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Synoptic Climatological Studies of the Baffin Island Area

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Abstract

Using a classification of MSL pressure map patterns for the area 55°–80°N, 50°–100°W, a daily catalog of synoptic regimes has been developed for July–August 1961–1972 and for other seasons for a shorter period. Temperature and precipitation conditions relating to the classification categories have been determined for several stations in eastern Baffin Island. The precipitation characteristics are of primary interest here. At Broughton Island there is a clear dominance of summer precipitation totals by the occurrence of lows centered over Baffin Island while in autumn and mid-winter this control is less pronounced. In autumn, patterns with lows in Davis Strait–Baffin Bay, or over Baffin Island, are the major contributors to precipitation. Examination of the vertically-integrated horizontal vapor flux for the central low type indicates strong flux convergence over the southeastern part of the island.

Apart from providing a useful basis for analysis of local and regional climatic characteristics, the classification and catalog are being applied in energy budget investigations. The basis has been laid for a synoptic climatology of energy budgets using satellite data (visual and IR imagery, and SIRS-B profiles) supplemented by synoptic weather observations.

Studies of the response of fast ice in Home Bay and of the Boas Glacier (naer Broughton Island) to climatic conditions show the importance of individual synoptic events. A preliminary characterization can be made of the synoptic types in relation to glacier and fast ice processes.

Examination of present and past glacierization of eastern Baffin Island in relation to climate suggests that a decline in summer temperatures in the area during the 1960's, and perhaps also the concomitant marked increase in persistence of sea ice in Baffin Bay, is related to a higher frequency of easterly and northeasterly airflow. Apart from the summer cooling, winters in eastern Baffin Island were milder and more snowy in the 1960's. Such anomalies are associated with a westward displacement of the mean 700 mb trough over eastern North America which encourages northward movement of cyclones into Baffin Bay. The evident sensitivity of this area to climatic fluctuations on both short and long time scales makes it a rewarding area for interdisciplinary environmental studies.

1. Introduction

This work began as an exploratory study of the synoptic conditions influencing the climate of Baffin Island, particularly with respect to its glacierization. First, the seasonal climatic characteristics were examined in terms of a classification of the MSL pressure field. Subsequently, the synoptic climatological results have been used as a basis for interpreting present climatic fluctuations and for estimating paleoclimatic conditions. This paper presents some of the general results derived from a number of specific studies.

2. Characteristics of the synoptic types

Classification categories. The MSL pressure field over the sector 55°–80°N, 50° 100°W (Fig. 1) has been classified on a daily basis for January, February, April, September, and October, 1961–5, July and August, 1961–70. A subjective scheme of 40 ("static") types was initially used (Barry, 1973); in order to simplify the classification scheme for present purposes, and to increase the sample sizes in each category, 12 type-groups are identified—six cyclonic and six anticyclonic (Figs. 2a and b). The frequency of these groups is shown in Table 1. Apart from April when anticyclonic patterns are dominant, reflecting the mean pressure field at this season over the Canadian Arctic Archipelago, the other seasons have a nearly equal frequency of cyclonic and anticyclonic patterns.

Precipitation. Before discussing the climatic characteristics of the type-groups, it is worth noting that September–October received 22–40% of the annual precipitation total for 1961–65 at the four stations on the east coast of Baffin Island (Cape Dyer, Broughton Island, Cape Hooper and Clyde). The next largest proportion, for the months considered, was in July–

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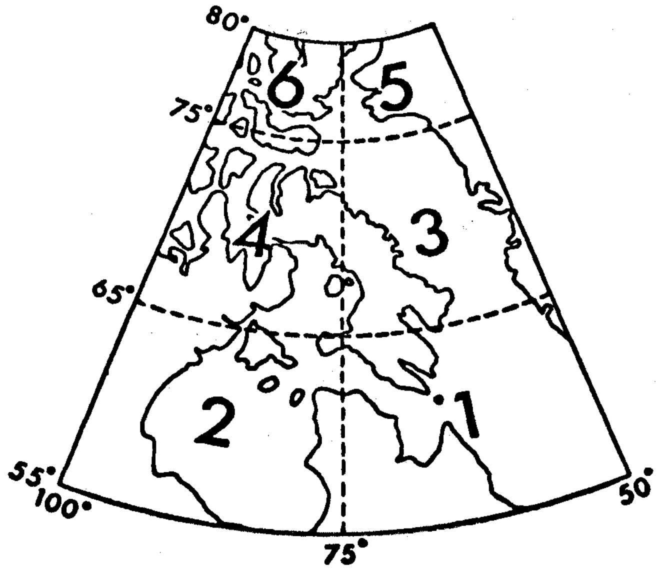

FIG. 1. Outline map of the area to which the MSL pressure field classification refers. Particular attention is given in the classification to sector 3.

TABLE 1. Frequency of type-groups (percent) 1961–65.

Type-Group	Jan-Feb	April	July-Aug (1961-70)	Sep-Oct
Cyclonic				
C1. Central low	11	7	16	15
C2. Davis St. low	10	4	9	14
C3. Baffin Bay low	19	9	5	13
C4. SW low	4	6	10	6
C5. SW low & others	5	2	9	9
C6. Inverted low	4	—	—	—
	53	28	49	57
Anticyclonic				
A1. Anticyclone	7	17	10	8
A2. Ridge	10	5	8	6
A3. Ridge, low to S.	2	7	10	3
A4. High in E, low to W.	3	5	10	7
A5. Ridge, Baffin Bay low (NE flow)	11	11	4	5
A6. Ridge, Baffin Bay low (N-NW flow)	14	27	9	14
	47	72	51	43

August with 12–16% for 1961–70, except at Clyde where the figure rose to 25% (Table 2).

The precipitation characteristics of the type-groups are summarized in Figs. 3 and 4. In mid-winter the central low/trough group is a major contributor to the total although at Broughton Island 31% occurred with the infrequent "inverted low" pattern and at Cape Hooper lows to the southwest or south were the most important. Clyde is different again in receiving 25% of its mid-winter precipitation from southerly flow patterns with a high or ridge over Baffin Bay–West Greenland.

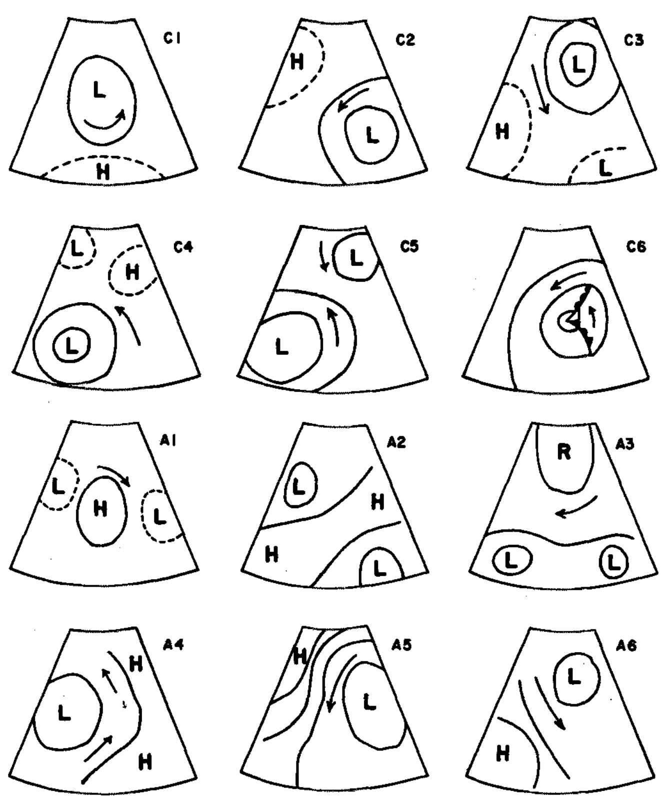

FIG. 2. Schematic maps of MSL pressure-type groups for the area shown in Fig. 1: (a) cyclonic groups; and (b) anticyclonic groups.

April accounts for only 4% of the annual precipitation as an average for the four stations and, as a result, the importance of any one type-group to the monthly total varies widely between stations. The anticyclonic patterns are the principal contributors, reflecting the high frequency of these types in spring.

In July–August the central low and the Davis Strait low groups account for 45–50% of the totals for 1961–70 at all four stations. The "raininess" of a particular pattern is indicated by the expression[1]:

$$\frac{P_A}{P}\frac{N}{N_A}(\times 100)$$

where

P = total seasonal precipitation over the period;

TABLE 2. Precipitation as percentage of the annual total (1961–65).

	Clyde	Cape Hooper	Broughton Island	Cape Dyer
Jan.-Feb.	7.3	3.5	6.4	10.8
April	1.9	7.2	3.8	3.8
July-Aug. (1961-70)	24.9	15.5	12.5	12.4
Sep.-Oct.	39.7	31.3	39.5	22.4
	73.8	57.5	62.2	49.4

[1] This is similar to the "specific precipitation density" (Maede, 1951), except that the latter refers to the frequency of days with precipitation, not all days.

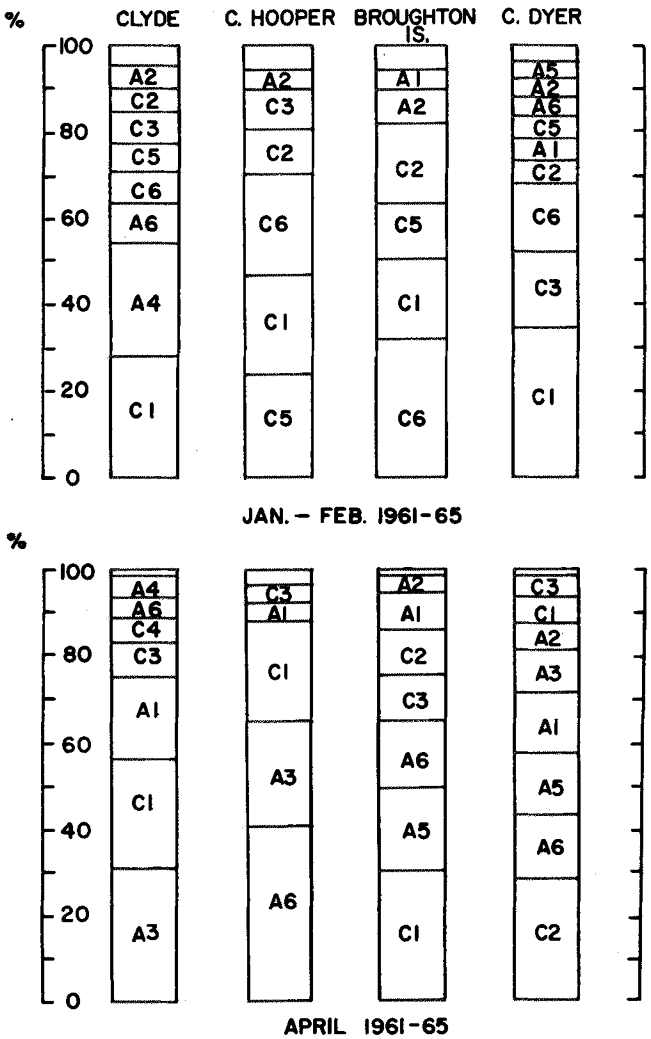

FIG. 3. The contribution of the different synoptic type groups to total precipitation January–February and April 1961–65 at Clyde, Cape Hooper, Broughton Island and Cape Dyer.

P_A = seasonal precipitation with group A over the period;
N = total number of days;
N_A = frequency of group A.

Table 3 shows that groups 1 and 2 are the most effective precipitation bearers in July–August. With the Davis Strait low (Group 2) there is a marked decrease in effectiveness northward. Ridge and anticyclone patterns have efficiencies of less than 50–60% in most cases.

In September–October, patterns with a low in Davis Strait–Baffin Bay, or a central low, contribute most of the precipitation although these are also the most frequent patterns. Ridge patterns with northerly flow are also important at Broughton Island. Table 3 shows a less consistent pattern of precipitation efficiency than in summer. This is especially the case at Broughton Island with anticyclonic patterns. In part the data reflect the inadequacy of a five-year data sample for such an analysis.

Analysis of vapor flux-divergence for the central low type in September–October 1961–65 (Fig. 5) shows large convergence (5–8 cm) over the Davis Strait and southereastern Baffin Island. This flux convergence represents 23 days of central low type (subtype 100) which gave a total of 6 cm precipitation at Broughton Island and 5 cm at Cape Dyer. Neglecting atmospheric storage changes and evaporation, these magnitudes agree well with the map values. A similar analysis for the Davis Strait low cases showed zero convergence over the area, however. It is probable that in this case, effects of orography in the onshore flow must be taken into account (Fogarasi, 1972).

Temperature. The temperature characteristics of the types will be only briefly considered. In July–August the Davis Strait low pattern gives the lowest mean daily temperature at all stations with values of only 0.5 C at Cape Hooper and 1.6 C at Broughton Island (Table 4). In view of the precipitation characteristics

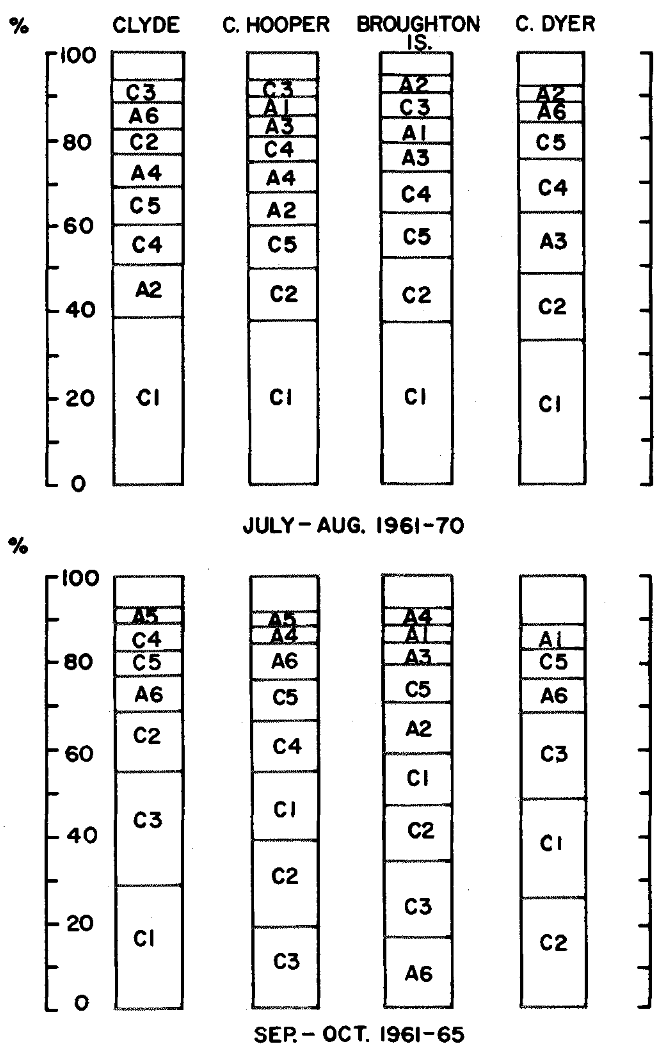

FIG. 4. The contribution of the different synoptic type groups to total precipitation July–August 1961–70 and September–October 1961–65 at Clyde, Cape Hooper, Broughton Island and Cape Dyer.

TABLE 3. Precipitation-effectiveness of the type-groups (percent).

Type-Group	Clyde	Cape Hooper	Broughton Is.	Cape Dyer
(a) July-Aug. (1961-70)				
Central low	249	244	238	213
Davis St. low	66	126	156	163
Baffin Bay low	108	78	123	38
SW low	92	60	100	125
SW low & others	96	108	114	94
Anticyclone	20	89	48	39
Ridge	138	41	62	27
Ridge, low to S	25	49	63	138
Ridge to E, low to W	75	73	16	25
Ridge (NE flow)	40	86	35	29
Ridge (N-NW flow)	68	35	24	53
(b) Sep.-Oct. (1961-65)				
Central low	196	108	82	156
Davis St. low	100	146	94	214
Baffin Bay low	193	149	126	149
SW low	95	189	47	28
SW low & others	76	110	103	76
Anticyclone	7	36	52	76
Ridge	43	33	188	24
Ridge, low to S	43	73	177	30
High to E, low to W	21	57	54	23
Ridge (NE flow)	81	71	51	32
Ridge (N-NW flow)	60	57	130	55

of this pattern, its frequency is clearly of glaciological significance It may be noted that approximately 38% of the July–August precipitation (w.e.) at Broughton Island (elevation 581 m) falls as snow. The warmest type in July–August at all stations is with an anticyclone to the east and southerly airflow. Mean daily temperatures are close to 7 C (6 C at Clyde) and this pattern has a particularly low precipitation effectiveness (⩽25%) over the Cumberland Peninsula.

3. Synoptic energy budgets

The pressure field classification provides a useful basis for stratifying the synoptic regimes in terms of conventional climatic parameters, but it is clearly vital for glaciological and sea ice studies to determine synoptic energy budget climatologies. A basis has been laid for this using satellite data supplemented by conventional synoptic weather observations for summer 1970 (Jacobs *et al.*, 1972).

Computations were made of the individual energy budget components and of net radiation using appropriate parameters estimated from a variety of data sources. These are summarized in Table 5. Figs. 6–8 show selected maps illustrating the type of product for conditions at local noon on 26 June 1970. There was a low centered in Davis Strait and a trough extending northward. The effects of cloud cover, high albedo and northerly airflow combine to give negative net fluxes over the western Davis Strait area, while in the warm sector of the system over the open water

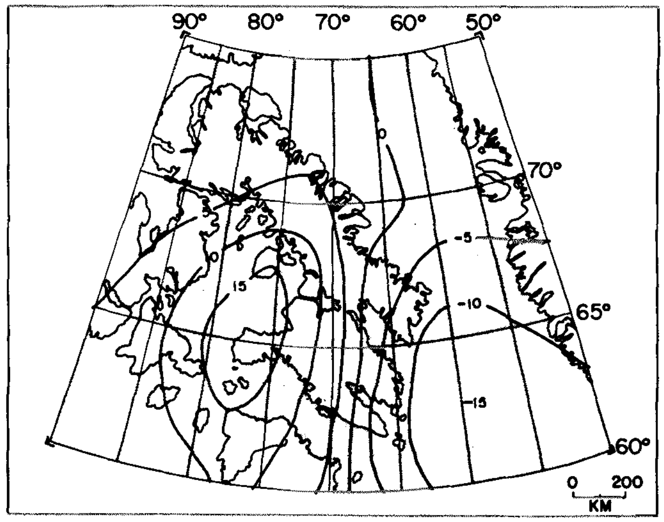

FIG. 5. Vapor-flux divergence (vertically integrated) for 23 days of central low synoptic type, September–October 1961–65 (cm).

of the Labrador Sea there are clear skies and warm air giving rise to a large positive energy flux to the surface. There is also substantial heat gain in the North Water of northern Baffin Bay due to its low albedo, in spite of air temperatures around −2 C. In general, albedo proves to be a key factor in determining surface energy fluxes in anticyclonic situations, while for cyclonic regimes the effect of cloud cover is at least as critical.

This work indicates the feasibility of determining regional energy budgets in the Arctic from a combination of satellite and conventional data. Such material will provide a vital input to the adequate determination of glacio-climatic interactions in the Arctic.

4. Climate-ice interaction studies

Glaciological studies on the Boas Glacier (55 km W.N.W. of Broughton Island) since 1969 show marked

TABLE 4. Temperature characteristics of the type-groups (°C).

	Clyde (3 m)	Cape Hooper (401 m)	Broughton Is. (581 m)	Cape Dyer (376 m)
(a) July-Aug. (1961-70)				
Warmest (High to E, low to W)	5.9	7.1	7.1	6.8
Mean daily	4.1	3.7	4.0	4.8
Coldest (Davis St. low)	2.7	0.5	1.6	3.6
(b) Sep.-Oct. (1961-65)				
Warmest (Central low)	−1.6	−3.1	−2.8	−2.5
Mean daily	−3.5	−4.7	−5.0	−4.5
Coldest (Ridge, N-NW flow)	−7.4	−8.4	−8.5	−7.2

TABLE 5. Data sources for energy budget terms.

Energy budget component	Parameter	Data source
Solar radiation absorbed at surface.	Surface albedo; cloud cover	Visual imagery (AVCS, APT, IDCS, Minimum brightness)
I-R flux from surface	Surface temperature	THIR temperature maps
Atmospheric I-R flux to surface	Temperature and optical thickness; Sasamori (1968) model with single cloud layer	SIRS-B temperature and humidity profile data
Sensible heat flux	Wind speed, temperature	Synoptic data
Latent heat flux	Wind speed, temperature, pressure, vapor pressure	Synoptic data

inter-annual fluctuations in glacier mass budget which can be correlated with the synoptic characteristics of the accumulation and ablation seasons (Andrews, Barry *et al.*, 1972). The month of June is apparently critical in terms of synoptic conditions and, therefore, radiation receipts and the surface albedo of the glacier. For example, the snowpack of 0.25 m was entirely removed in summer 1971. A major factor seems to have been 18 days of anticyclonic patterns in June, in spite of near-normal cyclonic activity in July–August (Table 6). In contrast, only 0.15 m of the 0.4 m snowpack was removed in 1970 following a June with 19 cyclonic days, many of them of the central low type and with cyclonic activity in July–August 1970 also near normal for the 1961–1970 decade. Although no detailed measurements were made the 1969 summer net budget was apparently similar to 1971; in this case the synoptic data suggest that the frequent anticyclones in July–August account for the observed condition on the glacier.

Investigations on the fast ice and pack ice in Home Bay (Jacobs, 1973) also demonstrate the significant impact of individual synoptic events on the ice growth and break-up processes. Warm, rainy cyclonic situations and warm, clear anticyclonic situations will both accelerate ablation through reduced albedo and increased net radiation. On the basis of these studies, a preliminary characterization of the synoptic types in relation to glacier and sea ice processes can be made. For the summer season, where there is good agreement between effects inferred from climatic data and those actually observed, the relationships are summarized in Table 7. This approach provides a basis for inferring glacial response from synoptic data,

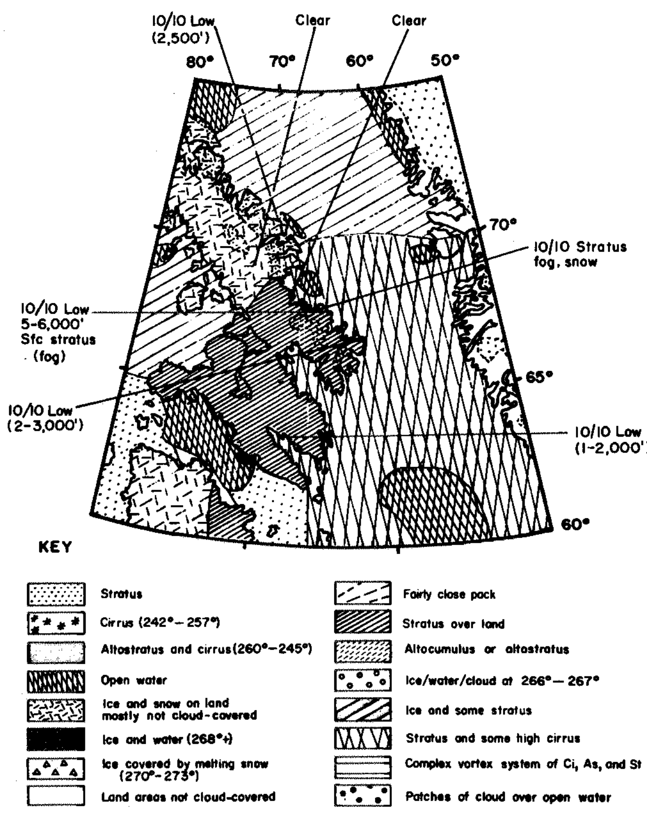

FIG. 6. An example of a cloud cover and ice cover analysis for the Baffin Island region, 26 June 1970, determined from visual and infrared imagery.

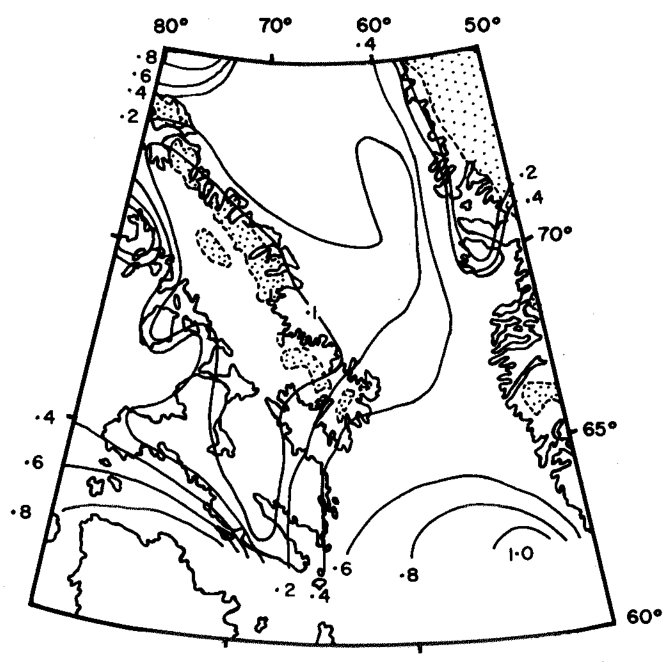

FIG. 7. Analysis of absorbed solar radiation at the surface, mid-day 26 June 1970 (cal cm^{-2} min^{-1}).

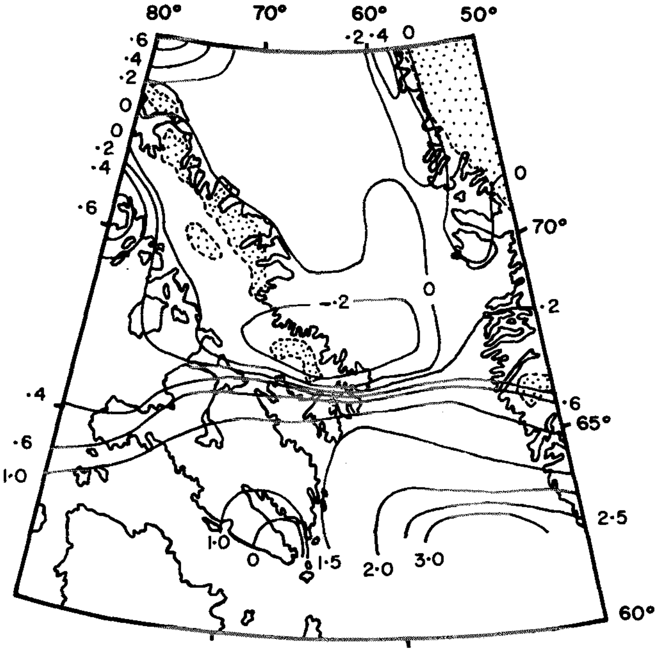

FIG. 8. Analysis of regional energy budget estimates, mid-day 26 June 1970 (cal cm^{-2} min^{-1}).

TABLE 6. Comparison of circulation regimes, summers 1969–71.

	July-Aug. Difference from 1961–70 (%) 1969	1970	1971	June Frequency (days) 1969	1970	1971
C1. Central low	−12.4	+0.5	+3.8	2	10	1
C2. Davis St. low	−2.9	+1.9	+0.3	7	4	3
C3. Baffin Bay low	+0.1	−1.5	+3.4	4	3	0
C4. SW low	+1.1	−5.4	−5.4	0	0	2
C5. SW low & others	−2.7	+0.5	−4.4	6	2	6
Cyclonic control	−16.8	−4.0	−2.3	19	19	12
A1. Anticyclone	+22.3	+7.7	−3.5	1	3	8
A2. Ridge	−5.2	−1.9	+1.3	3	3	1
A3. Ridge, low to S	−0.6	+1.0	+5.8	3	1	6
A4. High to E, low to W	−0.1	+1.5	−0.1	0	3	0
A5. Ridge (NE flow)	+6.0	−0.5	−3.7	2	0	1
A6. Ridge (N-NW flow)	−5.5	−3.9	+2.6	2	1	2
Anticyclonic control	+16.9	+3.9	+2.4	11	11	18

or for inferring synoptic conditions from glaciological evidence. Both cases are pertinent in palaeoclimatic reconstruction and climatic modeling.

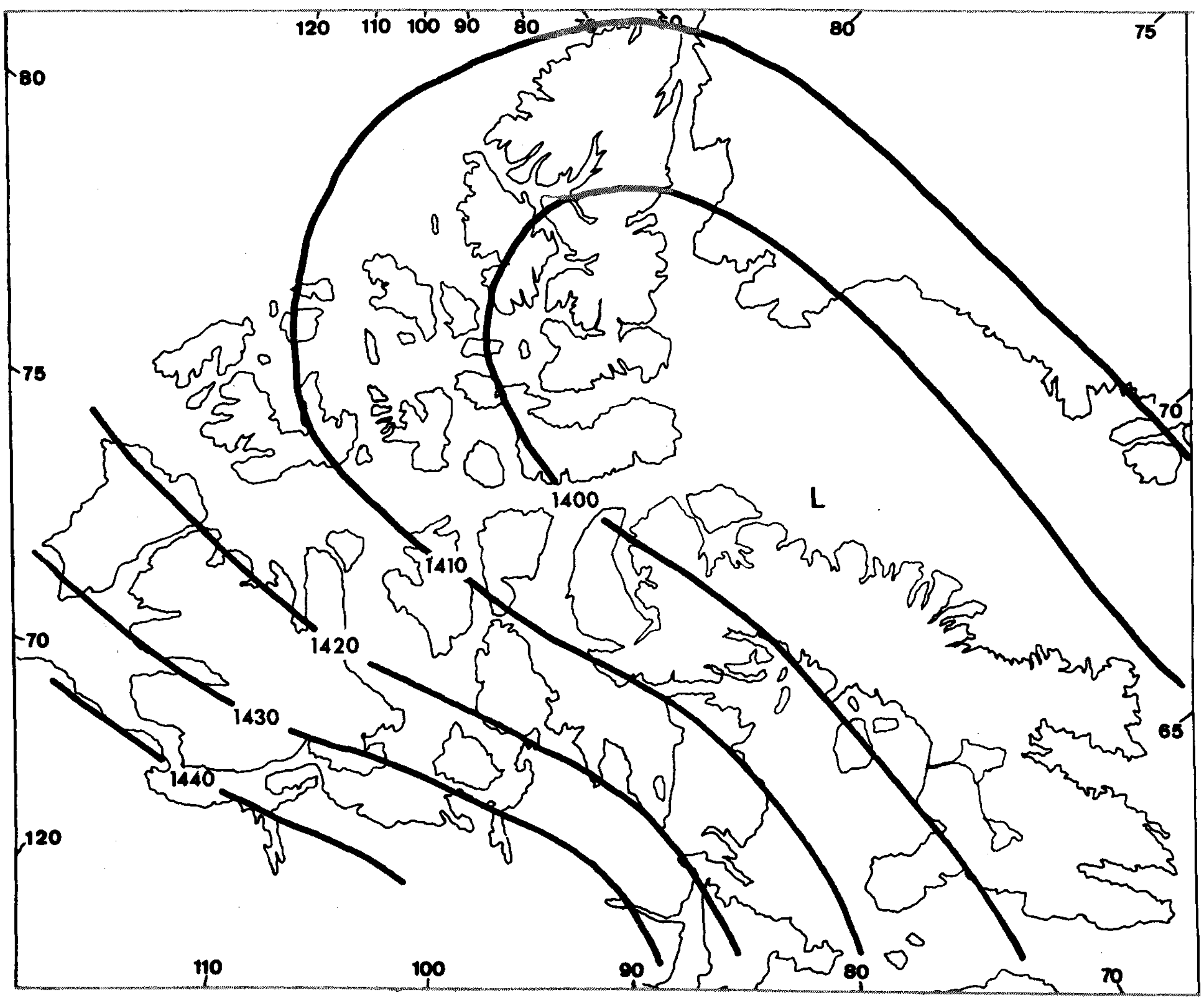

FIG. 9(a). Contours of the 850 mb isobaric surface over the Canadian Arctic Archipelago in July (from Bradley, 1973). 1951–60.

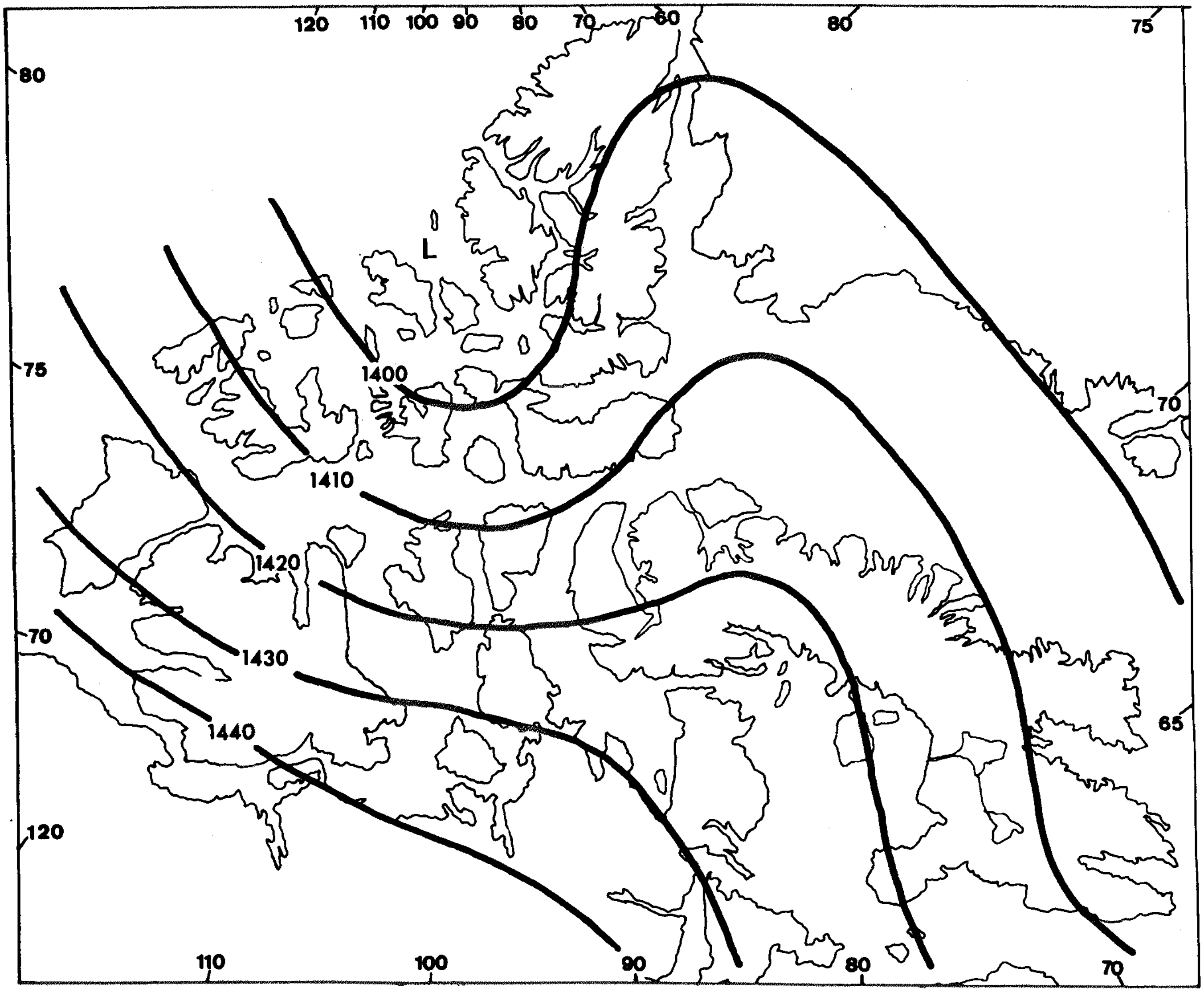

FIG. 9(b). Contours of the 850 mb isobaric surface over the Canadian Arctic Archipelago in July (from Bradley, 1973). 1961–70.

5. Climatic change studies

A major objective of our work is the assessment of decadal and longer term trends in glacio-climatic conditions in the eastern Canadian Arctic. Our premise is that on the regional scale these conditions are determined by the synoptic climatological events, although caution is needed in ascribing changing conditions solely to changes in the frequency of synoptic types (*cf.* Perry and Barry, 1973).

For the decade so far examined in detail through the synoptic catalog, there has been a marked increase in anticyclonic patterns at 850 mb over Baffin Island in July compared with the 1950's (Figs. 9a and b). Also, as shown in Table 8, the frequency of anticyclonic patterns increased in the latter half of the 1960's. Paradoxically, in terms of the generally higher temperatures for the anticyclonic type-groups, summer temperatures in the area *declined* in the 1960's

TABLE 7. Synoptic types in relation to processes on glaciers and fast ice in the summer season.

State	Favorable Weather	Favorable Synoptic Patterns: Glacier	Favorable Synoptic Patterns: Fast Ice
Advanced ice wastage	Clear; warm and windy; rainfall	*Central low*, low to SW, *ridge*, high, high in E	Central low, low to SW, high, high in E, central ridge
Retarded ice wastage	High overcast; snowfall; cold and calm	*Davis Strait low*, Baffin Bay low, *ridge over Baffin with NE flow*	

(Bradley, 1973b). Dunbar (1972) reports a marked increase in the late summer persistence of pack ice in western Baffin Bay since 1963 which may be related in part to more frequent easterly and northeasterly airflow (cf. Figs. 9a and b). Patterns of this type increased by 39% in 1966–70 compared with 1961–65, with a corresponding reduction in westerly and southwesterly patterns. However, the summer cooling is apparently widespread throughout the Canadian Arctic (Bradley, 1973a) so that a larger scale control must be sought. As far as Baffin Island is concerned, the recent climatic trend to cooler summers and, for the east coast, milder, more snowy winters, tends to be associated in both seasons with a westward displacement of the mean 700 mb trough over eastern North America, and this favors the northward movement of cyclones into Baffin Bay (Brinkmann and Barry, 1972). The fact that snow banks in the Cumberland Peninsula of Baffin Island and small glaciers and ice fields in the Queen Elizabeth Islands appear to be responding to the cooler summers and more snowy winters (Bradley and Miller, 1972; Hattersley-Smith and Serson, 1972) indicates the sensitivity of this sector of the Arctic to climatic fluctuations. Clearly it is a key area for interdisciplinary studies of the Arctic environment and its stability.

6. Further work

Our ongoing field program in eastern Baffin Island on the fast ice and on the Boas Glacier aims to provide a firmer basis for the synoptic energy budget studies in relation to ice mass balance, and to document a wide range of interannual fluctuations for analysis. It is planned to extend the synoptic catalog and to evaluate it more fully by comparison with objective schemes such as that of Fogarasi (1972). A classification of 700 mb height departures from normal for the area has already been prepared for July–August 1966–70 using the Lund (1963) correlation method, for example. Assessment of the effectiveness of these different approaches in discriminating between weather characteristics will be carried out in the near future.

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TABLE 8. Changes in frequency of type-groups in July–August.

Type-Group	1961–65	1966–70	Difference (% of total)
Central low	59	38	−7.0
Davis St. low	35	23	−4.0
Baffin Bay low	14	15	+0.3
SW low	33	30	−1.0
SW low & others	24	33	+3.0
Total cyclonic	165	139	−8.7
Anticyclone	19	43	+8.0
Ridge situations	24	28	+1.3
Ridge, low to S	25	39	+4.7
High in E, low to W	25	36	+3.7
Ridge (NE flow)	14	9	−1.7
Ridge (N–NW flow)	38	16	−7.3
Total anticyclonic	145	171	+8.7

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