temperatures in the central northern Pacific Ocean which had the effect of amplifying the standing long wave pressure pattern in the Northern Hemisphere. The observed displacement of the main centre of the eastern Canadian trough north and west is consistent with Namias's suggestions. The abrupt changes in freezing levels around 1962-64 reflect a lag in response to the initiation of this new circulation regime.

The large changes in freezing level height since 1963 have produced significant glaciological responses in the Canadian Arctic. Observations made in 1967 in the United States Range, central Ellesmere Island, led Hattersley-Smith[9] to conclude that the summers of 1963-66 "were the coldest sequence of summers since before 1925 . . . the equilibrium line (ELA) on the glaciers had been lowered to approximately 900 metres from a mean of about 1,200 metres in the years 1957-63". This fall in ELA by 300 m is similar to the drop in freezing level at Alert and Eureka (Table 1). Similarly, the ELA on the White Glacier, central Axel Heiberg Island, has been more than 400 m lower since 1963-64 than in the four years 1959-60 to 1962-63 (ref. 10). Again a similar fall in freezing level height over this area has been noted. Finally, a recent study of sea-ice extent in Baffin Bay and Davis Strait shows that a very marked

Table 1 Average July Freezing Level Heights, 0000 GMT.* Heights in Geopotential Metres

Station	Latitude	Longitude	(*a*) Freezing level 1955–63	(*b*) Freezing level 1964–72	Change (*b*–*a*)	Student's *t*	Statistical significance
Alert	82° 30′	62° 20′	1,230	900	−330	4.9	0.1%
Clyde	70° 27′	68° 33′	1,620	1,280†	−340	4.5	0.1%
Coppermine	67° 49′	115° 05′	2,280	2,090‡	−190	2.9	0.5%
Coral Harbour	64° 12′	83° 22′	2,100	1,860	−240	3.7	0.1%
Eureka	80° 00′	85° 56′	1,500	1,150	−350	7.2	0.1%
Frobisher Bay	63° 45′	68° 33′	2,010	1,710	−300	4.9	0.1%
Inuvik	68° 18′	133° 29′	2,500§	2,370	−130	2.2	2.5%
Isachsen	78° 47′	103° 32′	1,220	710	−510	7.3	0.1%
Mould Bay	76° 14′	119° 20′	1,310	1,150	−160	2.1	2.5%
Resolute	74° 43′	94° 59′	1,490	1,150	−340	4.7	0.1%
Sachs Harbour	71° 59′	125° 17′	1,790‖	1,640	−150	1.8	5.0%

*July 1955 soundings taken at 0300 GMT.
†1964–70 inclusive.
‡Data 1970–72 inclusive from Cambridge Bay (69° 06′ N, 105° 07′ W).
§Data 1955–60 inclusive from Aklavik (68° 14′ N, 135° 00′ W).
‖1956–63 inclusive.

is apparent for the summer months as a whole. A maximum freezing level depression of 510 geopotential metres occurred at Isachsen in the northwestern archipelago with other large decreases in a broad belt north to Eureka and Alert and southeast to Resolute, Clyde and Frobisher Bay.

Mean pressure contour maps for the same periods (Figs. 1 and 2) indicate that during the former period the area was dominated by a trough of low pressure over Baffin Bay and southern Baffin Island. In the subsequent period the principal low pressure centre occurs to the northwest with the southeastern Arctic dominated by a ridge of high pressure. Pressure gradients over the archipelago are also much stronger in the latter period indicating increased movement of air across the region, particularly from the north. A similar pattern of circulation change is observed at the 700 mbar level. The low pressure centre of 1964-72 is located precisely where the most significant falls in freezing level have occurred (Table 1). Increased advection of cool air across Baffin Island during the latter period accounts for the relatively large falls at Clyde and Frobisher Bay. Relatively small changes over the southwestern archipelago reflect little change in the circulation over that area.

The large changes in summer freezing levels across the area thus seem to be the result of changes in synoptic conditions. Namias[8] suggests that a "new climatic regime" began late in

change towards more severe ice conditions occurred in 1963 (ref. 11). Between 1952 and 1960 there were only four years when significant areas of ice were observed in September whereas "in the 1960s there was only one year in which ice was not present in September, and five years in which it survived until October". Such a deterioration clearly reflects the lower temperatures and increase in northerly flow over the area during the past decade.

In conclusion, the Canadian Arctic has recently experienced a significant climatic deterioration. Any further fall in freezing level heights or the persistence of recent conditions will undoubtedly result in increased glacierization throughout much of the eastern and northern upland area. This indicates the importance of carefully monitoring climatic conditions in the Canadian Arctic archipelago over the next few years.

This work was partly supported by a contract from the Glaciology Division, Department of Environment, Canada. I thank J. T. Andrews, R. Barry, A. S. Dyke, J. D. Ives, J. Jacobs and G. H. Miller for advice.

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Received March 14, 1973.

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