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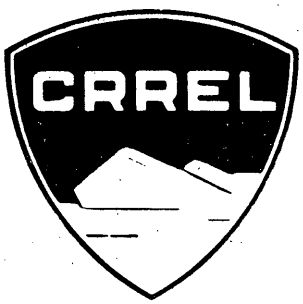

Special Report 216

SUMMER CLIMATE AT SELECTED SITES ON THE ROSS ICE SHELF AND THE GREENLAND ICE SHEET

Michael A. Bilello and Roy E. Bates

January 1975

PREPARED FOR
NATIONAL SCIENCE FOUNDATION
BY
CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

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PREFACE

This report was prepared by Michael A. Bilello, Meteorologist, and Roy E. Bates, Meteorological Technician, Snow and Ice Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. The study was sponsored by the National Science Foundation's Office of Polar Programs under Grant AG 394 as part of the Ross Ice Shelf and Greenland ice sheet programs, B.L. Hansen and C.C. Langway, Jr., co-principal investigators.

The report was technically reviewed by B. Lyle Hansen, James R. Hicks and Steven J. Mock.

Manuscript received 21 February 1974.

CONTENTS

ILLUSTRATIONS

TABLES

SUMMER CLIMATE AT SELECTED SITES ON THE ROSS ICE SHELF AND THE GREENLAND ICE SHEET

PART I: RESUME OF THE SUMMER CLIMATE ON THE ROSS ICE SHELF, ANTARCTICA

by

Michael A. Bilello

Introduction

Climatic summaries for several stations on and near the Ross Ice Shelf, Antarctica, were obtained to determine the type of weather that can be expected in the area between October and February. The information was required in support of an ice drilling project that will be conducted at approximately 82°30'S, 166°00'W during 1974-75.

Data sources

The most useful and complete weather observations for the area under investigation have been made at the U.S. Navy Station Brockton, which is located at 80°01'S, 179°52'W (Fig. 1). Six years of weather data (October 1966 - February 1972) have been summarized and published by the U.S. Navy (1973). Monthly averages of pertinent weather elements for the months October through February were extracted from these summaries (Table I). Most of the discussion in this resume is based on the data contained in this comprehensive summary.

Average monthly values of the climate at four stations surrounding the Ross Ice Shelf (McMurdo, Little America V, Byrd and Amundsen-Scott) were also compiled (Table II). These summaries were derived from data published by the U.S. Department of Commerce (1956-1964) and Wilson (1968). McMurdo and Little America V are near the seaward edge of the Ross Ice Shelf and Byrd and Amundsen-Scott (South Pole) stations are on the Antarctic Ice Sheet. These stations consequently are not as representative of the area of interest as is Brockton.

Microfilm of the original daily weather observations made during Dr. A.P. Crary's traverse on the Ross Ice Shelf from 25 October 1957 to 12 February 1958 (Fig. 2) was obtained from the Environmental Data Service, National Climatic Center, NOAA, Asheville, N.C. (Crary 1960). These observations, which were made three times a day at about 0600, 1200 and 1800 local time, were presented to show day-to-day weather conditions rather than as climatic summaries.

Discussion

The following brief discussions of each of the observed meteorological parameters attempt to describe the type of climate that may be expected in the area of operations. The interpretations are based on the summarized data given in Tables I and II and the daily account of the weather observed during the ice shelf traverse by Crary (Table III).

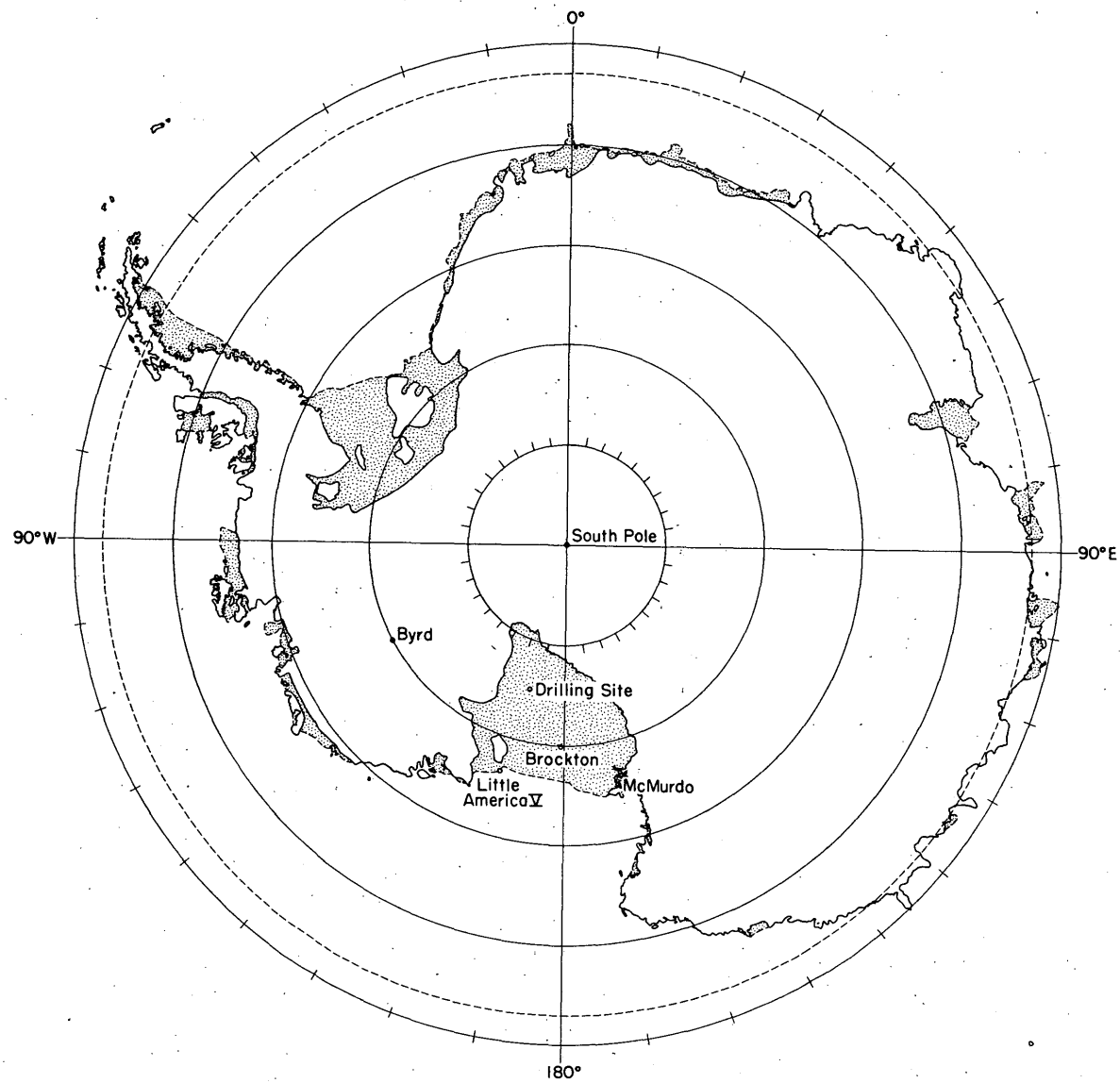

Figure 1. Location of stations in Antarctica.

Air temperature. Average air temperatures based on 6 years of data obtained at Brockton show that December and January are the warmest months (Table I). The average maximum and minimum values at this time range between 10° and 23°F, indicating that thawing conditions seldom occur, even during mid-summer. October appears to be quite cold and the first definite signs of significant warming occur in November. February, however, is apparently consistently warmer than November as indicated by the average minimum temperatures, which remain above 0°F. The ice shelf traverse temperature values (Table III) show these same trends. McMurdo is significantly warmer, and the Little America V region only slightly warmer than Brockton during this period (Table II).

Snowfall. Although it is suspected that the snowfall observations made at Brockton (Table I) were not entirely accurate, it appears that light amounts of snowfall can be expected during the summer months. The highest monthly average observed at Brockton during the season (2.0 in. in December) is small compared with the snowfall averages reported at McMurdo and Little America V

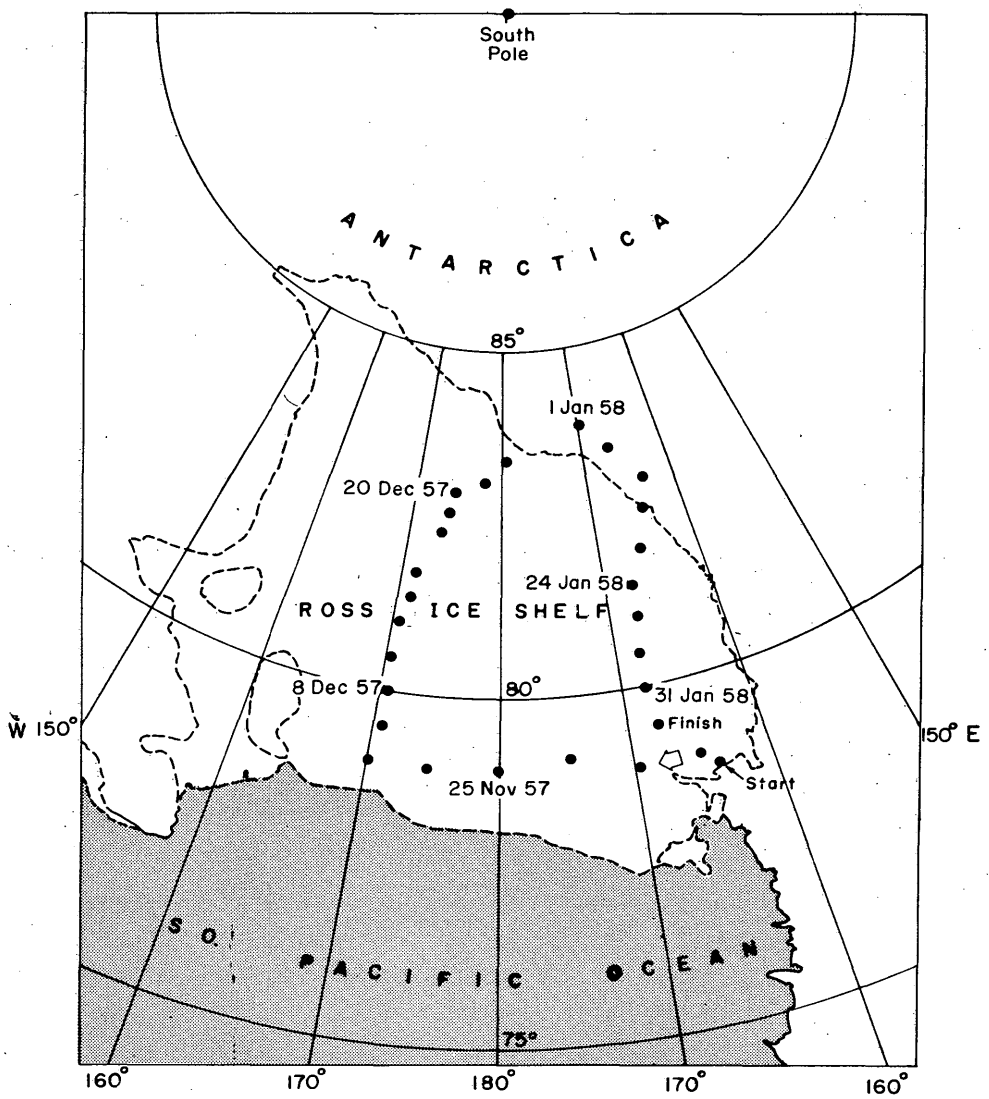

Figure 2. Plot of Crary's Ross Ice Shelf traverse.

between October and February. Note also that as much as 24 to 37 in. of snow can occur per month at Little America V between December and March (Table II).

During the 111 days of weather observations on the Crary traverse (Table III) heavy snow was reported on four days, moderate snow on five days, and light snow on 12 days. Snow amounts during these storms were not recorded. This total of 21 days of snow over 111 days of observation gives a frequency of 19%, which agrees with the percentages (12 to 23%) obtained for Brockton between November and February. However, the last part of the traverse was along the eastern edge of the Ross Ice Shelf (Fig. 2) and thus the data may not typify the summer climate near the center of the ice shelf.

Wind. The prevailing wind direction at Brockton is south or south-southeast throughout the summer (Table I). The records for Little America V also show winds from the south to southeast. The dominant winds at McMurdo come more from the eastern quadrant. A daily account of the wind direction in the Crary record (Table III) shows that the wind blew from all directions and that some of the strongest winds were from opposite directions, e.g. north-northeast at 17 knots on 3 November 1957 and south-southwest at 18 knots on 3 December 1957.

Average monthly wind speeds at Brockton in summer range between 6 and 9 knots. Daily wind speeds are quite variable, as indicated by the traverse record. Probably the most important phenomenon is high wind, which causes blowing and drifting show. From Crary's record it appears that on the Ross Ice Shelf about 10 such events can occur each summer. Depending on the condition of the snow cover, winds as light as 9 knots will occasionally move the snow. But winds of 15 knots or more are usually needed to cause major drifting, and drifting is significantly reduced when the snow surface is very hard.

Visibility. Low visibility, i.e. under 1 mile, occurs on the Ross Ice Shelf during periods of moderate to heavy snowfall, blowing or drifting snow, whiteouts and fog. During Crary's expedition such events occurred on about 14 days, a summer frequency of about 13%. At Brockton, the combined condition of visibility less than ¾ mile and ceiling less than 900 ft occurs 10 to 20% of the time between October and February. McMurdo shows similar percentages for visibility of less than ¾ mile between October and March. These figures from different sources show good statistical agreement.

Surface fogs occur about 10 to 15% of the time during summer at Brockton. Fewer fogs were observed during the Crary traverse than this frequency implies and they were both the light ground fog type as well as heavy fog. Between 23 and 27 December 1957 whiteout was reported during 3 days at approximately 83.5°S, 179.0°E. Fogs also occurred less frequently between November and February at Little America V than at Brockton. As noted earlier, blowing and drifting snow was observed about 10 times during Crary's 3½-month expedition. At Brockton and Little America V the reported frequency of blowing and drifting snow is about the same except that there is a marked increase during October and February.

Sky conditions. At Brockton, overcast skies can be expected from 37 to 60% of the time between October and February. Cloud and weather observations during Crary's traverse confirm these figures, since the skies were either clear or partly cloudy 50% of the time. McMurdo reported "clear weather" 32 to 53% of the time between October and March, but it is suspected that some high or partial cloudiness occurred during some of this time. The daily records by Crary showed only one entirely clear day, but there were stretches of 10 and 14 consecutive days of partial cloudiness and good visibility during the 3½-month period.

Summary

In summary, it can be stated that daily minimum and maximum air temperatures of from 0°to 25°F can be expected during December, January and February in the ice drilling area on the Ross Ice Shelf. Snowfall occurrence in summer is relatively infrequent and total amounts generally light. Occasional periods of strong winds with blowing and drifting snow can be expected, and although the predominant direction is south or southeast, the wind will blow from all directions as high and low pressure systems pass the region. Extended periods of good flying weather can be expected in the region during the summer months. However, intervals of poor weather, including heavy snow, fog, whiteout, and strong winds with drifting and blowing snow and reduced visibility, can be expected c the Ross Ice Shelf during each of the summer months.

Table I. Climatic summary, Brockton Station, Antarctica (80°01'S, 179°52'W).

Period of Record October - February, 1966-1972. From *Summary of Meteorological Observations, Surface, 1973,* U.S. Naval Weather Service Detachment, Asheville, North Carolina.

	OCT	NOV	DEC	JAN	FEB
Air temperature (°F)					
Avg	-24	-3	16	17	9
Avg max	-11	+8	22	23	18
Avg min	-36	-14	10	12	0
Snowfall (in.)	—	Trace	2	1	Trace
Snowfall (% of time)	2	12	14	11	23
Wind					
Avg speed (knots)	8.7	7.6	7.2	6.1	8.8
Direction	S	S	S	SSE	SSE
Visibility > ¾ mile and ceiling > 900 ft (% of time)	81	91	89	83	83
Fog (% of time)	14.5	13.5	13.6	14.0	9.7
Blowing snow (% of time)	18.4	7.9	2.2	4.5	13.8
Overcast sky (% of time)	37	39	60	54	58

Table II. Climatic summary for selected Antarctic stations.

McMurdo: 77°52'S, 166°48'E, elevation 8 ft.
Little America V: 78°11'S, 162°12'W, elevation 138 ft.
Byrd Station: 80°01'S, 119°32'W, elevation 5095 ft.
Amundsen-Scott (South Pole): elevation 9186 ft.

Period of record October - March 1957-64, except Little America V (1956-58). Data for this summary were taken from a number of U. S. Department of Commerce (ESSA and NOAA) *Climatological Data for Antarctic Stations* booklets. Some information was also obtained from USA CRREL Monograph I-A3c (Wilson 1968).

Air temperature (°F): Average monthly (Av), average maximum (Mx), average minimum (Mn)

		OCT			NOV			DEC			JAN			FEB			MAR		
	Mean ann.	Av	Mx	Mn	Av	Mx	Mn	Av	Mx	Mn	Av	Mx	Mn	Av	Mx	Mn	Av	Mx	Mn
McMurdo	0	-3	2	-11	15	22	9	26	29	22	26	30	21	16	21	12	-1	5	-6
Little America V	-9	-13	-5	-22	6	12	0	22	27	17	20	24	15	11	18	5	-9	-2	-16
Byrd	-18	-23	-16	-31	-6	-1	-13	5	9	0	5	9	-1	-5	1	-12	-19	-13	-26
South Pole	-56	-60	-55	-64	-37	-34	-41	-19	-16	-21	-20	-16	-23	-39	-34	-42	-67	-62	-73
Snowfall (in.)	*Ann. total*																		
McMurdo	≈ 50	4	–	–	2	–	–	3	–	–	6	–	–	4	–	–	13	–	–
Little America V	100	8	14	3	5	6	3	10	24	2	4	–	–	13	29	2	16	37	6
Byrd	40	1	3	T	1	3	T	2	6	T	2	8	T	2	7	T	1	2	T
South Pole	≈ 3	0.1	0.2	0	T	0.1	T	0.1	0.7	T	0.2	1.7	T	0.4	2.1	T	0.1	0.5	T
Number of days with snow																			
McMurdo	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Little America V	238	27	29	23	22	23	20	17	18	16	19	21	17	23	26	21	17	23	9
Byrd	167	13	24	5	10	19	5	16	19	11	13	18	7	15	24	9	18	23	11
South Pole	209	17	31	0	17	30	8	18	29	14	19	28	7	17	26	6	13	20	2

Table II (Cont'd). Climatic summary for selected Antarctic stations.

Wind: Avg monthly speed (mph) and prevailing direction

	OCT		NOV		DEC		JAN		FEB		MAR	
	Speed	Dir.	Speed	Dir.	Speed	Dir.	Speed	Dir.	Speed	Dir.	Speed	Dir.
McMurdo	14	E	11.5	ENE	11.5	ESE	12.0	E	15.0	ESE	18.0	E
Little America V	12.5	SE	10.5	SE	11.5	SSE	11.5	SE	11.5	SE	14.0	SE
Byrd	19.5	NE	17.5	NNE	15.0	NNE	13.5	NNE	16.0	NNE	18.0	NNE
South Pole	16.0	NNE	12.0	NE	11.0	NE	10.5	NE	12.5	NE	14.0	NNE

Visibility: Avg < ¼ to ⅛ mile (avg. no. of days)

McMurdo	7.0	3.0	3.0	3.0	3.0	5.0
Little America V	–	–	–	–	–	–
Byrd	8.2	2.8	2.4	1.6	3.2	4.3
South Pole	2.6	0.3	0.4	0.8	1.7	2.0

Fog and ice fog (% of time)

McMurdo	–	–	–	–	–	–
Little America V	13	6	7	6	6	14
Byrd	26	10	7	6	11	16
South Pole	29	11	8	13	19	26

Blowing and/or drifting snow (% of time)

McMurdo	–	–	–	–	–	–
Little America V	25	7	11	8	11	25
Byrd	31	19	16	9	18	27
South Pole	28	8	6	7	13	28

Clear sky (% of time)

McMurdo	42	35	53	32	36	32

Table III. Daily weather observations, Ross Ice Shelf Traverse, 1957-58.

Average of three measurements taken daily at 0600, 1200 and 1800 local time.

Date	Temp (°F)	Wind Dir	Wind Speed (knots)	Present weather*	Vis (miles)
Oct 1957					
25	-15	WSW	7	PC	8
26	5	SSE	18	C	2
27	23	SE	13	BS	½
28	20	E	20	HS BS	0
29	18	Var.	3	H	2
30	0	NE	4	F	5
31	20	E	19	BS	1
Nov 1957					
1	21	ESE	9	HS BS	½
2	20	ESE	5	MS	½
3	18	NNE	17	DS	¼
4	22	ENE	5	LS	2
5	5	SSW	6	K	8
6	0	Calm	0	H	6
7	9	SE	5	LS	2
8	9	SE	4	LS	3
9	9	SE	4	H	9
10	10	Calm	0	PC	11
11	9	Var.	2	H	2
12	-9	SW	4	C	2
13	2	NNE	2	H	4
14	-2	SE	8	H	6
15	5	SE	12	PC	8
16	5	SW	9	PC	8
17	3	SE	6	Cl	8
18	9	SE	2	PC	8
19	1	S	5	C	8
20	-4	SE	5	PC	8
21	-2	SSE	5	PC	8
22	7	E	6	H	7
23	9	S	6	H	8
24	5	S	4	F	¼
25	10	ESE	3	H	1
26	9	SSE	6	LS	1
27	5	SSW	7	PC	8
28	9	Calm	0	PC	8
29	20	Calm	0	PC	8
30	14	Calm	0	PC	8
Dec 1957					
1	14	Calm	0	PC	8
2	18	SE	6	C	2
3	12	SSW	18	LS DS	¼
4	12	WSW	10	DS BS	¼
5	14	SW	7	PC	8
6	16	Calm	0	PC	8
7	18	SE	3	C	6
8	18	Calm	0	F	¼
9	20	SSW	7	PC	8
10	27	SSE	20	DS BS	¼
11	25	SSW	10	PC	6
12	23	SSW	4	PC	8
13	19	SSW	7	PC	4
14	25	SSW	5	PC	3
15	27	SSE	4	PC	5
16	27	Var.	2	PC	6
17	25	NW	2	PC	8
18	23	Calm	0	PC	8
19	25	Var.	1	PC	8

Table III (Cont'd).

Date	Temp (°F)	Wind Dir	Wind Speed (knots)	Present weather*	Vis (miles)
Dec 1957 (cont'd)					
20	25	Var.	4	PC	7
21	Msg	-	-	-	-
22	Msg	-	-	-	-
23	30	ENE	2	LS WO	¼
24	28	Calm	0	LS WO	½
25	30	Var.	2	LS	6
26	23	Calm	0	PC	6
27	27	Var.	2	C WO	1
28	23	WNW	2	C F	¼
29	25	WNW	5	PC	8
30	21	Calm	0	PC	4
31	21	SSE	5	PC	35
Jan 1958					
1	27	WSW	3	C	35
2	25	WNW	3	PC	30
3	21	ESE	10	PC	8
4	27	SE	10	MS	4
5	25	SE	5	PC	8
6	21	S	14	DS	1
7	19	SE	7	PC	8
8	23	SE	8	PC	35
9	23	SE	7	PC	35
10	23	S	7	PC	35
11	16	E	6	LS	7
12	12	ESE	5	LS	9
13	16	SSE	8	PC	35
14	14	SE	5	PC	35
15	16	SE	4	PC	35
16	21	Calm	0	LS	9
17	27	Var.	3	F	5
18	23	N	8	PC	35
19	25	SE	7	FD	5
20	23	SSE	8	PC	35
21	19	SSE	8	PC	35
22	19	S	3	PC	35
23	18	S	8	PC	35
24	18	S	18	PC	35
25	16	SSE	10	PC	35
26	10	SE	7	PC	35
27	18	SE	8	PC	35
28	23	ESE	15	LS	3
29	16	SE	8	PC	35
30	16	S	7	PC	35
31	14	Var.	3	PC	35
Feb 1958					
1	9	SW	5	PC	35
2	9	S	8	PC	35
3	14	WSW	3	F	4
4	27	E	6	F	3
5	25	ESE	6	MS	5
6	21	E	5	MS	6
7	25	ESE	8	PC	35
8	25	ESE	12	HS	3
9	23	ESE	6	MS	4
10	19	WSW	10	HS	4
11	19	SE	10	PC	35
12	25	E	10	PC	35

* Present weather legend – PC Partly cloudy; C Cloudy; BS Blowing snow; DS Drifting snow; LS Light snow; MS Moderate snow; HS Heavy snow; H Haze; F Fog; K Smoke; Cl Clear; WO White out; FD Freezing drizzle

PART II: RESUME OF THE SUMMER CLIMATE AT SELECTED SITES ON THE GREENLAND ICE SHEET

by
Michael A. Bilello and Roy E. Bates

Introduction

This resume of the climate near several proposed 1974 summer drilling sites on the Greenland ice sheet considers two general areas of interest. One area, between 68° and 72°N latitude, is centered near Crete, and the other, between 63° and 65.2°N latitude, is near Dye 3 and South Site (Fig. 3). Climatic data were available for seven sites in the vicinity of these areas: Centrale, Eismitte, Hiran stations 26, 27, 28 and 30, and Dye 3 (Table IV). The objective of this investigation was to summarize the information at these stations and provide estimates of the summer climate at four other sites (Crete, Jarl Joset, Summit and South Site) for which no weather records were available. The information in Table IV was extracted from environmental and climatic studies of the Greenland ice sheet prepared by Haywood and Holleyman (1961), Hogue (1964), and the U.S. Air Force (1971).

Discussion of available climatic data

Air temperature. Examination of the available climatic data* showed that above-freezing air temperatures occur infrequently during the summer months near the crest of the Greenland ice sheet near 70°N latitude. A summary of the air temperatures (Table IV) shows that the highest monthly average maximum air temperature observed at Hiran stations 26, 27, 28 and 30 during June through August was 25°F. However, an extreme maximum temperature of 43°F was once observed at Hiran 26 in June. Average monthly minimum temperatures of from 8° to −13°F can be expected at the northern group of stations between June and August. At Dye 3 in the southern region, the highest average minimum of 13°F occurred in July. Average maximum air temperatures at all sites are considerably lower during April, May and September than during the three mid-summer months. In April the average values range from +7°F at Dye 3 to −19°F at Centrale.

Precipitation. Accurate measurement of precipitation on the ice sheet is extremely complicated because it is difficult to distinguish between falling snow and blowing and/or drifting snow during cloudy conditions. Precipitation gage records and information on snowfall amounts are therefore not available for the stations near Crete. However, mean annual precipitation accumulations on the surface of the ice sheet were obtained from profile studies in pits dug in the snow at numerous sites such as Eismitte, Centrale and Hiran stations 26 and 28. Contour maps of accumulation and mean annual amounts of snowfall are presented in several reports.† These studies indicated that about 8 to 15 in. of precipitation in water equivalent accumulates in this area per year.

In comparison, snow profile data obtained during several expeditions in southern Greenland and compiled by Benson (1961) show that the mean annual precipitation accumulation in this area is about 18 to 24 in. in water equivalent. Snowfall amounts recorded at Dye 3 show an average fall of 56 in. per year (U.S. Air Force 1971). Mean monthly values (Table IV) show that about 38 of this 56 in. of snowfall occurs between April and September.

* For example Bender et al. (1957), Expeditions Polaires Francaises (1954 and 1956), Hamilton and Rollitt (1957), Sorge (1935) and U.S. Air Force (1956).

† For example Bauer (1955), Diamond (1958), Bader (1961), Langway (1961), Bull (1958), Ragle and Davis (1962), Shumskii (1965) and Mock (1967).

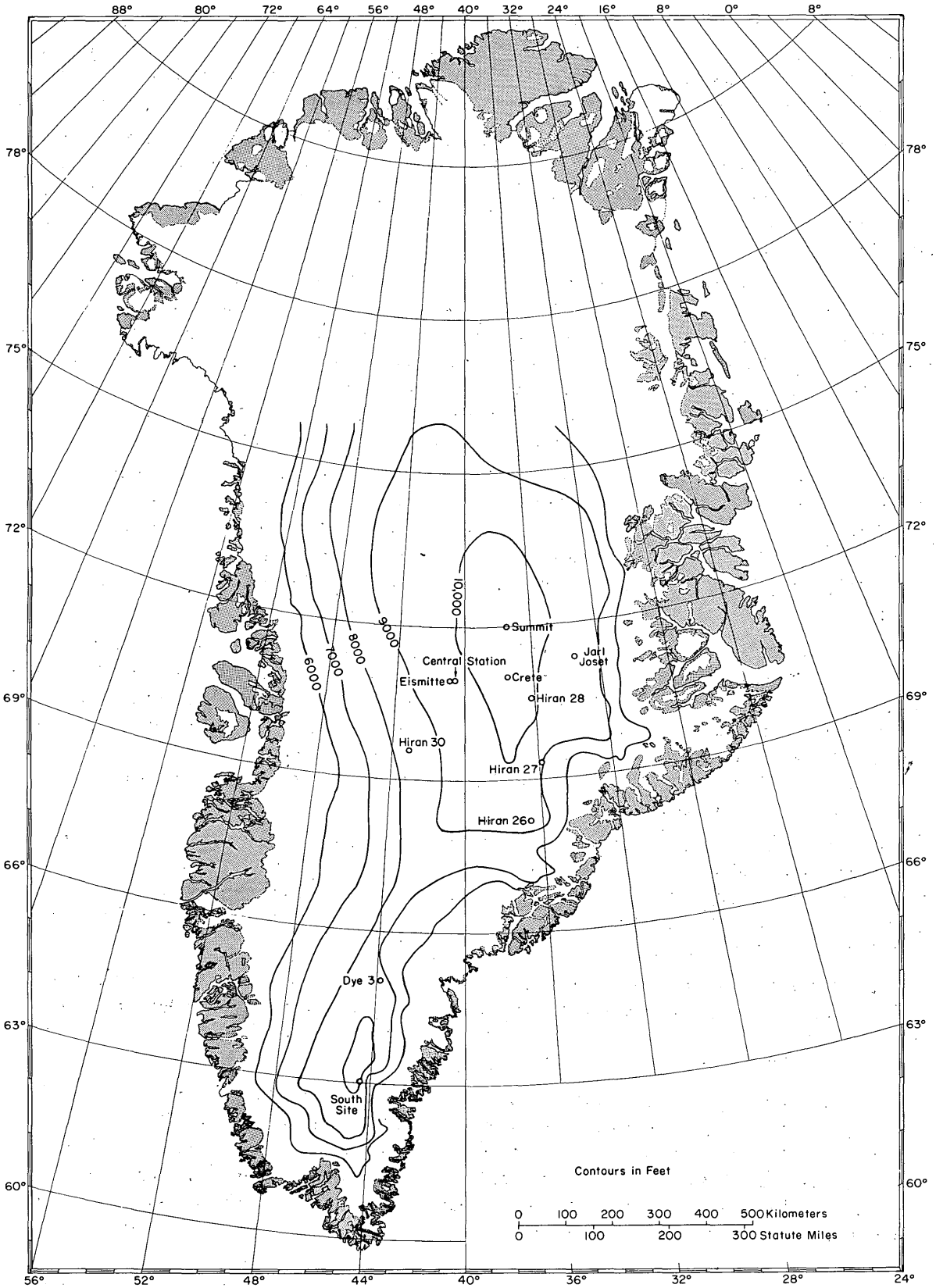

Figure 3. Location of stations on Greenland ice sheet.

According to Hogue (1964) heavy rainfall seldom occurs above 6000 ft on the Greenland ice sheet. However, at Watkins (≈75°N, 48°W, and elevation 8840 ft) rain was reported to have occurred in July 1933. Hogue also notes that in the Centrale-Eismitte area, drizzle and rain were each reported once in a three-year period, on 20 and 21 June 1950, respectively.

Eismitte and Centrale observe a greater frequency of snowfall from April through August than the four Hiran stations and Dye 3 (Table IV). However, since the period of record for the stations is brief, no meaningful comparisons can be made. It is possible, for example, that differences in observational procedures (frequency, equipment, etc.) during the short interval of record would result in some discrepancy.

Wind. Prevailing wind directions on the Greenland ice sheet are mostly determined by the katabatic or "gravity flow" downslope winds. At Station Centrale the prevailing wind direction is southeast from April through September (Table IV), and during most of this period Eismitte and Hiran station 30 also report winds from the east. These 3 stations are located on the west side of the crest of the Greenland ice sheet (Fig. 3). In contrast, Hiran stations 26, 27 and 28 are located on the east side of the crest and the prevailing wind directions at these sites between May and August are northerly. This major shift in direction may be due to the influence of downslope winds.

Wind speeds between April and September for the three stations on the western slope average 10 mph; for Hiran stations 26, 27 and 28 on the eastern slope the average speed is 7 mph. The literature notes that strong winds are generally associated with cyclonic storms and usually flow from a different direction than the prevailing wind. A maximum wind speed of over 45 mph was recorded at Centrale during the summer period (Hogue 1964). If a longer period of record were available stronger winds would undoubtedly have been reported at one of the sites.

The prevailing wind direction from April through September at Dye 3, in southern Greenland, is westerly, opposite to the directions observed at the northern stations. The average wind speeds at Dye 3 are similar to those observed on the west side of the crest. A maximum wind speed of over 60 mph was recorded during April at Dye 3 between 1963 and 1970 (U.S. Air Force 1971). As shown later, an estimate of the wind conditions at South Site will be made using the Dye 3 data. However, the stations are 140 miles apart and Dye 3 is about 1000 ft lower in elevation, so the estimate may not be too accurate.

Visibility. Except during the occasional periods of fog and blowing snow, visibility during the summer on the Greenland ice sheet is normally good. The statistics given in Table IV show that except for Eismitte, periods of fog with visibility less than ¼ mile occur during 0 to 9 days each month from April through September. Eismitte reported fog and poor visibility on 13 days during August and 15 days during September.

Reduced visibility on the ice sheet can also be produced by snowstorms and blowing snow. Centrale reports 14 to 17 days of blowing snow during April, May, June and September but only 6 in July and August (Table IV). However, no information was given on the duration of these storms; on some days they may have lasted as little as one hour.

Sky conditions. Information on mean cloudiness in the northern area of interest (i.e. excluding Dye 3) showed an average sky coverage of ≈55% during the period April through September (Table IV). Although the period of record is brief, it appears that more cloudiness was observed at Centrale and Eismitte than at the Hiran stations. Hogue (1964) noted that whiteout on the Greenland ice sheet occurs most frequently from April to September when the air is relatively moist and stratus clouds or fog form, thus severely reducing horizontal and vertical visibility.

Estimation of the climate at other sites

The climate at stations Crete, Jarl Joset, Summit and South Site (Table V) was estimated by interpolating and extrapolating the summarized information given in Table IV. Since Crete is located approximately midway between Hiran 28 and Centrale-Eismitte the summaries given in Table IV for these three sites were used to determine the climate at Crete (Table V). Jarl Joset and Summit are located outside the circle of stations having climatic information, and therefore some extrapolation of the data was necessary. The approach was to first use the Hiran 28 climatic data and the estimated values for Crete to evaluate Jarl Joset and then combine Crete and Jarl Joset's estimate to obtain the probable summer climate at Summit. Unfortunately, the only station near South Site where weather is recorded is Dye 3; consequently the estimate of the climate at South Site is mainly based on the records at that station. The results of the climatic estimates (Table V) show that air temperatures at Crete, Jarl Joset and Summit during the proposed drilling period from June through August average between −1° and 9°F; the coldest average daily minimum is −9°F in August, and the warmest maximum is 17°F in July. Results of a study on air temperature observations made from 5 to 26 June 1974 at Station Crete, Greenland (Bilello and Langway, in preparation), agree closely with the estimated values given for the area during June (Table V). The observed average maximum was +15.2°F, the average minimum was −11.1°F, and the overall average temperature for the 25 days was +2.1°F. These results compare with the estimated Crete values of +14°, −7° and +4°F respectively for June. According to Dye 3 data the region near South Site experiences average air temperatures of between 16° and 24°F during June, July and August. The average minimum and average maximum temperatures in this southern region during these months range from 5° to 35°F respectively (Table V).

As noted earlier, only limited information on snowfall amounts at stations near the Greenland summit was available. Although the records show that snowfall frequency in some cases is high, the amounts from June to August in the northern region of study are probably light. An interpolation of the annual snow accumulation given by Bader (1961) and others (see de Quervain 1969) indicates that the mean annual snow accumulation is about 20.1 cm (7.9 in.) near Summit, 25.8 cm (10.2 in.) at Jarl Joset and 28.9 cm (11.4 in.) at Crete. Snowfall records from Dye 3 indicate that the area near South Site can have substantial amounts of snow during the summer.

Winds near the summit of the ice sheet are difficult to predict due to insufficient information. Evaluation of the wind data from Eismitte, Centrale and Hiran 28 provided an indication of the wind conditions at Crete (Table V). To obtain estimates for Jarl Joset and Summit it was necessary to extrapolate the wind data available for Hiran 28 and the estimates for Crete. The results (Table V) indicate that Jarl Joset experiences the effects of a katabatic flow, but because Summit and Crete are near the peak of the ice sheet the prevailing wind direction in mid-summer is variable and/or from the northern or eastern quadrants. Average wind speeds at Jarl Joset and at the crest stations were estimated to range between 6 and 10 mph during each summer month. Analysis of wind measurements made during June 1974 resulted in an observed prevailing wind from the north and an average wind speed of 8.7 mph at Station Crete (Bilello and Langway, in preparation). A few calm periods and some brief intervals of blowing snow also were observed during the month. The latter phenomena generally occurred when the wind speed exceeded about 15 mph. Based on the wind data available from Dye 3 it is estimated that the region near South Site experiences stronger summer winds on the average than the stations to the north (Table V). Prevailing summer wind directions in the southern region are also quite different since they are from the west rather than north or east as they are at the northern group of stations.

Occasional periods of strong wind with blowing and/or drifting snow can be expected in the areas of interest. Intervals of low cloudiness, fog, snow, rain or drizzle will also reduce visibility and ceiling conditions and curtail aircraft activity in summer. However, the climatic records also

indicate that extended periods of only partial and/or high cloudiness and good visibility can be expected on the ice sheet during the summer months.

Summary

An attempt has been made to estimate the summer climatic conditions near several proposed ice drilling sites on the Greenland ice sheet. The main problem encountered in the investigation was that available meteorological data for the area were meager in terms of time and coverage.

Climatological data available for seven stations on the Greenland ice sheet were summarized and analyzed in order to estimate the weather conditions that can be expected in summer at four other surrounding locations. This ice sheet investigation was divided into two general areas: 1) the region between 68° and 72°N in which 9 of the 11 stations studied are located, and 2) the region between ≈63° and 65°N in which the other two stations (Dye 3 and South Site) are located.

Results of the analysis showed that average air temperatures of between -1° and 9°F can be expected during June, July and August in the Crete, Summit and Jarl Joset triangular region of Greenland. Near South Site mean daily temperatures are considerably higher during June, July and August, ranging from an average minimum of 8°F to average maximums above freezing.

Stations east of the crest on the ice sheet, on the average, record light winds (about 7 mph) mostly from the north or northeast in summer. At stations west of the crest the winds are stronger and from the east. It is assumed that at sites near the peak, e.g. Crete and Summit, the katabatic wind flow is reduced so that the winds in summer are probably variable, or a composite of surrounding stations, i.e. east or northeast at 7 to 10 mph. According to the weather observations made at Dye 3, the winds near South Site at 63°N in mid-summer are probably mostly from the west and average 9 to 10 mph.

Investigation of annual snowfall accumulations and frequency of fog with poor visibility indicates that the southern region under study experiences longer periods of inclement weather (including rain or drizzle) than does the northern section. However, even though good flying weather can be expected during much of the summer near the summit of the Greenland ice sheet, intervals of snow, fog, whiteout and strong winds with drifting or blowing snow can occur.

Table IV. Climatic summaries for Greenland ice sheet stations.

List of stations with published climatic data

Stations	Location	Elev (ft)
a. Centrale	70°55'N, 40°30'W	9,817
b. Eismitte	70°54'N, 40°42'W	9,840
c. Hiran 26	68°15'N, 36°30'W	9,594
d. Hiran 27	69°23'N, 35°55'W	9,040
e. Hiran 28	70°37'N, 36°10'W	10,298
f. Hiran 30	69°33'N, 43°10'W	8,394
g. Dye 3	65°11'N, 43°50'W	8,130

Air temperature (°F)

		APR			MAY			JUN			JUL			AUG			SEPT		
	Mean ann.	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min
a. Centrale	-18.8	-32	-19	-46	-2	7	-12	8	17	-2	10	18	2	4	12	3	-14	-4	-24
b. Eismitte	-23.2	-26	-14	-37	-6	6	-18	2	14	-9	10	19	1	-1	11	-13	-8	4	-20
c. Hiran 26	–	-4	11	-18	-2	10	-15	6	15	-3	14	23	5	9	19	1	–	–	–
d. Hiran 27	–	-10	4	-22	-2	10	-13	8	17	-2	16	25	8	8	17	-1	–	–	–
e. Hiran 28	–	-17	-6	-30	-12	1	-24	1	11	-10	7	14	-1	-3	6	-10	–	–	–
f. Hiran 30	–	-10	2	-22	-4	9	-16	8	19	-3	17	25	9	14	22	6	–	–	–
g. Dye 3	1.0	-4	7	-16	7	19	-5	16	26	5	24	35	13	19	30	8	7	16	-2

April through September temperature extremes: Max 43°F at Hiran 26 in June; Min -70° at Centrale in April (Dye 3 record not included).

Snowfall amounts (in.)

	APR	MAY	JUN	JUL	AUG	SEPT
g. Dye 3	2	2	7	9	5	13

Percent of days with snowfall

	APR	MAY	JUN	JUL	AUG	SEPT
a. Centrale	60	81	60	65	75	43
b. Eismitte	80	64	53	61	55	50
c. Hiran 26	23	26	30	47	26	–
d. Hiran 27	35	53	27	58	28	–
e. Hiran 28	25	29	23	55	21	–
f. Hiran 30	15	26	13	45	39	–
g. Dye 3	20	19	33	42	35	57

Wind data – average speed (mph) and prevailing direction

	APR		MAY		JUN		JUL		AUG		SEPT	
	Speed	Dir	Speed	Dir	Speed	Dir	Speed	Dir	Speed	Dir	Speed	Dir
a. Centrale	12.6	SSE	14.3	ESE	12.4	ESE	10.6	ESE	9.6	SE	11.2	ESE
b. Eismitte	11.9	S	9.4	E	8.7	E	9.4	E	7.8	E	10.6	E
c. Hiran 26	–	–	7.4	N	5.8	N	5.7	E	2.9	NE	–	–
d. Hiran 27	8.7	–	9.9	NNW	9.4	N	6.3	N	9.9	N	–	–
e. Hiran 28	–	–	7.1	WNW	6.1	N	3.8	NE	4.4	N	–	–
f. Hiran 30	10.4	E	9.2	E	8.7	E	7.8	E	9.8	E	–	–
g. Dye 3	13.0	WSW	10.0	W	10.0	WNW	10.0	WSW	9.0	W	13.0	W

Visibility – average number of days visibility less than ¼ mile due to fog

	APR	MAY	JUN	JUL	AUG	SEPT
a. Centrale	2	5	7	5	5	8
b. Eismitte	1	6	1	2	13	15
c. Hiran 26	2	2	8	8	9	–
d. Hiran 27	1	2	0	0	1	–
e. Hiran 28	–	1	0	3	3	–
f. Hiran 30	4	2	1	1	0	–
g. Dye 3	4	7	5	5	7	–

Mean cloudiness (%)

	APR	MAY	JUN	JUL	AUG	SEPT
a. Centrale	43	65	55	74	71	64
b. Eismitte	60	60	54	77	60	53
c. Hiran 26	39	43	47	52	47	52
d. Hiran 27	32	51	35	53	47	–
e. Hiran 28	–	46	47	63	57	–
f. Hiran 30	49	46	37	61	57	–
g. Dye 3	30	50	60	60	60	70

Average number of days blowing snow observed

	APR	MAY	JUN	JUL	AUG	SEPT
a. Centrale	14	16	14	6	6	17

Table V. Estimated climate at proposed drilling sites on the Greenland ice sheet.

List of proposed sites

Station	Location	Elev (ft)
a. Crete	71°07'N, 37°19'W	10,404
b. Jarl Joset	71°21'N, 33°29'W	9,403
c. Summit	72°00'N, 37°20'W	UNK (10,000+)
d. South Site	63°06'N, 44°24'W	9,020

Air temperatures (°F)

	APR			MAY			JUN†			JUL			AUG			SEPT		
	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min	Avg	Avg Max	Avg Min
a. Crete	-25	-13	-38	-7	5	-18	4	14	-7	9	17	1	0	9	-7	-11	0	-22
b. Jarl Joset	-21	-9	-34	-9	3	-21	2	12	-8	8	16	0	-1	7	-9	–	–	–
c. Summit	-23	-11	-36	-8	4	-19	3	13	-7	8	16	1	0	8	-8	–	–	–
d. South Site*	-4	7	-16	7	19	-5	16	26	5	24	35	13	19	30	8	7	16	-2

Snowfall amounts (in.)

	APR	MAY	JUN	JUL	AUG	SEPT
a. South Site*	2	2	7	9	5	13

Percent of days with snowfall

	APR	MAY	JUN	JUL	AUG	SEPT
a. Crete	55	58	45	60	50	46
b. Jarl Joset	40	43	34	57	35	–
c. Summit	47	50	39	58	43	–
d. South Site*	20	19	33	42	35	57

Wind data – average speed (mph) and prevailing direction

	APR		MAY		JUN		JUL		AUG		SEPT	
	Speed	Dir	Speed	Dir	Speed	Dir	Speed	Dir	Speed	Dir	Speed	Dir
a. Crete	–	–	10.3	ENE	9.1	E	7.9	E	7.3	ESE	–	–
b. Jarl Joset	–	–	8.7	N	7.6	NE	5.9	ENE	5.9	ENE	–	–
c. Summit	–	–	9.5	NE	8.4	ENE	6.9	ENE	6.6	E	–	–
d. South Site*	13.0	WSW	10.0	W	10.0	WNW	10.0	WNW	9.0	W	13.0	W

Visibility – average number of days visibility less than ¼ mile due to fog

	APR	MAY	JUN	JUL	AUG	SEPT
a. Crete	2	4	3	3	7	11
b. Jarl Joset	–	3	2	3	5	–
c. Summit	–	4	3	3	6	–
d. South Site*	4	7	5	5	7	–

Mean cloudiness (%)

	APR	MAY	JUN	JUL	AUG	SEPT
a. Crete	51	57	52	71	63	58
b. Jarl Joset	–	52	49	67	60	–
c. Summit	–	54	51	69	61	–
d. South Site*	30	50	60	60	60	70

* Taken from Dye 3 data given in Table IV.

† Actual values for Summit for 7-14 June 74 (observations made by S. Mock, USA CRREL):

Avg	Highest	Lowest
-2	+8	-17

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13. ABSTRACT

Climatic summaries for several sites on the Ross Ice Shelf, Antarctica, and selected locations on the Greenland ice sheet were analyzed to determine the type of weather that can be expected in these areas during the summer months. Daily minimum and maximum air temperatures of from 0° to 25°F are estimated to occur near 82.5°S and 166°W during December, January and February on the Ross Ice Shelf. Snowfall in summer is relatively infrequent and total amounts generally light, so that extended periods of good flying weather can be expected in summer. However, intervals of poor weather, including heavy snow, fog, whiteout and strong winds with drifting and blowing snow can occur each summer. Average minimum and maximum air temperatures during June, July and August range from 8°F to above freezing in the southern portion of the Greenland ice sheet and from -9° to 17°F near the summit. Stations east of the crest record light winds from the north and northeast, and those west of the crest stronger winds from the east. Winds near South Site at 63°N in mid-summer are predicted to be generally westerly and to average 9 to 10 mph. Snowfall and fog also apparently occur more frequently in the southern region of the ice sheet. Although good flying weather can be expected during much of the summer near the summit, intervals of snow, fog, whiteout or strong winds with drifting or blowing snow can occur.

14. KEY WORDS

Antarctica – climatology	Cold weather operations
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