SUMMER 1979: ICE CLIMATOLOGY OF THE CANADIAN ARCTIC

Balaram Dey

Howard University
Department of Geology and Geography
Washington, D.C. 20059

ABSTRACT

The study presents maps of ice cover in the Canadian Arctic which were determined from data obtained from the TIROS-N satellite. The maps show that in the summer of 1979 the extent of water was greater than that in summer 1978. The difference in particular in the southern Beaufort Sea and in Baffin Bay was caused by advection of heat by warm air masses which moved in to the Arctic from the southeast. In the central Canadian Arctic Archipelago the extent of open water remained limited. This is due to the effects of cold air mass which moved in from the north.

1. Introduction

The regular mapping of ice cover in the Canadian Arctic was begun in 1958 although some spot data is available for earlier years (Ice Atlas of Canada - Swithinbank, 1960). The accuracy of sea ice charts improved significantly with the launch of meteorological and resource satellites. At present, Ice Forecasting Central, Atmospheric Environment Service (AES), Ottawa produce reliable weekly ice charts of the Canadian navigable waters including the Canadian Arctic. The retreat of ice edge and the areal extent of open water at the end of each summer month can be presented in maps. It is this set of monthly maps that contain ice cover and open water data has been referred to as "ice climatology" of the Canadian Arctic.

The retreat of ice edge and consequently the areal expansion of open water are related to the atmospheric circulation and surface temperature patterns (Dey, 1980a, 1980b; Rogers, 1978; Walsh and Johnson, 1979), although in some areas oceanographic conditions play important role in the ice breakup process (Dey et al., 1979; Dey, 1980c). The purpose of this paper is to relate the areal and temporal variations of 1979 summer ice cover with the atmospheric conditions in the Canadian Arctic. Further, the areal and temporal variations of ice cover in 1979 are compared to that of 1978 summer season. Previous studies had indicated summer to summer variations of pack ice cover and open water in the Canadian Arctic (Dey, 1978, 1980d; Dey et al., 1979; Lindsay, 1974; Markham, 1975; Marko, 1978).

2. Sources of data and methodology

TIROS-N satellite images, sea ice charts, weather maps and temperature data, from the Ice Forecasting Central, A.E.S., Ottawa, and the Arctic Weather Center, A.E.S., Edmonton, during the period 1 June to 30 September 1979 constitute the source of data for the study of ice climatology in the Canadian Arctic. TIROS-N images were first used to delineate the location of ice edge. The existence of ice cover on the image was first established through the identification of distinct tonal contrast. In Figure 1 the area of open water in southern Beaufort Sea appears black to dark gray against the white background of ice covered area of Arctic Ocean. However, it should be noted that in the TIROS-N images, it is difficult to distinguish between open water and very thin ice cover. Transparent over-

overlays, showing geographical features easily recognized on satellite image are often used to assist in locating ice edge and open water. Maps showing ice edge location and areal extent of open water at the end of each month, June - September 1979 was prepared from TIROS-N images and weekly sea ice charts of the Ice Forecasting Central, A.E.S., Ottawa.

The atmospheric maps are mean monthly charts of 1000-millibar surface which show the positons of high and low pressure cells and the resultant direction of geostrophic winds. Obviously, there is a difference in time scale between ice cover maps and weather maps. The ice cover maps represent the synoptic conditions of ice cover and open water at a particular time. On the otherhand, the 1000-millibar surface maps represent the mean monthly weather conditions over the Canadian Arctic. Though ice cover may change from the time of one storm to the next, the retreat of ice edge and the expansion of open water at the final day of a month relate satisfactorily to the mean monthly 1000-millibar level atmospheric conditions over the Canadian Arctic (Dey, 1980a, 1980b).

3. Ice cover and open water record for the summer of 1979.

In winter, pack ice as well as landfast ice cover most of the Candian Arctic except the presence of leads and polynyas which frequently occur in Smith Sound, Baffin Bay, Lancaster Sound, Amundsen Gulf and Beaufort Sea (Dey, 1980e, 1980f, 1981; Dey and Richards, 1981). Ice activity in terms of leads and polynyas increases with the onset of spring. Of the many factors which act to deform ice cover in the Canadian Arctic, solar radiation absorption, above freezing temperatures, advection of warm water, ocean currents, tides and winds seem to be very important (Dey et al, 1979).

The expansion of open water particularly in southern Beaufort Sea, northern Baffin Bay and southern Davis Strait started in early June of 1979. Indeed, the retreat of ice edge and the expansion of open water in Beaufort Sea which started in early June continued at an accelerated rate through the months of July, August and September (Fig. 2-5). By the end of September, the polar pack retreated about 400 km from the southern shore of the Beaufort Sea.

Over Baffin Bay, the expansion of open water started from the northwest and southeast under the influence of North Water and warm West Greenland current (Fig. 2). The ice retreated towards the central and southwestern Baffin Bay during July and August (Fig. 3-4). By the end of September, most of Baffin Bay was ice free with the exception of the northwestern Baffin Bay especially along the coast of Ellesmere and Devon Islands where ice remained from late summer of 1979 to following fall (Fig. 5). This was an exceptional circumstance not observed previously. Occasionally ice remained at the end of summer in the area northeast of Home Bay.

Apart from Beaufort Sea and Baffin Bay, the expansions of open water in the central Canadian Arctic Archipelago did not start until July (Fig. 3) and the ice melting process was very slow. In the interior channels of the Canadian Arctic Archipelago the expansion of open water in 1979 summer was limited to small areas of Jones Sound, Lancaster Sound and in Foxe Basin.

Ice started to grow in early October and by the end of October most of the Canadian Arctic waterways, except the southeastern Baffin Bay, were ice covered. In summary, the areal expansion of open water in 1979 summer season was much more than that of 1978 particularly for the months of June and July in case of southern Beaufort Sea and June - September in case of Baffin Bay (Dey, 1980b).

4. Atmospheric circulation over the Canadian Arctic: summer 1979.

The mean monthly 1000-millibar surface weather charts for June - September 1979 (Figs. 6-9) over Beaufort Sea show southeasterly geostrophic winds, apparent in the pressure gradient, over southern Beaufort Sea. The offshore winds along with high values of accumulated melting degree days (Sachs Harbourin Figure 10) pushed the ice edge poleward resulting in vast areal expanse of open water in southern Beaufort Sea during 1979 summer season (Figs. 2-5).

Over Baffin Bay, the southeasterly winds resulting from the positions of a high pressure cell over southeastern Baffin Island and adjoining area dominated the 1979 summer season (Figs. 6-9). The southeasterly winds caused the advection of warm air masses from the south and as a result most of the ice except northwest coastal area melted during 1979 summer season (Fig. 5). However, the presence of summer ice along the eastern coastal region of Ellesmere and Devon Islands (Figs. 4-5) could be related to the advection of cold air mass from the north and northeast particularly from polar ice and the Greenland ice cap (Fig. 9).

The pressure gradients indicate that the circulation over the Canadian Arctic Archipelago was dominated by northerly and northwesterly winds (Figs. 6-9). This caused the advection of cold air masses and as a consequence open water area in the interior channels of the Canadian Arctic was very limited during the summer of 1979 (Figs. 2-5). Because of the invasion of cold air masses, the accumulated melting degree days value for Resolute was lower in 1979 than that of 1978 (Fig. 10).

During summer 1979, circulation patterns over the Canadian Arctic were very ideal for maximum retreat of ice edge and expansion of open water particularly over Beaufort Sea and Baffin Bay.

5. Conclusions

The satellite derived monthly ice cover variations data that have been reported in this study is a rapid means of synthesizing Canadian Arctic ice information. The areal variations of ice cover and open water at the end of each summer month were related to the monthly mean climatological conditions, i.e., the locations of high and low pressure cells, resultant winds directions and accumulated melting degree days. Ice climatology, i.e., the map showing ice cover and open water data at the end of each summer month, over a long period would help in forecasting summer ice in the Canadian Arctic so that navigation and drilling operations could be planned well in advance. Moreover, the open water and ice cover maps would help climatologists in their research on heat flux studies. Indeed, an early breakup is associated with the change in heat balance because water absorbs slightly more solar radiation than during the periods of normal breakup. Consequently, ice formation or freezeup may be delayed because of the time required for loss of the excess heat. An analysis of Baffin Bay ice dynamics indicates that early breakup was associated with late freezeup and late breakup with early freezeup (Dey, 1980f).

References

Dey, B. 1978. Use of Landsat and NOAA imagery for mapping deformation and movement of Baffin Bay ice. Proceedings of Fifth Canadian Symposium on Remote Sensing, Victoria, B.C., August 28-31, 1978 (available from the Canadian Aeronautics and Space Institute, Ottawa), pp. 200-208.

Dey, B., Moore, H. and Gregory, A.F., 1979. Monitoring and mapping sea-ice breakup and freezeup of Arctic Canada from satellite images. Arctic and Alpine Research. 11(2), 229-242.

Dey, B. 1980a. Variations of August ice cover in the Beaufort Sea and related weather conditions. Bulletin American Meteorological Society. 61(3), 213-217.

______. 1980b. Sea ice cover and related atmospheric conditions in Arctic Canada during the summer of 1978. Monthly Weather Review. 108(12), 2092-2097.

______. 1980c. Orbital sensing of Mackenzie Bay ice dynamics. Arctic. 33(2), 280-291.

______. 1980d. Monitoring annual variations in ice cover of Baffin Bay from satellite imagery. Proceedings of Fourteenth International Symposium on Remote Sensing of Environment, San Jose, Costa Rica, April 1980 (available from the Environmental Research Institute of Michigan, U.S.A.),pp. 989-998.

______. 1980e. Applications of satellite thermal infrared images for monitoring North Water during the periods of polar darkness. Journal of Glaciology. 25(93), 425-438.

______. 1980f. Seasonal and annual variationsin ice cover in Baffin Bay and nothern Davis Strait. Canadian Geographer. 24(4), 368-384.

______. 1981. Monitoring winter sea ice dynamics in the Canadian Arctic with NOAA-TIR images. Journal of Geophysical Research. 86(C4), 3223-3235.

______. and Richards, J.H. 1981. The Canadian north - utility of remote sensing for environmental monitoring. Remote Sensing of Environment. 11(1), 57-72.

Lindsay, D.G. 1974. Sea-ice Atlas of Arctic Canada, 1961-68. (available form the Department of Energy, Mines and Resources, Ottawa, Canada).

Markham, W.E. 1975. Ice Climatology of the Beaufort Sea. Canada Department of Environment, Victoria, B.C., Beaufort Sea Technical Report No. 26, 87p. (available from the Institute of Ocean Science, Victoria, B.C.).

Marko, J. 1975. Satellite Observations of the Beaufort Sea Ice. Canada Department of Environment, Victoria, B.C., Beaufort Sea Technical Report No. 34, 137p. (available from the Institute of Ocean Sciences, Victoria, B.C.).

Rogers, J.C. 1978. Meteorological factors affecting interannual variability of summer-time ice extent in the Beaufort Sea. Monthly Weather Review. 106(6), 890-897.

Swithinbank, C. 1960. Ice Atlas fo Arctic Canada (available from the Queens Printers, Ottawa, Canada).

Walsh, J.E. and Johnson, C.M. 1979. Interannual atmospheric variability and associated fluctuations in the Arctic ice extent. Journal of Geophysical Research. 84, 6915-6928.

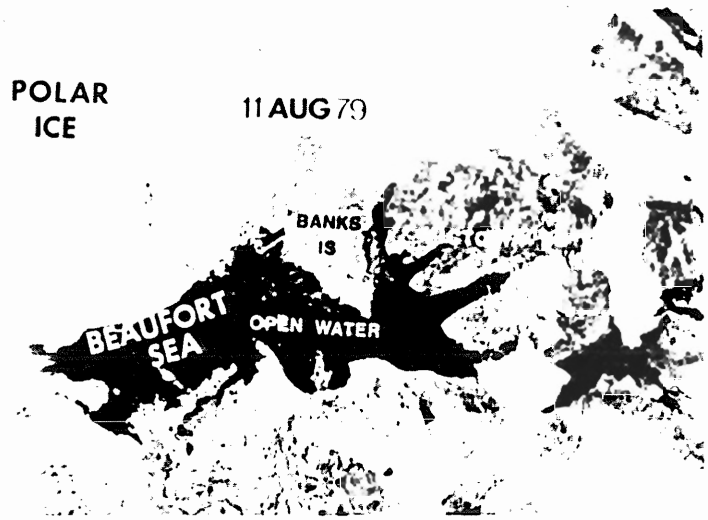

Figure 1: TIROS-N (Vis) image of 11 August 1979. It shows open water area in southern Beaufort Sea as indicated by black to gray tones.

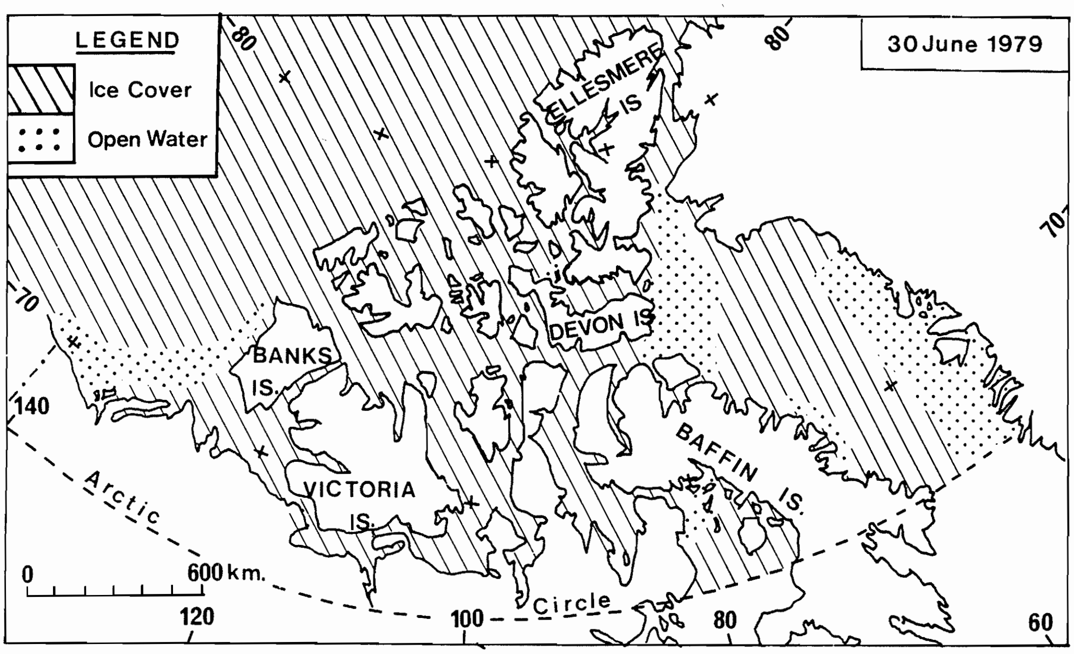

Figure 2: Ice cover and open water in the Canadian Arctic on 30 June, 1979.

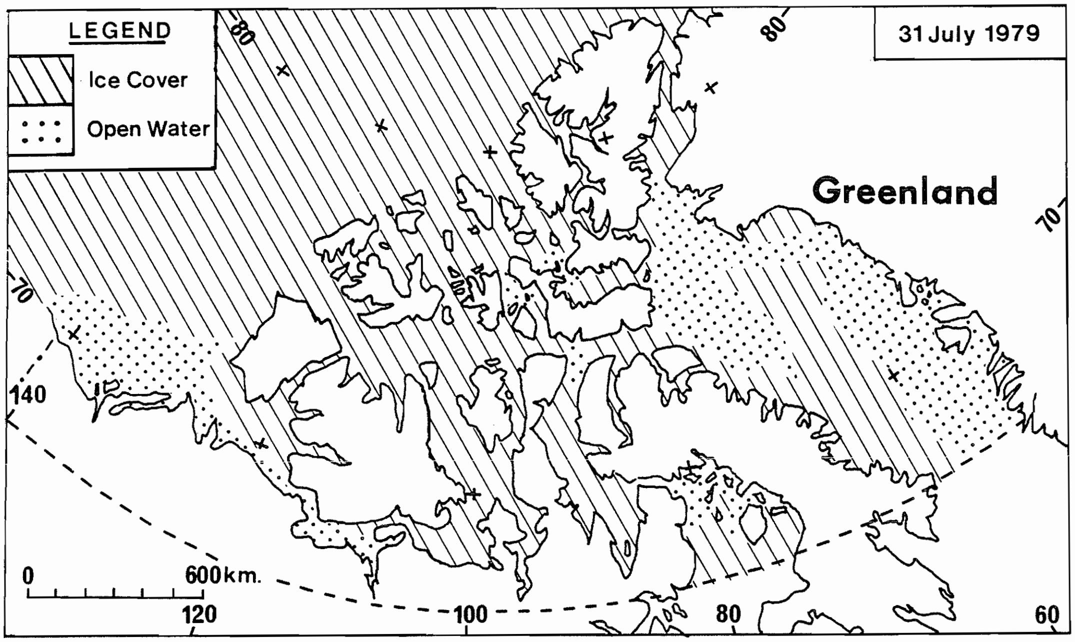

Figure 3: Ice cover and open water in the Canadian Arctic on 31 July, 1979.

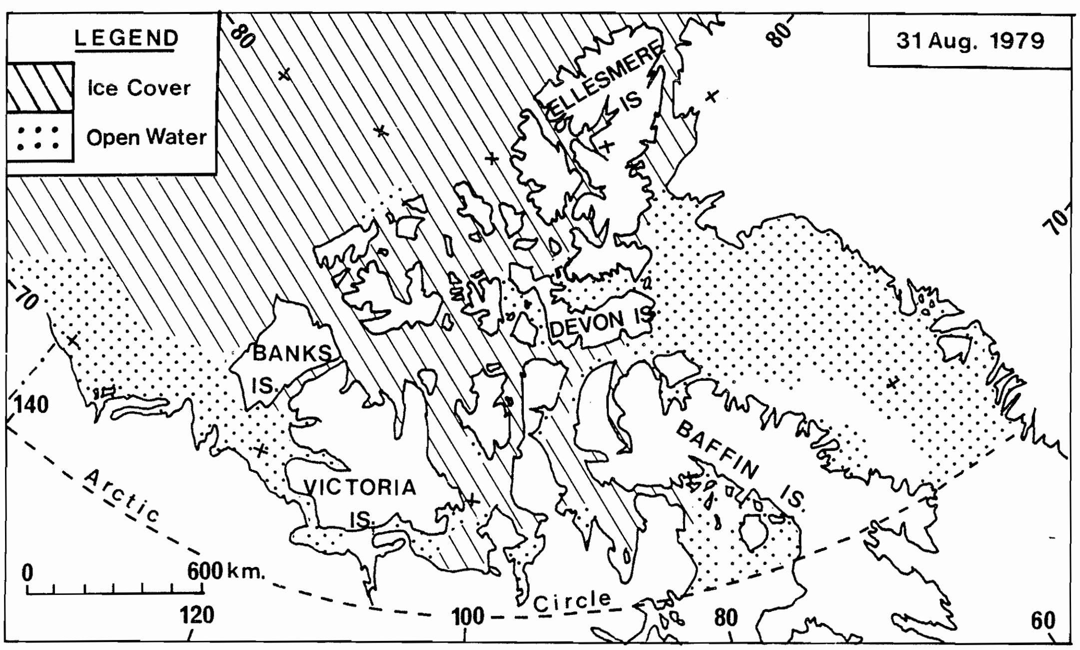

Figure 4: Ice cover and open water in the Canadian Arctic on 31 August, 1979.

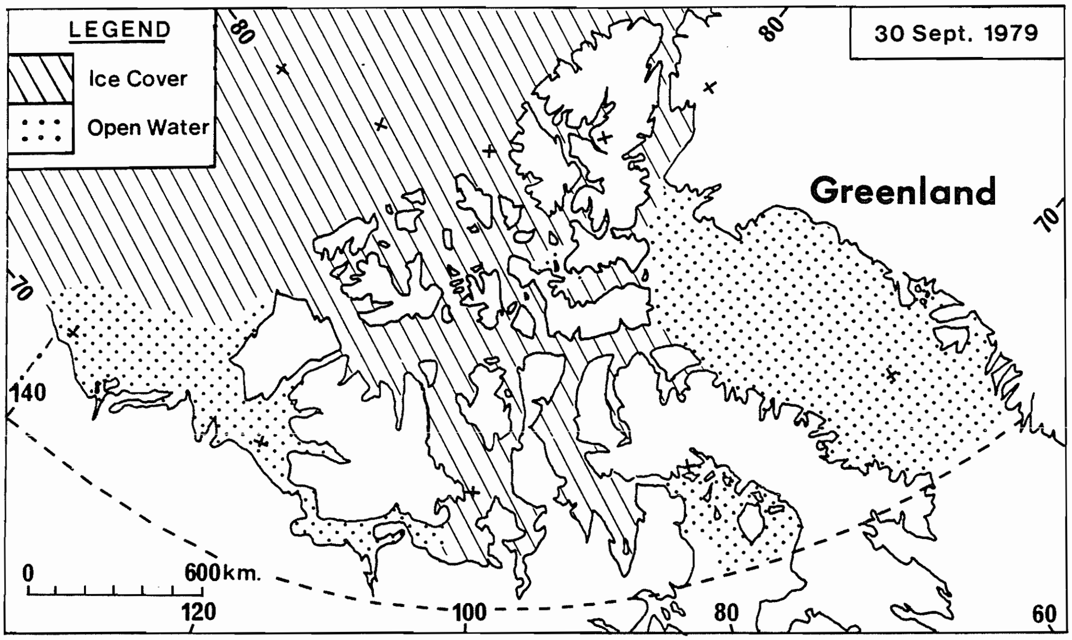

Figure 5: Ice cover and open water in the Canadian Arctic on 30 September, 1979.

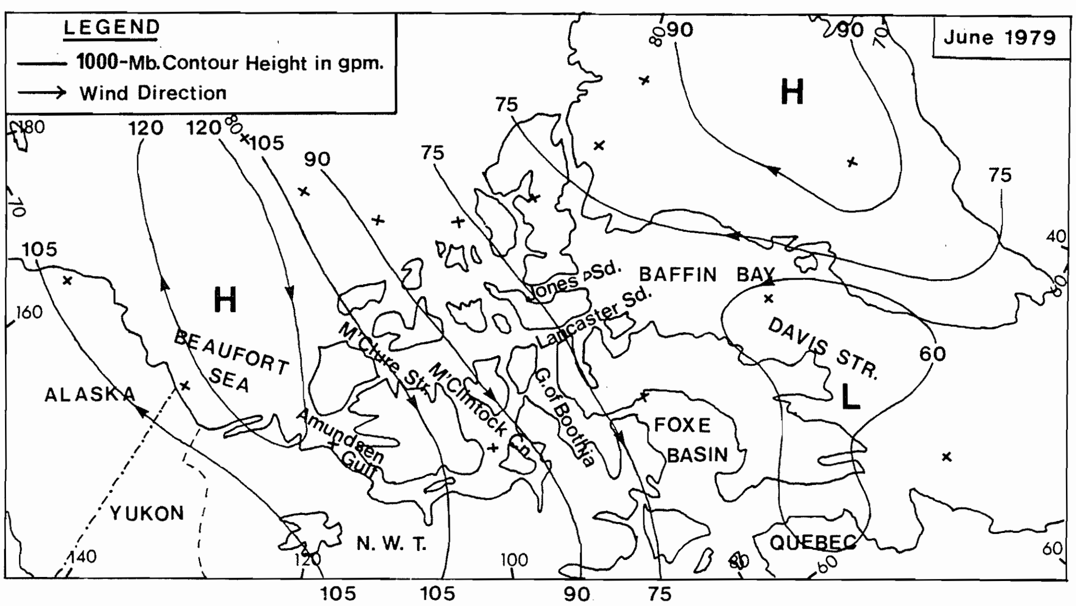

Figure 6: 1000-millibar weather map for the month of June 1979, showing south-easterly winds over eastern Baffin Bay and western Beaufort Sea.

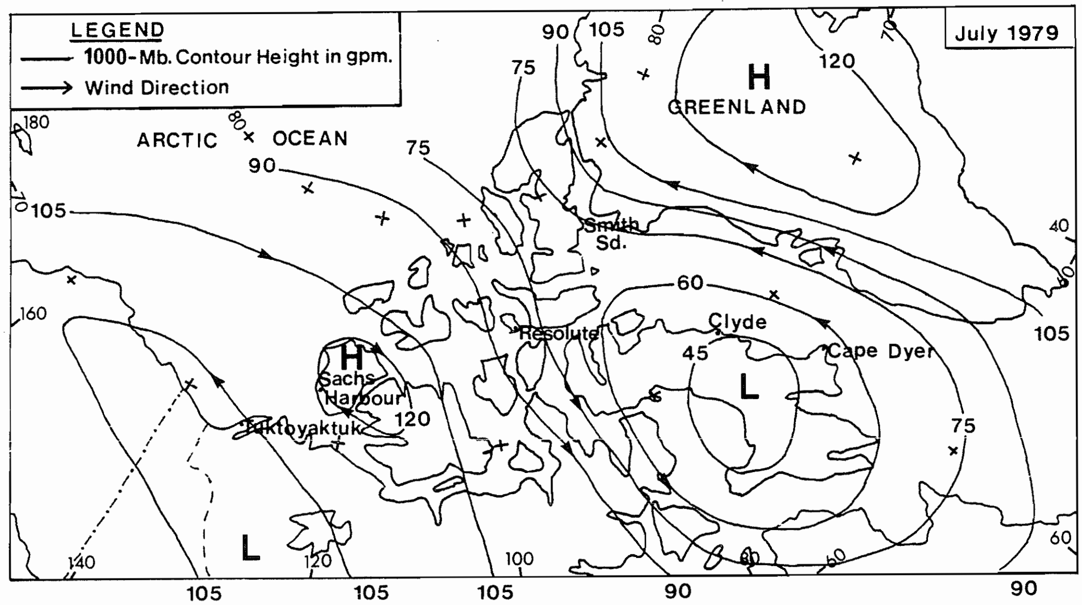

Figure 7: 1000-millibar weather map for the month of July 1979, showing south-easterly winds over Baffin Bay and Beaufort Sea.

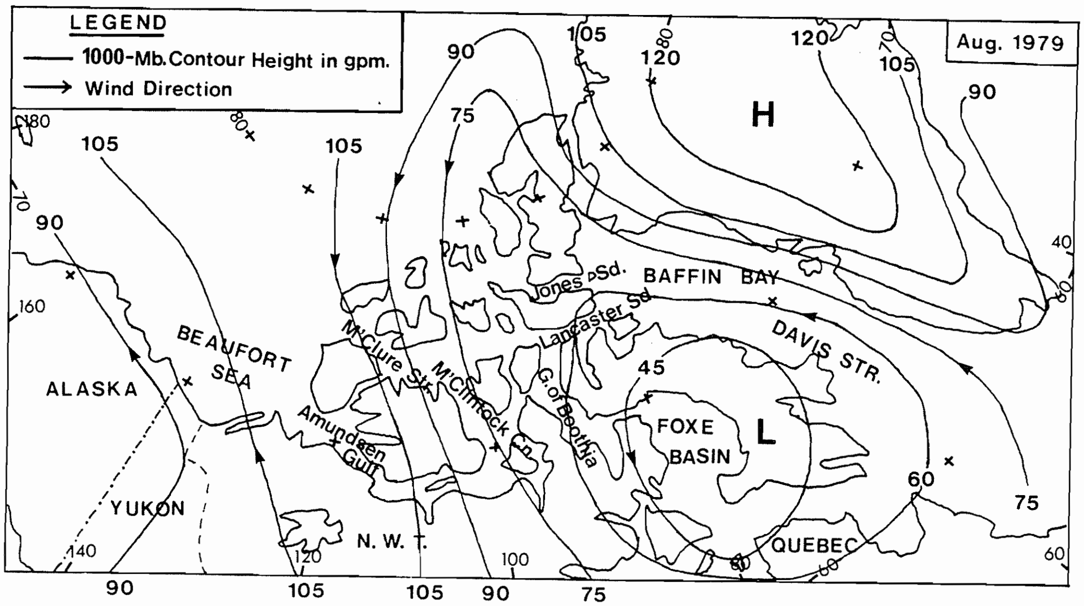

Figure 8: 1000-millibar weather map for the month of August 1979, showing south-easterly winds over Baffin Bay and Beaufort Sea.

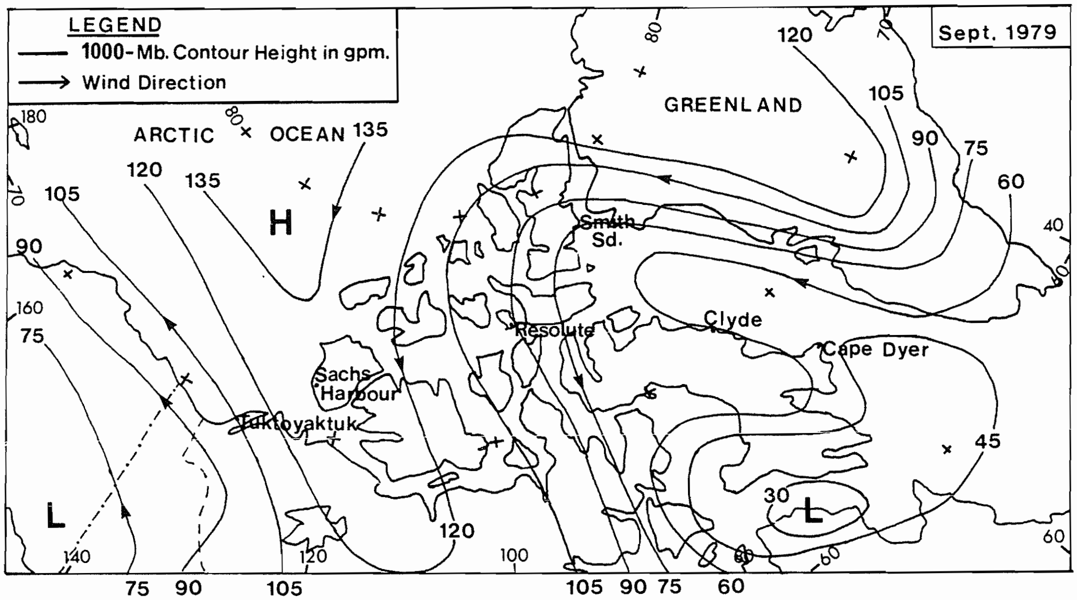

Figure 9: 1000-millibar weather map for the month of September 1979, showing south-easterly winds over Beaufort Sea and eastern Baffin Bay but northwesterly winds over western Baffin Bay.

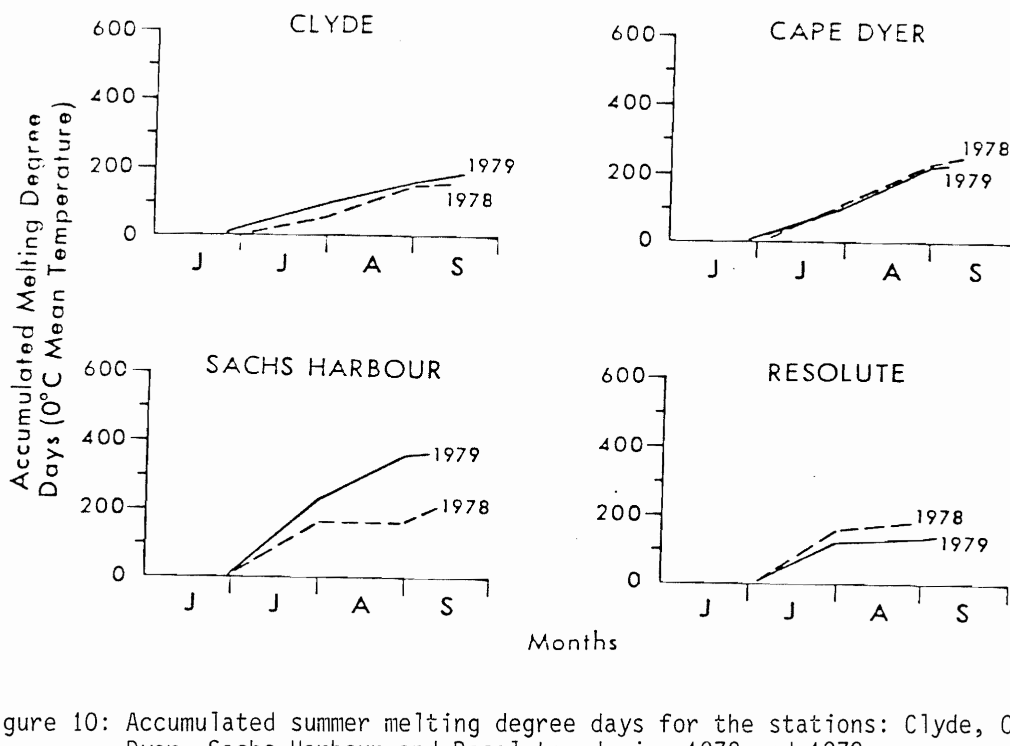

Figure 10: Accumulated summer melting degree days for the stations: Clyde, Cape Dyer, Sachs Harbour and Resolute, during 1978 and 1979 summer seasons.