THE CLIMATE OF THE ABLATION PERIOD ON THE BARNES ICE-CAP IN 1950

A Thesis

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CHAPTER I

INTRODUCTION TO THE PROBLEM

During the summer of 1950 the Arctic Institute of North America sponsored an expedition to Baffin Island. Under the leadership of Colonel P. D. Baird, Director of the Institute's Montreal Office, the expedition members studied biology, geology and sea ice in the area around Clyde (70°27' N - 68°31' W), and also glaciology and meteorological conditions on and at the edge of the Barnes Ice-cap. The general area of investigation is shown in Figure 1, where also the Department of Transport weather stations in northern Baffin Island are indicated. The glaciological work was carried out by Col. Baird and Mr. W. H. Ward of the U. K. Department of Scientific and Industrial Research assisted by J. Waller of McGill University and by the author. C. A. Littlewood of the Dominion Observatory, Ottawa, carried out gravimetric observations on the ice and around the southern edge. The meteorological observations on the ice-cap were carried out by the author, who spent ninety-two days at the Main Camp. This camp will be known as camp "A-1".

I. RESEARCH PROBLEM

Statement of the problem. It was the purpose of this study (1) to describe the meteorological conditions on the

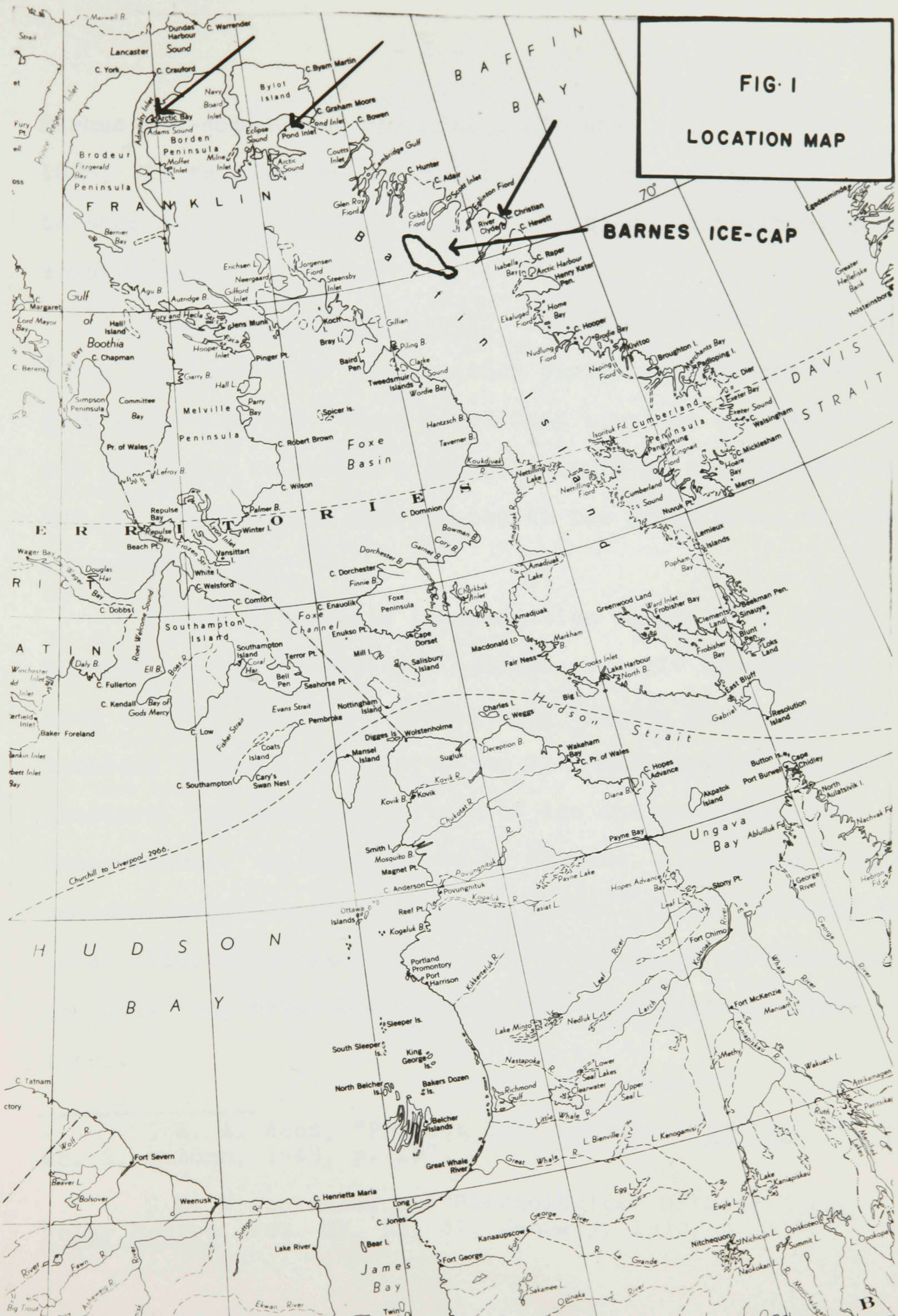
FIG. I
LOCATION MAP
BARNES ICE-CAP
BAFFIN BAY
DAVIS STRAIT
FRANKLIN
Foxe Basin
Hudson Strait
Ungava Bay
HUDSON BAY
James Bay
Arctic Bay
Pond Inlet
River Clyde

Barnes Ice-cap during the months of June, July and August 1950; (2) to describe the ablation in that period; and (3) to show the relationship between ablation and meteorological conditions.

Importance of the study. Nothing has been known about the climate of the ablation period on any Canadian glacier or ice-cap. Wood noted that previous to 1948 it was difficult to recall a single example of studies carried out in North America and devoted to the great areas of snow accumulation.[1]

In the systematic investigation of glaciers it is imperative that glaciologic and meteorologic research go hand in hand, since the problems of the two fields are intimately joined -- precipitation with alimentation of the glaciers, interior temperature of ice and firn with air temperatures. As pointed out by Ahlmann, glaciology requires meteorological observations of a special kind.[2] General and local climatological information is necessary to determine the ablation, with observations from the glacier surface itself.

1 W. A. Wood, "Project Snow Cornice," Arctic, Vol. I, No. 2, Autumn, 1948, p. 107.

2 H. W:son Ahlmann, "Glaciological Methods," The Polar Record, Vol. IV, No. 31, January, 1946, p. 316.

In the past twenty-five years glaciers and ice-caps around the North Atlantic have been studied, partly to determine their behaviour in a changing climate, partly to obtain a more detailed knowledge of the importance of the different meteorological factors in the process of ablation. A new approach to the problems of glaciology has resulted from these investigations, a special program of meteorological observations must be carried out, and new and improved methods must be applied to the problem of ablation and its dependence on the meteorological factors. This modern approach was the result of the cooperation of Ahlmann and Sverdrup on the Norwegian-Swedish Spitsbergen Expedition in 1934.[3] Their methods have later been applied to observations from the Froya Glacier on Clavering Island on the east coast of Greenland,[4] and recently Wallen has used the same methods in his study of a glacier in northern Sweden.[5]

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3 H. W:son Ahlmann, H. U. Sverdrup and H. Olsson, "Scientific Results of the Norwegian-Swedish Spitsbergen Expedition in 1934, Parts 1-8," Geografiska Annaler, Vol. XVII, 1935, and Vol. XVIII, 1936.

4 B. E. Eriksson, "Meteorological Records and the Ablation on the Froya Glacier in Relation to Radiation and Meteorological Conditions," Geografiska Annaler, Vol. XXIV, 1942, pp. 23-50.

5 C. C. Wallen, "Glacial-Meteorological Investigations on the Karsa Glacier in Swedish Lappland, 1942-1948," Geografiska Annaler, Vol. XXX, Haft 3-4, 1948, pp. 451-672.

Although a lack of radiation instruments and difficulties experienced due to the inaccessibility of the Barnes Ice-cap combined to limit the investigation, it is still possible to present a picture of the climatic conditions during the ablation-period of 1950. By comparing the results with observations from other arctic regions an increased understanding of the nature of a Canadian ice-cap is obtained.

II. DEFINITIONS OF TERMS USED

Ablation. The joint result of the processes consuming a snow or ice surface, i.e., melting and evaporation.

Gross ablation. Ablation due to superficial melting and evaporation.

Net ablation. The amount of water actually lost to a glacier by drainage.

Budget year. The period from first snowfall of winter through the ablation season of the following summer.

Regime of a glacier. The grand total of its entire accumulation and net ablation during a budget year.

Firn line. The firn line is the highest level on a glacier to which a winter snow cover recedes during the following ablation season. If there is superimposed ice, the firn line is the lower limit of the superimposed ice.

Neve area. Accumulation area.

Firn. Granular compacted snow, covering the surface of the neve area throughout the year.

Summer, or summer period. The three months of June, July and August.

III. OBSERVATIONS AND INSTRUMENTS

It was planned to investigate (1) the regime of the ice-cap; (2) the ablation at camp "A-1"; and (3) the meteorological conditions at the edge and at camp "A-1", both at the surface and at different levels above the surface.

The problem of the variations in the regime from one year to the next is still unsolved. No previous observations have been carried out, and as the ice-cap is very inaccessible it is most unlikely that further investigations will be carried out for many years. However, by studying the geology and botany along the edges of the ice-cap it was hoped to ascertain something of its behaviour over a longer period.

Character of the observations. The ice-cap station was established on May 27th, and from June 1st to August

26th the following meteorological observations were carried out every two hours from 0800 to 2200 daily: Pressure by mercury barometer, temperature and humidity at three feet and at twenty-three feet above the surface, temperature at thirteen feet, wind speed and direction at seven feet and at twenty-three feet above the surface. Also observations of clouds, cloudiness, fog, visibility and ceiling. Three times per day, at 0800, 1400 and 2000, maximum and minimum temperatures and precipitation were observed. Snowfall was measured by stakes, rain by means of an ordinary rain-gauge. Duration of the sunshine was recorded by a Campbell-Stokes recorder, and a barograph and a thermograph gave continuous records of pressure and temperature at three feet above the surface.

Instruments. The following instruments were kindly supplied by Mr. A. Thomson, Controller, Meteorological Division, Department of Transport, Toronto: Two MSC barographs, two S-N thermographs, one hand anemometer, two MSC type B sling psychrometers, two H-B mercury thermometers, two MSC minimum thermometers, two MSC maximum thermometers, one MSC rain-gauge and rain-graduate, two Stevenson screens, one mercury barometer.

One set of instruments was used by the biological party at camp "B" at the head of Clyde Inlet, the other at the ice-cap station. A collapsible aluminium ladder, twenty-three feet high, was erected at the ice-cap station. A thermo-couple was placed thirteen feet above the surface with leads to the foot of the ladder, where the temperature was read by a portable, calibrated Wheatstone bridge. The same Wheatstone bridge was used to read the temperatures from similar thermo-couples buried at various depths in the snow and in the underlying ice. The thermo-couples were made and calibrated by Ward at the U. K. Department of Scientific and Industrial Research.

A mercury thermometer, shielded by aluminium foil, was suspended under the woodern platform on top of the ladder.

Wind direction was observed by a wind vane on top of the ladder, and wind speeds both at seven feet and at twenty-three feet were measured by the hand-held anemometer.

The Stevenson screen facing north, the bottom two feet above the snow surface, housed the mercury thermometer, maximum and minimum thermometers and thermograph.

The sunshine recorder was placed on top of the screen, levelled off in all directions and the latitude scale set for $69^{\circ}40'$ N. (Latitude of the ice-cap station: $69^{\circ}42'$ N.)

The mercury barometer and the barograph were kept in the store tent.

The aluminium ladder is shown in Figure 2, and a diagram of camp "A-1" in Figure 3.

Fig. 2. The Ladder.

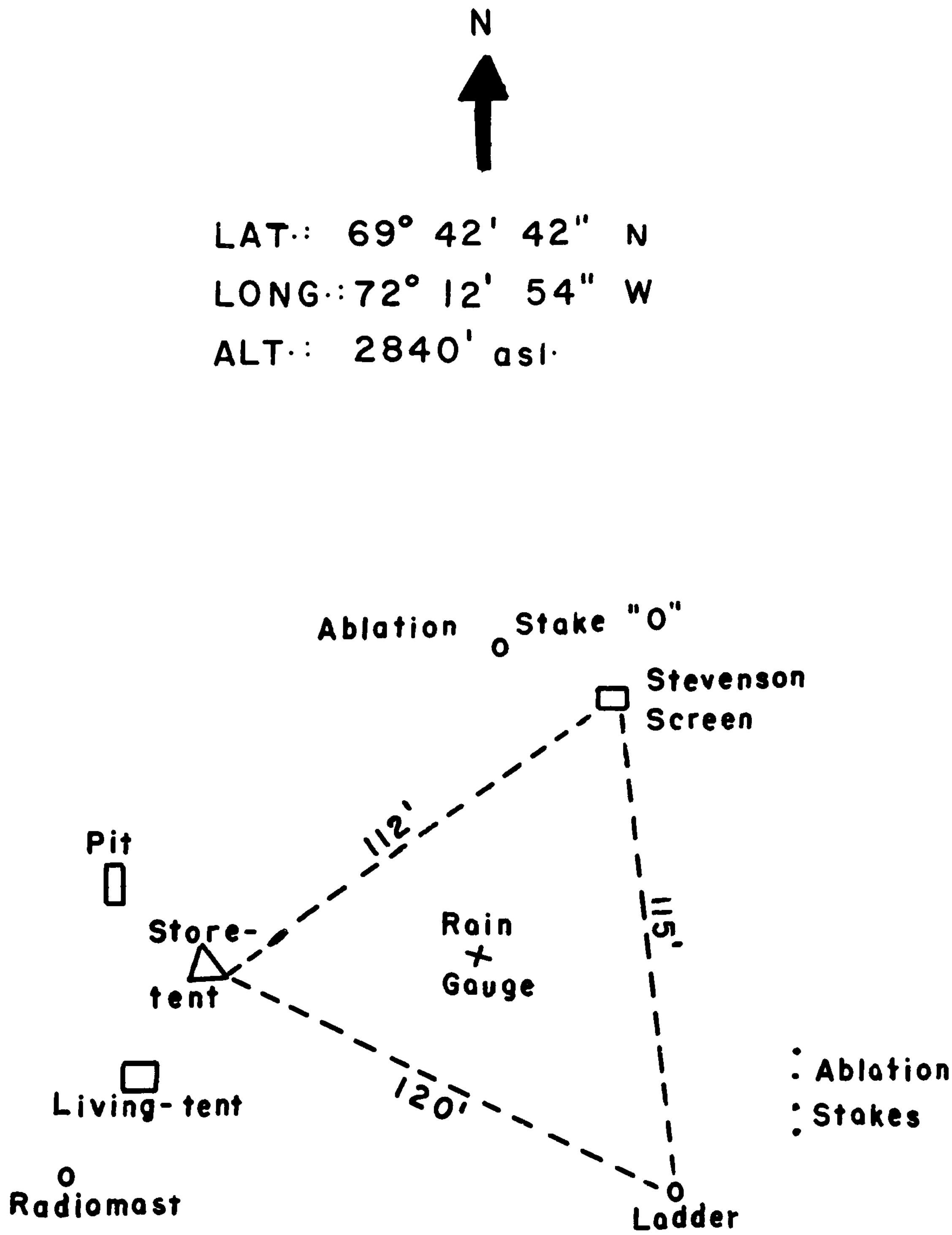

FIG. 3.

THE ICE-CAP CAMP.

IV. GENERAL OUTLINE OF THE WORK ON THE ICE-CAP

Baird, Ward and the author took off from Clyde on May 23rd in the expedition's ski-wheel equipped Norseman aircraft piloted by M. King. The weather was unstable, and inland from the head of Clyde Inlet the low ceiling forced the aircraft to return. A sand plain was seen at the head of the inlet, and the aircraft was landed there. Ward and the author remained and established camp "B". The following day the aircraft returned with members of the biological party, who, in addition to their special studies, carried out meteorological observations three times daily from May 25th to August 31st.

On May 27th Ward and the author were flown from camp "B" to the ice-cap and established camp "A-1" at an altitude of 2840 feet (866 meters) above sea level. The distance to the edge of the ice-cap was estimated to be twelve miles. The same evening the aircraft returned with Littlewood, who was to carry out astronomical and gravimetric work. Four days later the remainder of the meteorological instruments were brought in, and from June 1st to August 26th observations were carried out every second hour from 0800 to 2200 daily. During the first week ablation stakes were planted approximately two miles from the camp to the northwest, northeast, southeast and southwest. Ablation stakes were also planted at the camp site. On May 29th the first pit was dug, disclosing a snow depth of only thirty-nine inches underlain by coarse crystalline ice.

On May 31st Waller arrived to help Ward with the glaciological work. A generator and aluminium tubes were brought in, and Ward and Waller started the work of melting a hole in the ice for temperature measurements at different depths. On June 4th a depth of twenty-eight feet was reached, but, because of the low temperature of the ice, the melt-water refroze before the thermo-couples could be placed at this depth. Two thermistors (thermo-couples) were placed at fourteen feet and at eight feet below the surface. These were read throughout the summer until the camp was evacuated in August.

Baird arrived on June 9th, and five days later Ward and Waller left for a new location, camp "A-2", two miles from the southeast edge, where they carried on with glaciological work. The positions of the different camps are shown in Figure 4, which shows the area of investigation.

On June 24th Baird landed near the highest point of the ice-cap where the altitude was found to be 3680 feet; the top is probably 3700 feet above sea level. There was thirty-five inches of snow on the ice near the highest point. No firn was found anywhere on the ice-cap.

Gravimetric surveys were carried out between camp

FIG · 4 · AREA OF INVESTIGATION

"A-1" and the edge to the southeast, southwest and northeast. The thickness of the ice under camp "A-1" was found to be 1530 feet.

By July 20th the camp was entirely surrounded by meltwater streams, the nearest being some four hundred feet away.

The last snowfall of 1949-50 was recorded on July 8th, and the first snowfall of 1950-51 was recorded on August 5th. From August 1st to 5th the surface at the camp was free from snow, and measurements of the ice ablation were undertaken.

The ice-cap camp was evacuated on August 27th, after ninety-two days occupation, with eighty-seven days of continuous meteorological and glaciological observations. The investigations suffered from adverse weather conditions; strong winds and blowing snow at times made even the routine observations difficult or impossible to carry out.

V. THE BARNES ICE-CAP, ITS SIZE AND FEATURES

Although the Barnes Ice-cap has not been studied before, it must have been seen by Eskimos crossing from Foxe Basin to Clyde Inlet or in the other direction. An easy route leads just south of the southern lobe of the ice-cap. This portion of the ice-cap, and the valley running along it, can be seen in Figure 5.

Baird reports having seen the ice-cap from a dis-

Fig. 5. R.C.A.F. Photograph of the Southern Portion of the Barnes Ice-cap.

tance in 1934,[6] and again in 1939 when he tried to cross from the west coast to Clyde but had to turn back.[7] In 1940 Rev. M. Flint passed round the southern edge when he crossed the island from west to east. Canon J. H. Turner in 1941, and Constable Webster in 1945, both crossed from east to west along the same route.

The whole area was photographed from the air by the Royal Canadian Air Force in 1948 and in 1949, and a preliminary map was ready in the spring of 1950 on a scale of 5.33 miles to 1 inch. This unadjusted map was used by the members of the expedition.

The ice-cap covers approximately 2300 square miles. It is shaped as an irregular ellipse with the long axis lying northwest-southeast, parallel to the axis of the island. It is ninety-two miles long, the northern tip is at 70°31' N and the southern edge at 69°31' N. The width varies from a maximum of thirty-nine miles to fourteen miles across the narrow neck separating the southern lobe from the main ice-cap. The easternmost point lies at 71°54' W and the westernmost point at 74°44' W.

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6 P. D. Baird, "Preliminary Report, Baffin Island Expedition, 1950," Arctic, Vol. III, No. 3, December, 1950, p. 131.

7 "British Expedition to North Baffin Island, 1938-39," The Polar Record, Vol. III, No. 19, January, 1940, p. 226.

The southern lobe is almost circular, and the main camp was established in the centre of this lobe. The position was 69°42'42" N, 72°12'54" W. The locations of the glaciological camps "A-1", "A-2" and "A2Y" are shown in Figure 6, which also shows the gravimetric surveys as straight lines.

The ice-cap is nearly level. From the highest point, thirty miles to the northwest of camp "A-1", it slopes gently down to lakes and flat country on all sides. The maximum gradient of the surface near the camp was 45'. No high land is close to the ice-cap; the distance to the mountains, which rise to five thousand feet to the northeast and east of the ice-cap, is more than thirty miles. Land could be seen above the horizon only in a sector from 045° to 160°.

VI. OUTLINE OF THE THESIS

The first step is to investigate how the meteorological conditions in northern Baffin Island during the summer of 1950 compare with the average conditions in that area. This comparison is undertaken in Chapter II.

A comparison of the winter precipitation in 1949-1950 with the average for a long period is also carried out in that chapter, and as a result of these comparisons it is possible to state the degree of normality of the ablation conditions in the summer of 1950.

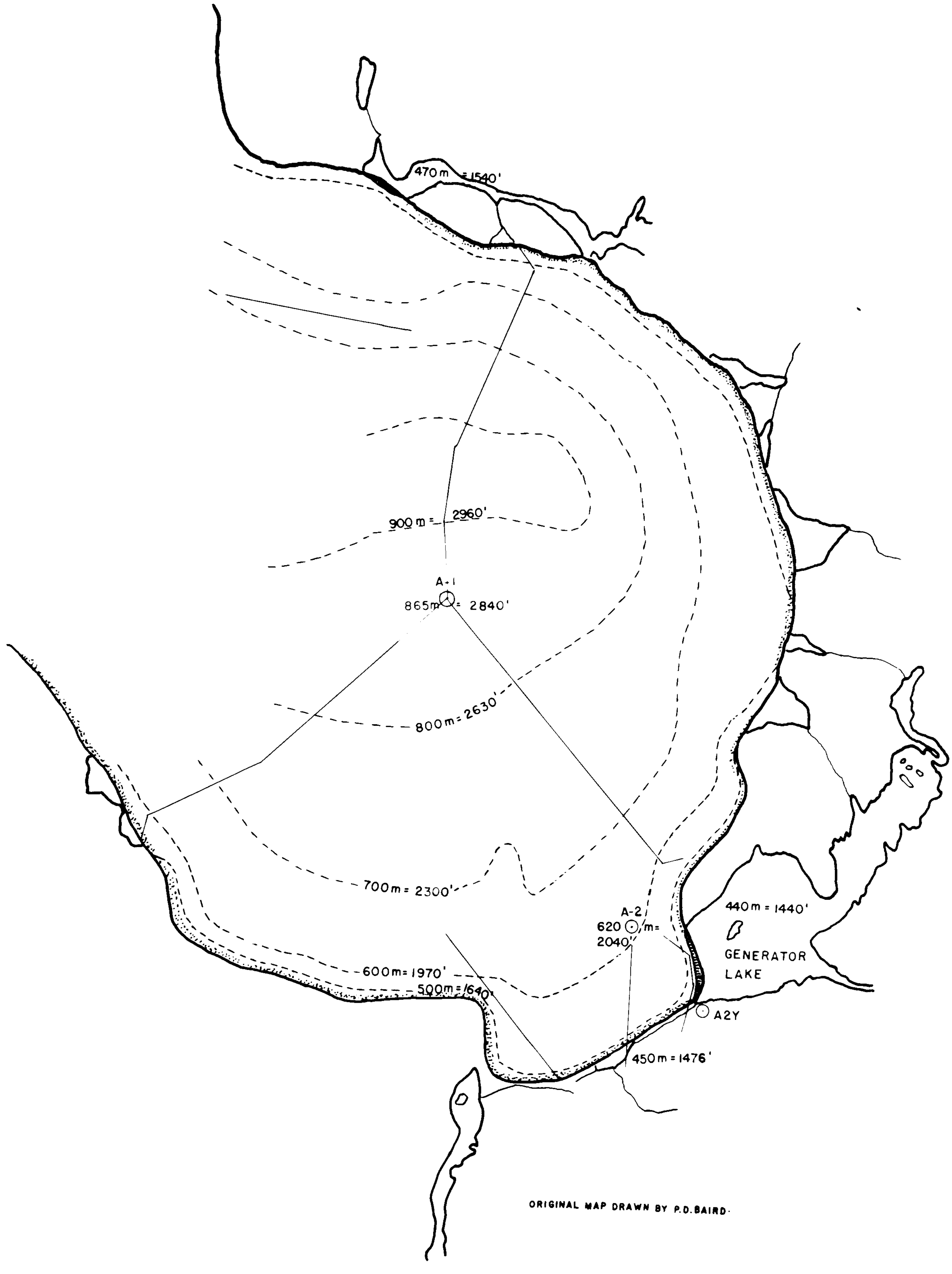

FIG. 6.

SOUTHERN LOBE OF THE BARNES ICE-CAP.

Chapter III deals with the meteorological observations on the ice-cap during the months of June, July and August 1950. The temperature gradient over the snow surface is discussed, and the temperature conditions compared to those observed over a snow surface in Spitsbergen and east Greenland. A comparison of temperatures at Clyde, camp "B" and the ice-cap is also undertaken. The influence of the ice-cap on the temperatures over the nearby land is studied with the help of Ward's observations from camps "A-2" and "A2Y".

Humidity, wind and pressure conditions are then treated, and copies of weather-maps for the stormy periods are presented, showing the possibility of cyclonic activity in northern Baffin Island. The chapter ends with a treatment of the observations of clouds, cloudiness, fog, precipitation and duration of sunshine.

Chapter IV is devoted to the ablation measurements. Six periods with characteristic weather and ablation conditions are distinguished, and from the results of the ablation studies the ice-cap is fitted into Ahlmann's classification of glaciers.

Chapter V deals with the temperatures of the snow and ice, and the seasonal warming at different depths is shown.

In Chapter VI an attempt is made to use Sverdrup's formula for computing ablation from certain known meteorological factors. The results are compared with the observed values.

In the final chapter the results are re-stated and summarized to show the conclusions of the study.

CHAPTER II

THE WEATHER IN NORTHERN BAFFIN ISLAND DURING THE BUDGET YEAR 1949-1950

The closest permanent post to the ice-cap station was Clyde, situated on the coast one hundred miles to the north-east, in position 70°27' N, 68°31' W.

Surface data are available from this station from November 1942, and the following tables show mean values of temperature, precipitation and wind[8] compared to the values for the summer months of 1950.

I. SURFACE DATA FROM CLYDE

<u>Air temperatures, degrees Fahrenheit.</u>

TABLE I

MEAN DAILY TEMPERATURE

Period: Nov. 1942 - March 1947

	June	July	August
Mean for period:	32.7	39.4	39.3
Mean for 1950:	34.2	43.8	39.9 (26 days)

8 T. J. G. Henry and G. R. Armstrong, <u>Aerological Data for Northern Canada</u>. Toronto: Department of Transport, 1949. p. 45

TABLE II

MEAN DAILY MAXIMUM TEMPERATURE

	June	July	August
Mean for period:	37.7	46.0	45.7
Mean in 1950:	39.6	52.0	44.8 (26 days)

TABLE III

MEAN DAILY MINIMUM TEMPERATURE

	June	July	August
Mean for period:	27.7	32.8	33.0
Mean in 1950:	28.8	35.6	34.9 (26 days)

TABLE IV

ABSOLUTE MAXIMUM TEMPERATURE

	June	July	August
Max. in period:	48.-	65.-	62.-
Max. in 1950:	50.5	68.7	52.8 (26 days)

TABLE V

ABSOLUTE MINIMUM TEMPERATURE

	June	July	August
Min. in period:	15.-	27.-	25.-
Min. in 1950:	22.4	28.4	30.0 (26 days)

Except for the August values of mean daily maximum and absolute maximum temperatures, all temperatures were higher during the summer of 1950 than the means for the four years 1943-1946.

Precipitation, inches of rain and snow. The total precipitation is the sum of rainfall and water equivalent of snowfall, calculated on the basis that ten inches of snow equals one inch of rain. T: trace.

TABLE VI

MEAN MONTHLY PRECIPITATION

Period: Nov. 1942 - March 1947.

	June	July	August
Rain :	0.07	0.80	1.20
Snow :	1.50	1.00	T
Total :	0.22	0.90	1.20

Total for the three summer months: 2.32 inches.

TABLE VII

MONTHLY PRECIPITATION

Summer 1950.

	June	July	August
Rain :	0.07	1.25	1.77
Snow :	11.90	T	4.00
Total :	1.26	1.25	2.17

Total for the three summer months 1950: 4.68 inches.

The summer of 1950 thus had more than twice as much precipitation as the average summer in the four years 1943-1946.

<u>Wind, direction and speed in m.p.h.</u>

TABLE VIII

WIND, PERCENTAGE FREQUENCY BY DIRECTIONS

Period: Oct. 1943 - March 1947.

	June	July	August	Mean
North :	28	27	26	27
Northeast:	8	12	11	10
East :	9	5	10	8
Southeast:	6	3	1	3
South :	9	4	7	7
Southwest:	5	12	3	7
West :	6	4	2	4
Northwest:	16	14	14	15
Calm :	13	19	26	19

TABLE IX

WIND, PERCENTAGE FREQUENCY BY DIRECTIONS

Summer 1950.

	June	July	August	Mean
North :	15	3	9	9
Northeast:	11	5	9	8
East :	16	10	5	10
Southeast:	8	10	9	9
South :	3	14	8	9
Southwest:	0	17	11	10
West :	1	2	0	1
Northwest:	23	13	40	25
Calm :	23	26	9	19

June and July 1950 had more calm weather than the average for the three years 1944-1946, while August had more wind with 40% of the winds from the northwest. The percentage of calm weather for the whole summer was the same in 1950 as the average for the three years 1944-1946. Figures 7 and 8 show the percentage frequency of wind by directions for the summer period.

WINDROSES.

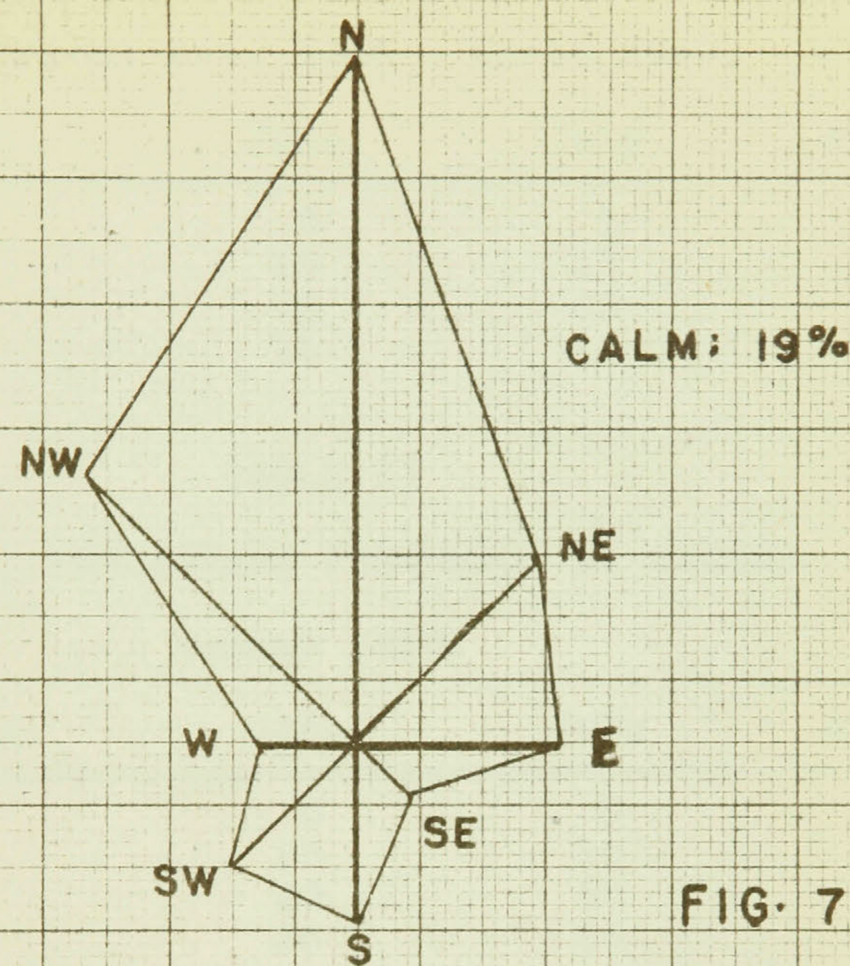

FIG. 7.

PERIOD 1944-46.

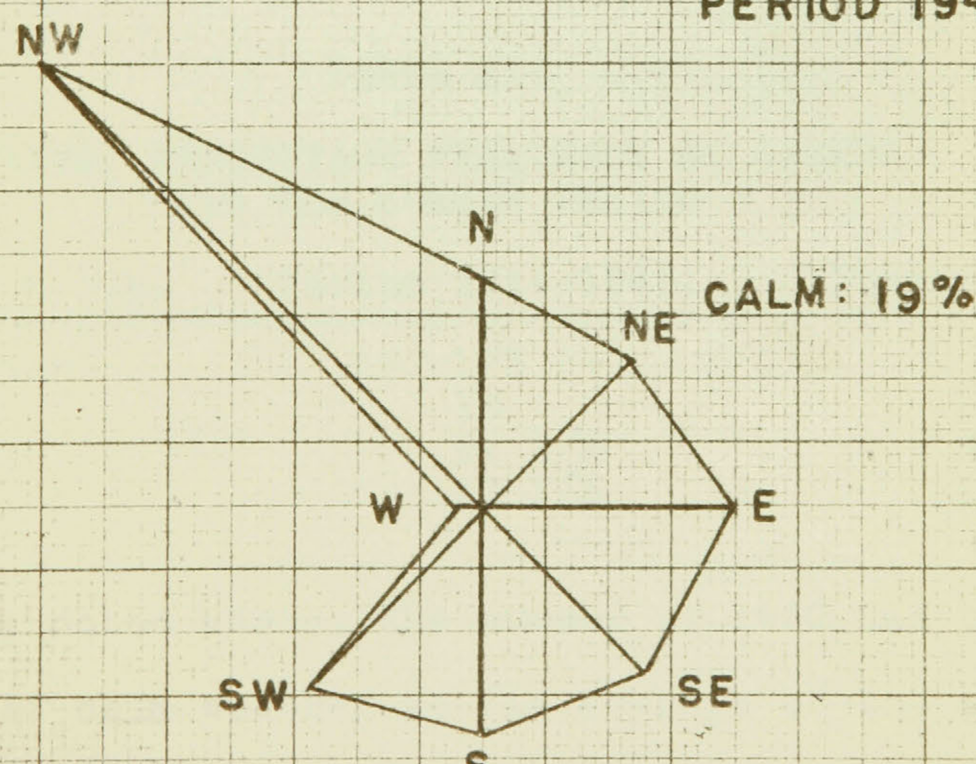

FIG. 8.

SUMMER 1950.

TABLE X

WIND, PERCENTAGE FREQUENCY BY SPEEDS

Period: Oct. 1943 - March 1947.

Speed in m.p.h.	June	July	August
39 and over	0	1	0
13 - 38	17	17	23
1 - 12	70	63	51
Calm	13	19	26

TABLE XI

WIND, PERCENTAGE FREQUENCY BY SPEEDS

Summer 1950.

Speed in m.p.h.	June	July	August
39 and over	0	3	0
13 - 38	28	18	44
1 - 12	49	53	47
Calm	23	26	9

TABLE XII

WIND, PERCENTAGE FREQUENCY BY SPEEDS
FOR THE SUMMER PERIOD

Speed in m.p.h.	Period 1944-1946.	Summer 1950.
39 and over	1/3	1
13 - 38	19	30
1 - 12	61 1/3	49 2/3
Calm	19 1/3	19 1/3

As noted above, the summer of 1950 had the same percentage of calm weather as the average of the three years 1944-1946, but it also had a considerably greater percentage of strong winds.

II. UPPER AIR DATA FROM CLYDE

Clyde is a Rawinsonde-station, and upper air data are available for the summers of 1949 and 1950. A comparison of the two summers is given in the following, being limited to the 900 millibar level. With a normal pressure gradient of 4mb./100feet the average height of the 900 mb. level is approximately 2850 feet. This is only a difference of ten feet from the altitude of the ice-cap station. The following tables show the conditions over Clyde, at the approximate height of camp "A-1", for the summers of 1949 and 1950. The ascents are carried out twice daily.

TABLE XIII

MEAN TEMPERATURES AT THE 900 MILLIBAR LEVEL

		June	July	August (26 days)
Mean temp. at 0800 :	1949:	31.1	40.5	36.0
	1950:	29.1	37.8	31.8
Mean temp. at 2000 :	1949:	30.3	39.7	32.9
	1950:	29.5	38.5	31.8

TABLE XIV

MEAN RELATIVE HUMIDITY AT THE 900 MILLIBAR LEVEL

		June	July	August (26 days)
Mean rel. hum. at 0800 :	1949:	69	68	75
	1950:	78	79	77
Mean rel. hum. at 2000 :	1949:	73	66	78
	1950:	77	68	75

The mean temperatures at the 900 mb. level in 1950 were somewhat lower, and the relative humidity on the whole higher than in 1949.

III. SURFACE DATA FROM POND INLET AND ARCTIC BAY

Apart from Clyde there are two other weather stations in northern Baffin Island, Pond Inlet (72°43' N - 78°30' W) and Arctic Bay (73°16' N - 84°17' W). The following data have been forwarded from Meteorological Division, Department of Transport, Toronto.

Pond Inlet.

TABLE XV

MEAN DAILY TEMPERATURE

Period: 1931 - 1949

	June	July	August
Mean for period :	35.4	41.7	40.5
Mean in 1950 :	34.3	42.4	40.4

TABLE XVI

MEAN DAILY MAXIMUM TEMPERATURE

	June	July	August
Mean for period :	40.9	47.9	45.4
Mean in 1950 :	38.9	48.5	45.2

TABLE XVII

MEAN DAILY MINIMUM TEMPERATURE

	June	July	August
Mean for period :	29.9	35.6	35.7
Mean in 1950 :	29.7	36.2	35.6

The temperatures at Pond Inlet during the summer of 1950 were very close to the long-term means, 1931-1949.

TABLE XVIII

MEAN MONTHLY PRECIPITATION

Period : 1931 - 1949.

	June	July	August
Rain :	0.41	1.12	1.26
Snow :	1.30	T	0.10
Total :	0.54	1.12	1.27

Total for the three summer months : 2.93 inches.

TABLE XIX

MONTHLY PRECIPITATION

Summer 1950.

	June	July	August
Total :	0.27	2.12	0.52

Total for the three summer months 1950 : 2.91 inches.

The precipitation at Pond Inlet during the summer of 1950 was thus also very close to the long-term mean.

Arctic Bay.

TABLE XX

MEAN DAILY TEMPERATURE

Period : 1937 - 1949.

	June	July	August
Mean for period :	35.8	43.5	41.0
Mean in 1950 :	37.1	42.5	41.6

TABLE XXI

MEAN DAILY MAXIMUM TEMPERATURE

	June	July	August
Mean for period :	41.8	51.0	46.7
Mean in 1950 :	44.0	48.8	47.5

TABLE XXII

MEAN DAILY MINIMUM TEMPERATURE

	June	July	August
Mean for period :	29.9	36.0	35.2
Mean in 1950 :	30.2	36.2	35.7

Also at Arctic Bay the summer of 1950 had temperatures very close to the long-term means, 1937-1949.

TABLE XXIII

MEAN MONTHLY PRECIPITATION

Period : 1937 - 1949.

	June	July	August
Rain :	0.23	0.72	1.24
Snow :	2.50	0.10	0.50
Total :	0.48	0.73	1.29

Total for the three summer months : 2.50 inches.

Precipitation data for the summer of 1950 are missing, but information obtained on visiting Arctic Bay in September 1950 seems to indicate a summer somewhat wetter than the normal.

IV. SUMMARY OF WEATHER IN NORTHERN BAFFIN ISLAND DURING THE SUMMER 1950

At Clyde the summer was slightly warmer than the average for the four years 1943-1946.

At Pond Inlet and Arctic Bay the summer of 1950 was very close to the average over long periods (nineteen years for Pond Inlet, thirteen years for Arctic Bay). This is quite remarkable, as the northern regions of Canada normally have a greater average variability of temperature from year to year than the southern regions. A list of ten stations at Hudson Bay-Hudson Strait and in Baffin Island show an average variation in mean daily temperature for July of 2.3 degrees F.[9]

The precipitation at Clyde was more than twice the normal (mean of four years), especially was the amount of snow in June and August well above average.

At Pond Inlet the summer precipitation was very close to the average for nineteen years. Precipitation data for 1950 from Arctic Bay are not available, but it seems likely that the summer was somewhat wetter than the normal.

At Clyde there were more northwest and southeast winds, and less north wind than the mean for the years 1944-1946, and a greater percentage of strong winds.

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9 R. DeC. Ward, C. F. Brooks and A. J. Connor, "The Climates of North America," Handbuch der Klimatologie, Band II, Teil J. Berlin: Verlag von Gebruder Borntraeger, 1938, p. 374.

In 1950 the temperatures at the 900 mb. level above Clyde, approximately the height of the ice-cap station, were slightly lower than in 1949. The relative humidity was higher. Studies of the vegetation at camp "A-2", on the land bordering the southern edge of the ice-cap, showed that in 1950 it was stunted compared to what could be seen of the previous summer's.[10]

It is safe to assume that the summer of 1950 was colder on the ice-cap than the summer of 1949, but the temperatures were probably not far from the normal over a longer period. The amount of summer precipitation was above the normal for a longer period, and probably above that of 1949.

As there is no firn on the Barnes Ice-cap, and no clear stratification in the ice, it is impossible to evaluate the adfreezing of new ice in previous years. The results of the ablation measurements must be seen in relation to the summer weather. The conditions were unfavourable for ablation compared to the summer of 1949, but not very different from an average ablation season. During the summer of 1950 a new layer of ice, approximately five inches thick, formed on the old ice surface above an altitude of 2500 feet. Less than that, if any, formed in 1949, as the ablation then must have been greater, but it is likely that an ice accumulation

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10 Personal information from W. H. Ward.

of the same order of magnitude takes place in some years, and this form of ice accumulation is likely to have been regular at an earlier stage.[11]

V. PRECIPITATION IN NORTHERN BAFFIN ISLAND DURING THE WINTER OF 1949-1950

When evaluating the regime of the ice-cap for 1949-1950 it is necessary to know the total accumulation. This presents no problem on the Barnes Ice-cap, as the winter snow was deposited on solid ice. The problem of comparing this year to earlier years, however, is more difficult. The following tables give the total precipitation at Clyde and at Pond Inlet for the winter 1949-1950, and the average values for long periods.

Clyde.

TABLE XXIV

MONTHLY PRECIPITATION 1949-1950

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1949:									1.34	1.24	1.88	0.74
1950:	0.34	0.73	0.45	0.34	1.10	1.26	1.25	2.17				

11 W. H. Ward, "Glaciology, Preliminary Report, Baffin Island Expedition, 1950," Arctic, Vol. III, No. 3, December, 1950, p. 143.

TABLE XXV

MEAN MONTHLY PRECIPITATION

Period : 1942 - 1947.

	J.	F.	M.	A.	M.	J.
Rain :	0	0	0	0	0	0.07
Snow :	2.40	2.30	0.80	0.40	3.80	1.50
Total :	0.24	0.23	0.08	0.04	0.38	0.22

	J.	A.	S.	O.	N.	D.	Year
Rain :	0.80	1.20	0.34	0	0	0	2.41
Snow :	1.00	T	1.00	11.0	8.00	1.10	33.3
Total :	0.90	1.20	0.44	1.10	0.80	0.11	5.74

At Clyde the snowfall from October 1949 to May 1950 amounted to 68.2 inches, (all precipitation fell as snow in this period), while the normal for the same period is 29.8 inches.

Pond Inlet.

TABLE XXVI

MONTHLY PRECIPITATION 1949-1950

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1949:									3.58	0.47	0.93	0.03
1950:	0.15	1.07	-	0.45	0.50	0.27	2.12	0.52				

TABLE XXVII

MEAN MONTHLY PRECIPITATION

Period : 1931 - 1949.

	J.	F.	M.	A.	M.	J.
Rain :	0	0	0	0	0	0.41
Snow :	2.20	1.20	1.90	3.60	1.20	1.30
Total :	0.22	0.12	0.19	0.36	0.12	0.54

	J.	A.	S.	O.	N.	D.	Year
Rain :	1.12	1.26	0.32	0	0	0	3.11
Snow :	T	0.10	2.80	7.10	3.90	2.90	28.2
Total :	1.12	1.27	0.60	0.71	0.39	0.29	5.93

At Pond Inlet the snowfall from October 1949 to May 1950 (not including March, data for which are missing) amounted to 36 inches,(all precipitation fell as snow in this period). The normal for the same period is 24 inches.

The normals for Clyde are only for a five year period, and are probably different from long-term means, but the figures indicate that both Clyde and Pond Inlet had considerably more snow during the winter 1949-1950 than the normal for longer periods.

It is reasonable to suppose that the accumulation on the Barnes Ice-cap in the budget year 1949-1950 was greater than the average. This fact, combined with the unfavourable conditions during the ablation-season, certainly resulted in less net loss of ice from the surface in 1950 than in 1949, and the period of snow free ice surface is probably longer in most years than the four days in 1950.

CHAPTER III

METEOROLOGICAL OBSERVATIONS ON THE BARNES ICE-CAP

I. TEMPERATURE

The temperature is the most important meteorological element in the study of ablation conditions, for it is a function of all other different meteorological factors, such as insolation, wind and humidity, which influence the ablation.

The temperature was observed every two hours from 0800 to 2200 daily by screened thermometers at three feet and at twenty-three feet above the surface, and by means of a thermocouple at thirteen feet. The temperature observations are complete for the period June 1st to August 26th, with the exception of July 6th when the weather prohibited all activity. On that day the thermograph filled with drifting snow; otherwise a continuous trace is available for the whole period. Controls of the thermograph were made three times daily by the dry bulb thermometer. The temperature varied very slowly, the greatest change being experienced on June 4th when the temperature rose eight degrees (F.) in one hour. This was caused by a sudden formation of fog on a clear night with strong outgoing radiation. Variations of five to seven degrees within a minute, as reported by Eriksson from the Froya Glacier in northeast Greenland,[12] were never experienced.

Mean temperatures for different periods, at three feet above the surface, are presented in the following tables.

TABLE XXVIII

MEAN TEMPERATURES

June: 26.2 July: 33.4 August: 28.9
Period May 30 - July 7 (last snowfall of 1949-1950): 26.7
Period July 8 - August 4 (no snowfall): 33.9
Period August 5 - August 26 (snow from August 5): 28.1
Mean daily temperature for period of investigation: 29.5

TABLE XXIX

MEAN TEMPERATURE FOR EACH DAY OF INVESTIGATION

Three feet above the surface

Date	May	June	July	August
1		17.7	32.4	33.3
2		17.1	31.2	34.7
3		24.5	37.2	34.0
4		21.7	30.8	31.0
5		25.9	29.0	29.5
6		26.7	--	32.5
7		26.8	25.7	30.0
8		23.6	29.6	31.2
9		21.9	31.1	31.1
10		24.6	34.6	32.9
11		23.6	29.5	31.8
12		24.4	31.0	30.2
13		24.7	32.5	27.1
14		22.6	33.5	27.0
15		17.1	32.7	22.1
16		22.4	32.6	24.6
17		21.5	35.1	22.8
18		23.5	34.6	21.4
19		23.4	36.4	27.0
20		23.9	35.3	26.6

12 B. E. Eriksson, "Meteorological Records and the Ablation on the Froya Glacier in Relation to Radiation and Meteorological Conditions," Geografiska Annaler, Vol. XXIV, 1942, p. 23.

TABLE XXIX (continued)

MEAN TEMPERATURE FOR EACH DAY OF INVESTIGATION

Three feet above the surface

Date	May	June	July	August
21		26.2	36.5	23.0
22		28.8	35.1	27.8
23		34.0	33.5	28.8
24		33.2	32.5	32.0
25		34.6	34.4	31.3
26		35.0	35.4	28.0
27		35.8	36.6	
28		35.4	33.2	
29		34.2	34.9	
30	21.8	32.3	38.1	
31	20.5		36.2	

The warmest day was July 30th with a mean temperature of 38.1; the coldest days were June 2nd and June 15th with a mean temperature of 17.1.

TABLE XXX

FIVE-DAY RUNNING MEANS OF MEAN DAILY TEMPERATURE

Date	June	July	August
1	20.3	33.5	35.3
2	20.3	32.8	33.8
3	21.4	32.1	32.5
4	23.2		32.3
5	25.1		31.4
6	24.9		30.8
7	25.0		30.9
8	24.7		31.5
9	24.1	30.1	31.4
10	23.6	31.2	31.4
11	23.8	31.7	30.6
12	24.0	32.2	29.8
13	22.5	31.8	27.6
14	22.2	32.5	26.2
15	21.7	33.3	24.7
16	21.4	33.7	23.6
17	21.6	34.3	23.6
18	22.9	34.8	24.5
19	23.7	35.6	24.2
20	25.2	25.6	25.2

TABLE XXX (continued)

FIVE-DAY RUNNING MEANS OF MEAN DAILY TEMPERATURE

Date	June	July	August
21	27.3	35.4	26.6
22	29.2	34.5	27.6
23	31.4	34.4	28.6
24	33.1	34.2	29.6
25	34.5	34.5	
26	34.8	34.4	
27	35.0	34.9	
28	34.5	35.6	
29	34.0	35.8	
30	33.1	35.1	
31		35.4	

Figure 9 shows mean temperature for each day, and five-day running means of mean daily temperature.

TABLE XXXI

DAILY MAXIMUM AND MINIMUM TEMPERATURE

Three feet above the surface

Date	June		July		August	
	Max.	Min.	Max.	Min.	Max.	Min.
1	26.0	9.3	37.3	27.4	35.3	31.2
2	28.3	5.9	36.0	26.3	39.0	30.3
3	27.0	22.0	42.2	32.2	35.8	32.2
4	29.0	14.4	33.3	28.2	33.2	28.7
5	29.6	22.2	31.3	26.7	32.7	26.2
6	29.7	23.7	--	--	33.9	31.1
7	35.1	18.5	30.1	21.3	31.9	28.1
8	25.0	22.1	32.4	26.7	36.0	26.4
9	29.5	14.3	35.2	27.0	37.1	25.1
10	27.3	21.8	36.0	33.1	33.7	32.0
11	27.8	19.4	32.1	26.8	33.3	30.2
12	27.5	21.3	33.1	28.8	33.1	27.2
13	26.9	22.5	35.7	29.3	30.2	23.9
14	29.0	16.2	35.7	31.3	29.0	25.0
15	28.6	5.6	33.1	32.2	27.2	16.9
16	24.8	19.9	35.1	30.0	28.9	20.2
17	25.9	17.0	37.3	32.8	26.7	18.9
18	27.0	20.0	36.5	32.6	29.6	13.1
19	28.0	18.7	39.9	32.9	28.0	26.0

TABLE XXXI (continued)

DAILY MAXIMUM AND MINIMUM TEMPERATURE

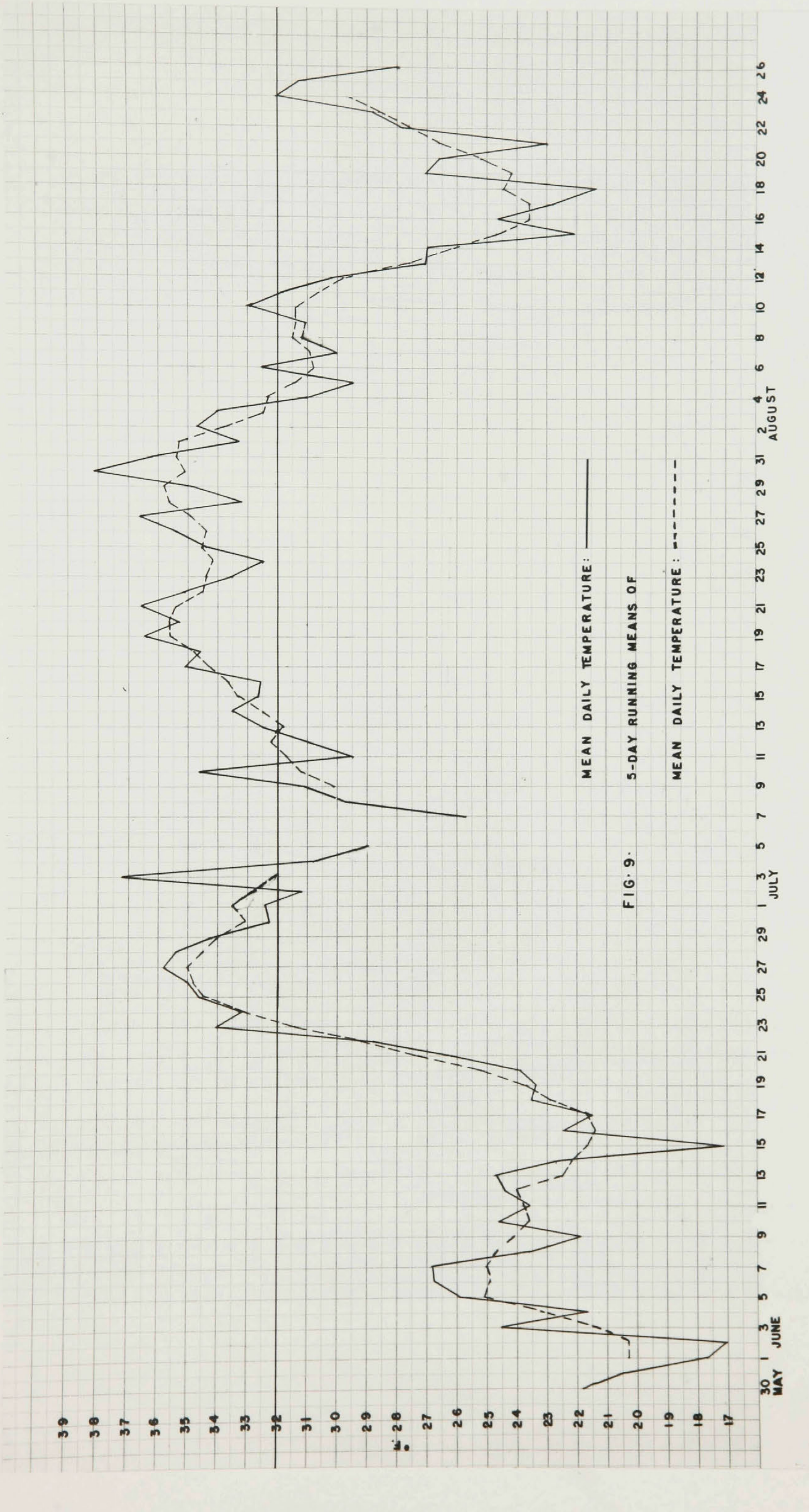
Three feet above the surface

Date	June		July		August	
	Max.	Min.	Max.	Min.	Max.	Min.
20	28.0	19.8	39.8	30.7	30.2	22.9
21	28.7	23.6	38.1	34.8	29.0	16.9
22	36.3	21.3	36.3	33.8	30.6	25.0
23	35.9	32.0	34.9	32.1	32.9	24.7
24	34.5	31.9	35.7	29.3	34.1	29.9
25	38.2	30.9	35.1	33.6	33.7	28.8
26	40.1	29.8	37.3	33.4	30.8	25.2
27	39.1	32.4	38.4	34.7		
28	39.0	31.7	37.1	29.2		
29	37.1	31.2	41.5	28.3		
30	36.8	27.8	40.2	35.9		
31			38.0	34.3		

	June	July	August
Mean daily maximum temperature:	30.9	36.2	32.2
Mean daily minimum temperature:	21.6	30.5	25.6

The absolute maximum was 42.2 on July 3rd, and the absolute minimum was 5.6 on June 15th. On the average the daily maximum was recorded at 1400 E.S.T., i.e., at 1411 local time, while the daily minimum was recorded at 0200 - 0400. The extremes occurred at 1300 and at 0200.

Figure 10 shows the daily maximum and minimum temperature.


°F.
39
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30 MAY
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 JUNE
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 JULY
2 4 6 8 10 12 14 16 18 20 22 24 26 AUGUST
MEAN DAILY TEMPERATURE:
5-DAY RUNNING MEANS OF
MEAN DAILY TEMPERATURE:

FIG. 9.

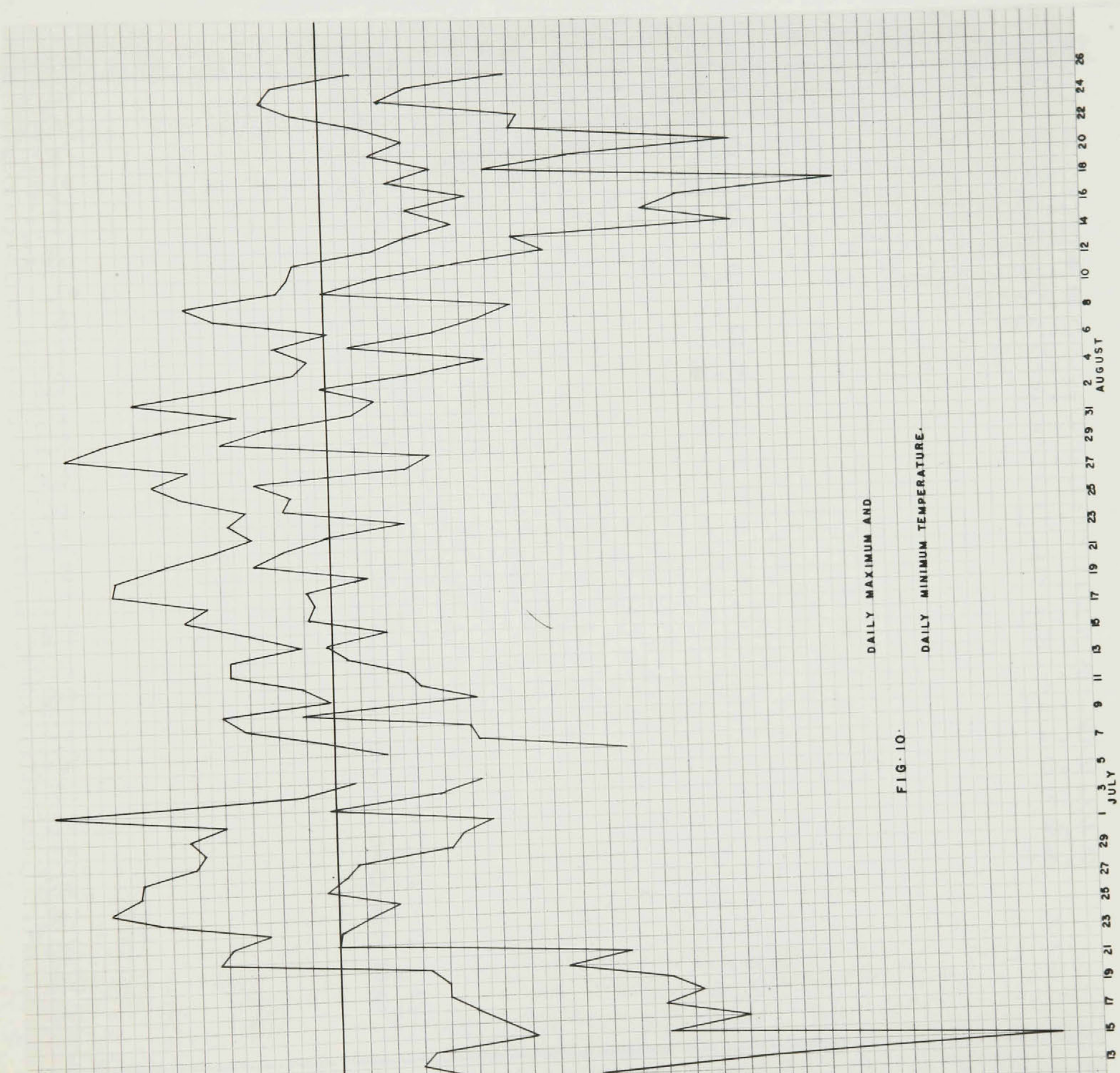


FIG. 10.

DAILY MAXIMUM AND

DAILY MINIMUM TEMPERATURE.

TABLE XXXII

DAILY RANGE OF TEMPERATURE

Date	June	July	August
1	16.7	9.9	4.1
2	22.4	9.7	8.7
3	5.0	10.0	3.6
4	14.6	5.1	4.5
5	7.4	4.6	6.5
6	6.0	--	2.8
7	16.6	8.8	3.8
8	2.9	5.7	9.6
9	15.2	8.2	12.0
10	5.5	2.9	1.7
11	8.4	5.3	3.1
12	6.2	4.3	5.9
13	4.4	6.4	6.3
14	12.8	4.4	4.0
15	23.0	0.9	10.3
16	4.9	5.1	8.7
17	8.9	4.5	7.8
18	7.0	3.9	16.5
19	9.3	7.0	2.0
20	8.2	9.1	7.3
21	5.1	3.3	12.1
22	15.0	2.5	5.6
23	3.9	2.8	8.2
24	2.6	6.4	4.2
25	7.3	1.5	4.9
26	10.3	3.9	5.6
27	6.7	3.7	
28	7.3	7.9	
29	5.9	13.2	
30	9.0	4.3	
31		3.7	
Mean daily range:	9.3	5.6	6.5

The maximum daily range of temperature was 23.0 degrees and occurred on June 15th. The minimum daily range was 0.9 degrees on July 15th. June 15th had clear weather during the night and was partly overcast during the day. There was only four hours of sunshine, but the low minimum temperature at night, caused by the strong outgoing radiation, resulted in the great daily range of temperature on that day. July 15th had overcast weather with rain and wet snow both during the night and day.

The mean daily range of temperature was greatest in June, 9.3 degrees, and the least in July, 5.6 degrees. The thermograph traces shown in Figures 11 and 12 illustrate the stabilizing effect of the melting snow surface in July.

A comparison of temperatures at Clyde, at camp "B" and at the ice-cap.

The following tables present a picture of the differences in temperatures at three locations; Clyde on the coast, the more continental camp "B" seventy miles inland at the head of the fiord, and the ice-cap station at 2840 feet above sea level.

TABLE XXXIII

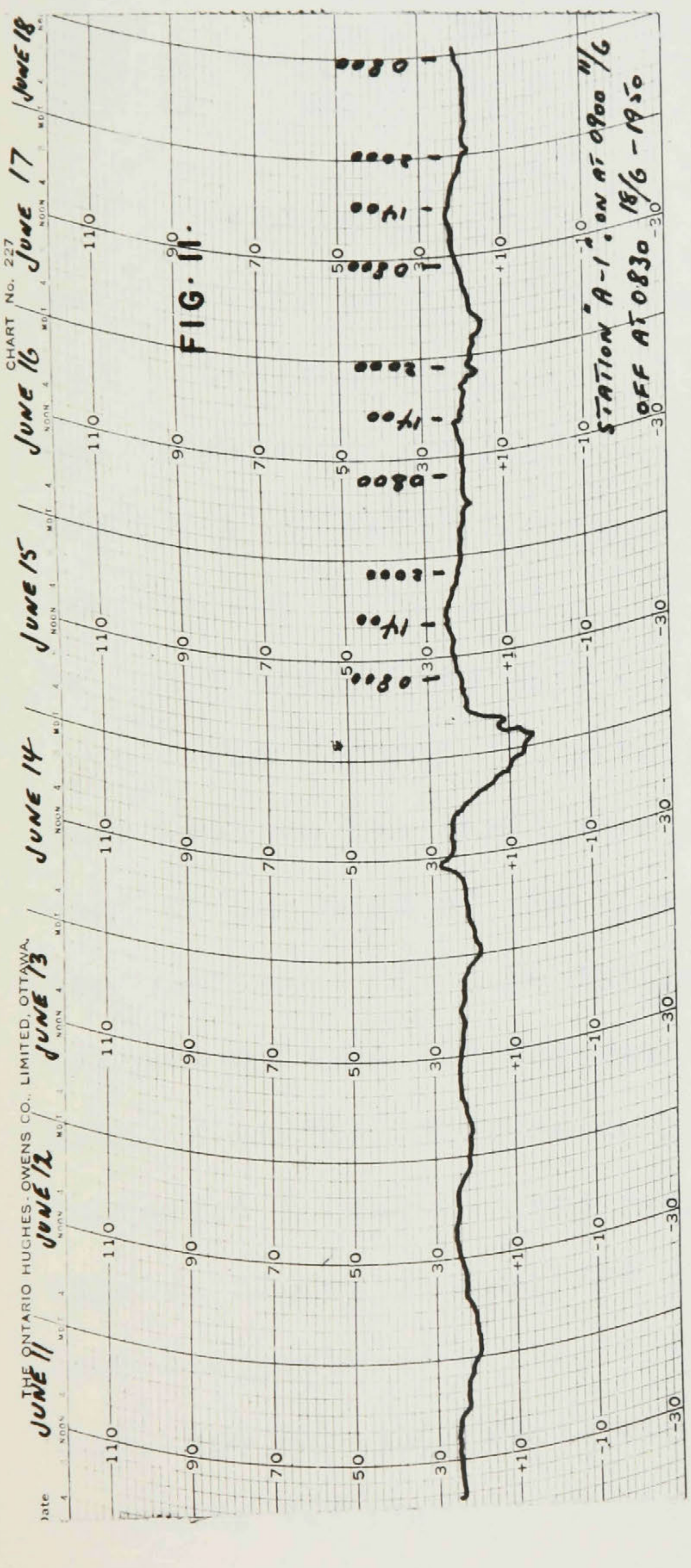
MEAN TEMPERATURES, JUNE

	0800	2000	Mean Maximum	Mean Minimum	Mean Daily
CLYDE	:33.7	34.8	39.6	28.8	43.2
STATION "B"	:38.6	37.8	45.2	32.1	38.7
ICE-CAP	:28.0	27.0	30.9	21.6	26.2

TABLE XXXIV

MEAN TEMPERATURES, JULY

	0800	2000	Mean Maximum	Mean Minimum	Mean Daily
CLYDE	:42.9	44.6	52.0	35.6	43.8
STATION "B"	:47.1	47.4	53.8	39.0	46.4
ICE-CAP	:33.4	34.0	36.2	30.5	33.4


THE ONTARIO HUGHES-OWENS CO., LIMITED, OTTAWA
CHART No. 227
JUNE 11
JUNE 12
JUNE 13
JUNE 14
JUNE 15
JUNE 16
JUNE 17
JUNE 18
FIG. 11.
STATION "A-1": ON AT 0900 11/6
OFF AT 0830 18/6 - 1950

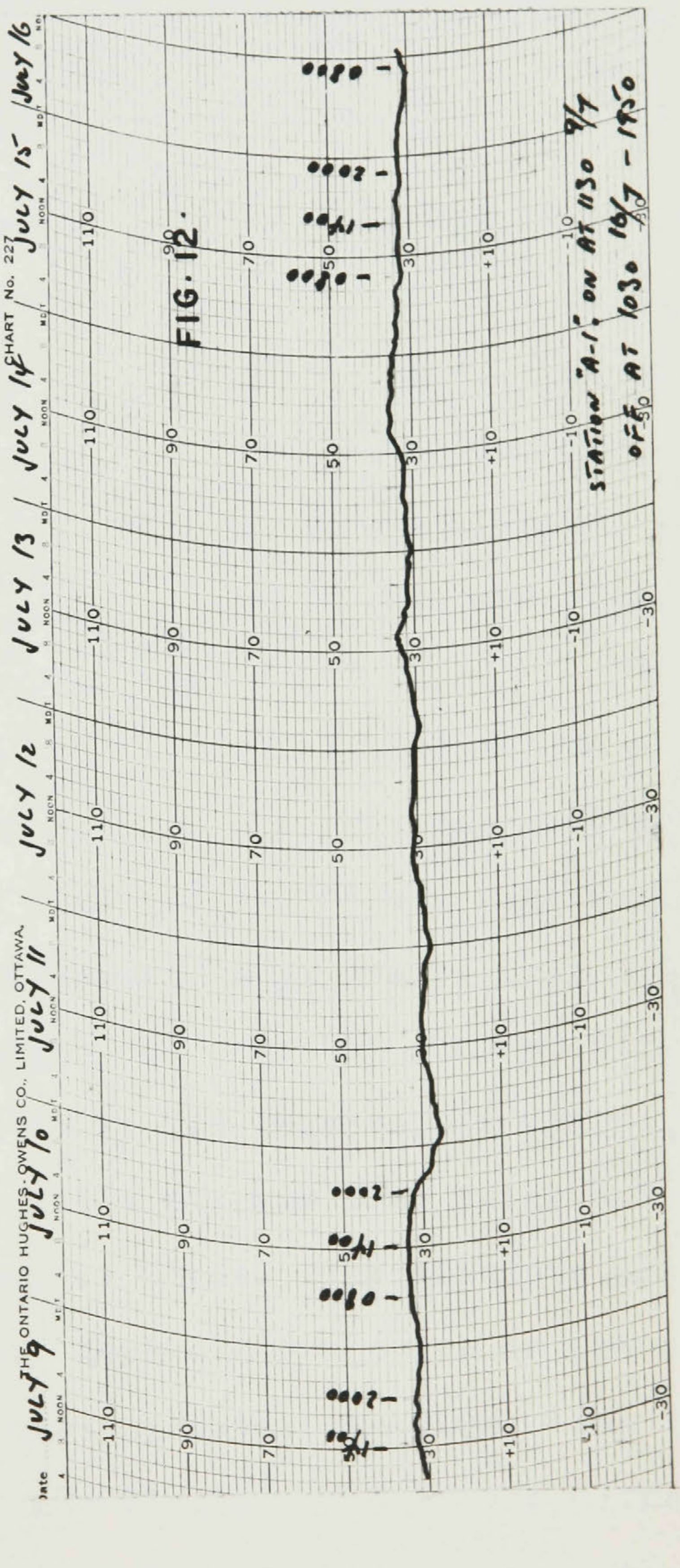

THE ONTARIO HUGHES-OWENS CO., LIMITED, OTTAWA
CHART No. 227
JULY 9
JULY 10
JULY 11
JULY 12
JULY 13
JULY 14
JULY 15
JULY 16
FIG. 12.
STATION "A-1": ON AT 1130 9/7
OFF AT 1030 16/7 - 1950

TABLE XXXV

MEAN TEMPERATURES, AUGUST (26 DAYS)

	0800	2000	Mean Maximum	Mean Minimum	Mean Daily
CLYDE :	38.8	39.9	44.8	34.9	39.9
STATION "B":	43.6	41.8	48.4	36.2	42.3
ICE-CAP :	29.6	29.3	32.2	25.6	28.9

Figures 13, 14 and 15 show the mean temperature at 0800 and 2000 and the mean maximum and minimum temperature at the three stations for each of the three summer months. The maximum temperature is plotted at 1400, although the time of occurrence of maximum temperature varied, and the minimum temperature is plotted at 0400. Both these times are close to the average time of occurrence.

The Figures illustrate the difference between the temperatures on the maritime coastal zone and the more continental zone at the head of the fiord with its relatively high summer temperatures. In June the difference was greatest; mean daily maximum was then 5.6 degrees higher at camp "B" than at Clyde. After a smaller difference in July, 1.8 degrees, it again increased in August, the mean daily maximum then being 3.6 degrees higher at camp "B" than at Clyde. The absolute maximum temperatures at the three camps did not occur on the same days, but the difference was again greatest in June, camp "B" recording 9.7 degrees higher than Clyde. In July the difference was less, 2.3 degrees, and in August it again increased to 6.4 degrees.

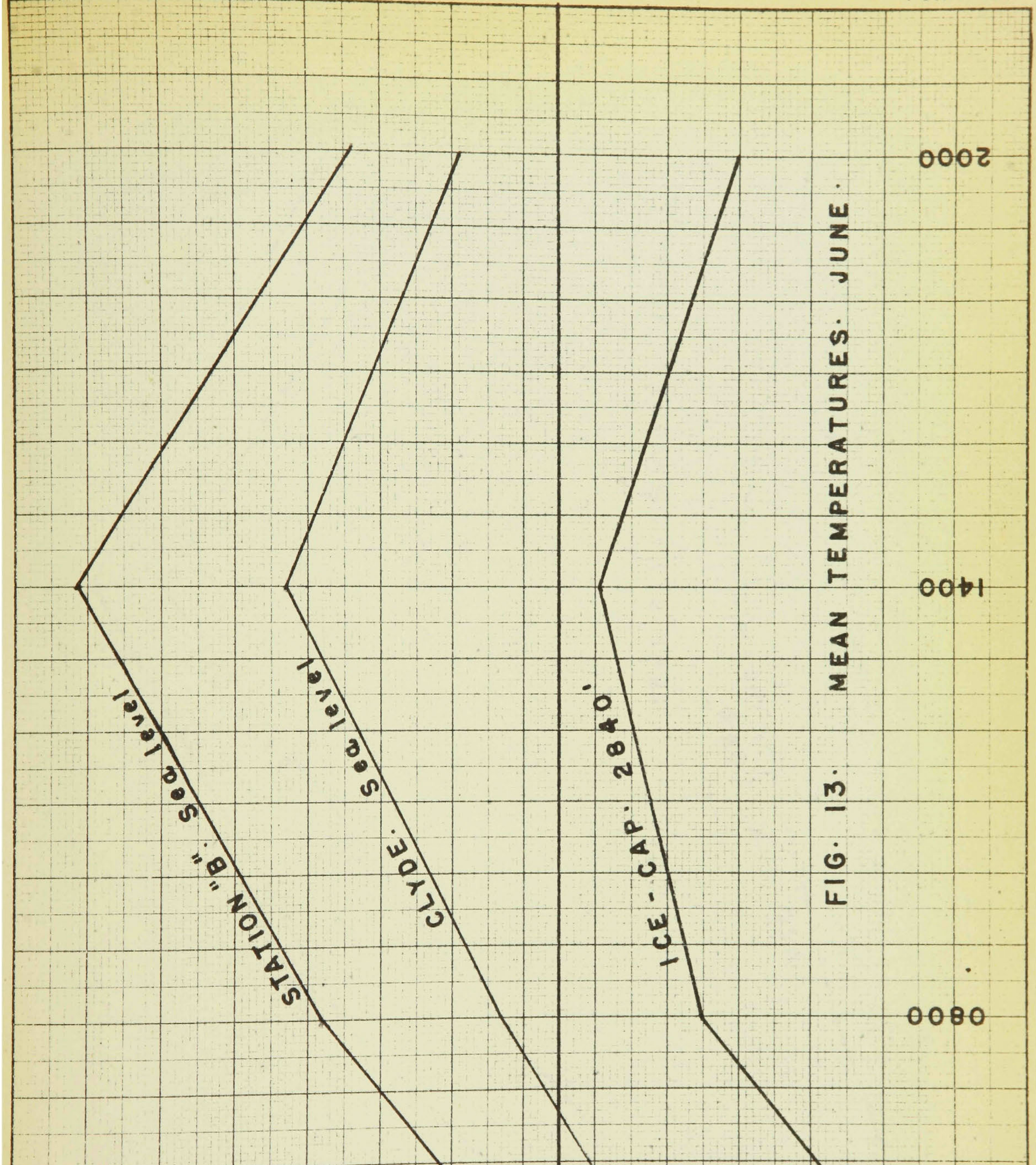


FIG. 13. MEAN TEMPERATURES. JUNE.

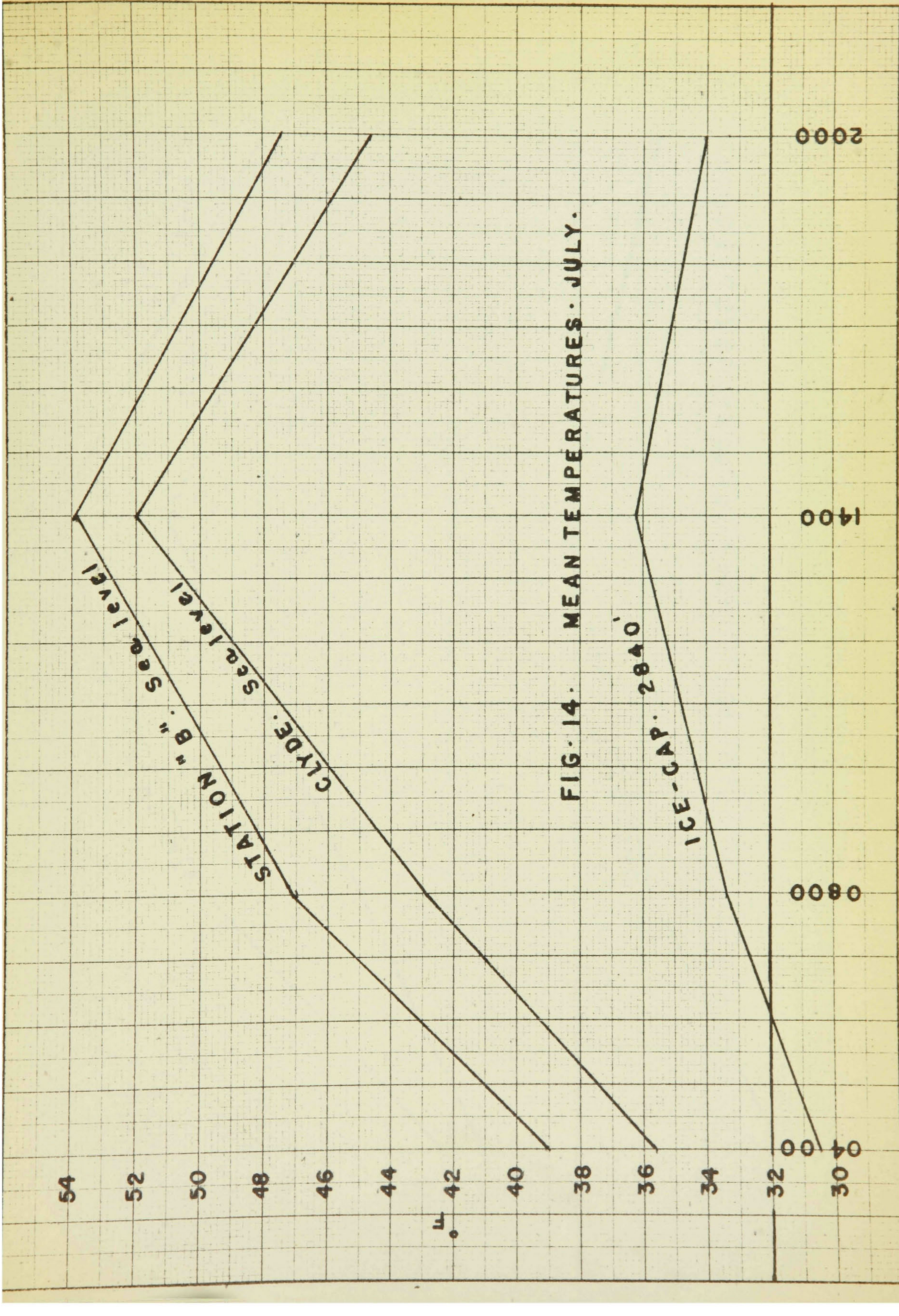


FIG. 14. MEAN TEMPERATURES. JULY.

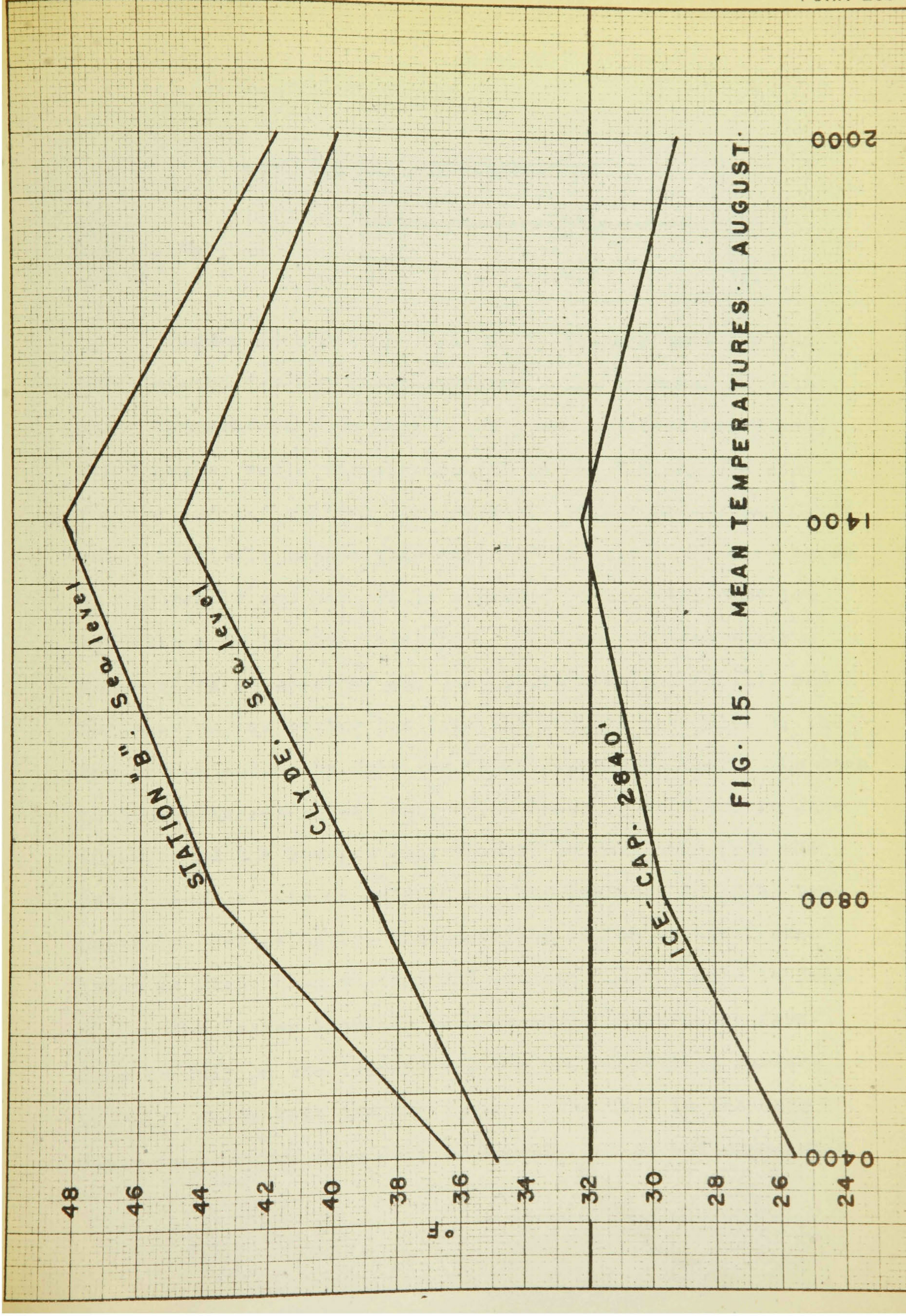


FIG. 15. MEAN TEMPERATURES. AUGUST.

TABLE XXXVI

ABSOLUTE MAXIMUM TEMPERATURE

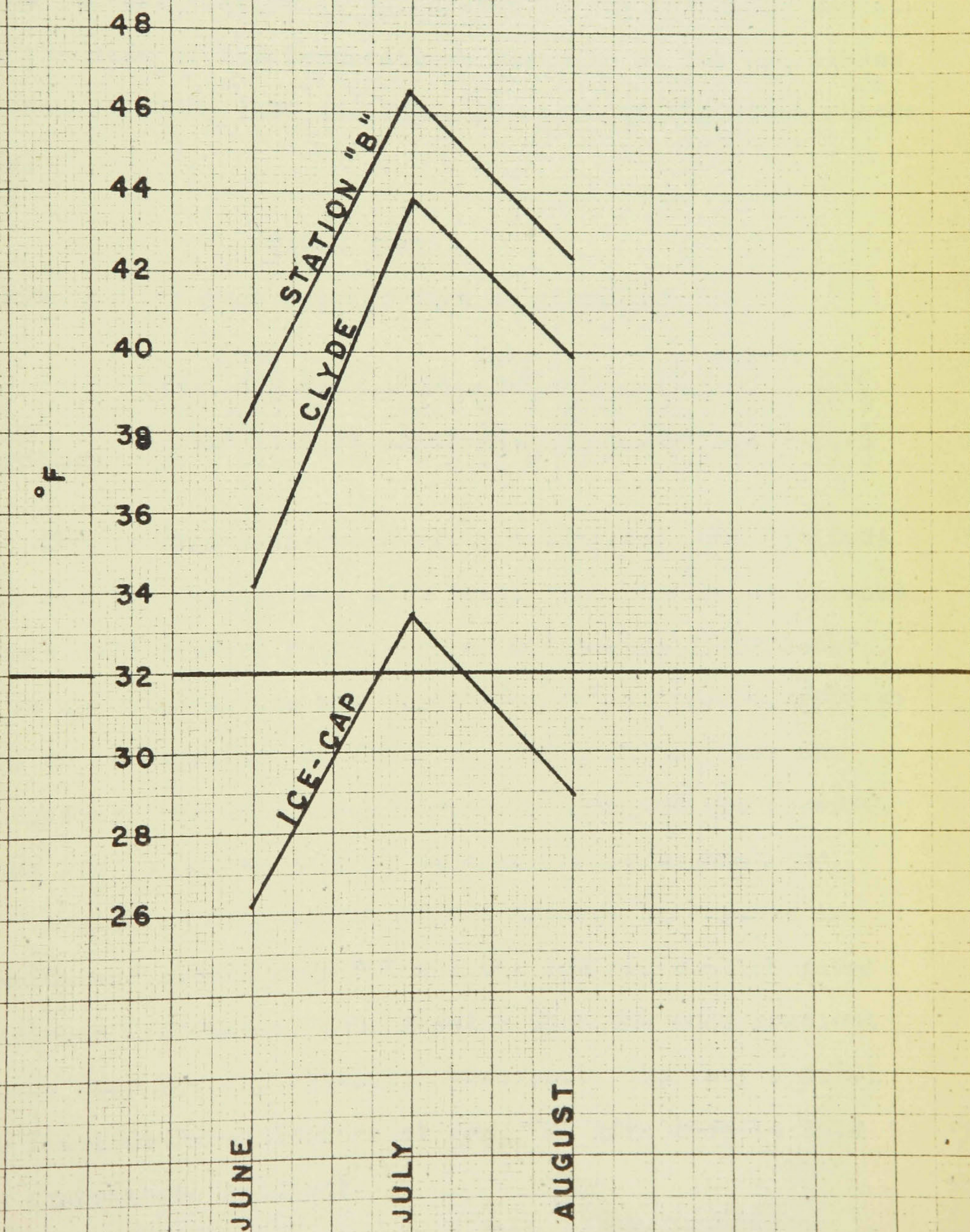
	June	July	August
CLYDE :	50.5	68.7	52.8
STATION "B":	60.2	71.0	59.2
ICE-CAP :	40.1	42.2	39.0

Figure 16 shows the mean daily temperatures for the three months for all three stations. The increase in mean daily temperature from June to July was greatest for Clyde, 9.6 degrees, while for station "B" it was 7.7 degrees and for the ice-cap station 7.2 degrees. This fact -- that Clyde gets relatively warmer than camp "B" in July -- is also shown by Figures 13 and 14. It is a result of the different ice conditions at the two locations. In June the mean mimimum temperature at camp "B" was just above freezing (32.1), and the sea-ice was moving out from the head of the inlet by the end of the month; by July 4th it was two miles away. The mean minimum temperature was well below freezing at Clyde in June (28.8), and the sea-ice only started to move away from the settlement as late as July 16th. The increase in local temperature, following the disappearance of the sea-ice, came later at Clyde than at camp "B" and was noticed more in July.

The lesser increase in mean daily temperature from June to July on the ice-cap was due to the melting surface in July, which kept the air cooled. The drop in the mean daily temperature from July to August, due to the decreasing

FIG. 16.

MEAN DAILY TEMPERATURE.



amount of insolation, was fairly uniform: 4.1 degrees at camp "B", 3.9 degrees at Clyde and 4.5 degrees on the ice-cap.

The average difference in temperature between Clyde and the ice-cap station is calculated in the following table, using the mean of the temperatures measured at the two places every day at 0800, 1400 and 2000, for each of the three summer months.

TABLE XXXVII

DIFFERENCE IN MEAN TEMPERATURES AT CLYDE AND "A-1"

	June			July			August		
	0800	1400	2000	0800	1400	2000	0800	1400	2000
CLYDE :	33.7	36.9	34.8	42.9	47.6	44.6	38.8	41.8	39.9
ICE-CAP :	28.0	29.1	27.0	33.4	34.7	34.0	29.6	31.1	29.3
DIFFERENCE:	5.7	7.8	7.8	9.5	12.9	10.6	9.2	10.7	10.6

The average difference was 9.4 degrees. The altitude of the ice-cap station was 2840 feet. The average difference was thus 0.33 degrees F/100feet, or 0.6 degrees C/100meter; this is the same as the mean gradient of the free atmosphere and is to be expected, as the air passing inland from the coast passes over land which is partly snow and ice covered, and the air is not subject to much warming from the land.

A similar calculation of the average difference in temperatures between camp "B" and the ice-cap station gives 0.8 degrees C/100meter, thus greater than the mean gradient but less than the dry adiabatic gradient. The very special local temperature conditions at camp "B" give rise to this large temperature gradient.

Temperature conditions at three levels above the surface at station "A-1".

Except for a very few cases the temperature increased with height above the surface of the snow. The following table shows the daily means of eight temperature observations, carried out every second hour from 0800 to 2200 daily, for the three levels above the surface.

TABLE XXXVIII

MEAN DAYTIME TEMPERATURE AT THREE LEVELS

	June			July			August		
Date	3ft	13ft	23ft	3ft	13ft	23ft	3ft	13ft	23ft
1	20.1	--	25.8	35.1	36.5	38.7	33.2	36.2	36.6
2	26.7	--	29.5	34.5	35.6	36.5	35.0	36.7	37.8
3	24.3	--	26.2	35.4	37.3	38.3	34.0	36.4	35.6
4	26.7	--	29.6	30.7	30.2	31.8	31.1	33.2	33.4
5	27.0	--	28.5	29.5	30.5	31.4	31.1	31.2	31.4
6	27.2	--	30.4	--	--	--	32.6	34.4	33.3
7	30.2	--	33.0	28.9	29.5	29.4	30.5	31.3	30.6
8	23.1	--	24.9	30.7	31.1	31.8	32.6	34.3	34.2
9	26.9	--	30.8	34.0	34.7	37.1	34.8	36.1	38.2
10	23.6	--	26.6	34.3	35.4	37.0	32.7	34.0	33.7
11	26.3	--	29.1	30.8	31.4	31.9	32.2	33.8	33.6
12	25.9	26.1	27.3	32.4	33.2	33.6	30.3	31.4	31.0
13	--	--	--	32.4	33.2	35.2	28.2	29.6	29.9
14	23.1	28.0	29.1	34.3	36.0	37.8	27.0	27.5	27.5
15	25.5	26.7	27.4	32.4	32.6	33.6	23.5	25.5	26.9
16	22.4	23.8	25.3	32.9	33.1	34.0	27.0	28.0	27.1
17	24.3	24.6	27.3	36.2	37.9	39.2	22.7	24.8	26.0
18	24.4	25.5	30.5	35.2	35.7	36.9	26.7	27.1	27.1
19	22.9	24.1	25.4	36.5	43.7	45.2	26.4	26.6	26.6
20	26.6	27.0	28.3	36.4	40.9	45.7	29.1	30.2	30.1
21	26.4	26.9	28.4	35.7	41.2	42.8	27.9	28.8	29.8
22	29.8	30.4	32.1	35.3	35.8	37.7	28.7	29.9	29.8
23	33.5	33.1	35.0	33.4	36.8	36.1	31.8	32.3	32.4
24	33.0	34.4	34.7	34.6	37.0	36.5	31.9	33.2	33.0
25	33.8	35.5	36.7	34.3	35.2	35.2	31.8	34.2	34.0
26	37.4	41.1	44.4	36.3	37.8	38.6	29.1	30.6	29.9
27	36.8	38.2	41.9	36.3	40.7	40.7			
28	36.3	38.8	40.8	34.5	41.8	43.2			
29	34.7	36.9	40.0	36.6	40.8	41.6			
30	33.2	37.4	36.7	37.8	39.6	39.9			
31				35.8	37.2	37.8			

These temperatures are set forth graphically in Figure 17. Above-freezing temperatures were recorded at all three levels from June 23rd to August 3rd, with the exception of the period July 4th to 8th when the last snowstorm of the 1949-1950 budget year occurred, and a single day, July 11th. The first snowfall of the 1950-1951 budget year was accompanied by temperatures close to the freezing point on August 4th and 5th. During the following week the temperatures fluctuated around freezing, falling below 32°F. on the 12th. Three days near the end of the month, August 23rd, 24th and 25th, were again near freezing.

Nineteen days out of the eighty-seven show irregularities in the temperature distribution, seventeen of them having the highest temperature at thirteen feet, while two days, June 23rd and July 4th, had the lowest mean temperature at thirteen feet.

The average increase in temperature between thirteen and twenty-three feet was 1.33 degrees, while the average decrease for the seventeen days with the highest temperature at thirteen feet was 0.46 degrees. As the temperatures at three feet and twenty-three feet above the surface were measured by well ventilated and shielded mercury thermometers, while the temperature at thirteen feet was measured by a thermo-couple, the reason for the higher temperature at thirteen feet was most probably insufficient shielding from

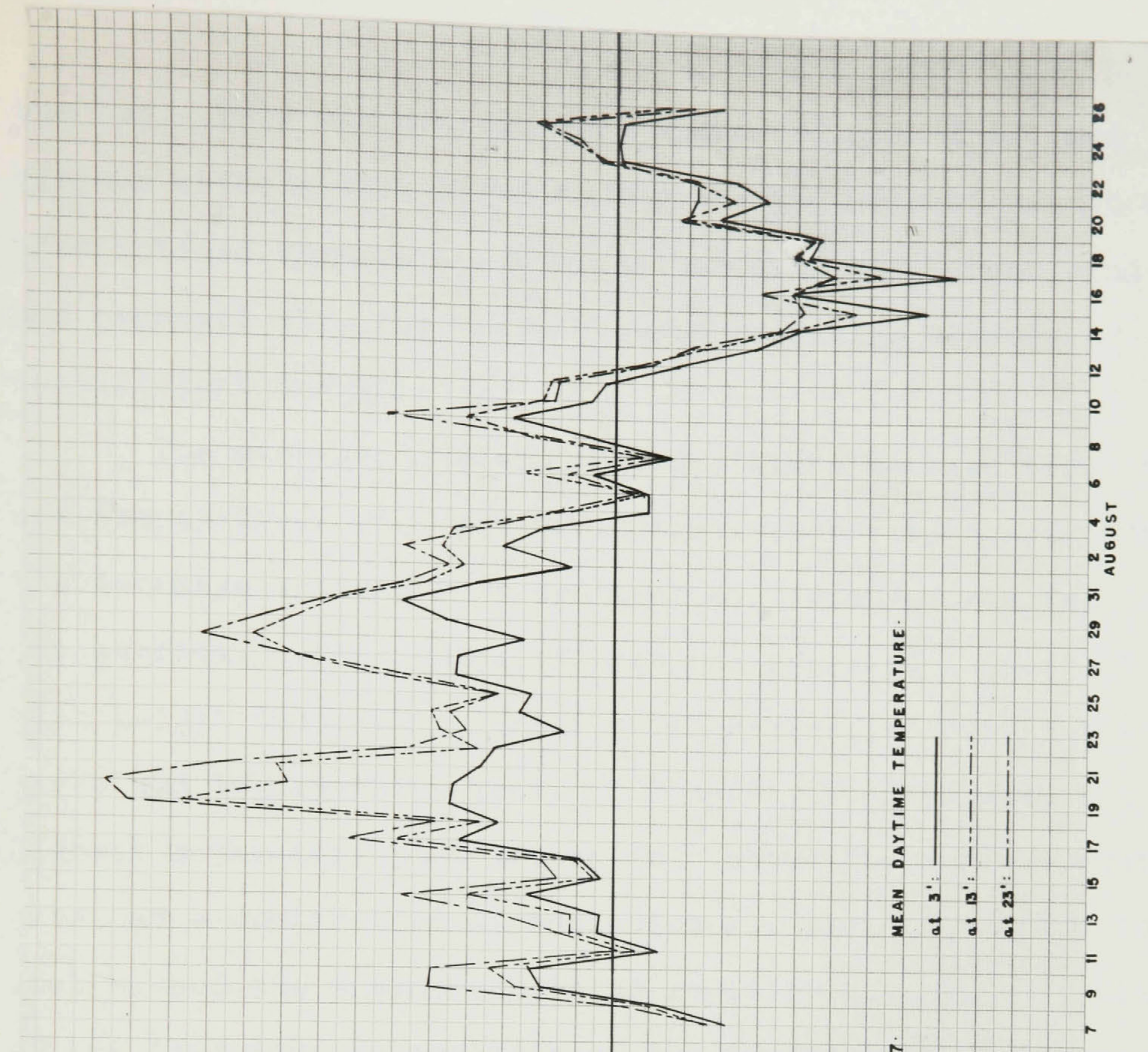


FIG. 17

the sun. This was noticed on a number of occasions, and various methods were tried to improve the situation. It was also noticed that on a few occasions with very light wind and overcast sky, the thermo-couple read high because of insufficient ventilation.

The average increase in temperature between three feet and twenty-three feet was 2.61 degrees, or very nearly twice the increase between thirteen feet and twenty-three feet above the surface. This indicates that the increase in temperature with height was nearly linear, 0.13 degrees F/foot, between three and twenty-three feet. The seventeen days with the highest temperature at thirteen feet above the surface must have had a combination of radiation and lack of ventilation that caused the thermo-couple to register too high, in spite of the fact that an analysis of the meteorological elements on these days does not show a common factor.

Figure 17 shows that the mean daytime temperature at three feet varied in much the same manner as the mean daily temperature (Figure 9), being slightly higher as the minimum temperature normally occurred at night and was used in the calculation of mean daily temperature.

During the melting period the snow surface was fairly constant at 32°F. in the daytime, thus cooling the lower layers of air, and the increase in temperature with height was most rapid in this period. In the period June 1st to June 22nd, with below-freezing temperatures at all three levels, the average increase in temperature from three feet to twenty-three feet above the surface was 2.96 degrees. The average increase in the period June 23rd to August 3rd, the main melting period, was 3.20 degrees. The last period, from August 4th to August 26th, showed an average increase of only 1.30 degrees.

The occurrence of below-freezing air temperatures near the snow surface during the period of ablation is different from that found by Eriksson on the Froya Glacier,[13] but it is much like the conditions on Isachsen's Plateau in West Spitsbergen, as reported by Sverdrup.[14]

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13 B. E. Eriksson, "Meteorological Records and the Ablation on the Froya Glacier in Relation to Radiation and Meteorological Conditions," Geografiska Annaler, Vol. XXIV, 1942, p. 25.

14 H. U. Sverdrup, "Results of the Meteorological Observations on Isachsen's Plateau," Geografiska Annaler, Vol. XVIII, 1936, p. 37.

TABLE XXXIX

FREQUENCY OF DIFFERENT TEMPERATURE INTERVALS AT THE THREE LEVELS IN PERCENTAGES OF THE TOTAL NUMBER OF MEASUREMENTS

(Daytime temperatures from 0800 to 2200)

Interval	3 ft.	13 ft.	23 ft.
< 24.1 :	7.8	4.4	2.7
24.1-26.0 :	9.2	6.6	6.2
26.1-28.0 :	13.3	10.0	10.5
28.1-30.0 :	10.4	8.6	10.8
30.1-32.0 :	11.1	12.6	11.2
32.1-34.0 :	19.4	13.8	15.4
34.1-36.0 :	18.4	14.5	12.9
36.1-38.0 :	9.2	12.6	10.1
38.1-40.0 :	1.2	9.3	8.3
40.1-42.0 :	0	3.0	5.0
42.1-44.0 :	0	2.9	3.3
44.1-46.0 :	0	> 44: 1.7	2.3
46.1-48.0 :	0		> 46: 1.3
No. of observations:	617	517	601

The frequency distribution is set forth in Figure 18. The frequency curve for the lowest level is most restricted and steepest, with a maximum frequency between 32.1° and 34.0° and a rather uniform distribution in the larger interval 32°-36°. At both ends of this interval the curve falls sharply. The secondary maximum in the interval 26.1°- 28.0° was due to the low temperatures in June, before ablation had commenced.

The frequency curves at the different levels follow each other quite closely; the occurrence of maximum frequency in the interval 34.1°-36.0° at thirteen feet, while both the three feet and twenty-three feet levels have maximum in the

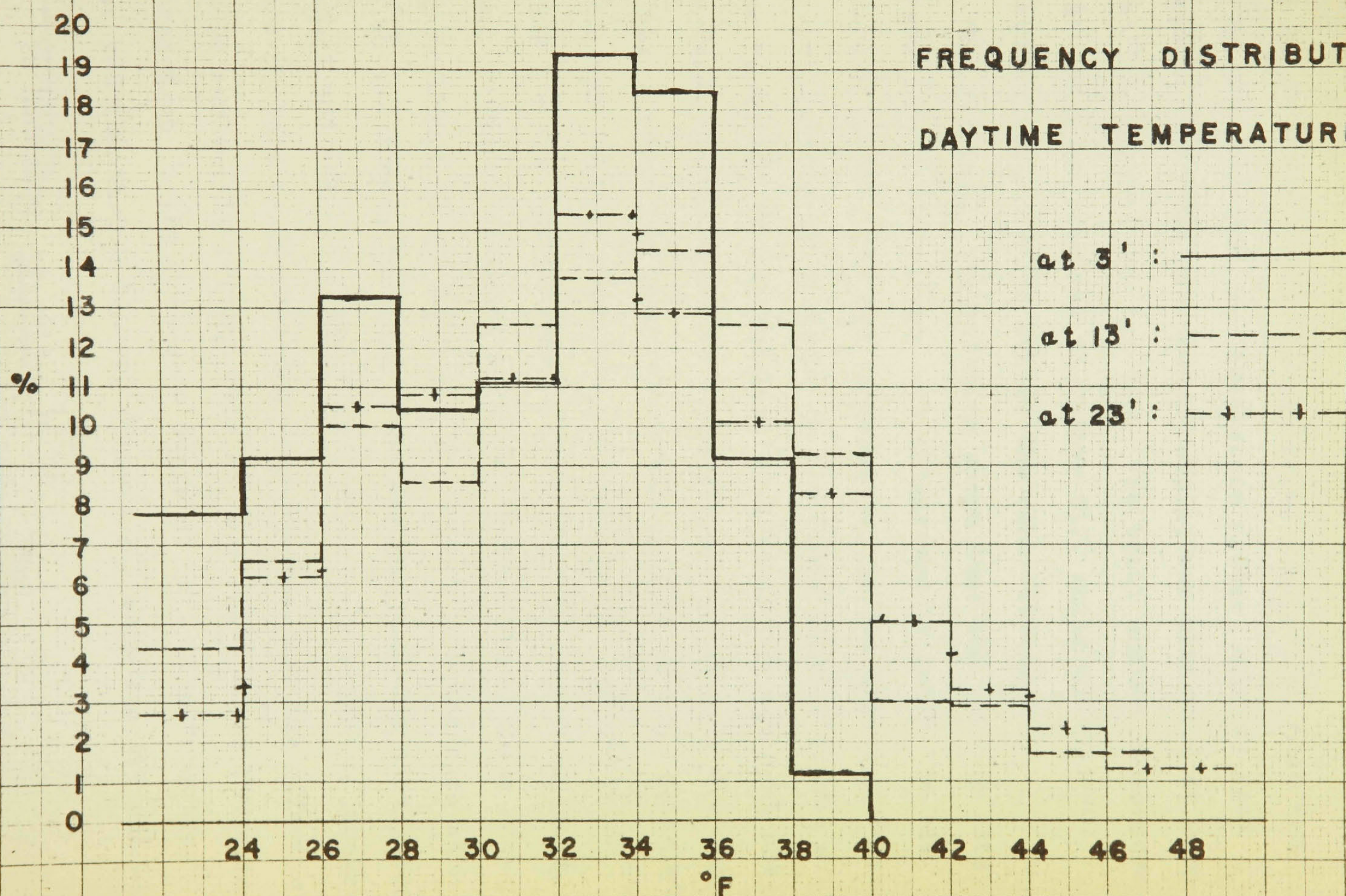

FIG. 18.

FREQUENCY DISTRIBUTION OF DAYTIME TEMPERATURES.

32.1°-34.0° interval, is due to the smaller number of observations at thirteen feet. As mentioned previously, this was caused by the fact that the Wheatstone bridge, used to read the temperatures from the thermo-couple, was also used at camp "A-2" at the edge of the ice-cap. The total number of measurements at thirteen feet was therefore 517, while 617 and 601 observations were carried out at the other levels.

The frequency distribution shows that the ice-cap acts as a temperature stabilizer. It endeavours to lower the air temperature to 32°, its own temperature, in the ablation season. The investigations by Eriksson on the Froya Glacier showed a maximum frequency in the interval 40.1°-41.9° at 4.8 feet above the surface, and no negative temperatures.[15] At only 3.2 inches above the surface the temperature was usually as high as 35.6°. At Clavering Island, therefore, the glacier is incapable of reducing the air temperature to freezing. On the other hand, Sverdrup found on Isachsen's Plateau[16] that the maximum frequency occurred in the interval 32.9°-34.3°, or the same as found on the Barnes Ice-cap. Furthermore, both the curves for 16.4 feet and for 1.6 inches above the snow surface on Isachsen's Plateau include below-freezing temperatures, and the effect of the cold surface is present even at 16.4 feet, where there is a marked drop in the frequency curve at 36°. The frequency curves for the Barnes Ice-cap (Figure 18) show exactly the same

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15 Eriksson, op. cit., p. 26.

16 Sverdrup, op. cit., p. 38.

characteristics, only the curve for the highest level shows a tendency to approach a symmetric form, as the cooling effect of the melting snow surface grows less.

The features of the frequency curves from Isachsen's Plateau and the Barnes Ice-cap correspond to the decidedly lower temperature in those localities, as compared to the Froya Glacier. A most important feature is that the frequency maximums on Isachsen's Plateau for the three heights 4, 100 and 500 cm. (1.6 inches, 3.3 feet and 16.4 feet) fall within the same temperature interval, 32.9°-34.3°. At the Barnes Ice-cap the frequency maximums for the three heights 3, 13 and 23 feet also fall within the same interval, 32.1°-36.0°, or within 32.1°-34.0° for the highest and lowest levels, the reason for the higher temperatures at thirteen feet being given above. On the Froya Glacier, however, the maximum frequency occurs at higher temperatures with increasing distance from the snow surface. This circumstance suggests that the supply of heat to the glacier by way of convection is especially large on the Froya Glacier in comparison with conditions on Isachsen's Plateau and the Barnes Ice-cap. Conditions seem very similar in the latter two locations.

Temperature and wind direction.

The relation between temperature and wind direction is seen by the following compilation.

TABLE XL

WIND DIRECTION AND MEAN TEMPERATURE
AT THREE FEET ABOVE SURFACE

Wind from :	N	NE	E	SE	S	SW	W	NW
Mean temp.:	29.1	29.7	30.8	30.7	31.7	29.0	34.9	33.2

The westerly and northwesterly winds seem to have been somewhat warmer than winds from other directions, the reason for this being the unequal distribution of wind directions throughout the summer. During the period June 25th to July 3rd west and northwest winds were almost exclusive; this was a period of clear weather and continuous insolation, therefore with higher temperatures. West and northwest winds were only recorded a few times earlier in June, when all the surrounding land was snow covered, and they were not recorded at all in the period August 10th to 26th, which was characterized by very persistent fog and below-freezing temperatures. Both temperature and wind is controlled by the general pressure distribution in the area. During periods of clear weather the long hours of insolation over snow free land will counteract the cooling of the air over the ice surface, as shown by the relatively high mean temperature (33.2^{o}) with northwest winds, which brought the air along the long axis of the ice-cap. Westerly winds, also connected with clear periods, brought the air over a shorter distance of the ice-cap, the cooling therefore being less. The mean temperature with west wind was 34.9^{o}. Southwest winds were frequent in August, bringing moist, cool air from the Foxe Basin area. When this air was cooled over the ice-cap, it gave persistent fog. This fog, and the usually overcast skies with southwest wind, caused a minimum amount of sunshine in August, and the mean temperature with southwest wind fell to 29.0°.

Diurnal variation of temperature.

The average march of temperature throughout the day at the three levels is shown in the following table.

TABLE XLI

MEAN VALUES OF TEMPERATURE AT TWO HOURLY INTERVALS FROM 0800 TO 2200 AT THREE LEVELS

	June			July			August		
Hour	3ft	13ft	23ft	3ft	13ft	23ft	3ft	13ft	23ft
0800	28.0	31.2	31.9	33.4	35.4	35.7	29.8	30.8	30.8
1000	28.5	31.9	32.2	33.9	35.7	37.4	30.7	32.2	31.8
1200	29.0	31.9	32.7	34.7	36.9	38.4	30.9	32.7	32.4
1400	29.1	32.3	32.8	34.7	37.3	38.4	31.1	32.8	32.5
1600	28.9	32.1	32.2	34.6	36.9	38.3	31.0	32.6	32.7
1800	27.8	30.9	30.3	34.5	36.2	37.3	30.1	31.4	32.1
2000	27.0	29.7	29.6	34.0	35.2	36.4	29.3	30.2	30.8
2200	25.3	--	28.7	33.1	34.3	35.6	28.7	29.2	25.3

These mean temperatures are set forth in Figures 19, 20 and 21. Figure 19 shows the temperature variations at three feet. July days were warmest, with the mean of all two-hourly temperature readings throughout the day above freezing. August days were warmer than June days, but all mean values fell below freezing. For all three months the maximum daytime temperature was recorded near 1400.

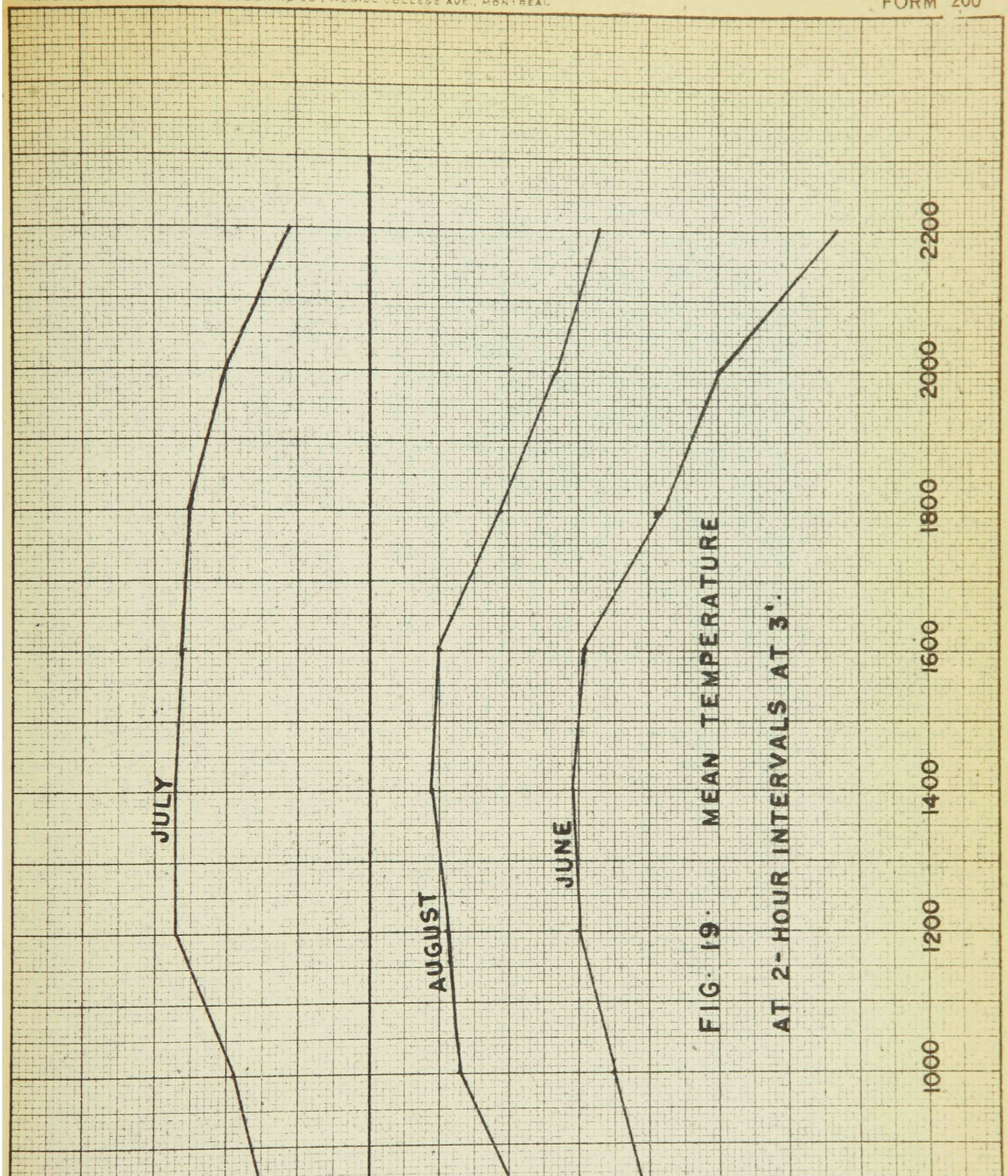
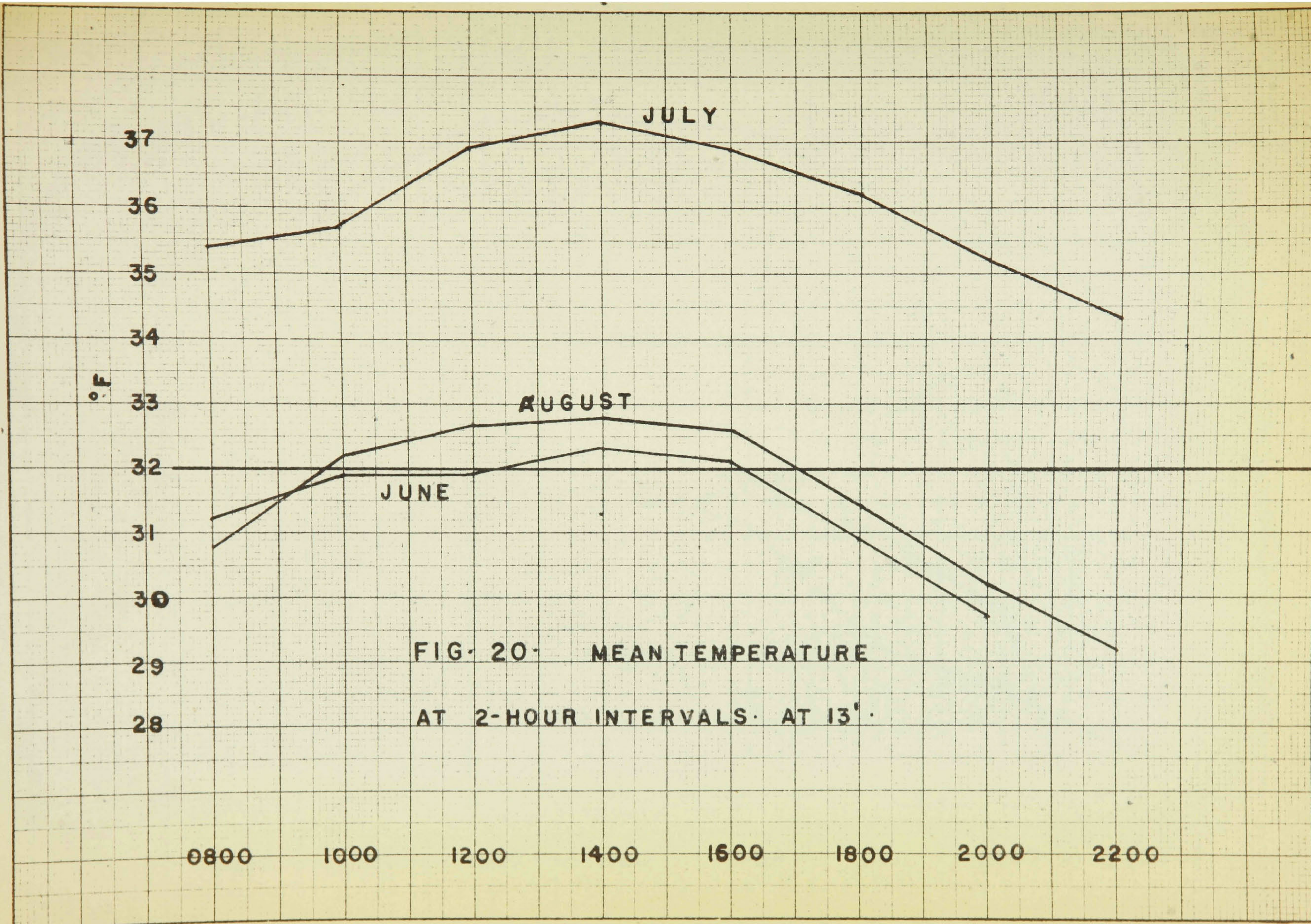


FIG. 19. MEAN TEMPERATURE AT 2-HOUR INTERVALS AT 3'.



FIG· 20· MEAN TEMPERATURE AT 2-HOUR INTERVALS· AT 13'·

FORM 200

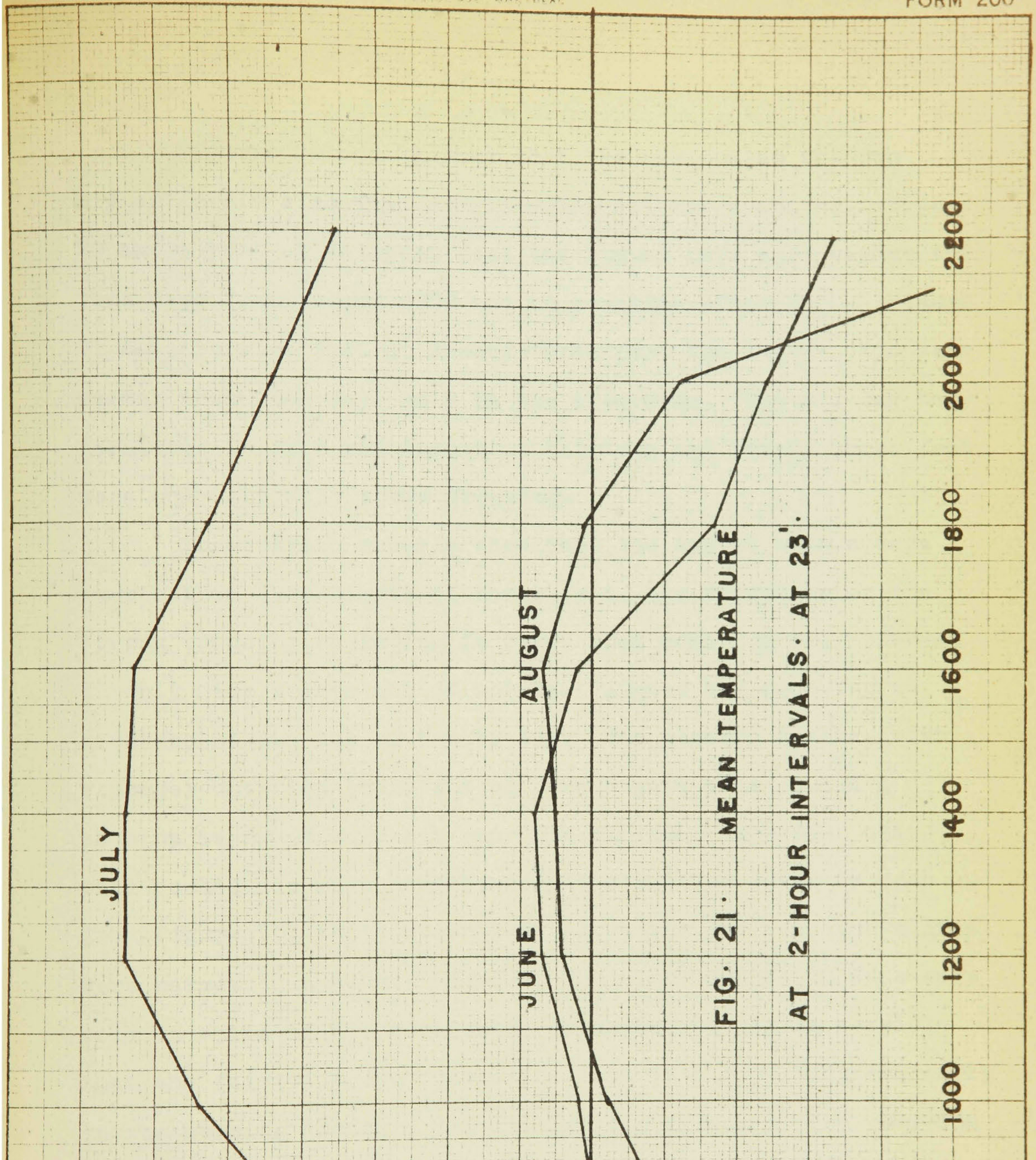


FIG. 21. MEAN TEMPERATURE AT 2-HOUR INTERVALS AT 23'.

Figures 20 and 21 show that the maximum at the two higher levels also fell near 1400 in all three months. Figure 20 shows that at thirteen feet the August days were warmer than June days from around 0900 and to sometime after 2000. Figure 21 demonstrates that at twenty-three feet the August days were warmer than June days only in the afternoon. The mid-day temperatures in June and August at thirteen and twenty-three feet were only slightly above freezing.

Thermograph records show that the August nights were warmer than June nights at three feet, the reason being the strong outgoing radiation in June, when some fog was recorded on only nine nights out of thirty. August had some fog on nineteen nights out of twenty-six. The clearer weather with stronger outgoing radiation on June nights thus caused a shallow layer of cold air near the surface. The fact that this cooled air must have been only a shallow layer is seen from Figure 20; at thirteen feet above the surface June nights were warmer than August nights. The clear nights in June were cold in spite of the continuous sunshine, but it is possible that the fairly strong insolation late in the evening and early in the morning counteracted the cooling effect of the outgoing radiation to some extent. The very frequent night-fog in August often lifted in the early part of the day, and the August daytime temperatures in the higher levels would increase above the corresponding temperatures in June, first at thirteen feet (around 0900 - Figure 20), later at twenty-three feet (around 1500 - Figure 21); sooner on days with sunshine than on overcast days.

Only thirteen days had above-freezing temperatures all through the twenty-four hours -- eleven days in the latter half of July, and two days in the beginning of August. The temperature showed a fairly well defined diurnal variation, both on days when it was partly or completely below freezing, as well as on days with above-freezing temperatures only. This feature is demonstrated by means of the following compilation, which for two groups shows the mean temperature at every second hour throughout the day at the three heights. (Table XLI and Figures 19, 20 and 21 also demonstrate the diurnal variation at all levels.)

TABLE XLII

MEAN TEMPERATURE EVERY SECOND HOUR ON THIRTEEN DAYS WITH ABOVE-FREEZING TEMPERATURES ONLY

Hour	3 ft.	13 ft.	23 ft.
0800	35.1	37.7	38.1
1000	35.5	38.5	38.7
1200	35.8	38.8	39.3
1400	36.3	38.8	40.0
1600	35.9	38.6	40.0
1800	35.6	37.6	39.1
2000	35.5	37.0	38.1
2200	34.9	36.0	37.1

TABLE XLIII

MEAN TEMPERATURE EVERY SECOND HOUR ON THIRTEEN DAYS WITH PARTLY OR COMPLETELY BELOW-FREEZING TEMPERATURES

Hour	3 ft.	13 ft.	23 ft.
0800	31.8	33.0	33.1
1000	32.4	33.9	34.1
1200	32.9	35.1	35.2
1400	33.1	35.3	35.3
1600	32.9	35.5	35.5
1800	32.3	34.5	34.8
2000	31.1	32.5	33.9
2200	30.2	31.7	33.6

Figure 22 shows the different conditions in the two cases. On days with above-freezing temperatures only, the surface remained at a temperature of 32°, and variation of air temperatures in the course of the day was due to the change in the heating of the air over snow free land, before the air passed over the ice surface. The cooling of the air by the ice surface was greatest in the lower layers, but there was still a marked difference between the thirteen and the twenty-three feet levels, (Figure 22 on the left). On those days the air was very stable below twenty-three feet.

On days with partly or completely below-freezing temperatures the surface was frozen during a considerable part of the day, and the surface temperature could, therefore, sink to low values but could not rise above 32°. The temperature at three feet above the surface averaged only 33.1° at the warmest part of the day in this case. The temperature at thirteen feet and at twenty-three feet was higher, but at

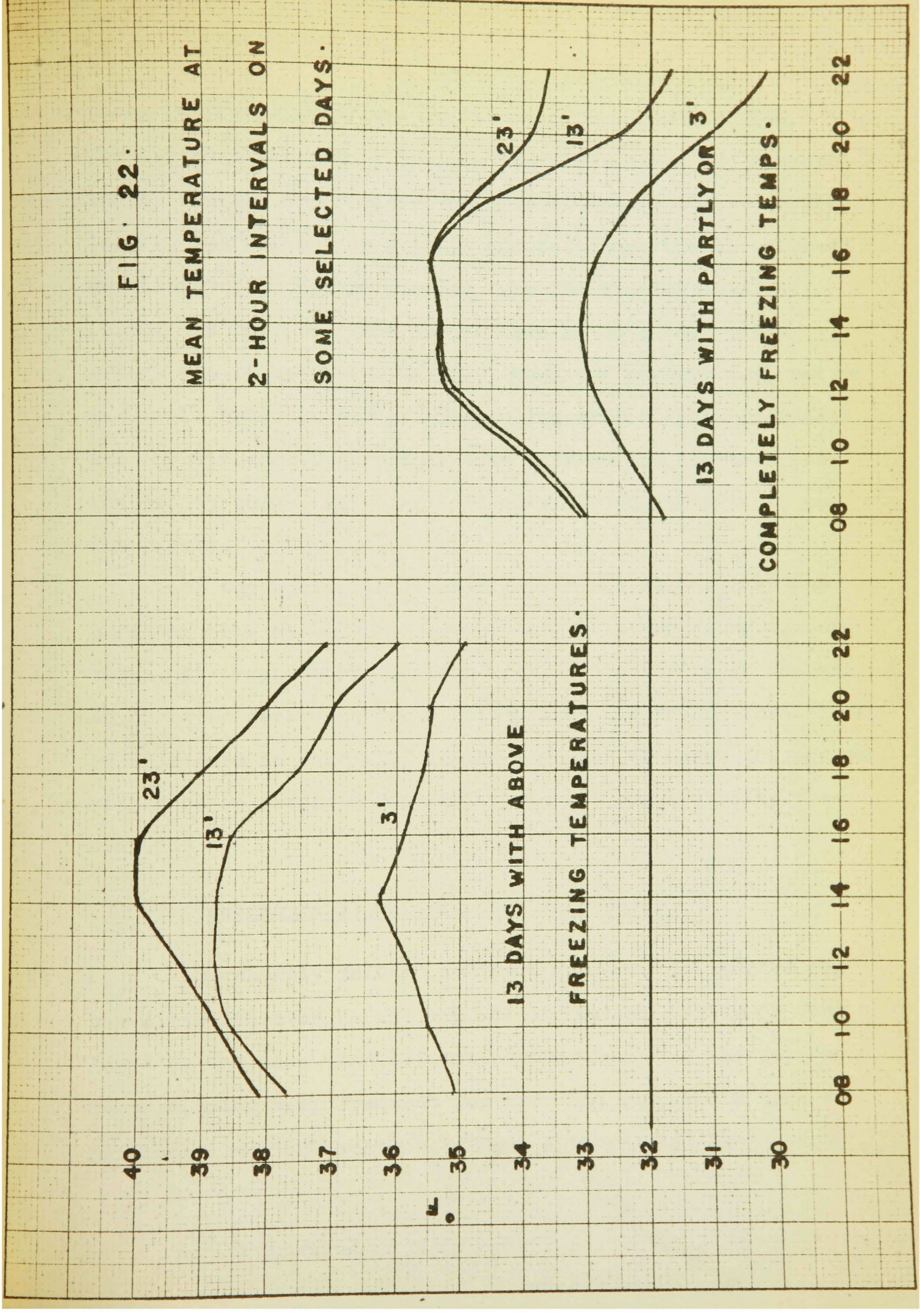


FIG. 22.
MEAN TEMPERATURE AT
2-HOUR INTERVALS ON
SOME SELECTED DAYS.
13 DAYS WITH ABOVE
FREEZING TEMPERATURES.
13 DAYS WITH PARTLY OR
COMPLETELY FREEZING TEMPS.
23'
13'
3'
°F
40
39
38
37
36
35
34
33
32
31
30
08
10
12
14
16
18
20
22

these two levels very nearly the same from 0800 to 1800. The air was less stable than in the first case, and the cooling of the air over the ice was restricted to a more shallow layer. The reason for this is the fact that the air already was fairly cold before passing over the glacier surface. During the day, when the surface was at 32°, the cooling effect was light, but from 1800, when the surface temperature sank well below freezing, the cooling effect again increased, and the difference in temperature between the thirteen and the twenty-three feet levels is very marked, (Figure 22 on the right).

On the whole the stratification was stable over the surface, also on days with completely below-freezing temperatures, at least below thirteen feet. In a few cases the air at thirteen feet was warmer than the air at twenty-three feet, as mentioned on page 54. In the majority of cases the air was stable up to twenty-three feet, however, and stability prevailed.

Temperature at the edge of the ice-cap.

The sharply defined southern limit of the August fog was often observed by the expedition members living at camp "A2Y" on the bare land off the southern edge of the ice-cap. They reported very frequent fog over the ice, while they experienced overcast weather. Three attempts had to be made by

Ward before he reached the ice-cap camp on August 25th. Each time he left in overcast weather but ran into thick fog approximately six miles from the edge. The differences in air temperatures over short distances are clearly demonstrated by the following table. The observations at the edge were carried out by Ward. Temperatures at camp "A-1" were read three feet above the surface, at the edge two and one half feet above the surface.

TABLE XLIV

TEMPERATURE DIFFERENCES OVER ICE AND LAND

Date	Time	Camp A2Y	2nd moraine	Ablation stake 2	Camp A-1	Snow cover south. edge	Weather, wind south. edge	Weather, wind, A-1
Aug. 4	1600	44.0	38.0	37.0	32.3	Bare ice, no snow on land.	Sunshine, light N. wind.	Thin overcast NW 7 mph
Aug. 6	1200	41.5	41.5	39.5	33.4	Bare ice, no snow on land.	Mist and drizzle, SW wind.	Fog, rain, SE 7 mph
Aug. 7	1400	36.5	35.5	36.0	30.2	Bare ice, no snow on land.	Rain, strong NE wind.	Fog, snow, N 30 mph
Aug 9	1000	44.0	40.0	40.0	35.2	Bare ice, no snow on land.	Sunshine, strong NW wind.	Sunshine, W 8 mph
Aug.10	1200	39.5	37.5	37.5	33.0	Bare ice, no snow on land.	Overcast, NW wind.	Fog, drizzle, NE 5 mph
Aug.11	2000	38.0	33.5	34.5	32.0	Bare ice, no snow on land.	Broken overcast, NW wind.	Broken overcast, NE 5 mph
Aug.13	1300	35.0	34.5	33.5	28.9	Snow on ice, some snow on land.	Overcast, light snow.	Overcast, fogbanks, SW 6 mph
Aug.14	1200	34.5	34.0	34.0	26.4	Snow on ice and on land.	Snowflurries, strong W wind.	Fog, drifting snow, SW 16 mph

TABLE XLIV (continued)

TEMPERATURE DIFFERENCES OVER ICE AND LAND

Date	Time	Camp A2Y	2nd moraine	Ablation stake 2	Camp A-1	Snow cover south. edge	Weather, wind south. edge	Weather, wind, A-1
Aug.16	1300	--	37.0	36.5	28.2	Snow on ice and on land.	Light snow, light W wind.	Fog, snow, SW 11 mph
Aug.17	1000	--	33.0	31.5	25.0	Snow on ice and on land.	Overcast, light snow, W wind.	Fog, drifting snow, SW 15 mph
Aug.19	1000	32.5	32.5	32.0	26.3	Snow on ice, little snow on land.	Overcast, strong W wind.	Fog, snow, S 19 mph
Aug.21	1000	36.5	36.5	37.5	28.0	Snow on ice, little snow on land.	Broken overcast, strong NE wind.	Overcast, NE 18 mph
Aug.26	2000	35.0	34.0	33.0	27.8	Bare ice, no snow on land.	Overcast, light E wind.	Overcast, N 8 mph
Mean:		37.2	36.0	35.6	29.7			

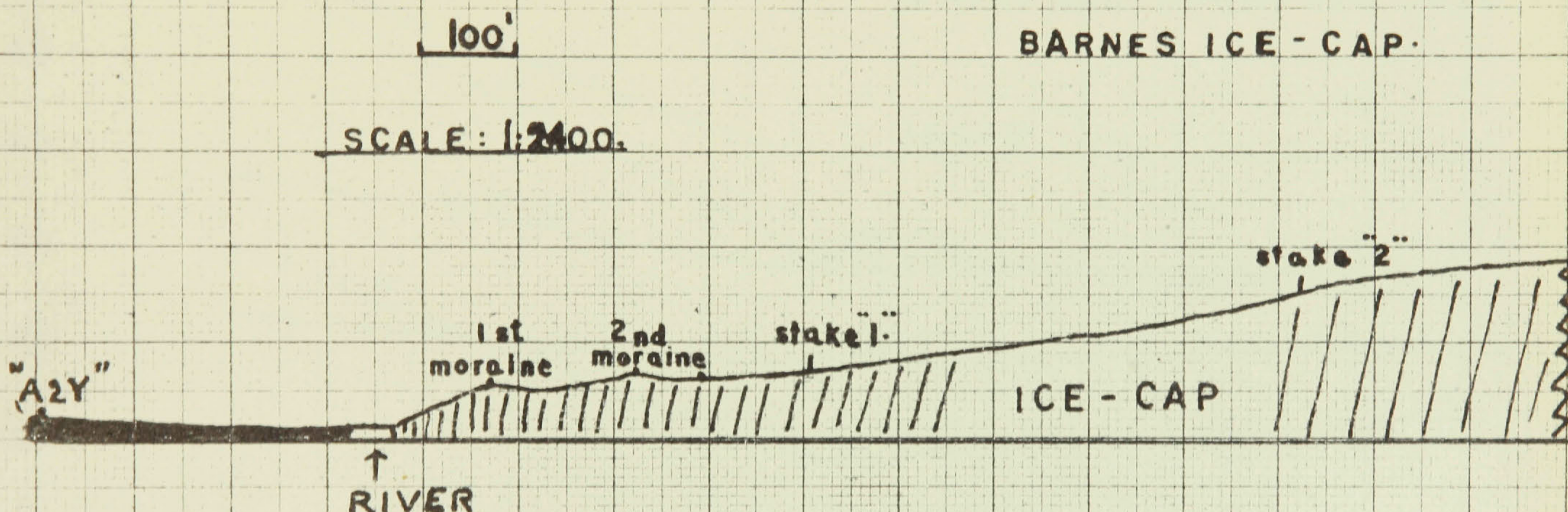
Figure 23 shows the profile of the southern margin of the Barnes Ice-cap with the observation points. Camp "A-1" was situated twelve miles from this edge. Some of the observations in Table XLIV are set forth in Figure 24, which shows the temperature increase on five days with northerly winds bringing air from the ice-cap over land completely free of snow. August 4th and 9th were sunny days, and the increase in temperature was rapid from "second moraine" to camp "A2Y", especially on August 4th which had light winds. August 11th, with broken overcast, had approximately the same increase as August 9th, possibly due to lighter wind; and August 10th, completely overcast, had a smaller increase in temperature from the ice to the snow free land. The smallest increase was recorded on August 7th; on that day rain and strong wind was recorded at the edge of the ice-cap.

During the period when the land is free of snow, the effect of the ice-cap on the climate of the surrounding land is surprisingly small. The air temperatures near the surface depend more on the amount and absorption of radiation. Temperature readings on the Seward Glacier in Alaska showed that the temperatures averaged 6°-10°F. lower on the glacier than at the camp site, which was on a rock crest of a nunatak in the middle of the glacier. Minimum temperatures at the glacier airstrip, 350 feet lower and two and one half miles from the research station, were found to be as much as 15°F. lower than

FIG. 23.

SOUTHERN MARGIN

BARNES ICE-CAP.

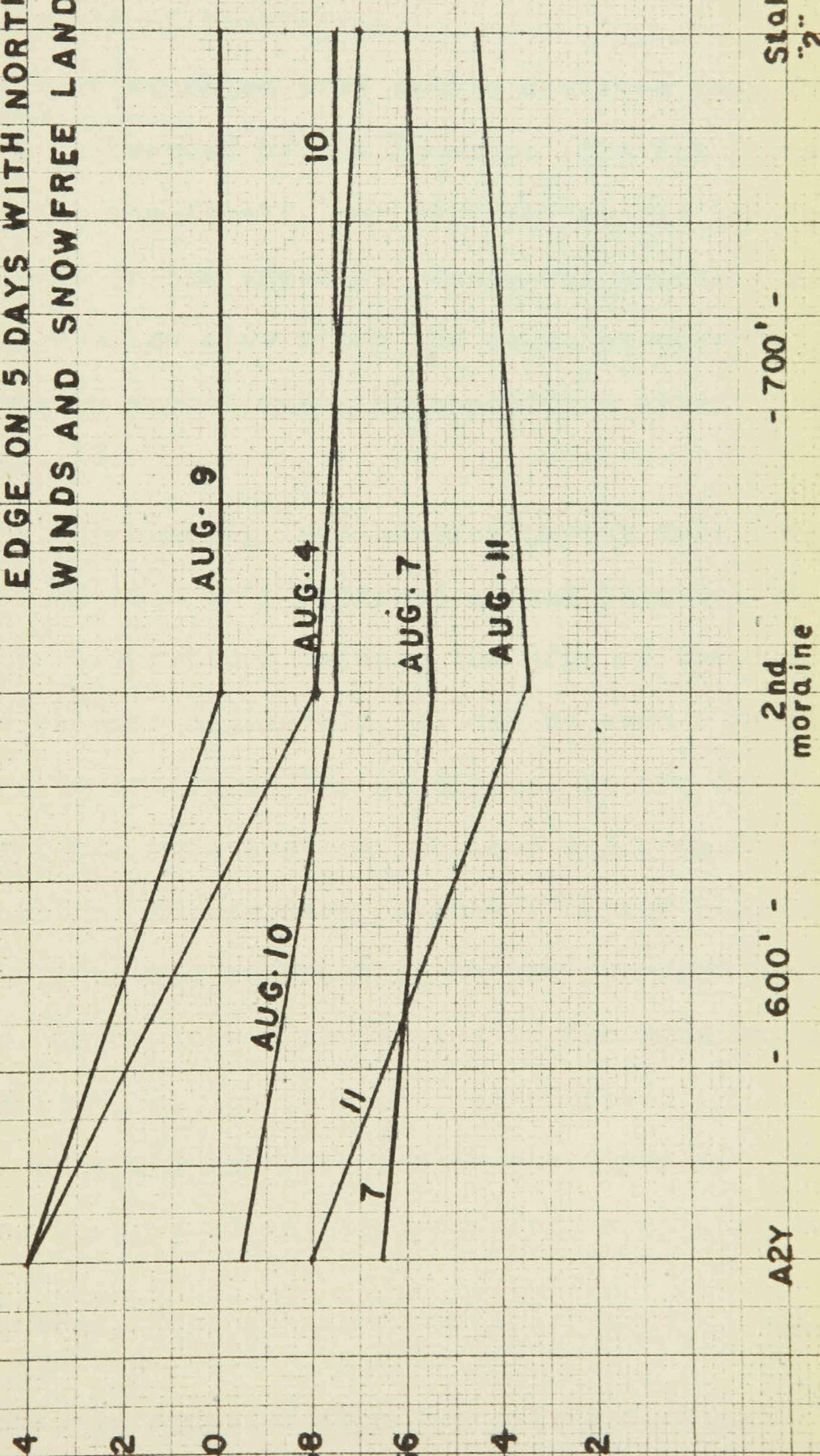


BASE LINE IS LEVEL OF "GENERATOR LAKE",

1440' asl.

FIG. 24.

TEMPERATURES AT THE SOUTHERN EDGE ON 5 DAYS WITH NORTHERLY WINDS AND SNOWFREE LAND.



those observed at the station.[17] The important factor in the increase of the surface air temperature is the presence of bare ground during periods of insolation.

The amount of sunshine some little distance away from the edges is not influenced by the ice-cap. The fog formation took place over the ice itself, but very seldom did the fog reach even the edge of the ice-cap. There was probably always a clear zone a few miles wide along the edge, as observed on several occasions in August when the expedition aircraft flew along the ice-cap.[18]

After the surrounding land becomes partly snow covered -- in the summer of 1950 this happened around August 13th -- the difference in temperature between the edge of the ice and the nearby land becomes negligible, as can be seen from Figure 25. This Figure demonstrates the conditions on two days, August 13th and 14th, with snow on the land and completely overcast weather; and on two days, August 19th and 21st, with some snow on the land and overcast or broken overcast weather. The increase in temperature from the ice to the land was slight on the 13th and 14th, and no increase was observed on the 19th and 21st. Some sunshine was recorded on the 21st, and the thin layer of snow on the ground was disappearing, resulting in the

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17 W. A. Wood, "Project Snow Cornice," Arctic, Vol. I, No. 2, Autumn, 1948, p. 111.

18 Personal information from the pilot, M. King.

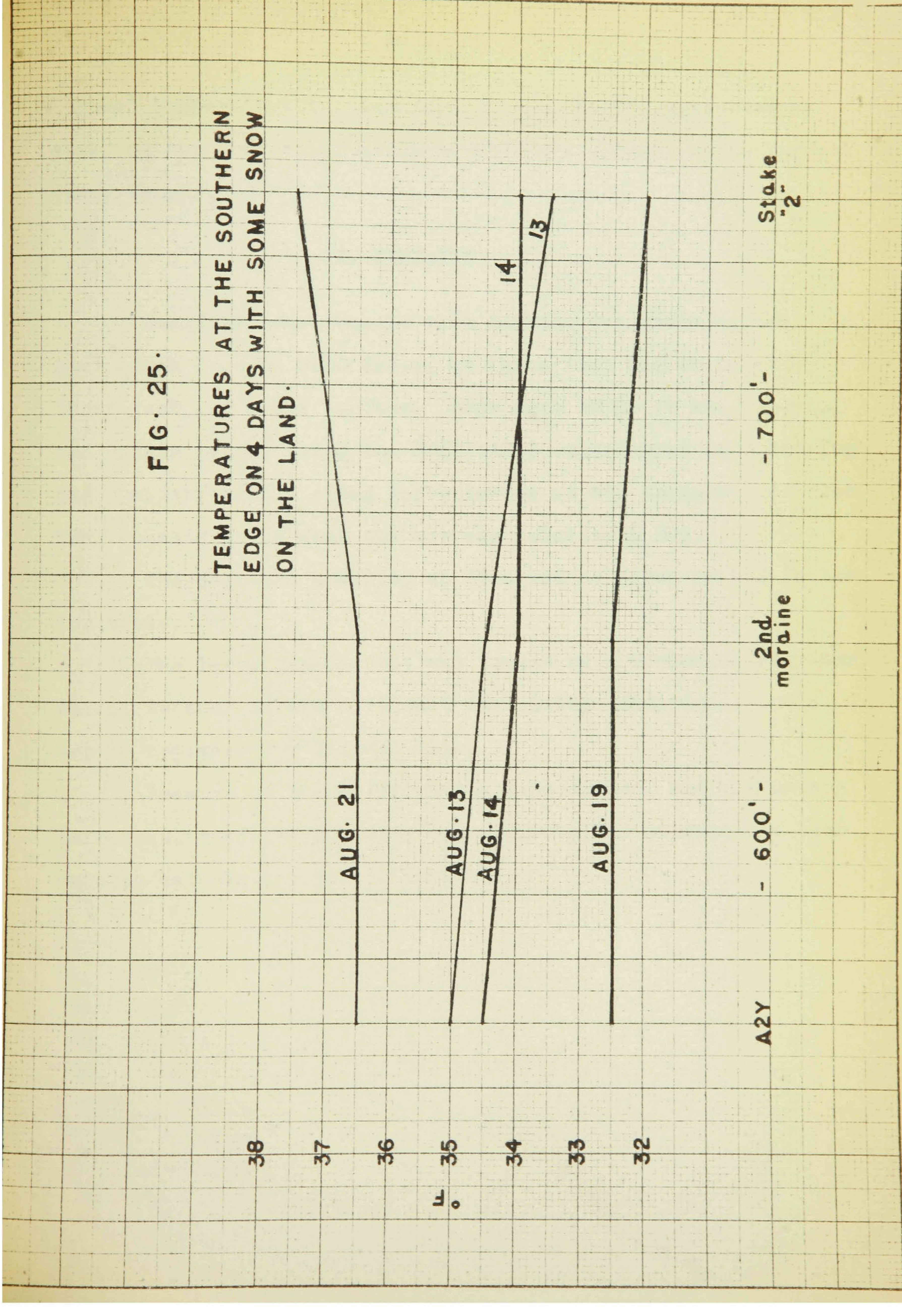

FIG. 25.

TEMPERATURES AT THE SOUTHERN EDGE ON 4 DAYS WITH SOME SNOW ON THE LAND.

highest temperature in nine days at camp "A2Y", again demonstrating the control of sunshine and bare ground on the surface temperatures.

II. HUMIDITY

Humidity measurements were carried out every second hour, from 0800 to 2200 daily, at three feet and at twenty-three feet above the surface. Some gaps occur in the records, the reason mainly being the difficulty experienced in measuring the humidity with a sling psychrometer at air temperatures near the freezing point when the air was relatively dry.

The relative humidity as observed is given in the following table.

The large gap in July was caused by a broken thermometer, which, because of the difficult travelling conditions, could not be replaced for fifteen days.

Because of the difficulties experienced, and the uncertain results of the humidity measurements, no attempt has been made to calculate absolute humidity.

TABLE XLV

MEAN DAILY VALUES OF RELATIVE HUMIDITY AT TWO HEIGHTS

Date	June 3 ft.	June 23 ft.	July 3 ft.	July 23 ft.	August 3 ft.	August 23 ft.
1	81	59	92	68	95	83
2	83	64	92	76	96	89
3	100	86	93	78	90	73
4	100	85	95	86	92	73
5	100	87	100	93	100	97
6	-	-	-	-	100	100
7	-	-	100	100	100	100
8	-	-	100	96	94	83
9	98	78	98	86	93	77
10	99	68	92	73	100	97
11	96	71	95	90	100	94
12	-	-	95	84	100	99
13	-	-	100	78	97	86
14	95	63	-	-	100	100
15	100	84	-	-	98	83
16	100	79	-	-	100	100
17	100	76	-	-	99	86
18	99	83	-	-	100	100
19	100	80	-	-	100	100
20	100	87	-	-	100	100
21	100	87	-	-	91	78
22	100	88	-	-	99	98
23	100	95	-	-	100	100
24	100	97	-	-	98	92
25	93	76	-	-	98	87
26	84	53	-	-	100	99
27	94	74	-	-		
28	86	60	82	-		
29	90	62	87	70		
30	91	73	82	71		
31			94	89		
Mean:	95.6	76.6	93.6	82.5	97.7	91.3

These values of relative humidity for the two levels are set forth graphically in Figure 26. The curve at twenty-three feet follows the curve at three feet fairly closely, the air at twenty-three feet being considerably drier. Directly above the snow surface the air was, as a rule, saturated with water

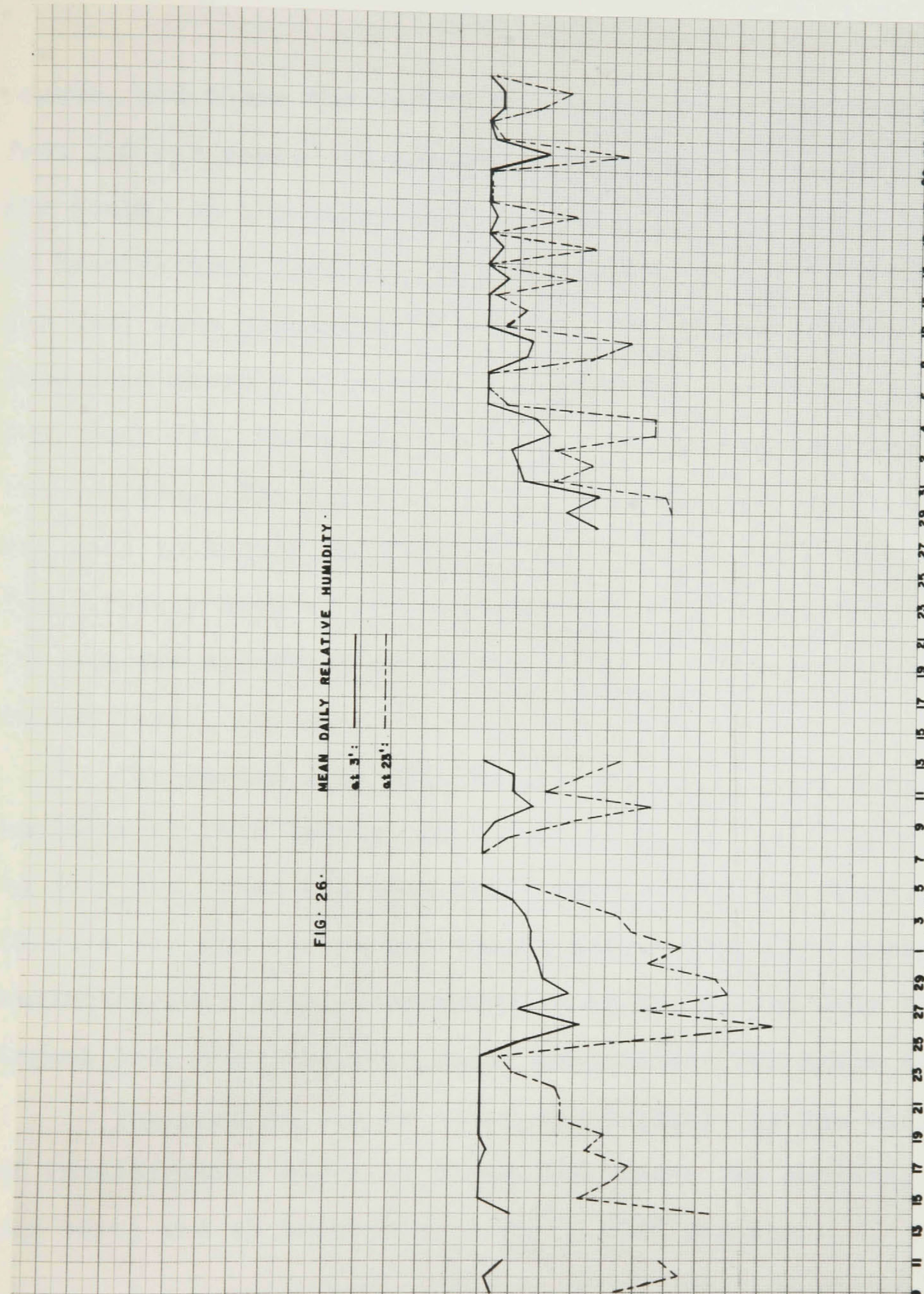

FIG. 26. MEAN DAILY RELATIVE HUMIDITY.

vapour, and there the relative humidity never deviated much from 100 per cent. At greater distances from the surface the air could, on the other hand, be very dry, and at the height of twenty-three feet relative humidities as low as below 50 per cent were occasionally observed. The relative humidity decreased sharply with height during June and July. Only one day, July 7th, showed saturated air at twenty-three feet above the surface. The decrease in relative humidity with height was less in August, corresponding to the period with persistent fog. Twenty days of the twenty-six days in August had fog, and the air was saturated or nearly saturated at twenty-three feet on ten days.

The period June 25th to July 4th, with relatively low humidity at both levels, corresponded to the period June 23rd to July 3rd, when the mean daily temperature was above 32° (Figure 9), and the period ending August 4th, (and probably beginning July 14th), corresponded to the period July 13th to August 3rd, when the mean daily temperature was again above 32°.

The mean values of relative humidity for the whole period of investigation were: at three feet above the surface, 95.7 per cent; and at twenty-three feet, 83.6 per cent.

<u>Humidity and wind direction.</u>

The relation between humidity and wind direction is seen in the following compilation.

TABLE XLVI

WIND DIRECTION AND MEAN RELATIVE HUMIDITY
AT THREE FEET ABOVE SURFACE

Wind from :	N	NE	E	SE	S	SW	W	NW
Rel. hum. %:	97.1	97.6	97.7	97.7	99.2	97.9	89.4	91.0

The westerly and northwesterly winds had the lowest relative humidity, the reason being that these winds were warmer than winds from other directions, (Table XL, page 62). The southerly winds had the highest relative humidity; as shown in Table XL the southwest winds were the coldest, which explains the high relative humidity. If the air from different directions had had the same absolute humidity, the warmest winds would have had the lowest relative humidity; conversely, the coldest winds would have had the highest relative humidity. It will be seen that conditions were almost so by comparing Tables XL and XLVI. However, there was one deviation; compared to the other wind directions the north winds were relatively dry and cold, and the south winds were relatively moist and warm. From a purely geographical point of view this is to be expected.

No certain diurnal variation of the relative humidity was observed.

III. WIND

Wind observations were carried out every two hours, from 0800 to 2200, at two heights, seven feet and twenty-three feet above the surface. A hand anemometer was used to measure the wind speed, while direction was observed with the help of a wind vane on top of the observation ladder. No recording instruments were available to measure the wind at night. Owing to the almost flat surface of the ice-cap, and the distance of more than thirty miles to the nearest higher land, no local factors influenced the wind.

On a few occasions a north (down-slope) wind was observed at the surface, while the upper wind, as observed by the drifting clouds, came from the south. This lower wind probably corresponds to the "Schwerewind" which is observed over most glaciers and has been especially investigated in Greenland.[19]

Eriksson measured a lower wind below two to four meters, with a direction opposite to that of the wind above two to four meters, on the Froya Glacier.[20] On no occasion was a similar thin layer of air (below six to thirteen feet) observed moving down-slope on the Barnes Ice-cap. The direction of the wind at the two levels always corresponded, and only on a few occasions did it differ from the direction of the upper wind as observed by the drifting clouds.

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19 K. Wegener, "Zusammenfassung der Wissenschaftlichen Ergebnisse," Wissenschaftliche Ergebnisse der Deutschen Gronland-Expedition Alfred Wegener 1929 und 1930-31, Band VII, 1940.

20 B. E. Eriksson, "Meteorological Records and the Ablation on the Froya Glacier in Relation to Radiation and Meteorological Conditions," Geografiska Annaler, Vol. XXIV, 1942, p. 27.

The frequency of the different directions is seen in the following table.

TABLE XLVII

NUMBER OF OBSERVATIONS, AND THE PERCENTAGE FREQUENCY OF THE DIFFERENT DIRECTIONS

	June		July		August	
Wind from	No.	%	No.	%	No.	%
N	38	17.8	8	3.5	27	15.4
NE	53	24.9	40	17.7	56	31.8
E	27	12.7	31	13.7	4	2.3
SE	26	12.2	28	12.4	10	5.7
S	3	1.4	28	12.4	8	4.5
SW	14	6.6	18	8.0	41	23.3
W	23	10.8	22	9.8	8	4.5
NW	25	11.7	43	19.0	18	10.2
Calm	4	1.9	8	3.5	4	2.3
Total	213	100	226	100	176	100

Figure 27 shows the percentage frequency of different wind directions for the three months. The predominant direction was northeast. The frequency of southerly winds increases during the summer. August had very frequent northeast and southwest winds, due to the long periods of prevailing low pressure, first over northern Davis Strait, later over Foxe Basin. These periods of low pressure will be discussed in the next paragraph.

The wind speeds and the difference in wind speed at the two levels are listed in the following table.

TABLE XLVIII

MEAN WIND SPEED AT SEVEN FEET AND AT TWENTY-THREE FEET IN MPH

Direction :	N	NE	E	SE	S	SW	W	NW
Mean speed at 7ft.:	9.7	12.8	8.6	10.0	11.1	10.3	6.7	7.1
Mean speed at 23ft.:	12.4	15.4	11.8	13.0	12.0	12.7	9.7	10.1
Difference:	2.7	2.6	3.2	3.0	0.9	2.4	3.0	3.0

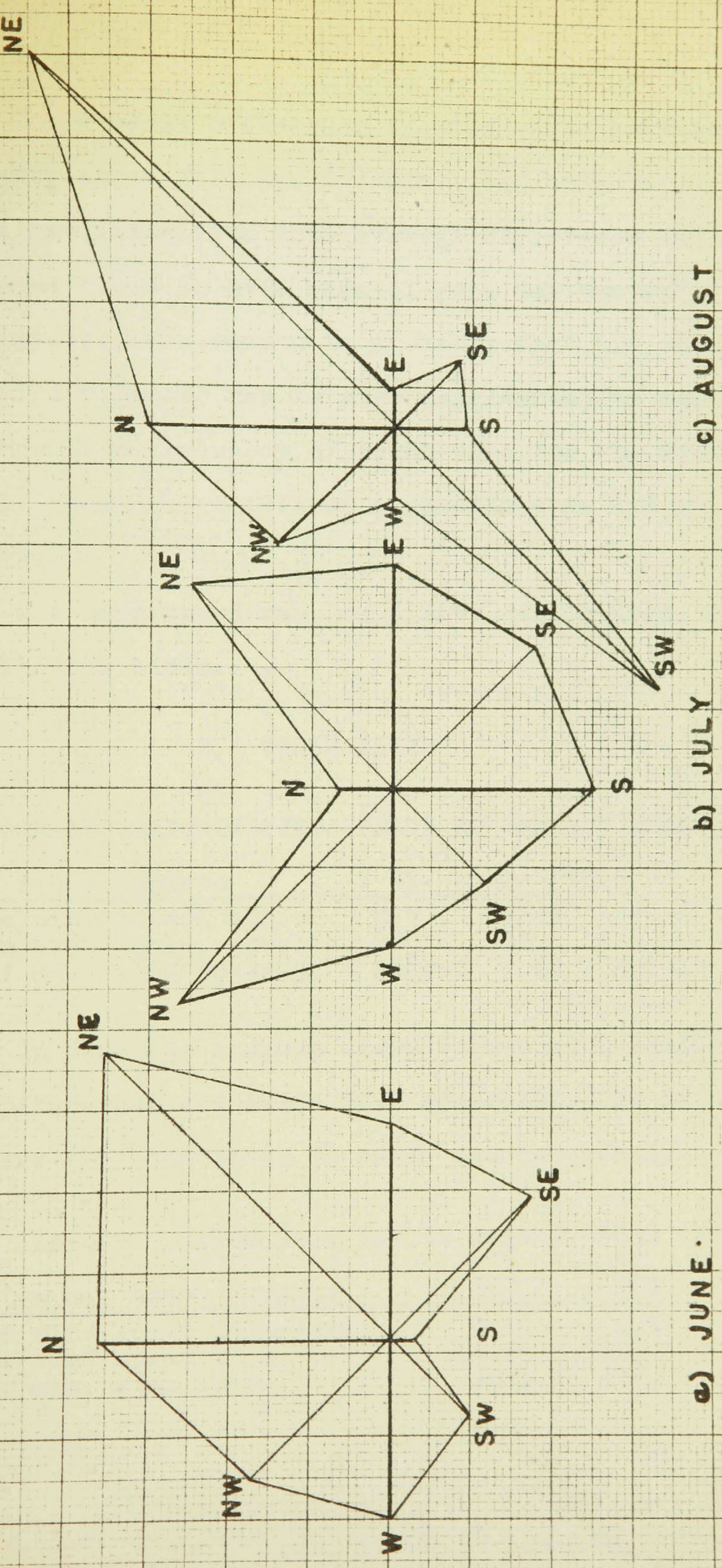


FIG. 27. WINDROSES.

The average difference in wind speed between seven feet and twenty-three feet was 2.6 mph. The only direction showing a large deviation from this average difference was South; the south wind seems to have been of more uniform speeds in the lower layers. The reason is probably that the observations of south wind were too few to give representative mean values. The percentage frequency of south wind for the whole period was 6.1, compared to 10.1 of southeast wind and 12.6 of southwest wind.

The wind speed was, as a rule, quite high, as seen in the following table.

TABLE XLIX

AVERAGE AND MAXIMUM WIND SPEEDS AT THE TWO HEIGHTS

Height above surface	7 ft.	23 ft.
Average wind speed, mph.:	9.7	12.4
Maximum wind speed, mph.:	37	50
Date of max. wind speed :	July 6	July 6 (wind from S.)

In order to compare these values with similar data from Spitsbergen and North East Greenland, the data in Table XLIX have been converted to meter and meter/sec.:

Barnes Ice-cap, period June 1st to August 26th:

Height in cm. above surface	213	701
Average wind speed in m/sec.:	4.3	5.5
Maximum wind speed in m/sec.:	16.5	22.4
Date of max. wind speed :	July 6	July 6

Isachsen's Plateau, West Spitsbergen, period June 26th to August 15th:[21]

Height in cm. above surface :	200	700
Average wind speed in m/sec.:	2.7	3.1
Maximum wind speed in m/sec.:	8.1	8.8
Date of max. wind speed :	July 6	August 2

Froya Glacier, Clavering Island, period July 31st to August 18th:[22]

Height in cm. above surface :	200
Average wind speed in m/sec.:	2.8
Maximum wind speed in m/sec.:	6.2
Date of max. wind speed :	August 9

Although the period of investigation on the Froya Glacier was much shorter than the other two periods, it is nevertheless possible to compare the data from Clavering Island to those from the Barnes Ice-cap. There is only a very slight difference in the wind speeds for the period August 1st to 18th on the Barnes Ice-cap, compared to the average over the whole summer:

	August 1-18		June 1-August 26	
Height in cm. above surface :	213	701	213	701
Average wind speed in m/sec.:	4.3	5.7	4.3	5.5

The wind is far stronger on the Barnes Ice-cap than on either Isachsen's Plateau or the Froya Glacier. The reason is

21 H. U. Sverdrup, "Results of the Meteorological Observations on Isachsen's Plateau," Geografiska Annaler, Vol. XVIII, 1936, p. 36.

22 Eriksson, loc. cit.

the frequent passages of cyclones near or over northern Baffin Island in the summer months. The most frequent wind speed lay between four and ten mph. -- nearly half of all observations -- as can be seen in the following table.

TABLE L

FREQUENCY OF DIFFERENT WIND SPEED INTERVALS IN PERCENTAGES OF THE TOTAL NUMBER OF MEASUREMENTS

Wind speed at 7 feet	0-2	2.1-4	4.1-6	6.1-8	8.1-10	10.1-12
% of observations	6.2	10.5	17.6	16.8	14.2	9.0

Wind speed at 7 feet	12.1-14	14.1-16	16.1-18	18.1-20	>20
% of observations	7.8	4.7	4.1	2.9	6.2

The total number of wind observations was 613.

A diurnal variation of the wind speed was not found, neither did the wind direction show any diurnal variation. The wind very closely followed the changes in pressure, as will be demonstrated in the next paragraph.

IV. PRESSURE

Maps of mean pressure at sea level in the northern hemisphere have been drawn by Dorsey. His map of mean pressure for July indicates a normal at Clyde of 1008.5 mb.[23] The altitude of the ice-cap station was 2840 feet; using the normal value for the vertical pressure gradient, 4 mb/100 feet,

23 H. G. Dorsey, Meteorological Characteristics of Northern Arctic America, thesis submitted for the degree of M.Sc., Massachusetts Institute of Technology, 1949, fig. 3, p. 27.

the normal pressure at the ice-cap in July should be approximately 895 mb. From Figures 28, 29 and 30 it seems likely that the normal pressure at camp "A-1" was approximately 905 mb. during the three summer months.

The average of three daily pressure readings, at 0800, 1400 and 2000, are listed in the following three tables, both for the ice-cap station and for the station at Clyde.

TABLE LI

MEAN DAILY PRESSURE AT CLYDE AND AT CAMP "A-1" IN JUNE

Date	Clyde	Camp "A-1"
1	1014.7	912.1
2	1014.8	909.9
3	1004.7	903.1
4	1002.4	902.7
5	1005.6	904.3
6	1006.8	905.3
7	1005.8	905.4
8	1000.2	901.6
9	1002.6	901.6
10	997.9	898.3
11	1001.9	900.2
12	991.9	886.7
13	989.1	885.2
14	1002.3	901.3
15	1003.2	900.9
16	1002.2	900.2
17	1008.3	904.1
18	1011.0	907.8
19	1009.7	902.7
20	1000.4	896.1
21	1007.6	902.4
22	1014.8	912.1
23	1022.5	922.3
24	1025.3	924.2
25	1021.8	921.3
26	1017.3	919.9
27	1012.5	917.2
28	1012.9	918.5
29	1012.6	918.8
30	1015.0	917.0

These pressure readings are set forth in Figure 28, top and bottom.

TABLE LII

MEAN DAILY PRESSURE AT CLYDE AND AT CAMP "A-1" IN JULY

Date	Clyde	Camp "A-1"
1	1014.9	917.7
2	1011.6	914.8
3	1005.1	906.8
4	996.7	903.0
5	999.8	899.6
6	990.8	896.1
7	1005.7	908.2
8	1011.2	913.1
9	1017.2	917.8
10	1013.8	912.2
11	1010.3	909.3
12	1006.6	906.4
13	1005.5	906.4
14	1006.0	907.4
15	1004.6	899.7
16	1006.7	909.1
17	1017.6	916.5
18	1016.5	916.9
19	1021.7	924.4
20	1023.6	927.1
21	1018.5	924.3
22	1013.5	917.9
23	1016.1	919.4
24	1010.7	917.0
25	1006.1	911.8
26	1007.9	913.4
27	1013.3	920.4
28	1018.5	929.2
29	1016.2	929.1
30	1014.5	921.0
31	1012.4	915.5

These pressure readings are set forth in Figure 29, top and bottom.

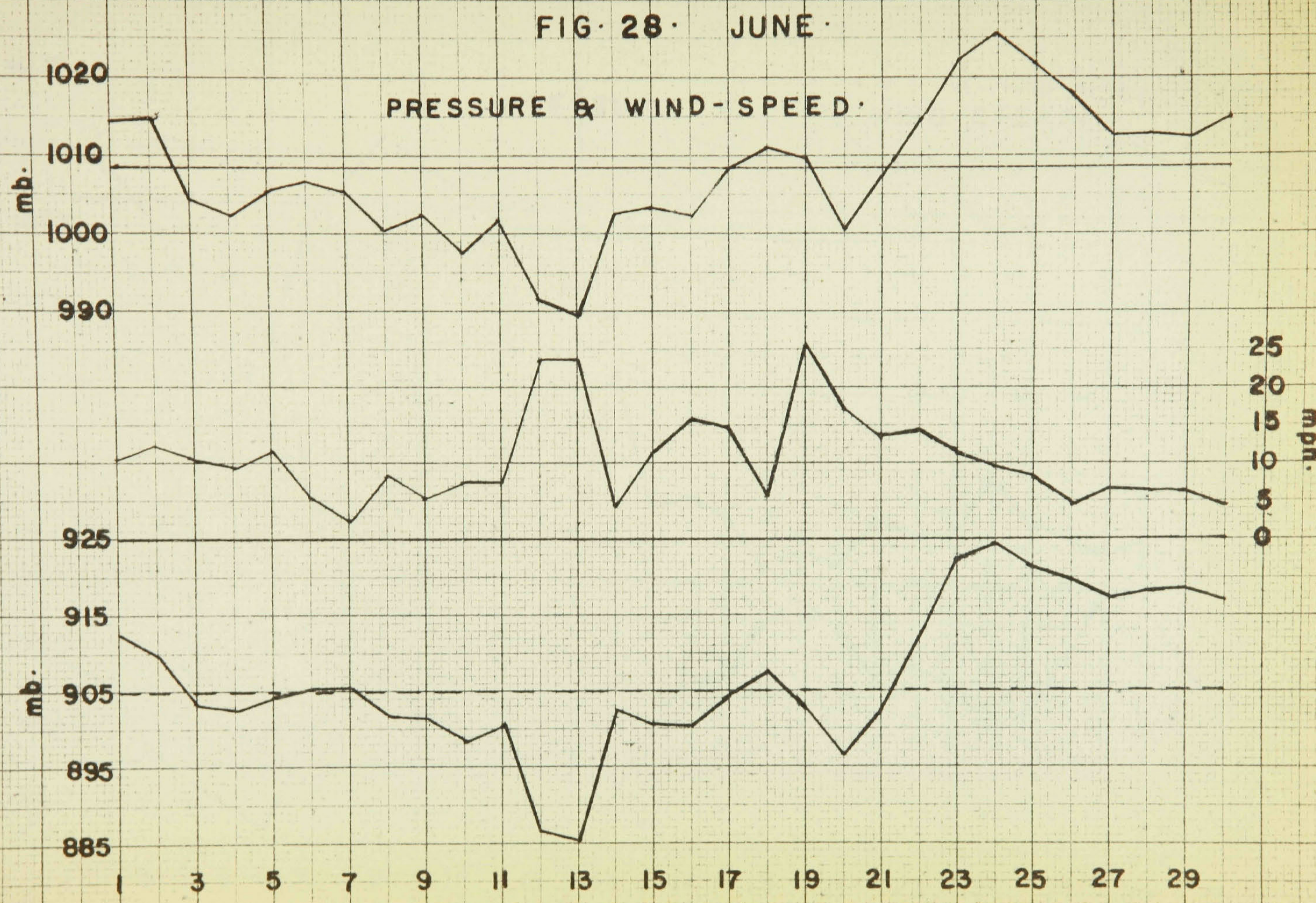


FIG. 28. JUNE.

PRESSURE & WIND-SPEED.

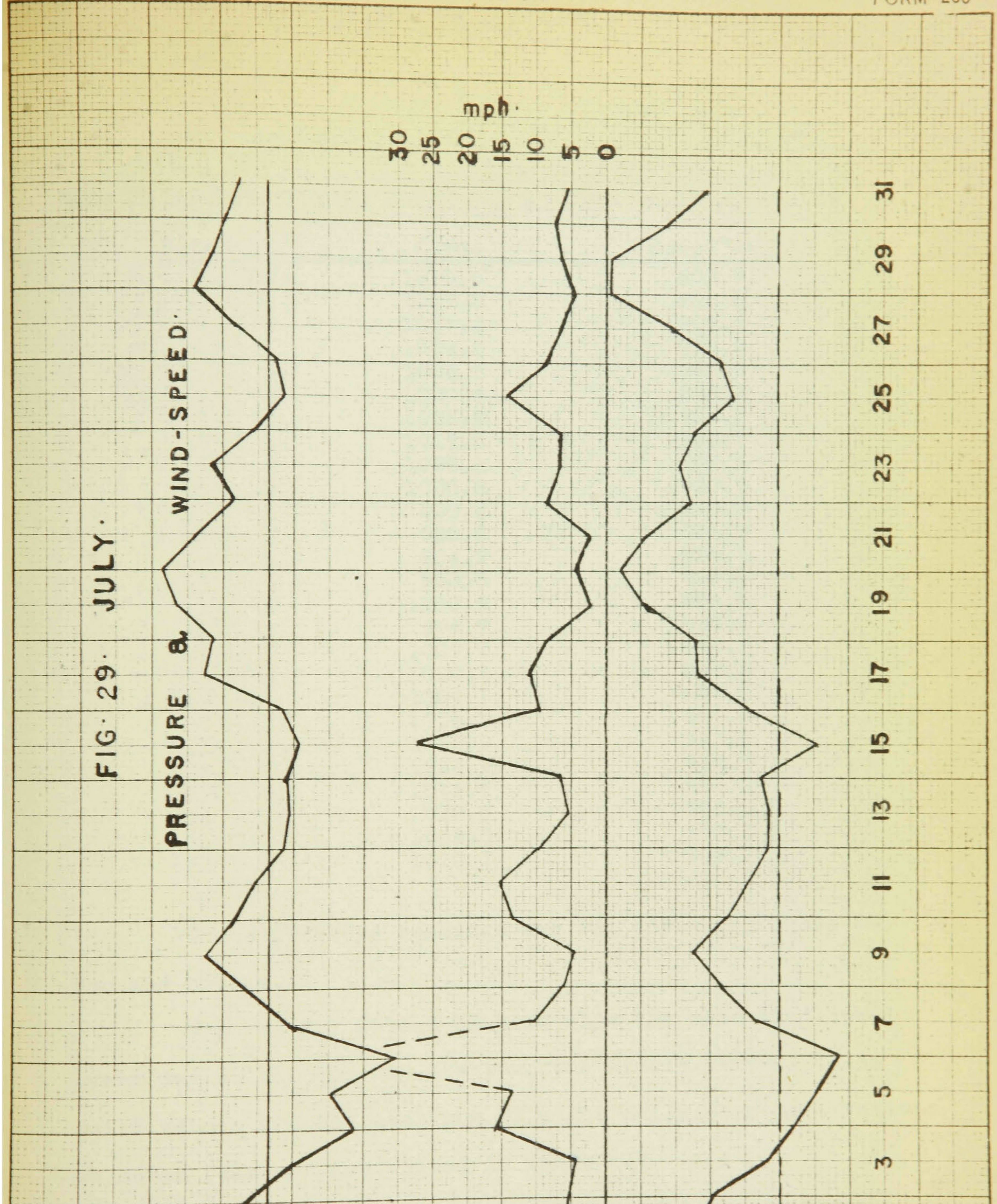


FIG. 29. JULY.
PRESSURE & WIND-SPEED.

TABLE LIII

MEAN DAILY PRESSURE AT CLYDE AND AT CAMP "A-1" IN AUGUST

Date	Clyde	Camp "A-1"
1	1010.5	908.9
2	1007.0	908.0
3	1007.4	907.3
4	1009.5	910.5
5	1004.8	902.6
6	1000.4	898.1
7	1006.2	905.3
8	1011.3	911.7
9	1005.1	907.1
10	1000.8	900.9
11	999.2	898.9
12	989.2	891.0
13	984.2	886.6
14	990.8	893.5
15	1002.6	904.5
16	994.7	896.4
17	1009.7	909.1
18	1002.1	897.2
19	1004.1	905.2
20	1018.5	917.8
21	1017.9	913.3
22	1014.9	912.7
23	1016.6	914.0
24	1012.0	905.8
25	1009.0	907.1
26	1010.7	909.3

These pressure readings are set forth in Figure 30, top and bottom.

Figures 28, 29 and 30 also show the mean wind speed every day at the ice-cap station, the middle curve. These daily values are the averages of eight daily wind observations at seven feet and are listed in Table LIV.

The top and bottom curves in Figures 28, 29 and 30 show the very close resemblance in pressure variations at Clyde and at the ice-cap station, more than one hundred miles apart,

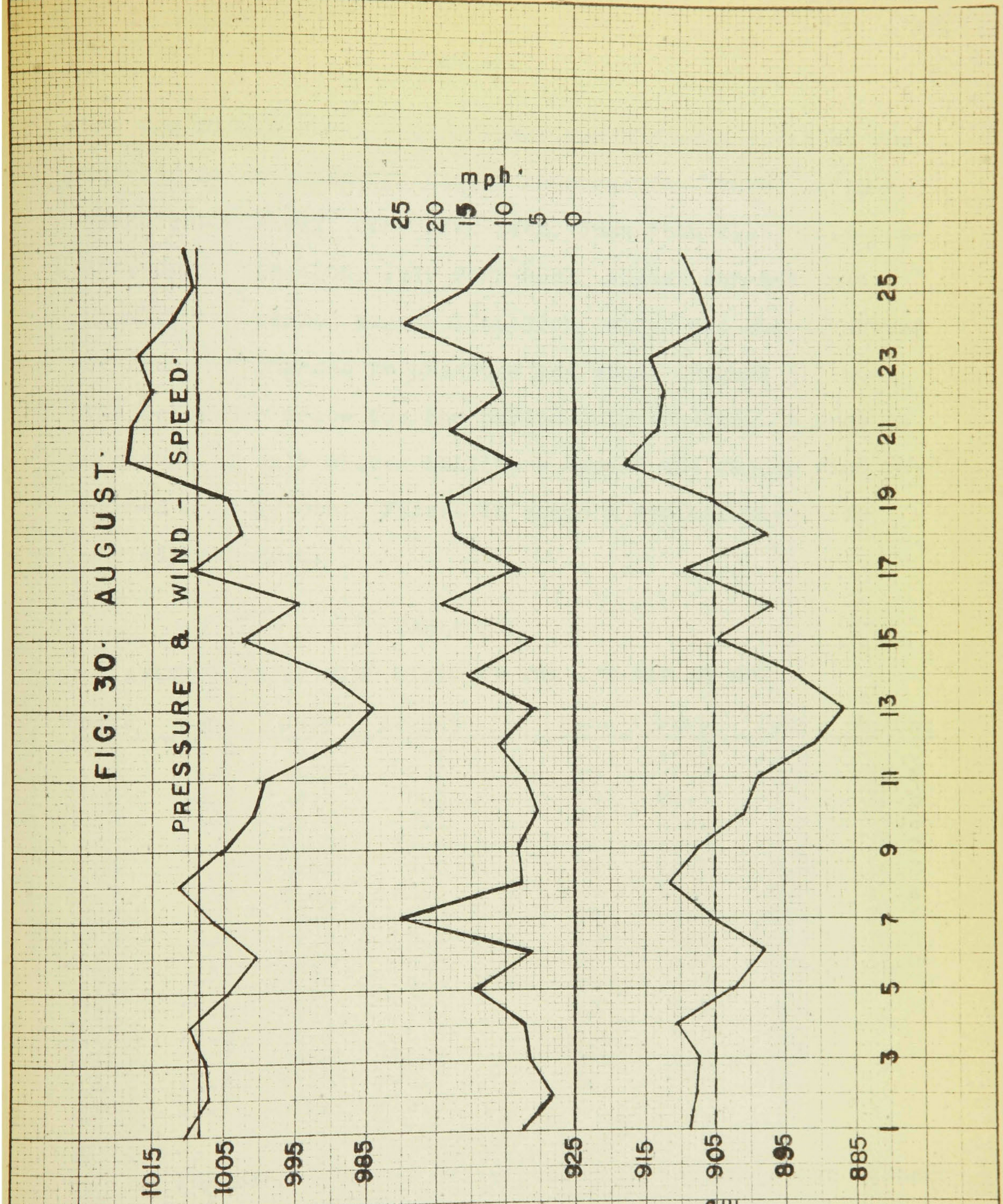


FIG. 30. AUGUST.
PRESSURE & WIND - SPEED.
mph.
25
20
15
10
5
0
mb.
1015
1005
995
985
925
915
905
895
885
1
3
5
7
9
11
13
15
17
19
21
23
25

and the middle curve demonstrates how the wind speed at the ice-cap is governed by changes in pressure. Seven periods stand out clearly: June 11th-14th, June 18th-21st, July 3rd-7th, July 14th-16th, July 24th-26th, August 4th-8th, and finally the period August 11th-25th, which was characterized by frequent changes in pressure and wind. Figure 31 shows the barograph trace for the period July 5th-8th. A drop in pressure of only eleven millibars caused the strong wind recorded on July 6th. Figure 32 shows a typical three-day period in August.

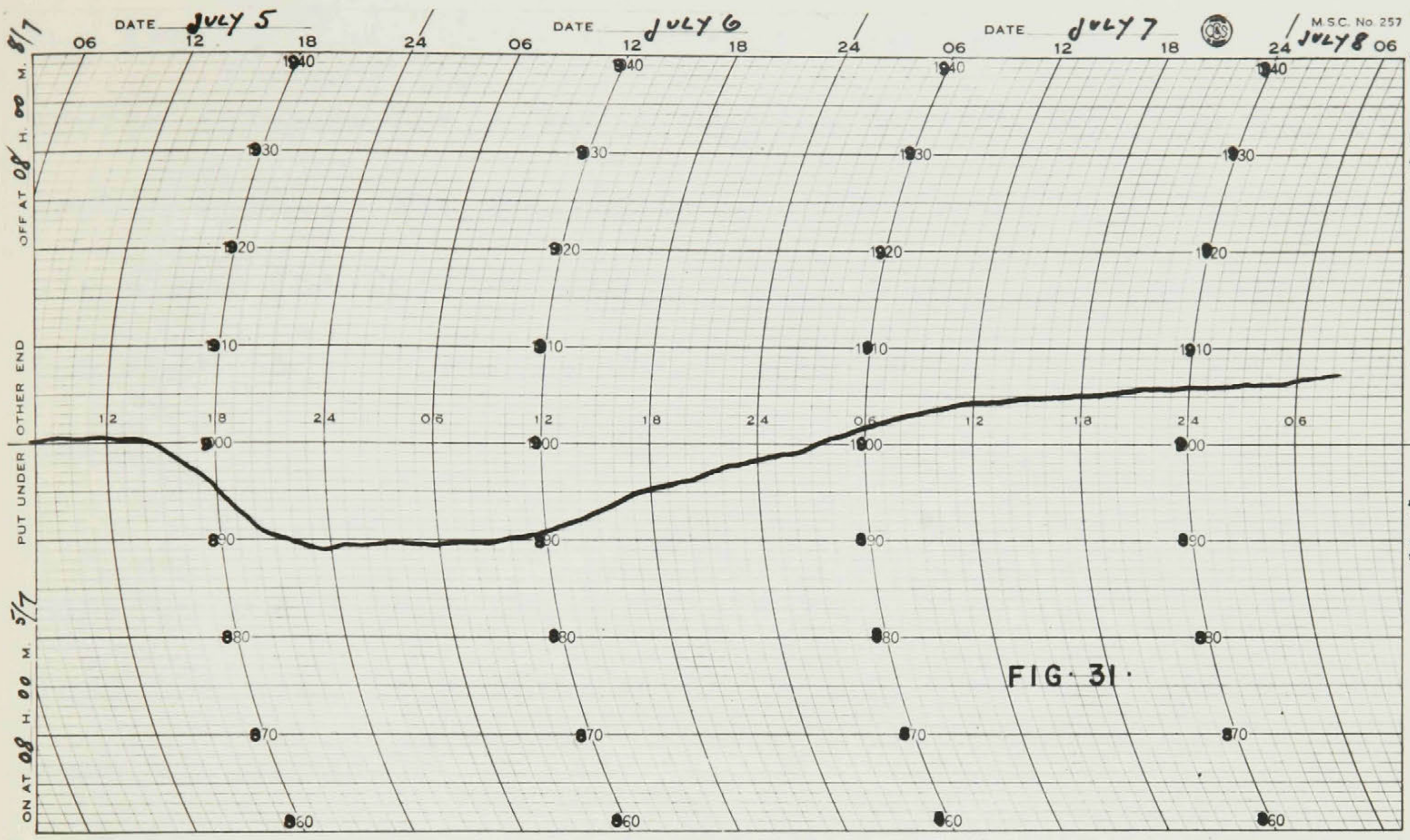
TABLE LIV

AVERAGE DAILY WIND SPEED ON THE ICE-CAP IN MPH

Date	June	July	August	Date	June	July	August
1	10.9	6.0	7.4	17	14.2	11.0	8.0
2	12.1	5.1	3.8	18	5.9	8.8	17.6
3	10.6	4.3	6.3	19	25.4	2.1	18.8
4	9.8	15.1	7.1	20	17.0	4.4	8.2
5	11.6	13.7	14.8	21	13.6	2.7	18.0
6	5.7	>35	7.0	22	14.5	8.6	10.8
7	2.3	11.0	25.0	23	11.3	6.9	12.4
8	8.1	6.8	8.0	24	9.6	6.1	24.4
9	5.5	4.9	8.3	25	8.8	14.7	15.7
10	7.9	13.6	5.8	26	4.7	8.4	11.0
11	7.6	15.1	7.3	27	6.9	6.6	
12	23.6	9.9	11.0	28	6.1	4.8	
13	23.8	5.8	5.6	29	6.1	6.7	
14	4.3	6.9	15.7	30	4.6	7.3	
15	11.3	27.3	6.1	31		5.5	
16	15.7	9.8	19.0				

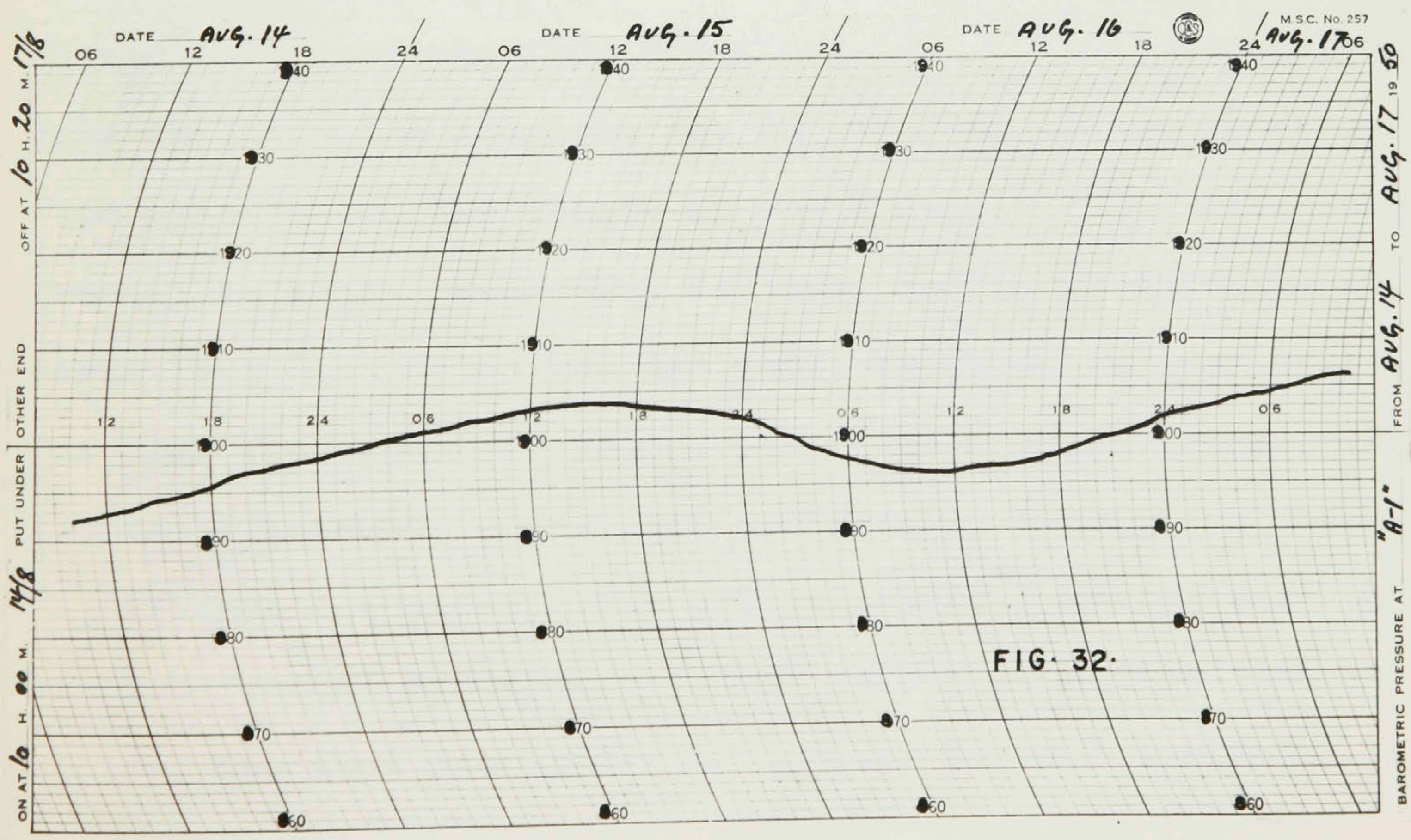
The mean pressure distribution in summer in the Eastern Canadian Arctic has been described by Hare.[24] The lowest pres-

24 F. K. Hare, The Climate of the Eastern Canadian Arctic and Sub-Arctic and its Influence on Accessibility, thesis presented for the degree of Ph.D., L'Universite de Montreal, 1950, pp. 47-48.



DATE JULY 5
DATE JULY 6
DATE JULY 7
M.S.C. No. 257
JULY 8
OFF AT 08 H. 00 M. 8/7
OTHER END
PUT UNDER
ON AT 08 H. 00 M. 5/7
BAROMETRIC PRESSURE AT "A-1"
FROM JULY 5 TO JULY 8 1950

FIG. 31.



DATE AUG. 14
DATE AUG. 15
DATE AUG. 16
M.S.C. No. 257
AUG. 17
OFF AT 10 H. 20 M. 17/8
OTHER END
PUT UNDER
ON AT 10 H. 00 M. 14/8
BAROMETRIC PRESSURE AT "A-1"
FROM AUG. 14 TO AUG. 17 1950

FIG. 32.

sure lies over southern Baffin Island and higher pressure over the Arctic Ocean. The resultant flow over most of the Eastern Arctic is a cyclonic rotation from North Greenland and the Arctic Ocean. The abundance of relatively warm Maritime Polar air along the Baffin Island coast is readily explainable, as the resultant flow over Davis Strait is from South and Southeast.

The northern parts of the Eastern Canadian Arctic are more affected than the southern parts by the cyclones moving into the area from the region of the American Arctic frontal zone in summer.[25]

The analysis of synoptic charts carried out by Hare showed that cyclonic flow dominates the whole Baffin Island area in July; the isopleth for 65 per cent frequency of cyclonic flow passes down the length of the island.[26] The frequency of frontal activity, according to Hare, decreases abruptly northwards from Fort Chimo (50 per cent) to Clyde (20 per cent). The high frequency of cyclonic curvature, together with low frontal frequency, shows that non-frontal arctic cyclones are significant elements in the circulation.[27] Hare notes that the non-frontal cyclones are less common in summer than in winter, and that precipitation is rare in such systems.

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25 Ibid., p. 50.

26 Ibid., figs. 30, 31, p. 57.

27 Ibid., p. 58.

The precipitation measured on the ice-cap was quite heavy at times; the following figures are the precipitation measured for each of the seven periods with low pressure and high wind:

June 11th-14th	:	7.5 inches of snow	
June 18th-21st	:	2.6 inches of snow	
July 3rd-7th	:	11.25 inches of snow,	0.2 inches rain
July 14th-16th	:		0.32 inches rain
July 24th-26th	:		1.02 inches rain
August 4th-8th	:	5.98 inches of snow,	0.26 inches rain
August 11th-25th	:	some snow on all but three days	

The synoptic charts of the summer show that during the first period a well developed frontal system passed over the region of the Barnes Ice-cap. Figure 33 shows the situation on June 13th, and explains the heavy precipitation, which was frontal. The next period, June 18th-21st, did not, with absolute certainty, see a frontal passage as far north as Clyde, although the low pressure area over Baffin Island did belong to a frontal system. Figure 34 shows the weather map as drawn at Dorval Airport on June 21st. The much smaller amount of snow during this period suggests that the Barnes Ice-cap was experiencing only the northern part of the extensive low pressure.

The third period with low pressure and high winds, July 3rd-7th, was a case of a real arctic cyclone developing frontal characteristics and moving southeastwards towards Davis Strait. Figure 35 shows the situation on July 3rd with a front over the western arctic islands, and a Low forming over the Sverdrup Islands. Figure 36 shows the situation three days later, when

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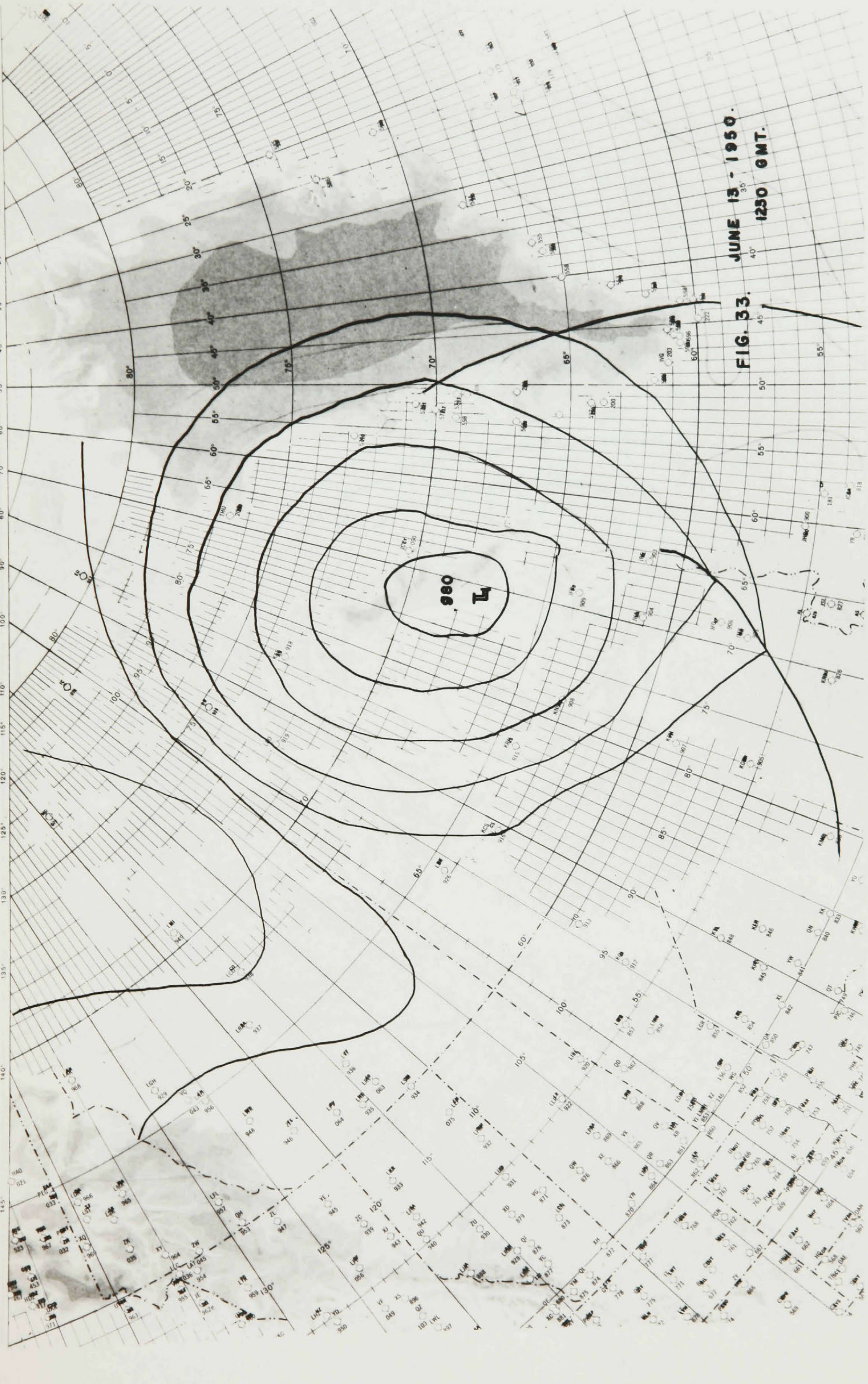
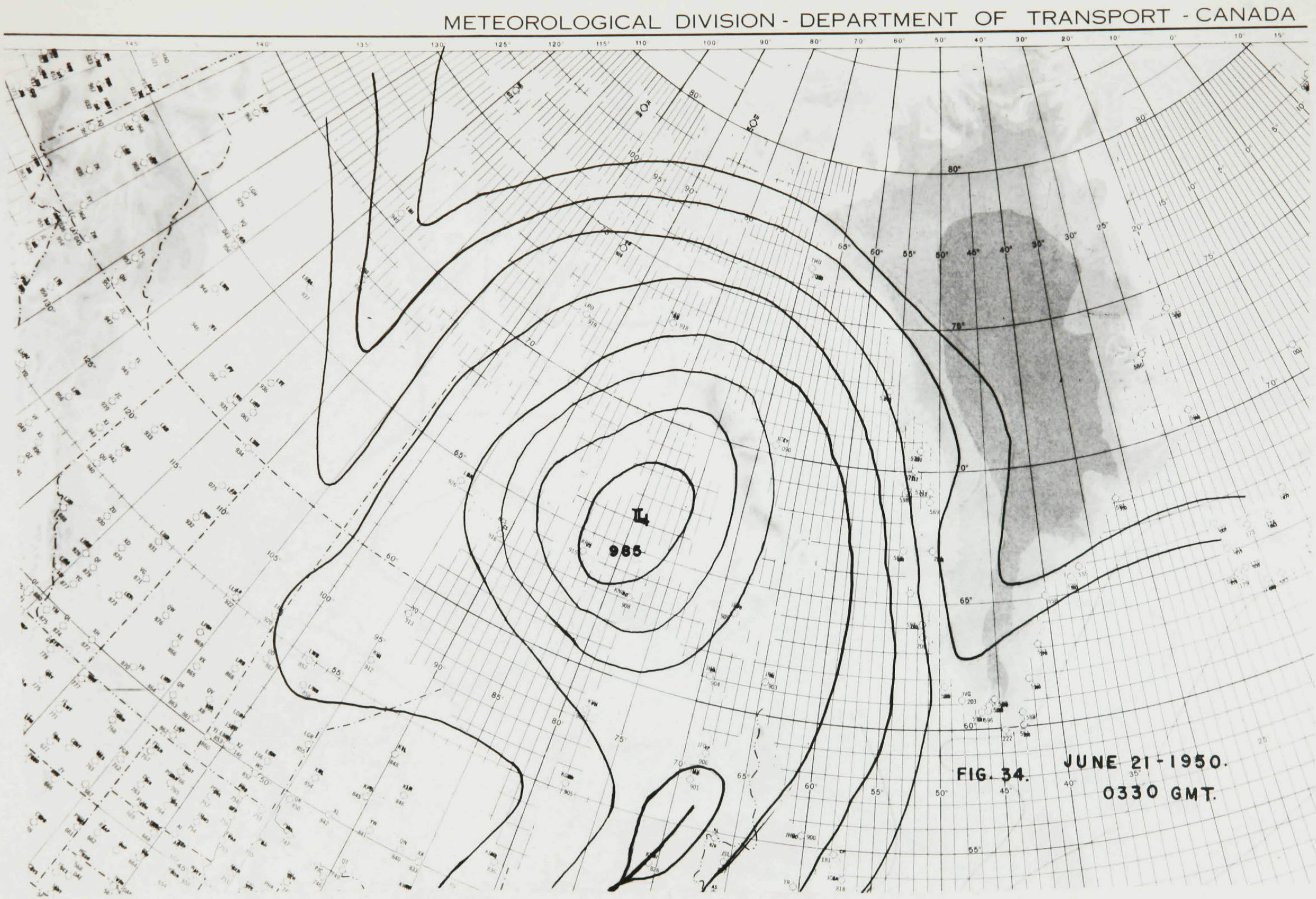


FIG. 33.



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985
JUNE 21-1950.
0330 GMT.

FIG. 34.

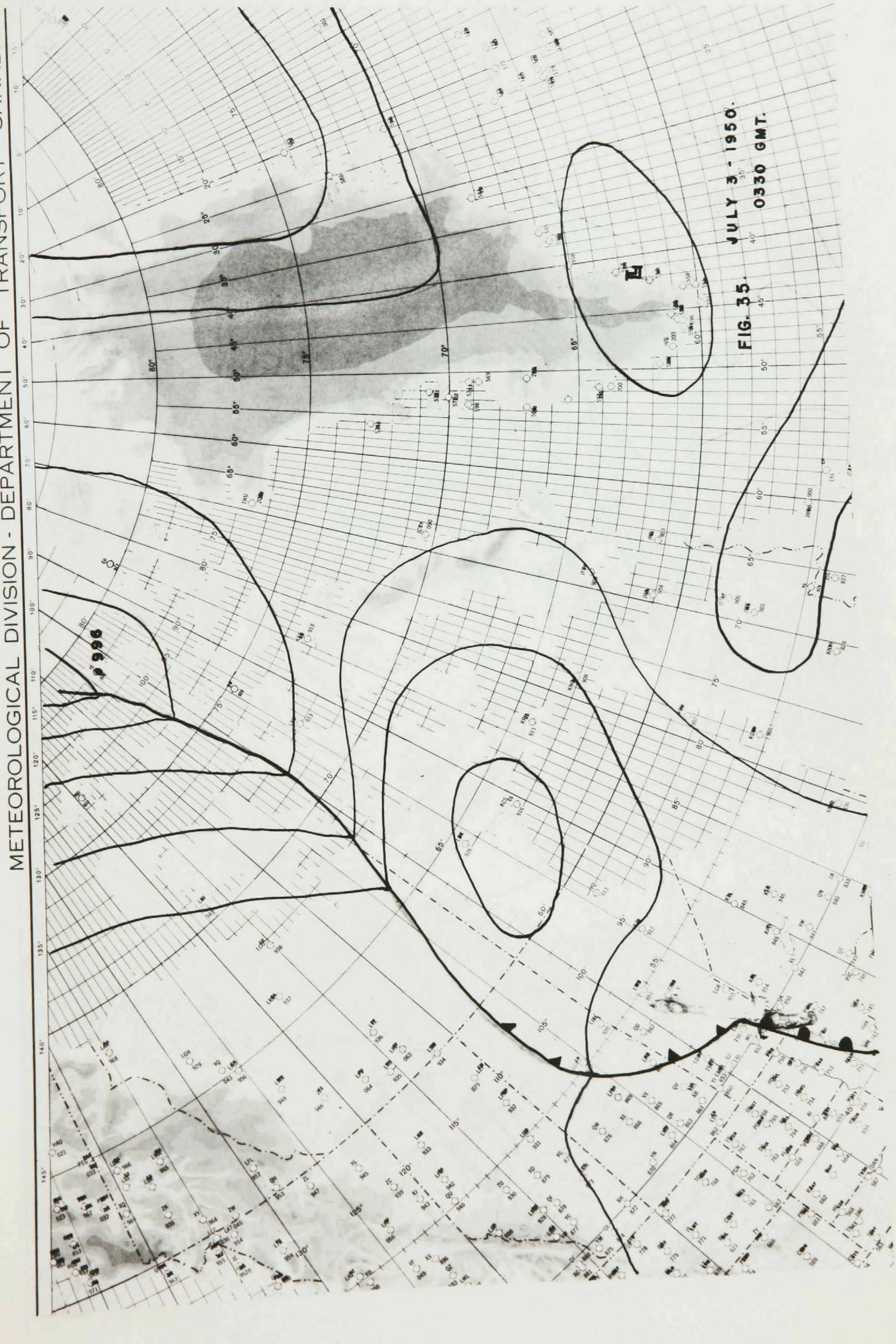

METEOROLOGICAL DIVISION - DEPARTMENT OF TRANSPORT - CANADA
JULY 3 - 1950.
0330 GMT.

FIG. 35.

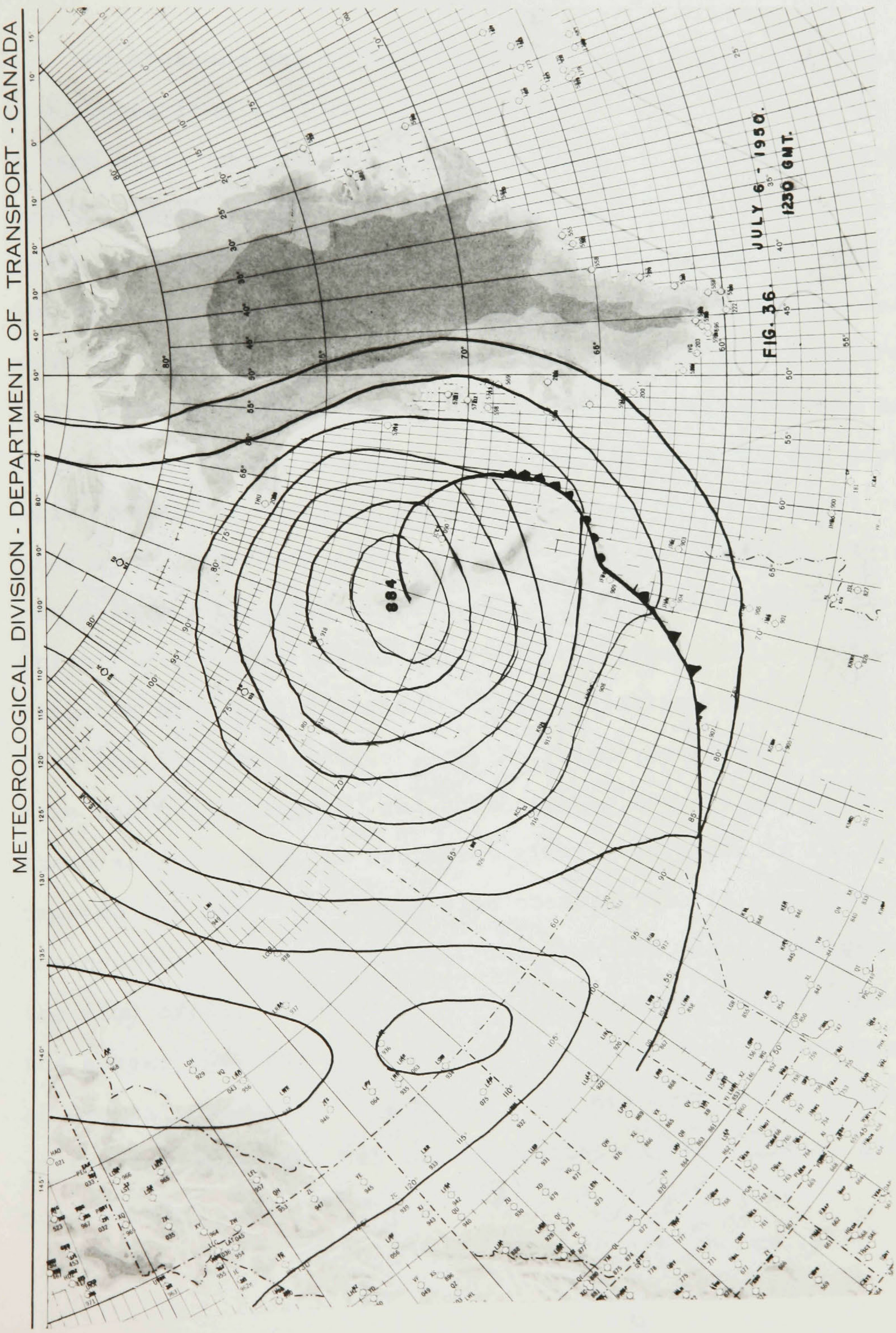


FIG. 36. JULY 6 - 1950. 1230 GMT.

the low pressure was situated over the region of the ice-cap, and the maximum wind was recorded, over fifty mph in gusts. A very heavy snowfall was recorded during the passage of this system, 11.25 inches, and also some rain. The rest of July seems to have had no fronts as far north as Baffin Island. The variations in pressure and wind speed were caused by movement of cyclones far outside the area. The fairly heavy precipitation during the period August 4th-8th indicates the presence of a frontal system, but the weather maps for the period show no sign of any such system; there was only a general reduction in air pressure and a steepening of the gradient. This was probably the time at which the non-frontal cyclone formed, which for the next eleven days -- until August 19th -- was situated over Davis Strait and gave prevailing northeast winds over the ice-cap in August. This cyclone moved westwards to Foxe Basin on the 19th, and until August 26th it was situated there and gave rise to southwest winds. As shown in Table XLVII, page 86, 55 per cent of the wind observations in August showed northeast or southwest winds. The pressure, and consequently the wind speed, varied more rapidly in August than earlier in the summer, but the extremes were less than during the passages of frontal cyclones. The weather was overcast, and a great deal of fog was observed, but the precipitation was lighter, although more common.

V. CLOUDS, CLOUDINESS AND FOG

The detailed observations of the cloud forms are of no special importance to the problem of ablation and climate on the Barnes Ice-cap. It is sufficient to mention that during the summer the sky did not appear altogether as monotonous as it often does in the Arctic. Frequently numerous cloud forms were observed. The following values for the relative frequency of typical cloud forms demonstrate this feature:

Cloud form :	Fog	St.-forms	A - forms	Ci - forms
Frequency % :	21.2	48.9	13.5	16.4
	70.1			

The cloudiness as observed on the ice-cap from June 1st to August 26th is presented in the following table. The cloudiness for a certain day is the average of eight observations on that day.

TABLE LV

CLOUDCOVER IN TENTHS OF THE SKY COVERED

Number of days

CLOUDCOVER :	0/10	1/10	2/10	3/10	4/10	5/10	6/10	7/10	8/10	9/10	10/10
June, 30 days:	1	3	1		1	1	2	3	1	6	11
July, 31 days:		2		3		2		1	1	7	15
Aug., 26 days:					1	1		1	3	6	14
Total period:	1	5	1	3	2	4	2	5	5	19	40

A total of forty days, or 46 per cent of the time, had completely overcast sky. The cloudiness was considerably higher with winds from South and Southeast than with winds from West or North; a typical sequence of frontal clouds was observed on several occasions. The cloudiness increased during the summer, June having completely overcast sky 37 per cent of the time, July 48 per cent of the time, and August a maximum of overcast weather, 54 per cent of the time.

The relation between cloudiness and wind direction is seen in the following compilation.

TABLE LVI

WIND DIRECTION AND MEAN CLOUDINESS IN TENTHS OF THE SKY COVERED

Wind from :	N	NE	E	SE	S	SW	W	NW
Mean cloudiness:	6.6	8.5	8.0	10.0	10.0	9.6	5.6	5.2

A diurnal variation of the cloudiness was not observed.

Figure 37a shows the mean cloudiness with different wind directions for the whole period, June 1st to August 26th.

Fog.

June had 129 hours of fog, the probability of fog thus being 0.18.

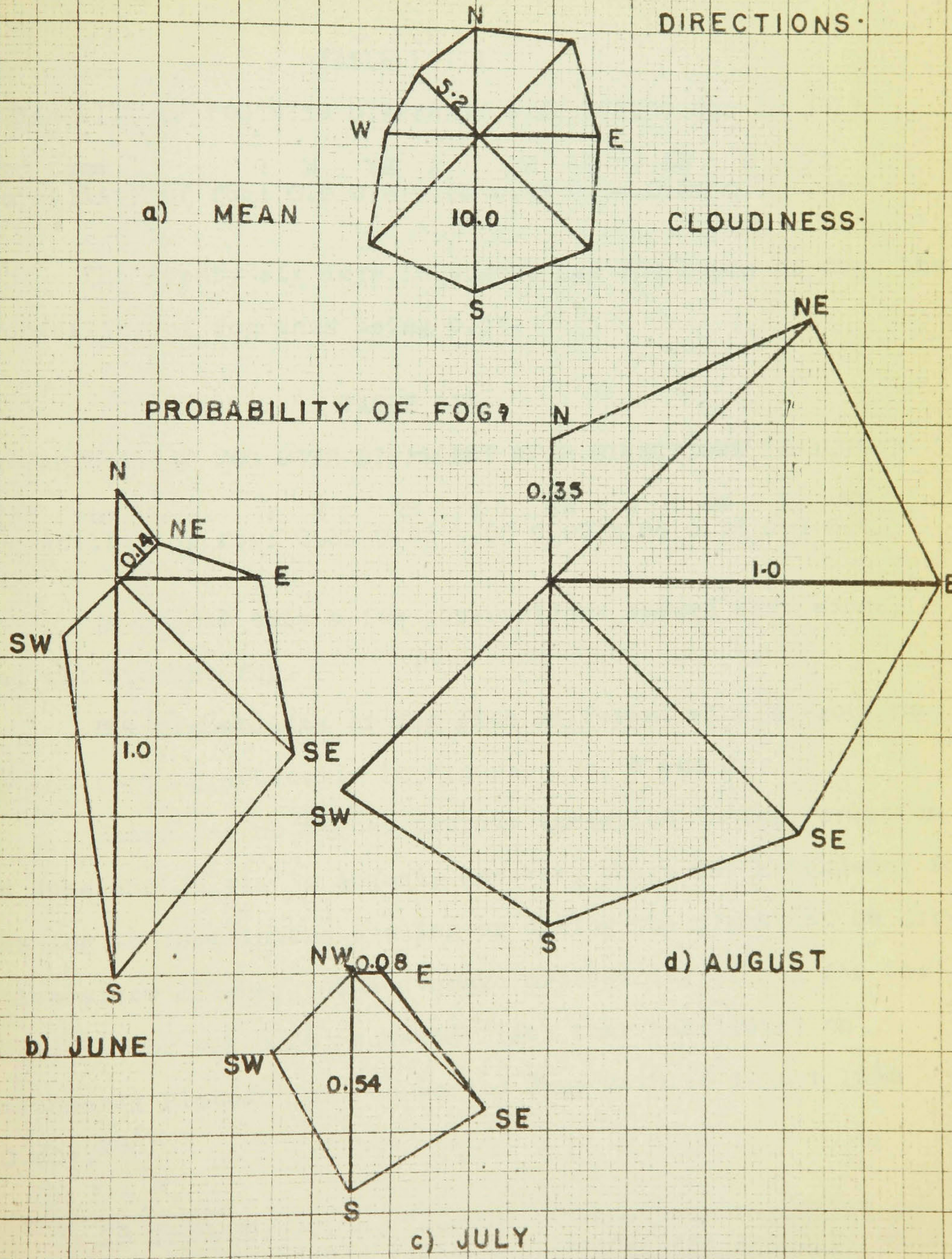
TABLE LVII

PROBABILITY OF FOG WITH DIFFERENT WIND DIRECTIONS IN JUNE

Wind from :	N	NE	E	SE	S	SW	W	NW
Probability of fog:	0.22	0.14	0.35	0.62	1.00	0.20	0.0	0.0

In June only a few observations showed south winds, and all brought fog.

FIG·37·
CLOUDINESS & FOG WITH DIFFERENT WIND-DIRECTIONS·



July had 160 hours of fog, the probability of fog thus being 0.22.

TABLE LVIII

PROBABILITY OF FOG WITH DIFFERENT WIND DIRECTIONS IN JULY

Wind from	N	NE	E	SE	S	SW	W	NW
Probability of fog:	0.0	0.0	0.08	0.47	0.54	0.28	0.0	0.04

The twenty-six days in August had 334 hours of fog, the probability of fog thus being 0.54.

TABLE LIX

PROBABILITY OF FOG WITH DIFFERENT WIND DIRECTIONS IN AUGUST

Wind from	N	NE	E	SE	S	SW	W	NW
Probability of fog:	0.35	0.93	1.00	0.90	0.88	0.76	0.0	0.0

In August only a few observations showed east winds, and all brought fog.

The probability of fog with different wind directions is set forth graphically in Figures 37b, c and d.

There was no marked diurnal variation in fog formation in June and July. In August, however, there was a tendency for the fog to form in the evening or during the night and to dissolve after mid-day. The average probability of fog for the whole period was 0.30, somewhat less than that found on Isachsen's Plateau for the period June 26th to August 15th (0.40).[28]

28 H. U. Sverdrup, "Results of the Meteorological Observations on Isachsen's Plateau," Geografiska Annaler, Vol. XVIII, 1936, p. 42.

There was a very sharp increase in the probability of fog in August; for more than half the time the visibility was one mile or less, and all wind directions except west and northwest had a high probability of fog. The east coast and all the fiords were free of ice by that time, and the air was more humid than during the previous months. The west and northwest winds were consistently free from fog even in August. These wind directions brought the air along the axis of the island, and the distance to open water was more than two hundred miles. As witnessed by the lack of fog, these winds were much drier than the air from other directions.

VI. PRECIPITATION

TABLE LX

MONTHLY PRECIPITATION IN INCHES

	Rain	Snow
June :	0.07	16.98
July :	1.84	11.35
August :	0.41	21.68
Total :	2.32	50.01

The probability of occurrence is given in the following table, (the number of observations when rain, drizzle or snow was observed divided by the total number of observations).

TABLE LXI

PROBABILITY OF RAIN, DRIZZLE AND SNOW

	Rain	Drizzle or frozen drizzle	Snow
June :	0.02	0.02	0.12
July :	0.12	0.03	0.11
August :	0.05	0.03	0.29

In June and July drizzle was especially frequent when fog was present. In August the percentage of drizzle was the same as in July, although fog was more frequent. By that time the temperatures had fallen sufficiently to give snow, and 29 per cent of all observations in August recorded falling snow.

Most of the precipitation in July was frontal as described previously.

VII. DURATION OF SUNSHINE

A Campbell-Stokes recorder was used to record the hours of sunshine. The duration of sunshine was never influenced by topography, the station being situated on a large, plane snow surface with a practically unscreened horizon. The distant mountains in the Northeast and East were lower than the altitude of the sun throughout the period.

The following table gives the duration of sunshine in fractions of an hour for each day, and the total hours of sunshine from midnight May 31st.

TABLE LXII

DURATION OF SUNSHINE

Date	June Hours	June Total	July Hours	July Total	August Hours	August Total
1	18.9	18.9	8.3	215.1	8.9	368.2
2	11.5	30.4	1.0	216.1	0.2	368.4
3	0	30.4	0.7	216.8	6.9	375.3
4	2.6	33.0	9.6	226.4	8.9	384.2
5	0	33.0	3.2	229.6	0	384.2
6	11.2	44.2	0	229.6	0	384.2
7	4.8	49.0	0.2	229.8	1.5	385.7
8	0.2	49.2	0	229.8	4.3	390.0
9	2.8	52.0	0.6	230.4	7.2	397.2
10	2.7	54.7	10.9	241.3	0	397.2
11	0.6	55.3	4.3	245.6	0	397.2
12	0	55.3	1.2	246.8	1.8	399.0
13	0	55.3	0.7	247.5	0.2	399.2
14	7.4	62.7	2.6	250.1	0	399.2
15	4.0	66.7	0	250.1	1.8	401.0
16	7.3	74.0	0	250.1	0.4	401.4
17	0.1	74.1	16.0	266.1	2.3	403.7
18	2.2	76.3	2.4	268.5	0	403.7
19	0	76.3	14.7	283.2	0	403.7
20	4.3	80.6	0.4	283.6	0.5	404.2
21	1.6	82.2	0	283.6	2.1	406.3
22	4.2	86.4	1.2	284.8	2.3	408.6
23	0	86.4	18.2	303.0	0.1	408.7
24	19.8	106.2	0	303.0	0.3	409.0
25	20.0	126.2	0	303.0	1.7	410.7
26	20.0	146.2	0	303.0	2.6	413.3
27	20.0	166.2	18.4	321.4		
28	15.7	181.9	18.0	339.4		
29	8.7	190.6	14.6	354.0		
30	16.2	206.8	5.2	359.2		
31			0.1	359.3		
Total:	206.8		152.5		54.0	

Figure 38 shows the duration of sunshine for each day.

Twenty-one days, or nearly 25 per cent of the time, had no sunshine, and only two short periods had an amount approaching the maximum possible at that latitude. Those periods were June 24th-28th and July 27th-29th.

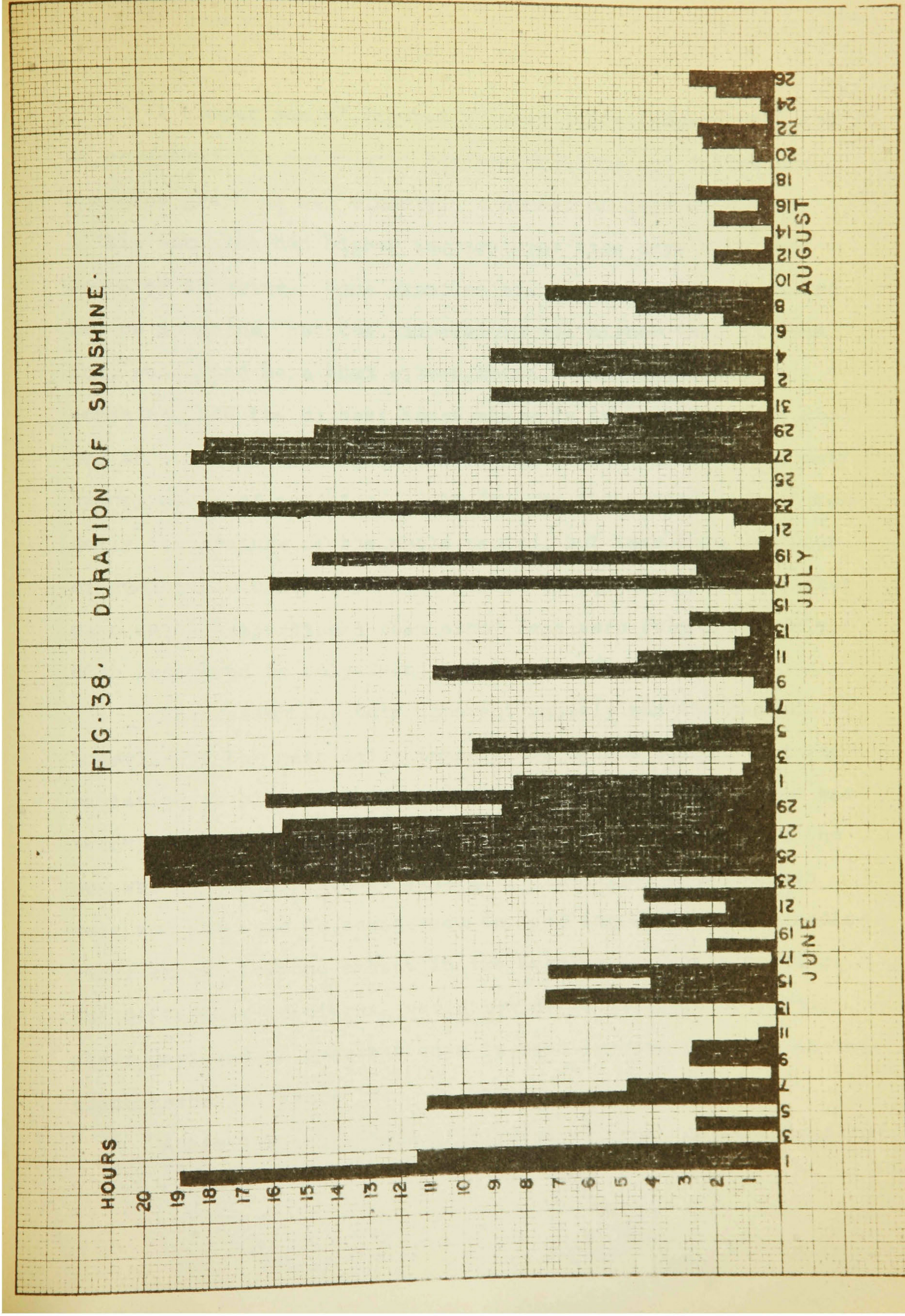


FIG. 38. DURATION OF SUNSHINE.
HOURS
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
JUNE
JULY
AUGUST
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
2 4 6 8 10 12 14 16 18 20 22 24 26

A comparison of Figures 9 (mean daily temperature) and 38 show that the mean daily temperature does not follow the sunshine graph at all closely. A number of days with very little sunshine had higher temperatures than days with many hours of sunshine. Some examples are the following: June 3rd had no sunshine, but the temperature was higher than on June 2nd, which had more than eleven hours. June 13th, with no sunshine, had the highest temperature in two weeks. June 23rd had no sunshine but higher temperature than the 24th with nearly twenty hours of sunshine. July 3rd had the second highest mean daily temperature of the whole period, but less than one hour of sunshine. Other days with little or no sunshine and higher mean daily temperatures than sunny days were July 21st, July 30th (compared to July 28th) and August 10th.

The reason for this apparent anomaly was the marked lowering of the mean daily temperature by the strong outgoing radiation on clear nights, in spite of the fact that there was twenty-four hours sunshine until July 19th. On that date the sun was at the horizon at midnight. The night sunshine was weak and not able to counteract the cooling by long-wave radiation, except to some extent in the evening and early morning. The difference in diurnal variation of temperature on partly clear days and on overcast days is readily seen from the thermograph trace in Figure 12.

A similar comparison of Figures 17 (mean daytime temperatures) and 38 is undertaken in Figure 39. The mean daytime temperatures follow the sunshine graph more closely than does the mean daily temperature. This was to be expected, as night temperatures are not considered in this case. The sunshine, even on days when it was strong and almost continuous, was not able to heat the air over the ice-cap to any great extent, the underlying surface always being at or below the freezing point.

As indicated here and discussed previously (page 60), the ice-cap acts as a temperature stabilizer. On clear days the temperature remained relatively low, on clear nights the long-wave radiation cooled the air. On overcast days the heating of the air during the daytime was less, but the cooling at night was also less, the result being a smaller diurnal variation of temperature. As discussed under temperature and wind direction (page 62), it is clear that the heating of the air on sunny days takes place over the snow free land surrounding the ice-cap, the temperatures over the ice itself depending on the duration of sunshine and on the distance the air has travelled over the ice-cap surface. July 31st and August 2nd were two days with very similar conditions, except that on August 2nd the wind direction backed to the North in the evening, thus bringing the air over a longer distance of ice surface. How this increased the cooling of the air can be seen from the following:

	Hours of sunshine	Mean daytime temp.	Wind
July 31 :	0.1	35.8	SW
August 2:	0.2	35.0	SW backing to N

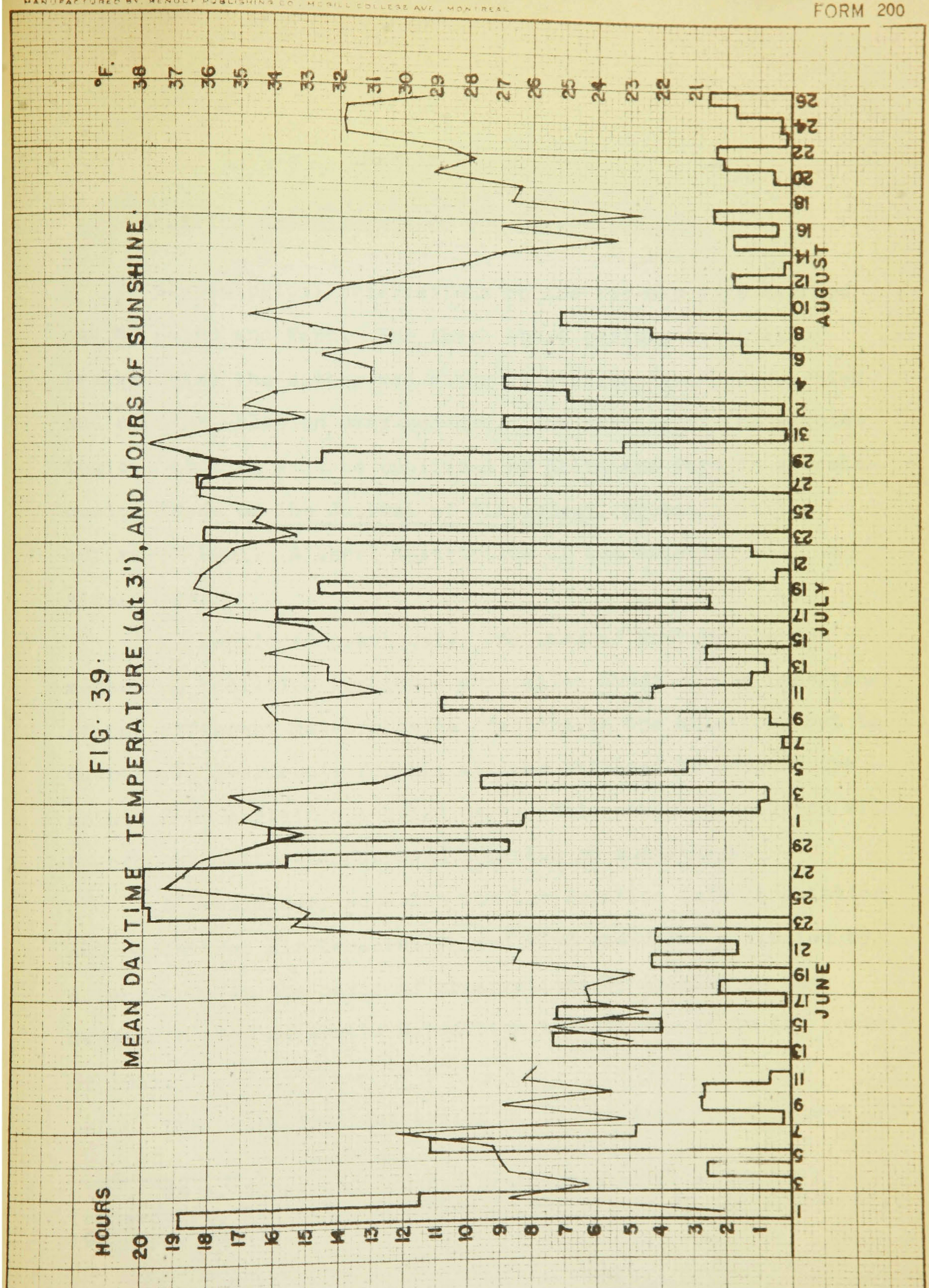


FIG. 39.
MEAN DAYTIME TEMPERATURE (at 3'), AND HOURS OF SUNSHINE.

CHAPTER IV

ABLATION MEASUREMENTS ON THE BARNES ICE-CAP

Glaciological observations on the ice-cap were carried out by Baird and Ward. For three short periods (a total of twelve days) the author was alone at station "A-1" and carried out routine ablation measurements. The results of the glaciological studies will be published by Baird and Ward in a forthcoming issue of The Journal of Glaciology, probably in the autumn of 1951. A short description of the ablation will be given here.

As mentioned previously, the lack of instruments for measuring radiation prohibits a detailed study of the importance of the different meteorological factors in the ablation, but in Chapter VI Sverdrup's formula will be utilized to compute the ablation on certain specified days. This computed ablation will be compared with the observed ablation on those days.

A preliminary equation for the relation between ablation and radiation, air temperature and wind speed was evaluated by A. Angstrom on the basis of observations by Ahlmann on the Swedish-Norwegian Arctic Expedition to Spitsbergen in the summer of 1931.[29]

The collaboration between H. U. Sverdrup and H. W:son

29 A. Angstrom, "On the Dependence of Ablation on Air Temperature, Radiation and Wind," Geografiska Annaler, Vol. XV, 1933, pp. 264-71.

Ahlmann during the Norwegian-Swedish Spitsbergen Expedition in 1934 brought the problem of ablation much nearer to its solution. It must be borne in mind, however, that the relations discovered by Sverdrup[30] do not hold in all cases. Both Sharp[31] and Ahlmann[32] quote Wallen's results from the Karsa Glacier in Sweden, where Sverdrup's relations were found not to hold true.

The importance of the different meteorological factors in ablation vary from one morphological type of glacier to another.

The ice-caps and glaciers in Spitsbergen are "temperate" according to Ahlmann's classification,[33] as the temperature is at freezing point throughout the year at a depth of twenty-five meters.[34] In a temperate glacier the temperature should remain at the melting point, except in winter when the top layers have a negative temperature to a depth of a couple of meters.

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30 H. U. Sverdrup, "The Eddy Conductivity of the Air over a Smooth Snow Field," Geofysiske Publikasjoner, Vol. XI, No. 7, 1936, 69 pp.

31 R. P. Sharp, "Review Article," Arctic, Vol. III, No. 2, August, 1950, p. 115.

32 H. W:son Ahlmann, "The Contribution of Polar Expeditions to the Science of Glaciology," The Polar Record, Vol. V, Nos. 37-38, January-July, 1949, pp. 324-31.

33 F. E. Matthes, "Glaciological Studies," The Geographical Review, Vol. XXXVII, 1947, p. 154.

34 A. R. Glen, "The Oxford University Arctic Expedition to North East Land, 1935-36," The Geographical Journal, Vol. XC, 1937, p. 307.

The Barnes Ice-cap does not fit readily into Ahlmann's classification; if only temperatures are considered, it must be called a "sub-polar" ice-cap. This group is characterized by below-freezing temperatures in the accumulation area, even in summer, to a depth of at least one hundred meters. The air temperatures, however, should be only slightly below freezing, and thaw water is found in the accumulation area in summer.[35] The peculiarity which puts the Barnes Ice-cap in a separate class is the fact that there is no firn line in the usual meaning of the word. On arrival on May 27th the whole ice-cap and the adjoining land was snow covered; by the end of July there was melting snow and partly bare ice over the whole ice-cap. This also took place in 1948 as can be seen from Figure 40. The photograph was taken in August of that year, looking northwest over the ice-cap. Melt-water streams and bare ice can be seen over the whole surface. Thus there is probably normally no accumulation of snow. During the ablation season melt-water trickled down and part froze on to the old impervious ice surface, while the rest became slush or flowed into hollows and formed lakes. Old depressions in the ice formed river channels from whence the slush discharged to the edge. Above an altitude of about 2500 feet (midway between the edge and camp "A-1") several centimeters of newly formed ice, or coarse crystalline

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35 H. W:son Ahlmann, "Accumulation and Ablation on the Froya Glacier; its Regime in 1938-39 and 1939-40," Geografiska Annaler, Vol. XXIV, 1942, p. 10.

Fig. 40. R.C.A.F. Photograph of the Barnes Ice-cap.

snow, remained when persistent snow fell again during August. At about 2500 feet, probably somewhat higher on the northern part of the ice-cap, runs a line corresponding to the firn line. Above this line the adfreezing shows a net gain during the year, i.e., above this line is the true accumulation area.[36]

On June 24th a flight was made to the highest point of the ice-cap, approximately 3700 feet above sea level. Less snow was found there than at the main camp thirty miles to the South-east: thirty-five inches (eighty-nine cm) at the top, forty-three inches (109 cm) at camp "A-1". This difference in snow depth was partly due to the undulating ice surface; the snow is blown into hollows and the smooth snow surface thus conceals the irregularities of the underlying ice. A similar difference in snow depth of the order of ten to twenty cm could be measured at points only a few feet apart at the main camp. The ice-cap appears to be a blanket of ice, overlying rolling topography similar to the land to the West, and consisting of dense glacier ice. The first pit, dug on May 30th, disclosed that there was no progressive icification of the snow. Two thin bands of ice, one cm and one-half cm thick, testified to thawing periods after the first snowfall of the previous year, but the structure of the snow did not vary at different depths in the pit. Figure 41 shows the first pit, which later was dug ten feet into the solid ice. It is possible that thawing periods occurred in late

36 P. D. Baird, unpublished paper.

Fig. 41. The First Pit.

August or early September 1950, producing thin ice crusts similar to those observed in this pit. Figure 17 (page 55) illustrates how the mean daytime temperature rose above freezing at the end of August; a few days of intermittent melting with subsequent freezing will cause formation of crusts. Similar thin, discontinuous ice crusts were observed in Spitsbergen and have been described by Ahlmann.[37]

The thickness of the underlying ice at camp "A-1" was 1530 feet; ice depths were measured across the southern lobe by the anomalies of gravity.[38]

I. ABLATION

The simplest method for measuring ablation is by planting stakes. A small, irregular valley-glacier with great differences in altitude demands a large number of observation posts, while on a uniform plateau-glacier or ice-cap, like the Barnes Ice-cap, a smaller number suffices. The stakes used were of bamboo, a little more than seven feet long. The positions and dates of erection of these stakes are shown in Figure 42. Unfortunately, due to bad weather and also to the later melting of the snow with consequent rapid streams and great areas of water and slush, it was found to be impossible to obtain continuous readings from stakes 1, 3 and 4. Stake 2 was passed when travelling to and

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37 H. W:son Ahlmann, "The Stratification of the Snow and Firn on Isachsen's Plateau," Geografiska Annaler, Vol. XVII, 1935, p. 37.

38 Personal information from C. A. Littlewood, Dominion Observatory, Ottawa.

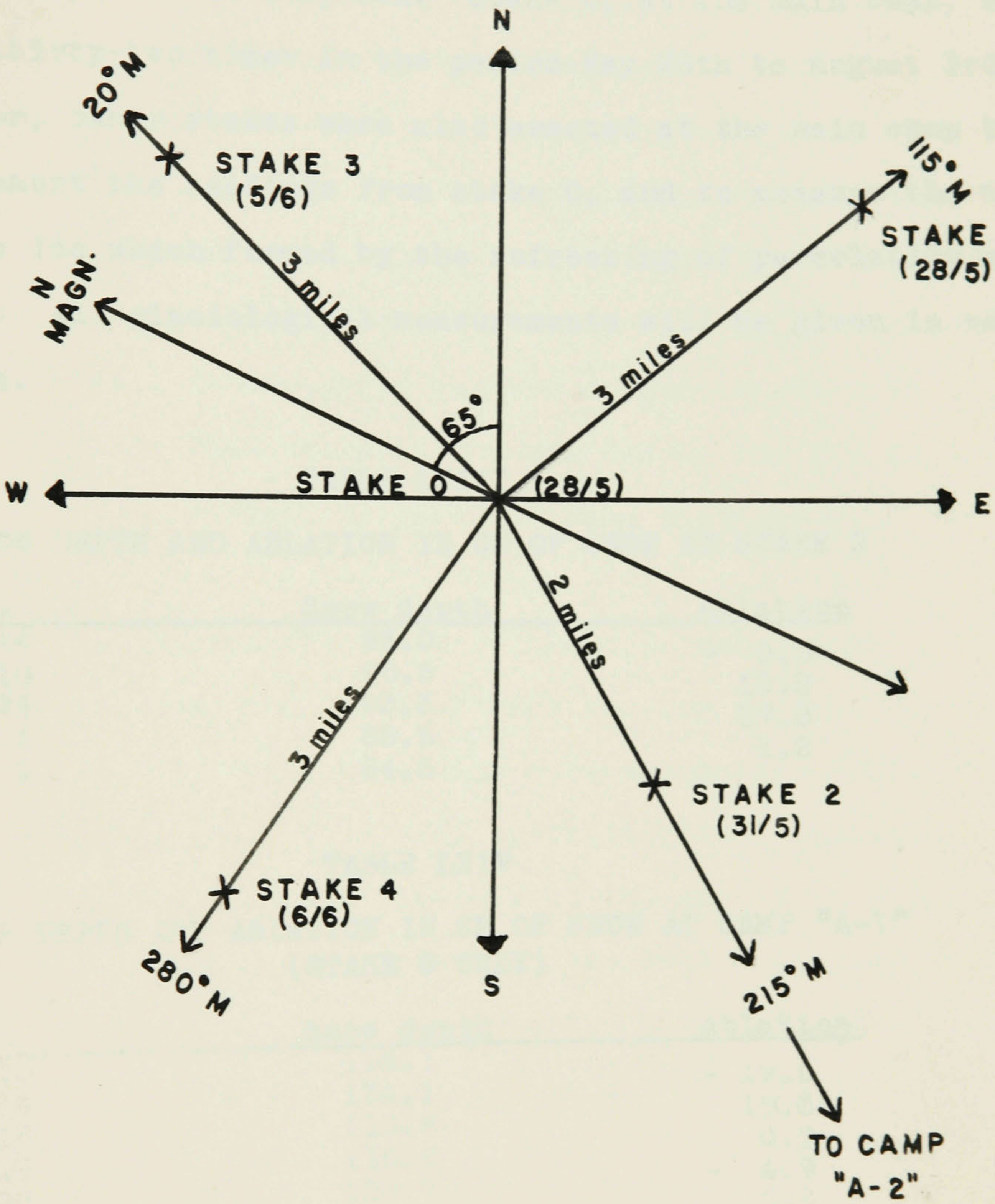


FIG. 42.
DIRECTIONS & DISTANCES
FROM "A-1" TO ABLATION STAKES.

from camp "A-2", and six readings were obtained during the period May 31st to July 9th. Stake 0, at the main camp, was read thirty-two times in the period May 28th to August 3rd. However, other stakes were also erected at the main camp to supplement the readings from stake 0, and to measure the amount of new ice which formed by the refreezing of percolating melt-water. All glaciological measurements will be given in centimeters.

TABLE LXIII

SNOW DEPTH AND ABLATION IN CM OF SNOW AT STAKE 2

Date	Snow depth	Ablation
June 14	96.0	- 0.5
June 18	96.5	13.2
June 26	83.3	17.8
July 1	65.5	1.2
July 9	64.3	

TABLE LXIV

SNOW DEPTH AND ABLATION IN CM OF SNOW AT CAMP "A-1"
(STAKE 0 ONLY)

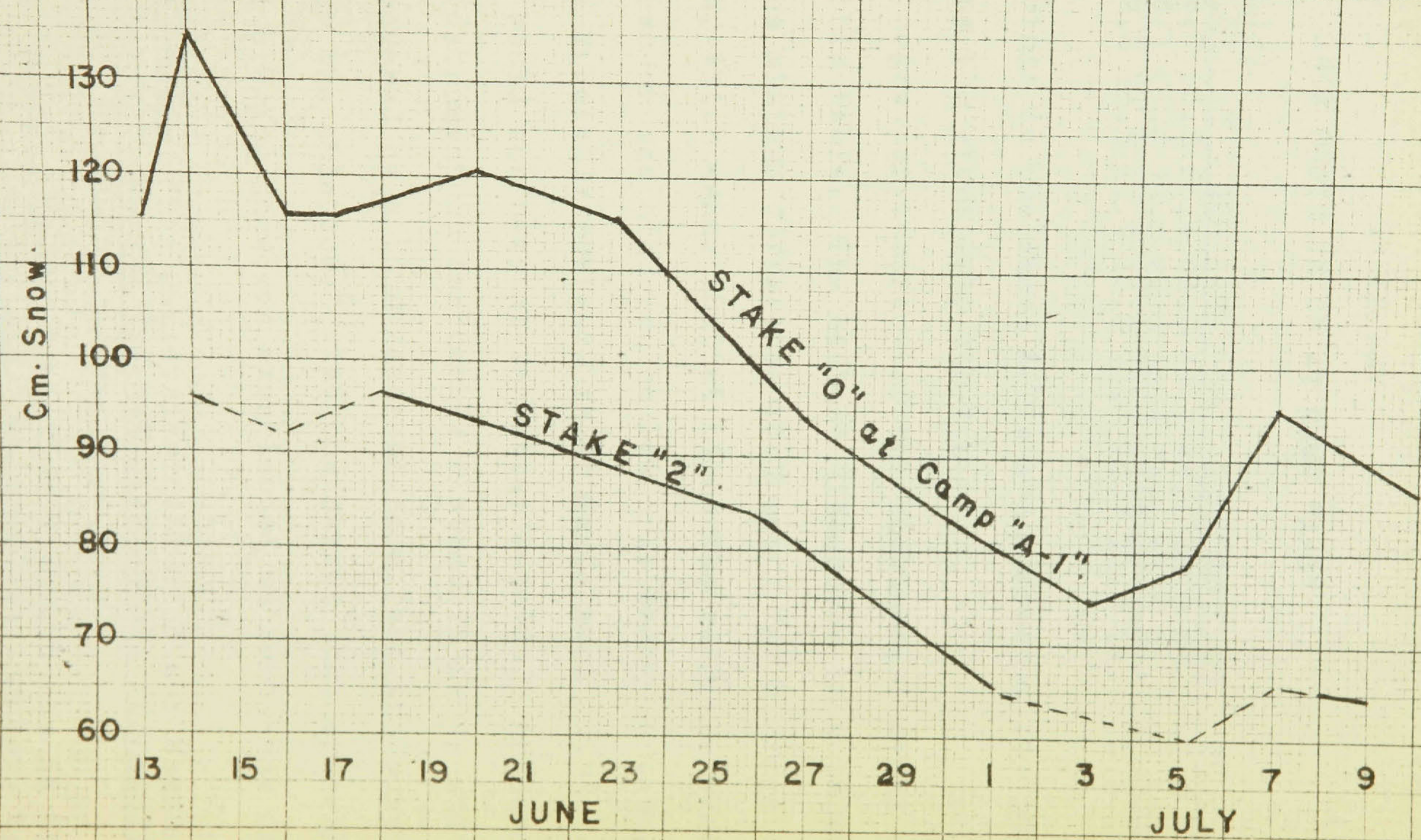
Date	Snow depth	Ablation
June 13	115.1	- 19.0
June 14	134.1	18.3
June 16	115.8	0.0
June 17	115.8	- 4.9
June 20	120.7	5.6
June 23	115.1	5.9
June 24	109.2	15.2
June 27	94.0	10.7
June 30	83.3	8.4
July 3	74.9	- 3.8
July 5	78.7	- 17.1
July 7	95.8	9.4
July 10	86.4	

Figure 43 shows the snow depth and ablation at these two points, two miles apart, for the period June 13th to July 10th. As only five readings were available for stake 2, the lower curve does not show the irregularities due to snowfall on June 12th-13th, June 17th-19th and July 4th-7th, which are seen in the upper curve, where for the same period thirteen readings have been plotted. For the period June 20th to July 1st there is a tendency for the two curves to run parallel, which suggests that the ablation was fairly uniform at different points on the ice-cap, at least at some distance from the sloping edge.

The exposed situation of the main camp, with consequent drifting of snow, and the fact that the ice surface was irregular, made it very difficult to obtain accurate measurements of snow depth and ablation. This difficulty is clearly demonstrated by a series of simultaneous readings at the main camp presented in Table LXV. Stake 0 was planted on May 28th. On June 26th, during a period of clear weather with relatively great ablation, a series of dowels were planted at a distance of 150 feet from stake 0, and the snow depth was calculated as the mean of three readings, one from each of three dowels situated seven yards apart. The average difference in snow depths measured by this method and by stake 0 was 12.7 cm. The main reason for this difference was the undulating ice surface as mentioned previously, but as seen from Table LXV the difference in snow depth varied

FIG. 43.

DEPTHS OF SNOW AT 2 POINTS 2 MILES APART.



from day to day due to the difference in drifting around the different stakes.

TABLE LXV

SNOW DEPTH IN CM AT CAMP "A-1"

Date	(July) 5	7	10	17	18	19	20	22	26	30	31
Stake O:	78.7	95.8	86.4	74.5	69.9	66.1	62.8	56.5	43.8	31.8	28.0
Dowels :	66.1	81.3	74.5	62.5	58.6	55.4	51.5	41.7	28.3	19.4	15.0
Diff. :	12.6	14.5	11.9	12.0	11.3	10.7	11.3	14.8	15.5	12.4	13.0

Readings in the above table are corrected for heavy drift during the storm July 6th-7th.

The degree of accuracy of the snow measurements can be seen from this table. The maximum difference in snow depth was 15.5 cm, the minimum difference 10.7 cm. The average difference was 12.7 cm, which means that at times the readings were probably more than two cm too high or too low. It seems certain, however, that even a specially designed instrument, such as Devik's Ablatograph,[39] would not have given better results. Ahlmann used a similar instrument on Isachsen's Plateau in 1934, and when the float was covered by a thin layer of snow, the instrument would not register the ablation.[40] At the Barnes Ice-cap falling, drifting, or blowing snow was experienced on forty-one days out

39 O. Devik, "Ein Registrierinstrument zur Messung der Ablation," Det Kgl. Norske Videnskabers Selsk. Forhandlinger, Bd. II, No. 31, Trondhjem, 1929.

40 H. W:son Ahlmann, "Ablation Measurements at the Headquarters on Isachsen's Plateau," Geografiska Annaler, Vol. XVII, 1935, p. 49.

of eighty-seven, and under such conditions no present method will give accurate values for the ablation. Because of the changing conditions, new methods were required at different stages. For the first month, from May 28th to June 26th, a single stake, stake 0, was used. This stake was subject to heavy drifting during the storm July 6th-7th. On June 26th, after ablation had commenced and melt-water appeared on the ice surface, eight dowels were planted in a smooth area 150 feet southeast of the camp. The average snow depth to the ice surface, which probably already had risen slightly, was 96.5 cm. On July 31st the snow depth was zero. There was still some wet snow in hollows, but equal areas had bare ice. Ice ablation measurements were started on a smooth, dry ice surface. The distance from a fixed horizontal bar to the ice surface was measured every morning until August 5th, when new snow froze on to the surface and made ice ablation measurements very difficult to carry out. The ice surface lost 4.2 cm of the newly formed ice by ablation in the period July 31st to August 5th. On August 14th three new dowels were planted, and the snow depth was recorded as the mean of three readings for the rest of the period.

In spite of the difficulties encountered, the measured amounts of ablation corresponded well with the variations in temperature, depending far more on high temperatures on odd days than on the average temperature of longer periods, as established by Ahlmann.[41]

The following table gives the daily ablation and snow depth. Measurements were carried out every morning except in the early part of June.

TABLE LXVI

ABLATION AND SNOW DEPTH IN CM OF SNOW

	June		July		August	
Date	Snow depth	Ablation	Snow depth	Ablation	Snow depth	Ablation
28/5	90.9					
1	89.6	1.3	75.4	2.5	11.3	2.5
2		- 7.6	72.9	4.1	8.8	2.0
3	97.2	0.0	68.8	4.5	6.8	1.6
4	97.2		64.3	- 1.6	5.2	1.2
5		- 1.0	65.9	- 7.5	4.0	- 10.8
6	98.2		73.4	- 7.7	14.8	0.0
7		1.8	81.1	- 0.2	14.8	- 2.2
8	96.4	0.0	81.3	3.7	17.0	1.6
9	96.4	- 0.8	77.6	3.3	15.4	- 1.2
10	97.2	0.0	74.3	4.0	16.6	1.3
11	97.2	0.0	70.3	0.5	15.3	1.3
12	97.2	- 17.8	69.8	0.2	14.0	- 12.1
13	115.0	- 19.0	69.6	1.4	26.1	4.2
14	134.0		68.2	1.0	21.9	3.5
15		18.3	67.2	1.0	18.4	- 1.7
16	115.7	0.0	66.2	3.9	20.1	1.3
17	115.7		62.3	3.9	18.8	- 4.1
18			58.4	3.2	22.9	?
19		- 4.8	55.2	3.9	?	
20	120.5		51.3	4.2	37.8	1.3
21			47.1	5.6	36.5	0.6
22		5.6	41.5	1.2	35.9	0.3
23	114.9	5.9	40.3	2.2	35.6	2.2
24	109.0	6.0	38.1	2.8	33.4	- 0.8
25	103.0	6.7	35.3	7.2	34.2	1.1
26	96.3	2.5	28.1	1.3	33.1	0.0
27	93.8	4.5	26.8	2.7	33.1	
28	89.3	5.5	24.1	0.7		
29	83.8	3.9	23.4	4.2		
30	79.9	4.5	19.2	4.4		
31			14.8	3.5		

41 H. W:son Ahlmann, "The Stratification of the Snow and Firn on Isachsen's Plateau," Geografiska Annaler, Vol. XVII, 1935, p. 41.

The snow depth was measured on June 26th to check the above value, and the depth was found to be 96.5 cm, only 0.2 cm different from the calculated depth. On August 5th the snow depth must be considered as having been zero, although some snow was still left at the foot of the ablation stakes. The values given above for the remaining period are therefore 4.0 cm too high. This would give a snow depth of 29.1 cm in the area around the camp on August 26th and check measurements on that date gave a snow depth of 29.4 cm, or a difference of only 0.3 cm. The ablation measurements and snow depth calculations were thus fairly accurate during periods of net accumulation, May 28th to June 27th and August 5th to August 26th. The period of net ablation, however, June 27th to August 5th, presented problems which made accurate measurements quite difficult. The snow depths given in Table LXVI are those existing at the site of the stakes, while the surface in general was free of snow from July 31st to August 5th. As mentioned previously, the surface lost 4.2 cm of ice by ablation during the first four days of August.

II. PERIODS OF ABLATION

Figure 44 shows the daily snow depth as given in Table LXVI, the daily maximum temperature, the five-day running means of mean daily temperature and days with snowfall and strong wind, the maximum wind speeds given in mph. Several periods can be distinguished, and these are indicated in the Figure.

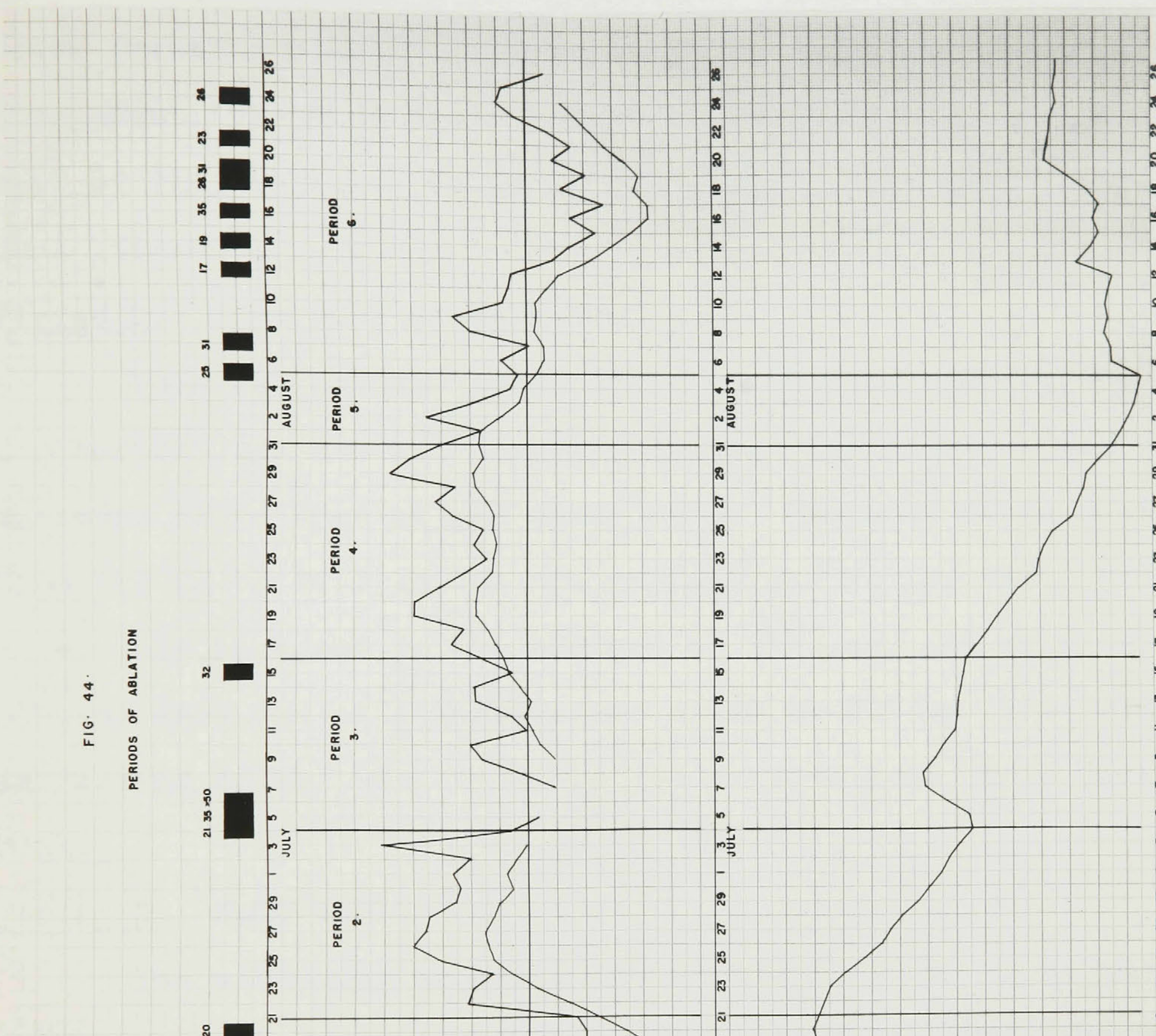


FIG. 44.

PERIODS OF ABLATION

Period 1. May 28th to June 21st.

This period was cold, the mean temperature being well below freezing : 22.9°. Winter snow accumulation continued throughout, the snow depth increasing from 90.9 cm to 119 cm. Most of this snow was added in two storms, June 12th-13th and June 19th-20th.

Period 2. June 21st to July 4th.

This was a fine, sunny period with mean temperature for the period just above freezing : 32.9°. The ablation was steady and more rapid than at any other time. The snow depth decreased from 119 cm to 64.3 cm, on the average 4.2 cm per day. Melt-water soon appeared on the surface of the ice, and all the remaining snow was at a temperature close to 32° by June 28th. Adfreezing of melt-water to the ice surface took place from June 26th.

Period 3. July 4th to July 16th.

The midsummer ablation period was interrupted by storms in this period, much new snow being added. The total accumulation and ablation were nearly equal; snow depth on July 4th being 64.3 cm and on July 16th 66.2 cm. The maximum snow depth for the period was measured after the first storm, being 81.3 cm on July 8th. The temperatures were mainly below 32°, very low during the storm July 4th-6th. Mean temperature for the period was 31.1°.

Period 4. July 16th to July 31st.

Ablation continued throughout this second ablation period.

The snow depth decreased from 66.2 cm to a theoretical depth of 14.8 cm, i.e., an average rate of 3.4 cm per day. The mean daily temperature was above freezing every day of this period, the mean temperature for the period being 35.0°.

On July 17th dark patches of slush were visible in the downslope directions, and the next day saw the camp entirely surrounded by slush, with a rapid stream of slush and water breaking out some 400 yards from the camp. Two days later another stream broke out on the other side of the camp, and the two streams drained the area around the camp, which was situated on a slight dome. On July 31st the area was in general free from snow, and the thickness of the new ice formed in the period June 26th to July 31st was found to be 16.5 cm.

<u>Period 5.</u> July 31st to August 5th.

This was the period of bare ice surface. The mean temperature for the period was 33.1°. Ablation removed 4.2 cm of ice, leaving a net increase of 12.3 cm for the whole summer.

<u>Period 6.</u> August 5th to August 26th.

Temperatures dropped in August, the mean temperature for the last period being 28.1°. Accumulation was renewed and a succession of storms added snow rapidly until August 20th, when the snow depth was 37.8 cm. There was a small amount of ablation after that date, but it was obvious on the last day at camp "A-1" that the snow cover was there to stay.

III. THE BUDGET YEAR 1949 - 1950 AT CAMP "A-1"

On June 10th the snow depth at the main camp was 97.2 cm of density 0.33. Between June 10th and June 22nd the precipitation totalled 0.18 cm of rain and 38.9 cm snow of density 0.17. Precipitation in July totalled 4.7 cm rain and 28.8 cm snow of density 0.18. The density of the new layer of ice on the surface was 0.91.

The following calculation gives the water equivalent of accumulation and ablation during the budget year 1949-50 at camp "A-1":

Water equivalent of winter precipitation to June 10th	: 32.1 cm
Water equivalent of precipitation, June 10th to June 22nd	: 6.8 cm
Water equivalent of precipitation in July	: 9.9 cm
Total water equivalent to August 1st	: 48.8 cm
Water equivalent of 12.3 cm new ice on surface	: 11.2 cm
Lost by evaporation and run-off	: 37.6 cm

The new budget year commenced on August 5th, nearly one month earlier than the averge in Spitsbergen and North East Greenland.[42] The total snowfall in the remaining period of investigation amounted to 55.1 cm, or approximately 9.9 cm of water. Added to this was 1.0 cm of rain. In spite of some ablation a snow cover of 33.1 cm thickness on the last day of observations suggests that a great percentage of the total precipitation falls

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42 H. W:son Ahlmann, "Glaciological Research on the North Atlantic Coasts," R. G. S. Research Series, No. 1, 1948, p. 49.

early in the budget year. Tables XXV and XXVII (page 34) show that also at Clyde and Pond Inlet the heaviest precipitation is experienced in August.

IV. A COMPARISON OF GLACIERS

The quantity of water deposited on the ice surface depends largely on the geophysical character of the glacier. According to Ahlmann it may rise to 100 per cent of the water present during the ablation season on a sub-polar glacier.[43] It is not possible from the available data to evaluate the percentage of present water that did freeze on to the surface of the Barnes Ice-cap, but it seems likely that it was nearer to 50 per cent of the melt-water, at least at the altitude of the main camp. Closer to the top of the ice-cap more of the available melt-water was probably deposited on the ice surface; previous research on this problem indicates that the thickness of the newly formed ice increases with increasing altitude.[44]

The thickness of the superimposed ice at camp "A-1" was such that failure to take it into account when determining the regime of the ice-cap would give completely false results. As seen from the calculation on page 135, the gross ablation was 48.8 cm of water, while the net ablation amounted to 37.6 cm of

43 H. W:son Ahlmann, "The Froya Glacier in 1939-40," Geografiska Annaler, Vol. XXVIII, 1946, p. 251.

44 V. Schytt, "Refreezing of the Melt-Water on the Surface of Glacier Ice," Geografiska Annaler, Haft 1-2, Vol. XXXI, 1949, p. 224.

water.

Apart from some bands of organic material in the older ice it was found impossible to distinguish annual layers of newly formed ice. The bands of organic material could not be dated and did not appear to be a yearly occurrence. Ahlmann studied newly formed ice on some glaciers in Norway and noted that this new ice is directly connected to the glacier ice, and is distinguished by its smaller grains from the old and coarse crystalline glacier ice.[45] No such difference was noted on the Barnes Ice-cap.

The melting process as observed in Baffin Island was strikingly similar to that observed in North East Land, Spitsbergen, and described by several authors. Sandford,[46] Ahlmann[47] and Glen[48] all mention the overwhelming influence upon the conditions of the surface by thaw.

The similarity between the Barnes Ice-cap and ice-caps in Spitsbergen is a direct result of the relatively similar

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45 H. W:son Ahlmann and A. Tveten, "The Recrystallization of Snow into Firn and the Firnification of the Latter," Geografiska Annaler, Vol. V, 1923, cited by Ahlmann in Geografiska Annaler, Vol. XXVIII, 1946, p. 250.

46 K. S. Sandford, "The Glacial Conditions and Quarternary History of North East Land," The Geographical Journal, Vol. LXXIV, 1929, p. 465.

47 H. W:son Ahlmann, "Melting Process during the Ablation Period," Geografiska Annaler, Vol. XV, 1933, pp. 201-06.

48 A. R. Glen, "The West Ice of North East Land," The Geographical Journal, Vol. XCVIII, 1941, p. 139.

meteorological conditions mentioned previously (page 61). The different conditions on several glaciers investigated by Ahlmann are illustrated in a diagram published by him.[49] This diagram is presented here as Figure 45, the only difference being the addition of the Barnes Ice-cap. The lower limit of the accumulation area on that glacier was 2500 feet or 760 meters, and the accumulation = ablation at this "firn" line can be calculated as follows. On June 22nd the snow depth at camp "A-2" was 116.9 cm, the same as at camp "A-1". The line lay midway between the two camps, and the snow depth can therefore safely be taken as being the same at the "firn" line. The density was 0.35.

Water equivalent of winter precipitation to June 22nd	:	40.9 cm
Water equivalent of precipitation in July	:	9.9 cm
Accumulation = Ablation at the "firn" line	:	50.8 cm

In Figure 45 the different glaciers represented are:

V: Vatnajokull, Iceland.

11b, 9, 11a: Norwegian coastal glaciers.

13b, 12, 13a: Norwegian inland glaciers.

4, 5, 6, 8: Glaciers in East Greenland. (8 is central part of East Greenland)

1: Fourteenth of July Glacier, West Spitsbergen.

B: Barnes Ice-cap, Baffin Island.

3: North East Land, East Spitsbergen.

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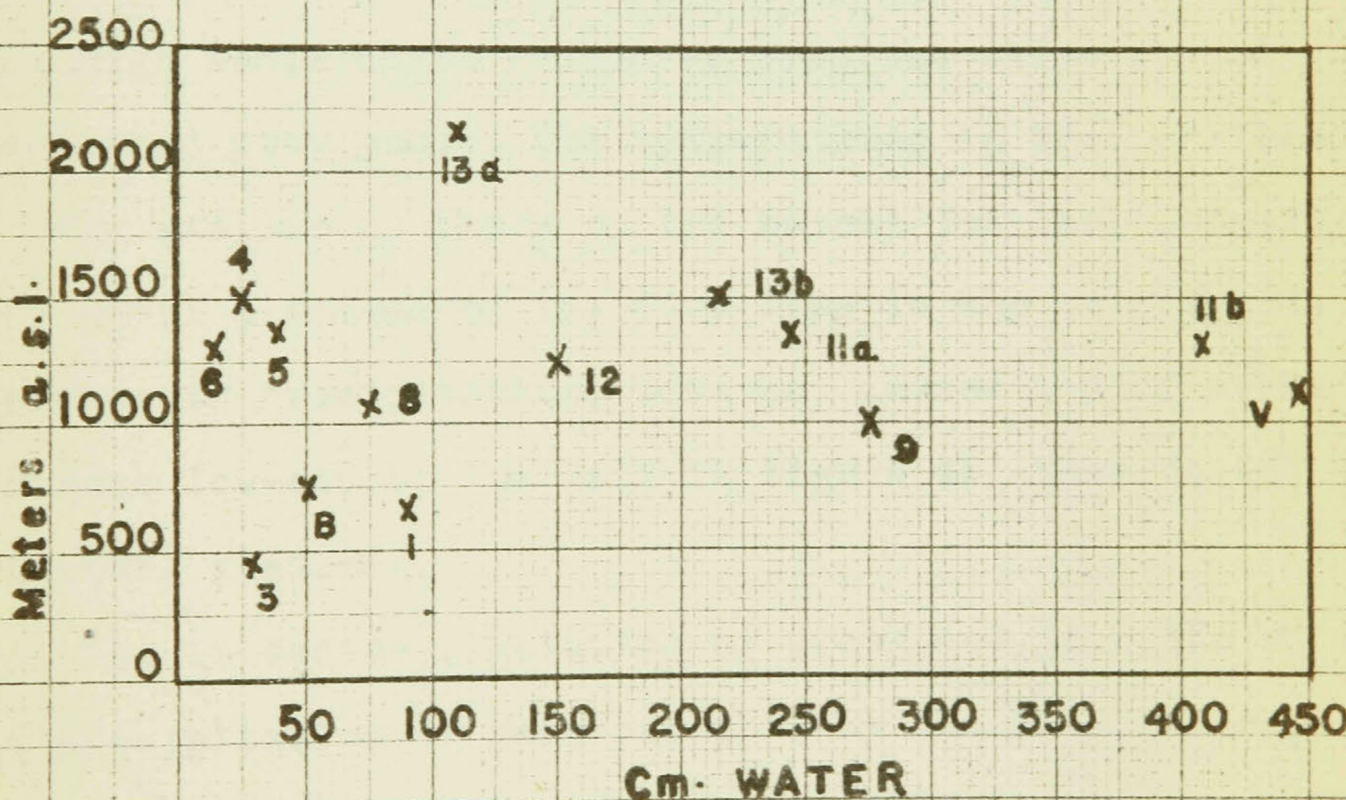
49 H. W:son Ahlmann and S. Thorarinsson, "The Vatnajokull Glacier. Preliminary Report on the Work of the Swedish-Icelandic Investigations, 1936-1937," The Geographical Review, Vol. XXVIII, 1938, fig. 11, p. 431.

FIG. 45.

ACCUMULATION = ABLATION AT THE FIRN-LINE, AND ALTITUDE OF THE FIRN-LINE OF DIFFERENT GLACIERS.



The grouping of the different glaciers is caused by the difference in climate. The Barnes Ice-cap is situated between the Fourteenth of July Glacier which has arctic-maritime climate and North East Land which has arctic-continental climate resulting in a low firn line and small accumulation = ablation.

The relation of the firn line altitude to the accumulation (ablation) depends on both the amount of precipitation and the summer temperature. In East Greenland the high firn line is due not only to the very small accumulation, but also to the relatively high temperature resulting from the clear sky of summer. As mentioned previously, the temperatures in West Spitsbergen were very similar to those on the Barnes Ice-cap; therefore the nearly equal altitude of the firn line in the two places. The difference in precipitation, however, causes a displacement of the Barnes Ice-cap to the left in Figure 45, towards the more continental glaciers.

The extensive glaciation of Greenland in spite of the small precipitation is made possible by the insignificant ablation in the vast accumulation areas.[50] Conditions are reversed in maritime Iceland. Spitsbergen and Baffin Island take up an intermediate position in respect to the magnitude of both ablation and precipitation.

Ahlmann states that not only are most of the world's

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50 H. W:son Ahlmann, "Accumulation and Ablation on the Froya Glacier, its Regime in 1938-39 and 1939-40," Geografiska Annaler, Vol. XXIV, 1942, p. 15.

glaciers retreating, but in many regions the present retreat is the most rapid ever recorded.[51] The glacier caps of North East Land are practically dead, and the Froya Glacier in North East Greenland is almost dead.[52] The reason for this wasting away of the glaciers around the North Atlantic is the general intensification of the atmospheric pressure gradient, resulting in increased supplies of warm air to the regions round the northernmost part of the Atlantic. The most important cause of the reduction in ice area is the negative regime created by the great ablation, which is due to the increased transfer of heat through the atmosphere. Wallen concludes that the increased heat supply from the air is in turn caused by increased summer temperatures, increased summer humidity and a prolongation of the ablation season.[53]

The problem of the increase in atmospheric circulation into the Arctic is not well known on the west side of Greenland,[54] and it is not possible to state that it can be readily detected from observations on the Barnes Ice-cap. All indications were

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51 H. W:son Ahlmann, "Den nutidiga klimatfluktuationen ock dess utforskande," Norsk Geografisk Tidskrift, Bind II, Nos. 7-8, Oslo, 1947.

52 H. W:son Ahlmann, "Researches on Snow and Ice, 1918-40," The Geographical Journal, Vol. CVII, 1946, pp. 11-28.

53 C. C. Wallen, "The Shrinkage of the Karsa Glacier and its Probable Meteorological Causes," Geografiska Annaler, Haft 1-2, Vol. XXXI, 1949, pp. 275-91.

54 R. Scherhag, "Die Erwarmung der Arktis," Journal Conseil Permanent International pour l'Exploration de la Mer, Vol. XII, 1937, pp. 263-276.

that the ice-cap was at least stationary, and certainly not receding. Vegetation grew right up to its edge, there was obvious activity on the ice-cliffs in the lakes, and on the ground moraines could be observed forming.[55]

55 Personal information from P. D. Baird and W. H. Ward.

CHAPTER V

TEMPERATURES OF THE SNOW AND ICE ON THE BARNES ICE-CAP

The scientific program of the expedition included a study of the temperatures of the firn from the surface and down to the greatest depth to which it was possible to sink holes by means of a 2000 watt generator and heating elements. It was hoped that it would be possible to determine the general character of the distribution of temperature in the firn. The measurements were to be undertaken by means of thermo-couples which would be lowered into the melt-hole. Because of the extreme cold of the underlying ice, the maximum depth attained was a little less than three meters from the ice surface.

On June 3rd thermo-couples were placed in the winter snow: No. 153 at 15 cm, No. 154 at 30.5 cm, and No. 155 at 61 cm below the surface. On June 28th No. 153 was moved from the surface and buried at the present ice surface, under 89 cm of snow. On June 30th No. 154 was reset to 30 cm.

On June 4th three thermo-couples were placed in the underlying ice: No. 156 at 25 cm, No. 157 at 145 cm, and No. 158 at 298 cm below the ice surface. Figure 46 illustrates the positions of these thermo-couples.

The temperature variations at different depths are shown in Figure 47. The temperatures of the surface snow increased during the early part of June, except for a drop on June 9th-10th

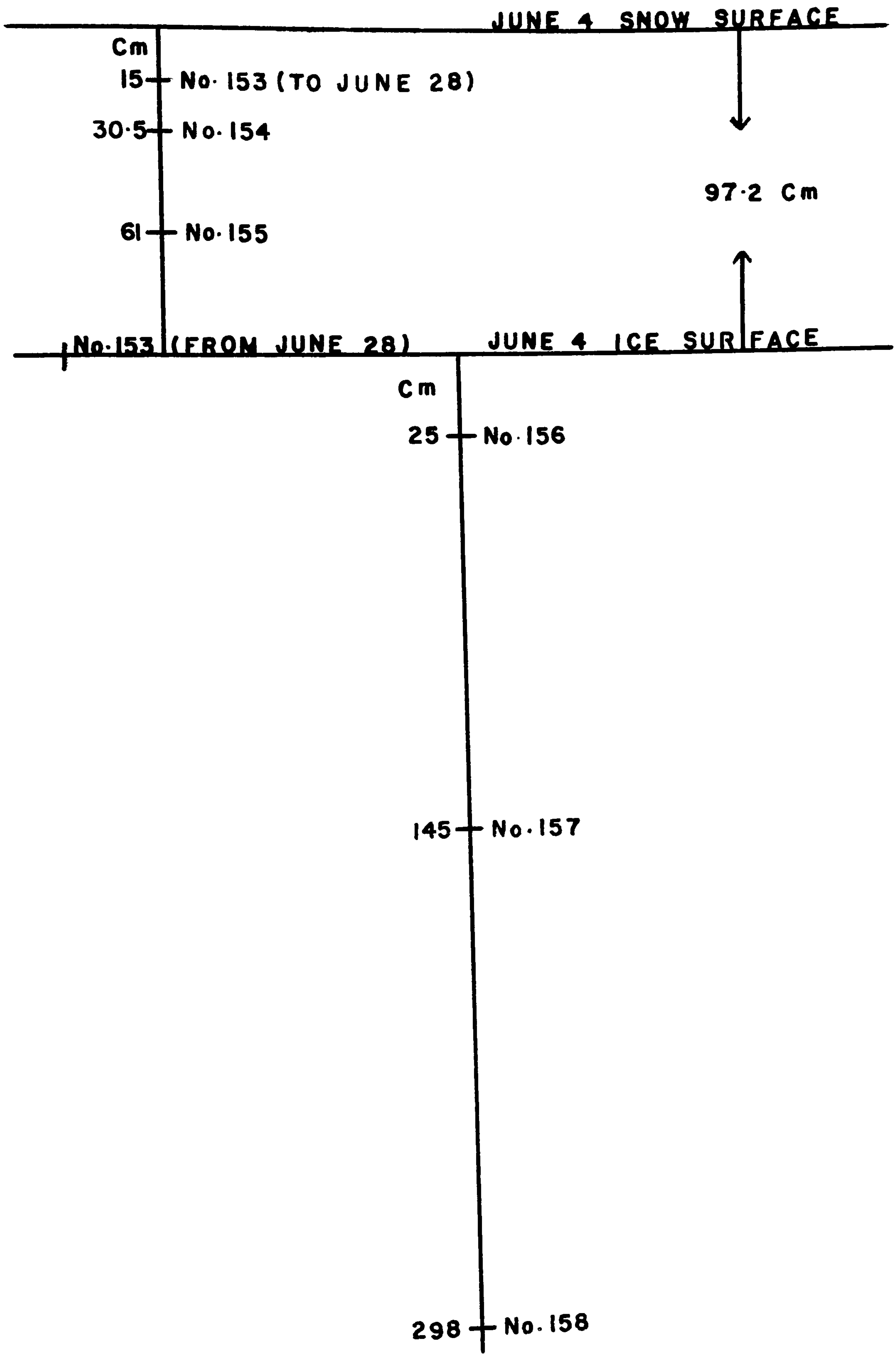
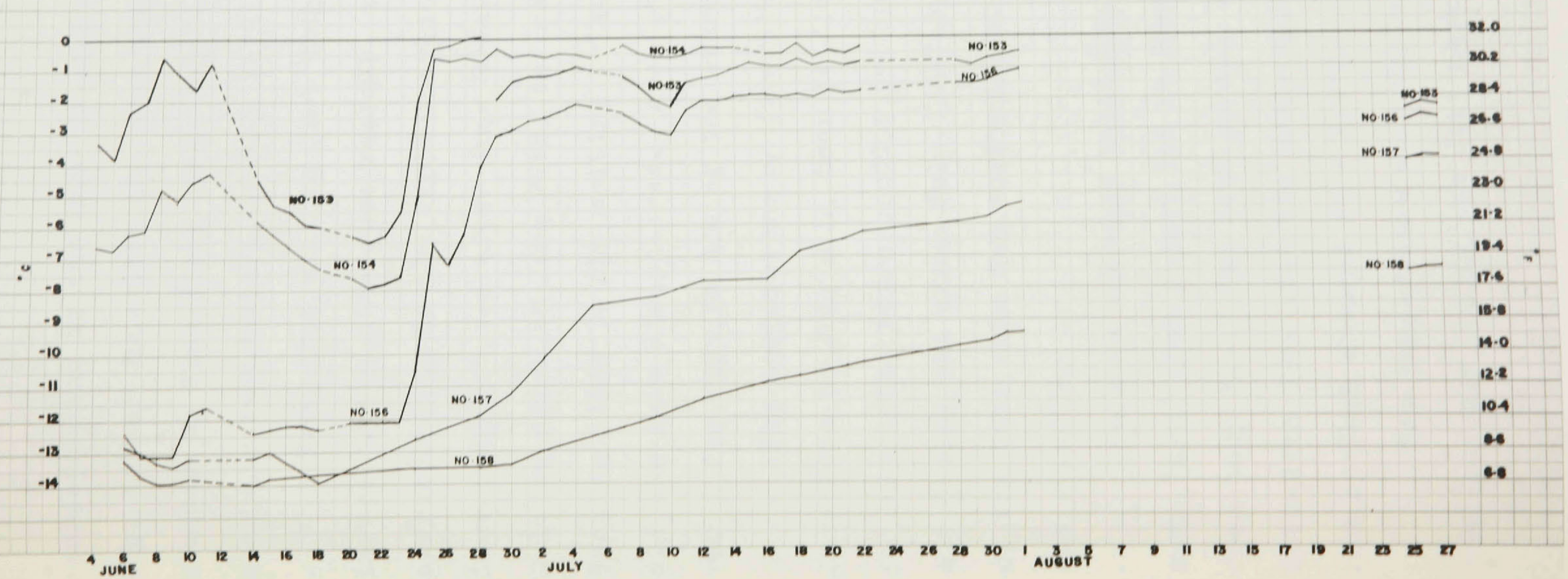


FIG. 46. POSITIONS OF THERMISTORS.

FIG· 47·

THE INCREASE IN TEMPERATURES OF SNOW AND ICE DURING THE SUMMER·



corresponding to the drop in mean air temperature on June 8th-9th. After June 11th the snow temperature again dropped to a minimum on June 21st. This was caused by the sharp drop in mean air temperature on June 14th and 15th.

From June 21st to June 25th the temperatures in the upper layers of the snow rose rapidly, 1.5 to 1.8 degrees (C) per day, corresponding to the rapid increase in mean daily and daily maximum temperatures after June 20th. The surface snow reached the melting point on June 27th, the rest of the thinning snow cover keeping close to the melting point till the end of July, when all the snow disappeared. A slight dip in temperatures was noted for a few days following the storm in early July.

The temperature of the 28th June ice surface rose from June 29th to July 4th, then it dropped to a mimimum of - 2.2°C on July 10th, corresponding to the drop in temperatures of the air during the storm July 3rd-7th. On August 1st the temperature of the 28th June ice surface, now overlain by 16.5 cm of new ice, was - 0.5°C.

Because the only available Wheatstone bridge was used at camp "A-2" from August 1st to 25th, no temperature records exist from camp "A-1" for that period, but the readings on August 25th-26th-27th show that the temperature in the top layer of the ice had by then dropped to - 2.3°C.

The temperature at a depth of 25 cm in the old ice also rose sharply during the last week of June (5.6 degrees C in two days) and was also influenced by the cold period in early July. By August 1st the temperature had risen to - 1.1°C, but by August 27th it again dropped to - 2.7°C. The temperatures in the lower depths of the ice increased more slowly, and they were not visibly influenced by fluctuations in the air temperatures. The drop registered during the first days was probably caused by the disturbance of the temperature distribution caused by the melting of the hole. From the middle of June to August 27th both the curve at 145 cm and that at 298 cm show a slow but steady increase, on the average 0.14 degrees C and 0.09 degrees C per day, respectively.

The summer was too short, and the ice too cold to allow the temperature even at a depth of only 25 cm to rise to the melting point.

The following table gives the temperature at different depths, mainly the morning readings. Usually the temperatures were also observed in the afternoon or evening, but the daily variation was small (0.1 - 0.2 degrees C), and the seasonable warming is well illustrated by plotting the morning readings as function of time, as is done in Figure 47.

TABLE LXVII

SNOW AND ICE TEMPERATURES AT CAMP "A-1", DEGREES C

Date	SNOW 15 cm	SNOW 30.5 cm	June 28 ice surface	ICE 25 cm	ICE 145 cm	ICE 298 cm
4/6	- 3.3	- 6.6				
5	- 3.8	- 6.7				
6	- 2.3	- 6.2		-12.4	-12.4	-13.2
7	- 2.0	- 6.1		-13.1	-13.0	-13.7
8	- 0.6	- 4.8		-13.1	-13.3	-13.9
9	- 1.1	- 5.2		-13.1	-13.4	-13.9
10	- 1.6	- 4.6		-11.8	-13.2	-13.8
11	- 0.8	- 4.3		-11.6		
14	- 4.5	- 5.8		-12.4	-13.2	-14.0
15	- 5.3	- 6.2		-12.3	-13.0	-13.8
16	- 5.5	- 6.6		-12.2		
17	- 5.9	- 7.0		-12.2		
18	- 6.0	- 7.3		-12.3	-13.9	-13.7
20	- 6.3	- 7.6		-12.1		
21	- 6.5	- 7.9		-12.1		
22	- 6.3	- 7.8		-12.1		
23	- 5.5	- 7.6		-12.1		
24	- 2.0	- 5.0		-10.5	-12.6	-13.5
25	- 0.3	- 0.6		- 6.5		
26	- 0.2	- 0.7		- 7.2		
27	0.0	- 0.6		- 6.2		
28	0.1	- 0.7		- 4.1	-11.9	-13.5
29		- 0.3	- 1.9	- 3.1		
30		- 0.6	- 1.4	- 2.9	-11.2	-13.4
1/7		- 0.5	- 1.2	- 2.6		
2		- 0.6	- 1.2	- 2.5	-10.1	-13.0
3		- 0.5	- 1.1	- 2.3		
4		- 0.5	- 0.9	- 2.1		
5		- 0.6	- 1.0	- 2.2		
7		- 0.2	- 1.2	- 2.4	- 8.5	-12.3
8		- 0.5	- 1.5	- 2.7		
9		- 0.6	- 2.0	- 3.0	- 8.2	-12.0
10		- 0.6	- 2.2	- 3.1		
11		- 0.5	- 1.4	- 2.3		
12		- 0.3	- 1.3	- 2.0	- 7.7	-11.4
13		- 0.3	- 1.2	- 2.0		
14		- 0.3	- 1.0	- 1.9		
15		-	- 0.8	- 1.8		
16		- 0.5	- 0.9	- 1.8	- 7.7	-10.9
17		- 0.5	- 0.9	- 1.9		
18		- 0.2	- 0.7	- 1.8	- 6.8	-10.7
19		- 0.6	- 0.9	- 1.9		
20		- 0.4	- 0.8	- 1.7		
21		- 0.5	- 0.9	- 1.8	- 6.4	-10.4
22		- 0.3	- 0.8	- 1.7	- 6.2	-10.3
28			- 0.8	- 1.5	- 5.9	- 9.8
29			- 0.9	- 1.5		
30			- 0.7	- 1.4	- 5.7	- 9.6
31			- 0.6	- 1.2	- 5.4	- 9.4
1/8			- 0.5	- 1.1	- 5.3	- 9.4
25			- 2.4	- 2.8	- 4.0	- 7.5
26			- 2.2	- 2.6	- 3.9	- 7.4
27			- 2.3	- 2.7	- 3.9	- 7.4

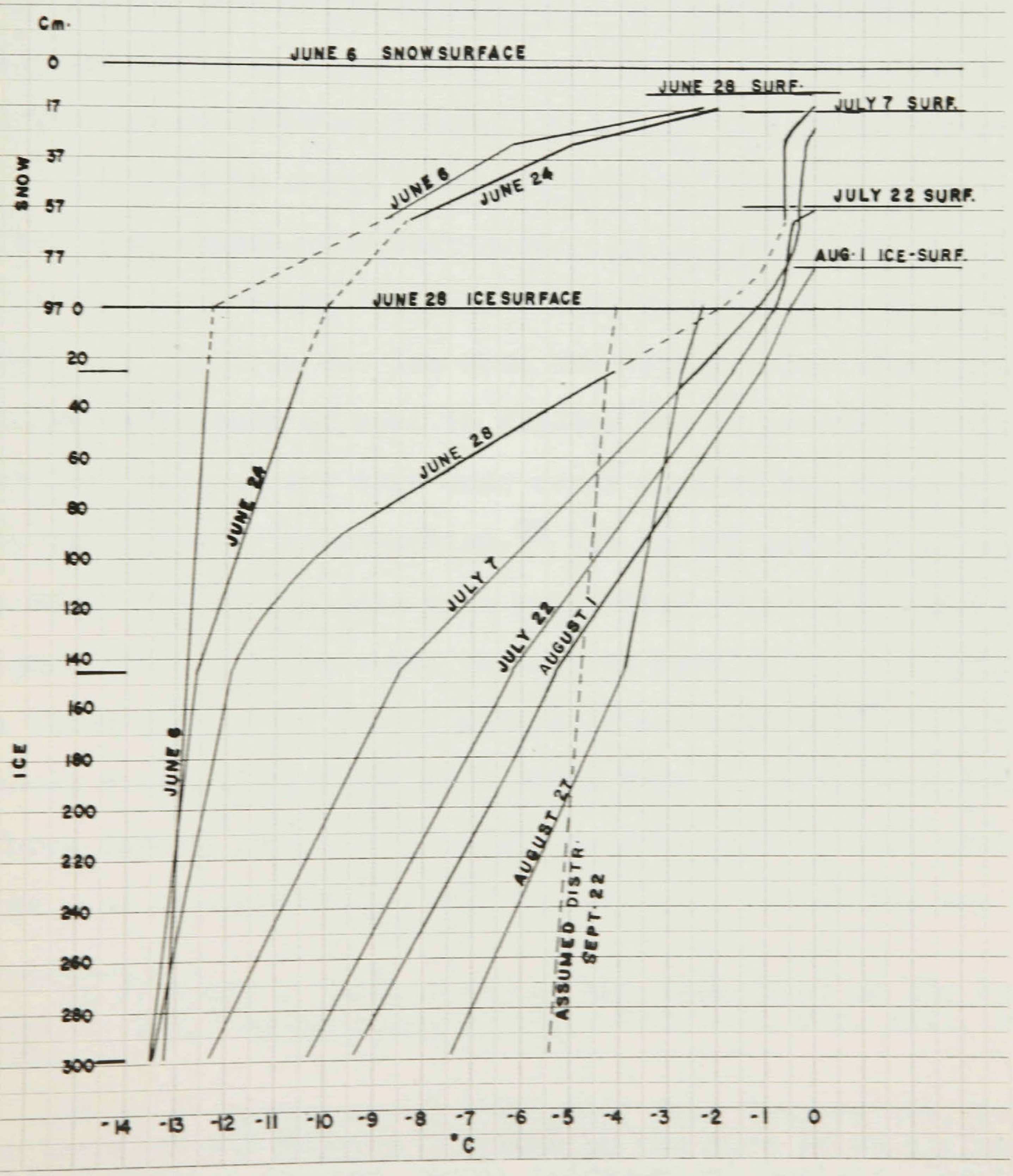
In Figure 48 the vertical distribution of temperature in the snow and in the ice on some selected days is shown.

The characteristics on June 6th are the uniform low temperatures in the ice, and the rapid increase towards the top of the snow layer. The snow covered ice is protected from the incoming radiation by the reflecting and absorbing layer of snow in the spring. The only available heat is the conducted heat, but snow is a poor conductor. When the surface snow begins to melt, the heat is transported more rapidly towards the ice surface, and after June 24th the ice temperatures began to rise more rapidly. The increase in the upper layers of the ice was especially rapid between June 24th and 28th, corresponding to the period when the surface snow reached the melting point. The percolating water now became more important in transporting the heat than the previous conduction. The freezing water released latent heat, and the temperatures in the upper layers of the glacier ice rose to a maximum on August 1st. The temperature gradient then was 0.03 degrees C per cm in the ice, from 0°C at the snow free ice surface (18 cm above the 28th June ice surface) to - 9.4°C at a depth of 316 cm. After the first snowfall in August the temperatures in the upper layers of the ice began to drop, while the temperatures were still rising below 105 cm.

Nothing is known about the winter conditions. It seems that the temperatures then are very uniform in the upper layers of the ice, judging from the distribution on June 6th. A theo-

FIG. 48.

VERTICAL DISTRIBUTION OF TEMPERATURE IN SNOW & ICE



retical curve for September 22nd may be obtained by assuming that the temperature at the 28th June ice surface dropped the same amount during the twenty-six days after August 27th as during the same number of days before that date, and further assuming that the drop at the 25 cm depth also equalled that of the preceding twenty-six days. The lower depths of the ice would still experience an increase of temperature, and the theoretical distribution would be as shown by the dashed curve in Figure 48.

Compared to other known glaciers and ice-caps in the northern hemisphere, the Barnes Ice-cap is exceptionally cold. The reason is possibly that the winter snow cover is too thin to effectively insulate the ice from the winter cold. Schytt notes that the deficiency of heat in glacier ice is greater within the areas that have a very thin snow cover than within those where there is a greater accumulation.[56] It is not possible to say to what depth the winter cold wave penetrates, but Hughes and Seligman state that seasonal variations have never been detectable below a depth of twenty meters in any glacier,[57] and Figure 48 shows a marked decrease in warming from the surface and down to three meters. The summer heat was felt much less at greater depths, and it is unlikely that the seasonal variations are felt

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56 V. Schytt, "Refreezing of the Melt-Water on the Surface of Glacier Ice," Geografiska Annaler, Haft 1-2, Vol. XXXI, 1949, p. 222.

57 T. P. Hughes and G. Seligman, "The Temperature, Melt-water Movement and Density Increase in the Neve of an Alpine Glacier," Monthly Notices, Royal Astronomical Society, Geophysical Suppl. Vol. IV, No. 8, 1939, page. 617.

as deep as twenty meters in the ice.

The Barnes Ice-cap is too small to cause a large degree of cooling and direct self-preserving effects through increased precipitation. The climate of the region is continental in winter, and there is no direct accumulation of snow. Because of the low temperature of the ice, however, accumulation of new ice takes place above a certain "firn" line, and it may be said that the ice-cap is self-preserving in an unusual sense. The "firn" line will move up or down the ice-cap depending on the summer temperatures.

CHAPTER VI

ABLATION AS A FUNCTION OF RADIATION AND METEOROLOGICAL CONDITIONS

Total incoming radiation can be measured by a so-called "actinograph", and intensity of radiation by an "actinometer". No such instruments were available, and the problem of how much heat the surface received by processes of radiation must be left unsolved.

In general the snow surface receives heat by incoming (short-wave) radiation, by conduction from the air if the air temperature increases with height, and by conduction from below if the temperature in the snow increases with depth. Heat is also received if the content of water vapour in the air increases with height, since then water vapour is transported towards the surface where it condenses, and the heat of condensation is liberated.

The surface loses heat by outgoing (long-wave) radiation, by conduction to the air if the air temperature decreases with height, and by conduction downwards if the snow temperature decreases with depth.[58]

The relative significance of radiation and conduction in ablation varies not only with altitude and the general character

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58 H. U. Sverdrup, "The Eddy Conductivity of the Air over a Smooth Snow Field," Geofysiske Publikasjoner, Vol. XI, No. 7, 1936, p. 34.

of the climate, but also with the latitude. Radiation is greatest in high-lying parts; at low altitudes the conduction is of greater importance than radiation, as observed in West Spitsbergen and North East Land.[59]

Several meteorological elements must be considered when calculating the ablation, as it depends not only on temperature, but also on wind velocity, turbulence and specific humidity of the air. The high temperature on some days is more decisive for ablation than mean air temperature.[60]

Sverdrup derived formulae for computing the ablation, based on the results of the work in Spitsbergen in 1934.[61] These formulae, however, can be used only when meteorological observations are available from two or three levels above the surface. This is ordinarily not the case, and Sverdrup therefore developed simplified formulae, which permit a computation of the ablation when observations from one level only are at hand.

Assuming that the average amount of heat which is lost in twenty-four hours is approximately proportional to the amount of

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59 H. W:son Ahlmann, "The Contribution of Polar Expeditions to the Science of Glaciology," The Polar Record, Vol. V, Nos. 37-38, 1949, p. 328.

60 H. W:son Ahlmann, "Contribution to the Physics of Glaciers," The Geographical Journal, Vol. LXXXVI, No. 2, 1935, p. 106.

61 H. U. Sverdrup, "The Ablation on Isachsen's Plateau and on the Fourteenth of July Glacier in Relation to Radiation and Meteorological Conditions," Geografiska Annaler, Vol. XVII, 1935, pp. 145-66.

heat received by radiation income in the same period, the simplified formula takes the form:[62]

1) $$80H = aI + 24bM$$

H is the computed total ablation of the surface, measured in cm of water.

a and b are constants; $a = 0.15$ and $b = 0.32$.

I is the radiation income, measured in gramme calories per square cm.

$$M = \left(t_a + \frac{600 \cdot 0,623}{c_p \cdot p} \cdot (e_a - 4.58) \right) \cdot u_b =$$

$$\left(t_a + m \cdot (e_a - 4.58) \right) \cdot u_b$$

t_a is the air temperature in degrees C at a cm above the surface.

c_p is the specific heat of the air.

p is the barometric pressure in mm Hg.

e_a is the pressure of water vapour in mm Hg at a cm above the surface.

u_b is the wind speed in m/sec at b cm above the surface.

On the Barnes Ice-cap the normal pressure was 905 mb = 679 mm, and m is therefore 2.32.

The formula is developed for a period of surface melting, the temperature of the surface is then 0°C, and the tension of the water vapour at the surface is 4.58 mm.

When the radiation income and ablation are given for periods of twenty-four hours, the formula for the Barnes Ice-cap

62 Ibid., p. 151.

will take the form:

2) $80H = 0,15I + 24 \cdot 0,32 \cdot (t_a + 2,32 \cdot (e_a - 4,58)) \cdot u_b$

or: $80H = 0,15I + 7,68M$

In order to demonstrate the validity of his formula, Sverdrup selected all the overcast days on Isachsen's Plateau on which the air temperature directly above the surface was always above freezing. He found eleven such days, and computed the ablation for each twenty-four hour period. The computed and observed values came very close, the differences being of the order of millimeters of water.[63]

Since no values of I, the radiation income, are available from the Barnes Ice-cap, an attempt will be made here to calculate the ablation on six overcast days, all of which had similar cloud conditions to six days in the same period on Isachsen's Plateau.[64] Although there is a difference in latitude of approximately six degrees between the two positions, it is reasonable to expect nearly the same amount of radiation on completely overcast days in summer, the sun being above the horizon most of the day.

For similar conditions then, values for I, the incoming radiation, have been chosen from Sverdrup's table of diurnal values of the total radiation income.[65] The following table

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63 Ibid., p. 152.

64 H. U. Sverdrup, "The Eddy Conductivity of the Air over a Smooth Snow Field," Geofysiske Publikasjoner, Vol. XI, No. 7, 1936, table IV, pp. 64-68.

65 Ibid., table VII, p. 69.

contains the different factors for the six days chosen, and the difference between the observed and computed ablation. No days in early July were chosen, because the lack of a wet-bulb thermometer prohibited humidity measurements and calculation of water vapour pressure.

TABLE LXVIII

SIMPLIFIED COMPUTATION OF THE ABLATION ON SIX OVERCAST DAYS WITH POSITIVE TEMPERATURES

Date	H_{obs} cm water	I grcal/cm^2	t_{91} °C	e_{91} mm	u_{213} m/sec	M	H_{comp} cm water	$H_{obs} - H_{comp}$ cm water
23/6	2.06	400	0.88	4.81	4.92	6.96	1.42	0.64
30/7	1.76	450	2.96	4.70	3.24	10.50	1.85	- 0.09
31/7	1.40	350	1.90	5.05	2.46	7.36	1.36	0.04
2/8	0.80	270	1.26	4.93	1.68	3.48	0.84	- 0.04
3/8	0.64	500	0.79	4.50	2.79	1.67	1.10	- 0.46
10/8	0.46	250	0.22	4.75	2.57	1.57	0.62	- 0.16

The differences between the observed and the computed ablation are on the whole greater than those calculated by Sverdrup, a reasonable result considering the uncertainty of the I-values used above. The order of magnitude of the differences are, however, the same as those from Spitsbergen, and it is almost certain that less approximate methods than those applied here would give a closer correlation between the observed and the computed values.

Sverdrup applied his formula to observations from North East Land as well as West Spitsbergen, and the results were consistent. He states that the formula can probably be applied at other localities,[66] and the above computation strongly suggests that the formula is a technical formula which under different conditions will give very accurate results, if the necessary information is available regarding radiation and meteorological elements.

The formula was derived on the assumption that the air temperatures were above freezing for the whole twenty-four hour period. Sverdrup found, however, that by giving the constant a the value 0.13 the formula could be used with satisfactory accuracy for periods with below-freezing temperatures. The total ablation can thus be calculated by means of the same formula, if a is given a value between 0.13 and 0.15.

The formula combines the effects of the factors which influence the ablation, but the relative importance of the different factors is quite obscured. A knowledge of the effects of the separate meteorological elements on the ablation is only possible if a continuous and complete record of radiation is available for the whole ablation season.

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66 H. U. Sverdrup, "The Ablation on Isachsen's Plateau and on the Fourteenth of July Glacier in Relation to Radiation and Meteorological Conditions," Geografiska Annaler, Vol. XVII, 1935, p. 163.

CHAPTER VII

SUMMARY AND CONCLUSIONS

I. SUMMARY

The thesis describes the meteorological conditions on the Barnes Ice-cap in Baffin Island during the period of ablation in 1950. The weather in northern Baffin Island during the budget year 1949-1950 is discussed, and a short account is given of the ablation measurements and temperature measurements of the underlying ice. An attempt is made to calculate the ablation from meteorological data on a few selected days, and the results are compared with the actual ablation observations.

THE BUDGET YEAR 1949 - 1950

The surface temperatures at Clyde were, with few exceptions, higher during the summer of 1950 than the means for the four years 1943-1946.

At Clyde the summer precipitation of 1950 was more than twice the average summer precipitation for the four years 1943-1946.

The mean temperatures at the 900 millibar level over Clyde in the summer of 1950 were somewhat lower than those in 1949; the relative humidity was higher than in 1949.

The temperatures and precipitation at Pond Inlet during the summer of 1950 were very close to the long-term means, as were the temperatures at Arctic Bay.

Studies of the vegetation at the edge of the ice-cap showed that in 1950 it was stunted compared to the previous summer's.

The winter snowfall (1949-1950) at Clyde was more than twice as heavy as the average, and at Pond Inlet it was one and a half times the normal.

METEOROLOGICAL OBSERVATIONS

Temperature.

The mean daily temperature for the whole period of investigation was 29.5°; the absolute maximum, recorded on July 3rd, was 42.2°. The absolute minimum, recorded on June 15th, was 5.6°.

The mean daily temperature increased more at Clyde from June to July than it did at camp "B" or at the ice-cap.

The average difference in mean daily temperature between Clyde and camp "A-1" was 9.4 degrees F, i.e., 0.6 degrees C/100 meters. This is the same as the mean gradient of the free atmosphere.

The temperature increased with height above the glacier surface in 78 per cent of all temperature observations. The reason for the irregularities in the remaining 22 per cent of the observations was probably either insufficient shielding of the thermo-couples at thirteen feet, or a lack of ventilation. The increase of temperature with height in the lower layers of the air was most rapid in the melting period, when the snow surface was at a constant temperature of 32°. The average increase between three feet and twenty-three feet above the surface was 2.61 degrees F.

The occurrence of below-freezing temperatures near the surface during the period of ablation was different from the conditions on the Froya Glacier in East Greenland, but much like the conditions on Isachsen's Plateau in West Spitsbergen.

The frequency distribution of temperatures above the surface on the Barnes Ice-cap shows the same characteristics as the frequency distribution on Isachsen's Plateau. On the Froya Glacier the distribution was found by Eriksson to be different; there the glacier was incapable of reducing the air temperature to the freezing point.

The westerly and northwesterly winds were somewhat warmer than winds from other directions, the reason being the periods of clear weather and continuous insolation connected with these wind directions. Northwest winds brought the air along the long axis of the ice-cap, and the cooling was more pronounced than that noted with westerly winds, which brought the air over a shorter distance of the ice-cap.

The clear nights in June were cold at the surface due to the strong outgoing radiation. August nights were warmer at the surface but colder at the higher levels. The clear weather in June thus resulted in a greater diurnal variation at the surface than in any of the other months.

The temperatures were found to increase rapidly at some little distance from the edge of the ice-cap. The surface temperature of air that swept off the ice increased up to six degrees over short distances (600 feet or less), if the land was free of snow and heated by the sun. On overcast days the increase was less, and when the surrounding land was snow covered the increase became negligible.

Humidity.

The humidity measurements were not satisfactory, mainly because it was difficult to measure humidity with a sling psychrometer at air temperatures near or below the freezing point.

The relative humidity never deviated much from 100 per cent near the surface, but at twenty-three feet above the surface relative humidities as low as below 50 per cent were occasionally observed.

Especially in June the relative humidity decreased sharply with height, mainly during the period with maximum ablation, which began June 21st.

Wind.

The average difference in wind speed between the two levels, seven feet and twenty-three feet, was 2.6 mph. As a rule the wind speed was quite high; the average at seven feet was 9.7 mph and at twenty-three feet 12.4 mph. The wind was far stronger on the Barnes Ice-cap than on either Isachsen's Plateau or the Froya Glacier.

Pressure.

The pressure variations at Clyde and at the ice-cap station were very similar. The changes in wind speed followed the changes in pressure quite closely. Several frontal systems passed over the northern areas of Baffin Island during the summer, giving strong winds and heavy precipitation. A non-frontal cyclone was situated over Davis Strait for eleven days in August; thereafter it moved westwards to Foxe Basin, where it was situated for the next seven days.

Clouds, cloudiness and fog.

Of all cloud observations 70 per cent showed St-forms; otherwise numerous forms were observed. Nearly half the observations showed completely overcast sky. A typical sequence of frontal clouds was observed on several occasions.

The probability of fog increased from 0.18 in June to 0.54 in August. The probability of fog for the whole period was somewhat less than that found in West Spitsbergen, where the water content of the air is high due to the nearness of open water.

The west and northwest winds were consistently free of fog even in August, the reason being a distance of more than 200 miles to open water in those directions.

Sunshine.

Only eight days had an amount of sunshine approaching the maximum possible. Twenty-one days -- nearly 25 per cent of the time -- had no sunshine. The mean daily temperature was often lower on days with many hours of sunshine than on days with overcast weather, the reason being the lower minimum temperatures on clear nights.

The ice-cap acts as a temperature stabilizer in the period of ablation. On clear days the melting surface keeps the air temperatures relatively low, and on clear nights the long-wave radiation from the surface cools the air. On overcast days the diurnal variation of temperature was less than on sunny days, but in both cases the actual air temperature at the ice-cap station depended on the initial temperature of the air when it was over the adjoining land, and on the distance travelled over the ice surface. The initial temperature is governed by insolation and the ratio of snow covered to snow free land.

ABLATION MEASUREMENTS

The Barnes Ice-cap does not fit readily into Ahlmann's classification of glaciers, the most important reason being the absence of a firn line in the usual meaning of the word.

In 1950, as in 1948, there was melting snow and partly bare ice over the whole surface. Above an altitude of approximately 2500 feet several inches of newly formed ice remained when persistent snow fell again in August. The adfreezing shows a net gain during the year above a line which corresponds to the firn line and is situated at about 2500 feet, or somewhat higher on the northern part of the ice-cap.

The measurements of the snow depth showed differences over short distances because of the undulating ice surface. The wind will always smooth the snow surface, and thus the hollows and domes in the ice surface are concealed.

The ablation was fairly uniform at different points on the ice-cap, at least some distance away from the sloping edge. The degree of accuracy of the daily snow measurements was not altogether satisfactory, but over longer periods these measurements did not differ much from the control measurements.

Periods of ablation.

Six periods can be distinguished in the ablation season; only in two of them did the snow ablation exceed the snow accumulation. In Period 2, June 21st to July 4th, the snow depth decreased by 54.7 cm, and in Period 4, July 16th to 31st, it decreased by 51.4 cm.

In Period 5, July 31st to August 5th, the ablation removed 4.2 cm of newly formed ice, leaving a net increase of 12.3 cm for the whole summer. Probably around 50 per cent of the melt-water present at the altitude of camp "A-1" froze on to the surface, while nearer the top of the ice-cap more of the available water was deposited on the ice surface.

The melting process as observed in Baffin Island was strikingly similar to that in Spitsbergen as described by several authors.

Classification.

The total accumulation (≅ ablation) at the "firn" line was calculated to be 50.8 cm of water. The altitude of the "firn" line was approximately 760 meters. These values place the Barnes Ice-cap close to the ice-caps in Spitsbergen in a general classification of glaciers -- a direct result of the relatively similar meteorological conditions.

The Barnes Ice-cap is not receding. Studies of the vegetation and moraines along its southern edge indicate that it is at least stationary.

TEMPERATURES OF THE SNOW AND ICE

The temperatures of the snow were influenced by the air temperatures before melting commenced. After June 23rd the percolating melt-water transported heat downwards to the ice surface, and there was a rapid increase in the temperatures of the snow and the top layer of ice. The temperature at a depth of 25 cm in the ice rose rapidly from -12°C to around -2°C, and then it fluctuated near -2° through most of July, until the thinning snow cover finally disappeared near the end of the month.

The temperature at 145 cm in the ice rose steadily from -13.9°C on June 18th to -3.9°C on August 27th. The effects of the period of cold weather from July 4th to 7th were noticed as a slowing-up of the daily temperature increase. On August 27th the temperature at a depth of 158 cm in the ice was still rising, having then attained a maximum of -3.9°C.

The temperature at 298 cm rose steadily but more slowly from -14°C on June 14th to -7.4°C on August 27th, and it was still rising on that day. No effects were noted at that depth of the temperature fluctuations over the surface.

When the ice surface was covered by a thin layer of new snow the temperatures began to drop in the upper layers, while the summer heat was still felt below 105 cm.

CALCULATION OF ABLATION

Sverdrup's formula for computing the ablation from meteorological data was used on six days with completely overcast sky. The incoming radiation was not known, but values for this factor were selected from Sverdrup's table of radiation income in Spitsbergen, using only days with similar conditions in the two places.

The differences between the calculated and the observed ablation were greater than those found in Spitsbergen, but not excessive despite the uncertainty of the values of incoming radiation. The maximum difference between the observed and the calculated ablation in twenty-four hours was 0.64 cm of water, and the minimum difference was 0.04 cm of water.

II. CONCLUSIONS

THE BUDGET YEAR 1949 - 1950

The summer of 1950 was colder on the Barnes Ice-cap than the summer of 1949, but the temperatures were not far from the normal over a longer period. The amount of summer precipitation was above the normal for a longer period, and probably above that of 1949.

The conditions were unfavourable for ablation compared to the summer of 1949, but not very different from an average ablation season.

More new ice formed on the surface in 1950 than in 1949, but it is probable that an ice accumulation of the same order of magnitude, approximately five inches, takes place in some years, and such accumulation is likely to have been regular at an earlier stage.

The winter accumulation on the ice-cap in 1949-1950 was greater than average. This fact, combined with the unfavourable conditions during the summer, resulted in less net loss of ice from the surface in 1950 than in 1949, and the period of snow free ice surface is longer in most years than the four days in

1950.

METEOROLOGICAL OBSERVATIONS

Temperature.

The Barnes Ice-cap and Isachsen's Plateau in West Spitsbergen are both capable of reducing the air temperature to freezing. On the Froya Glacier in East Greenland the conditions are different. There the supply of heat to the glacier by way of convection is much greater than in the other locations.

The temperature on the Barnes Ice-cap was only indirectly dependent on the wind direction; the governing factor was the pressure distribution -- the clear weather and continuous insolation connected with high pressure. The variation of air temperature during the day was due to the diurnal change in the heating of the air before passing over the glacier surface, and not due to a difference in the cooling effect of the ice-cap surface at different times of the day.

On the whole the stratification was stable over the surface, in the majority of cases up to twenty-three feet above the surface.

The effect of the ice-cap on the climate of the surrounding land is surprisingly small. When the snow covered the ice-cap and the adjoining land no differences in temperature could be detected. In the summer the presence of the large melting surface, at a constant temperature of 32°F, would be expected to influence the air temperatures over a wide area, but on sunny days with bare ground this was found not to be the case. The formation of fog was also restricted to the ice-cap itself. There was, as far as could be observed, always a clear zone along the edge. This zone was usually up to six miles wide.

Wind.

Only on a few occasions was a down-slope wind observed, which differed in direction from the upper wind. The direction of the wind at the two levels above the surface was always the same. The absence of a katabatic wind was due to the slight gradient of the surface.

Pressure.

The reason for the strong winds on the ice-cap was the frequent passages of cyclones near or over northern Baffin Island. At least two well developed cyclones passed over the region of the ice-cap, and non-frontal cyclones were significant in the general circulation. It seems that well developed frontal systems may form or travel farther north than is generally recognized.

ABLATION

A "firn" line, dividing the the areas of net accumulation and net ablation, could be located at approximately 2500 feet above sea level on the southern lobe. The net accumulation was not snow or firn, but several inches of new ice, which formed on the old glacier surface.

The ablation corresponded well with the changes in temperature, depending more on high temperatures on odd days than on average temperatures of longer periods.

The new budget year commenced on August 5th, nearly one month earlier than the average in Spitsbergen and North East Greenland. A great percentage of the total precipitation falls early in the budget year.

Apart from some bands of organic material in the old ice, it was found to be impossible to distinguish annual layers of new ice. The bands of organic material did not appear to be a yearly occurrence.

Classification.

Ahlmann has classified glaciers by the accumulation (= ablation) at the firn line and the altitude of the firn line.[67]

"Arctic-continental" glaciers, according to Ahlmann, have an accumulation at the firn line of 0-50 cm of water, and "arctic-maritime" glaciers have an accumulation of 50-100 cm of water and an altitude of the firn line of 0-750 meters above sea level. More pronouncedly continental climates are characterized by less accumulation and a higher firn line.

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67 H. W:son Ahlmann, "The Fourteenth of July Glacier," *Geografiska Annaler*, Vol. XVII, 1935, p. 217.

The Barnes Ice-cap, with an accumulation at the "firn" line of 50.8 cm, and an altitude of that line of 760 meters, must be placed on the dividing line between "arctic-continental" and "arctic-maritime" glaciers.

From only one season's observations it is not possible to state that the general "warming of the Arctic" is making itself felt in the area of Baffin Island. The studies of the Barnes Ice-cap seem to indicate that such is not the case. The ice-cap is at least stationary, and certainly not receding.

TEMPERATURES OF THE SNOW AND ICE

The winter conditions are characterized by uniform, low temperatures in the ice. At a depth of only 25 cm temperatures as low as -13°C were recorded in the beginning of June. The ice was protected from the incoming radiation by the snow cover in spring. The only heat available was the conducted heat, but snow is a poor conductor. After melting commenced, the heat was transported more rapidly to the ice surface, and the lower layers of ice gradually felt the effect of the summer heat.

Compared to other known glaciers and ice-caps in the northern hemisphere the Barnes Ice-cap is exceptionally cold. The reason is probably that the average winter snow cover is too thin to effectively insulate the ice from the winter cold. The ice-cap is too small to cause a direct self-preserving effect through increased precipitation over the ice-cap itself.

However, due to the low temperatures of the ice a certain accumulation of new ice takes place during the ablation season, and in an unusual sense the ice-cap may be said to be self-preserving.

CALCULATION OF ABLATION

The results of the calculation of ablation indicate that Sverdrup's formula is a technical formula, which will give accurate results in different localities if the necessary information is available regarding radiation and meteorological conditions.

The relative importance of the different meteorological factors in the process of ablation is obscured, and an investigation of this problem is only possible if a continuous and complete record of the radiation is available for the whole period of ablation.

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