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A SUMMARY OF WEATHER OBSERVED AT CRETE AND SUMMIT STATIONS, GREENLAND June 1974

M.A. Bilello, C.C. Langway, Jr., and S. Mock

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Daily observations of air temperature, atmospheric pressure, wind speed and direction were made at Crete Station on the Greenland ice sheet from 5 to 24 June 1974. The average air temperature during this period was −16.6°C (+2.1°F), and ranged from a minimum of −30°C (−22°F) to a maximum of −6°C (+21.2°F). The wind speed averaged 7.6 knots and was predominantly from the north. Extended periods of clear or partly cloudy weather were observed, although ground fog and reduced surface visibility occurred simultaneously. During passages of low pressure troughs, light snow, blowing snow and a whiteout were observed; at these times visibility became quite limited. At Summit Station the minimum air temperature observed between 7 and 14 June 1974 was −27°C (−16.6°F) and the maximum was −13°C (+8.6°F). These observations, however, were not made during the coldest or warmest part of the day, so the true

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extremes were probably greater than these. During passage of a low pressure trough at both stations, the pressure at Crete Station dropped 9 mb over a 45-hour period, and that at Summit Station dropped 6 mb over a 37-hour period.

PREFACE

This report was prepared by M.A. Bilello, Meteorologist, Dr. C.C. Langway, Jr., Supervisory Geologist, and Dr. S.J. Mock, Geologist, of the Snow and Ice Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory (USA CRREL).

The work was performed under National Science Foundation, Office of Polar Programs, Grant no. 750-6750 and State University of New York, Buffalo, New York, Grant no. 50-1825.

This report was technically reviewed by Dr. A.J. Gow and J.H. Cragin.

The daily meteorological observations at Crete Station were made by a USA CRREL team which included: Dr. C.C. Langway, Jr., J.H. Cragin, and K.J. Miller. The observations at Summit Station were made by Dr. S.J. Mock of USA CRREL.

The authors express gratitude to the Atmospheric Sciences Laboratory, U.S. Army Electronics Command (USAEC) for the loan of the USAEC meteorological measuring set used in this study. The loan was arranged by Dr. C.C. Langway, Jr., and R. May of USA CRREL through the kind cooperation of M. Diamond and Colonel W.C. Petty of USAEC.

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INTRODUCTION

Documented information on the weather occurring on the Greenland ice sheet, especially in the vicinity of the summit, is scarce and limited in scope. Summarized studies on meteorological data collected during extended expeditions by, for example, the Wegener (1935, 1939) and Victor (1950) parties, and brief summer stays by a number of other individuals and government agencies are available in published reports such as those of: Dorsey (1945), Diamond (1958), Putnins and Schallert (1962), Hamilton (1958), Carles (1953), and Hogue (1964). In addition, a bibliography on the climate of Greenland published by the U.S. Department of Commerce was compiled in 1957 (Bender et al. 1957). Consequently, although the amount of information provided in this current study is also brief, it is hoped that the remoteness of the region in which the weather was observed will make it useful.

Surface weather observations were made during the Greenland Ice Sheet Program* ice core drilling field operation at Crete Station, Greenland, from 5 to 24 June 1974. This ice drilling site is located near the central portion of the ice sheet's crest at latitude 71°07'N, longitude 37°19'W (Fig. 1), and an elevation of about 10,405 ft (3,171 m).

The meteorological measurements at Crete Station were taken about every 3 hours during each day by the CRREL team: Dr. C.C. Langway, Jr., J.H. Cragin, and K.J. Miller.

The meteorological parameters measured were wind speed and direction, air temperature and dew point, atmospheric pressure, and snowfall amounts. Visual observations of the weather conditions, such as fog and snow, as well as the visibility range and cloud types, amounts and base heights, were also measured. This study describes the procedures and operation of the instrumentation used to measure each of the weather elements and provides the data obtained. The information collected was reviewed for reliability, summarized, and then analyzed for presentation purposes.

METEOROLOGICAL EQUIPMENT AND OPERATION

The meteorological measuring set used in this program was borrowed from the Atmospheric Sciences Laboratory, Fort Monmouth, New Jersey. Most of the information in the following discussion on the description, use and physical characteristics of this set was taken from U.S. Army Electronics Command, Atmospheric Sciences Laboratory Draft Technical Manual DTM-11-6660-236-35-1, AMSEL-BL-FM, 14 February 1973 (USAEC 1973a). This set (Fig. 2), coded AN/TMQ-22(XE-4), is a prototype engineering development model currently undergoing further evaluation. It is a compact, lightweight, portable unit intended for use by personnel at noninstrumented airfields where it is impractical to establish permanent weather stations, or by airborne troops or special groups such as engineering or artillery units during maneuvers.

* This program is supported by the U.S. National Science Foundation and is conducted by teams from several organizations and governments. The prime participants are: United States (CRREL and University of Nebraska), Denmark (University of Copenhagen and Technical University of Denmark), and Switzerland (University of Bern).

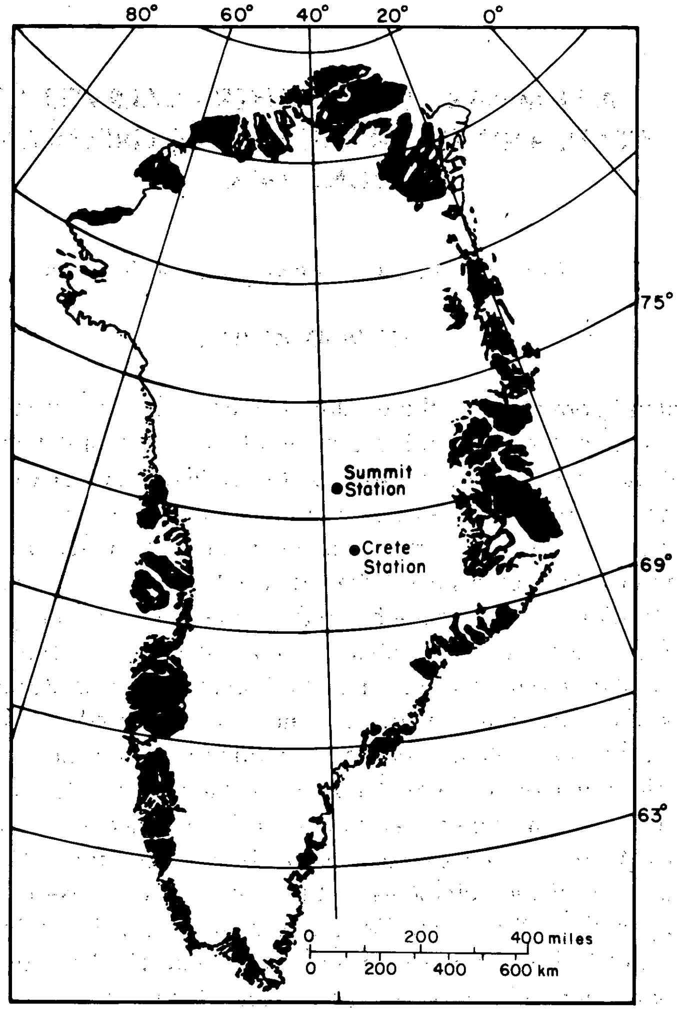

Figure 1. Locations of climatic stations on the Greenland ice sheet.

This set is contained in a metal case measuring 16 by 12 by 7 in. and weighs about 30 lb. The case contains an automatic pressure release valve to allow transportation at high altitudes. All components are packed in the case and the instruments are capable of withstanding drops of up to 4 ft. The unit is powered by six flashlight batteries. When the measurement sensors and instrument panel assembly are removed from the main case, the operational weight of the meteorological equipment is reduced to about 8 lb.

Discussions with members of the CRREL field team revealed that no damage or disruptive incidents occurred to any of the equipment during its transit to and from USA CRREL, at Hanover, New Hampshire, and the point of installation at Crete, Greenland. Malfunction of the dew-point sensor, however, developed during the period of equipment operation; this failure will be discussed later. Also, the batteries had to be replaced on about a weekly basis. The reasons given for the relatively short lifetime of the batteries were that the environment was excessively cold and the power control was occasionally inadvertently left on. The U.S. Army Electronics Command has also printed an Operator's and Organizational Maintenance Draft Technical Manual DTM 11-6660-236-12-1 (USAEC 1973b) for use with this meteorological measuring set.

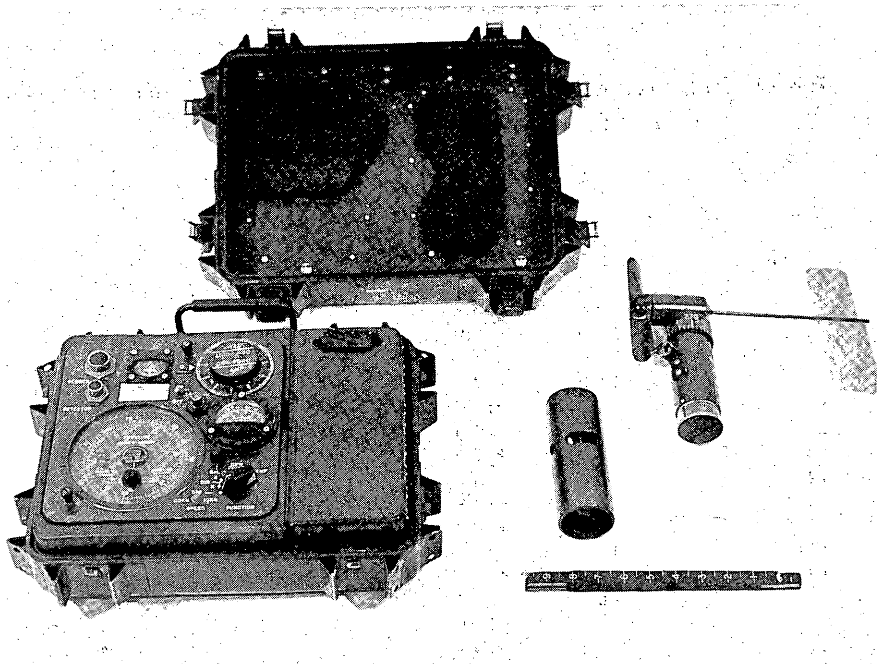

Figure 2. USAEC - Meteorological measuring set AN/TMQ-22(XE-4).

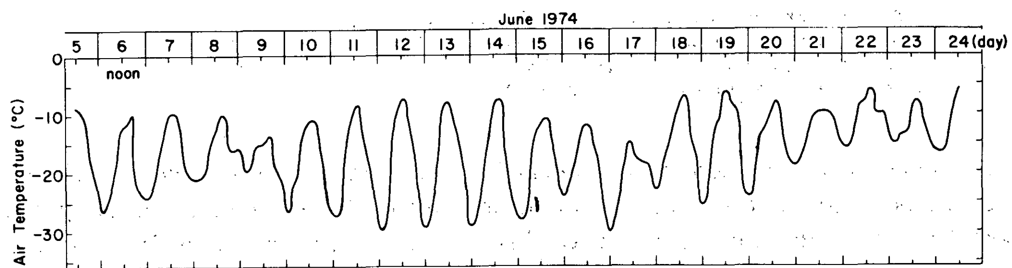

Figure 3. Daily air temperatures, Crete Station, 5-24 June 1974.

CRETE STATION OBSERVATIONS

Air temperature

The air temperature sensor provides a range of from −50°C to +50°C (−58°F to +122°F) and consists of an air temperature thermistor mounted in an aspirator housing which draws a fresh air sample for each measurement. The thermistor is thermally isolated from the other components inside the aspirator so that it is affected only by the air being drawn in by the fan. A temperature error chart provided with the operation instruction manuals shows that between the temperature range of −10°C to −25°C (+14°F to −13°F) the instrument requires a temperature correction of −2°C (−3.6°F). Daily checks of the temperature sensor on the Greenland ice sheet, using mercury bulb thermometers and a maximum and minimum reset type thermometer, however, showed that a correction of −5°C (−9°F) was required in this temperature range.

A plot of the daily temperature curve, utilizing all the temperature data collected for the period 5 to 24 June 1974 at Crete Station, is shown in Figure 3. A dominant trend of major

Table I. Daily maximum and minimum air temperatures (°C and °F) at Crete Station, Greenland, 5-24 June 1974.

	Maximum		*Minimum*	
	°C	*°F*	*°C*	*°F*
5 June	−8.8	+16.2	–	–
6	−10.0	+14.0	−26.4	−15.5
7	−9.8	+14.4	−24.4	−11.9
8	−10.0	+14.0	−21.2	−6.2
9	−14.0	+6.8	−19.7	−3.5
10	−11.0	+12.2	−26.6	−15.9
11	−8.5	+16.7	−27.6	−17.7
12	−7.2	+19.0	−29.8	−21.6
13	−8.0	+17.6	−29.3	−20.7
14	−7.6	+18.3	−29.0	−20.2
15	−10.6	+12.9	−28.0	−18.4
16	−12.0	+10.4	−24.0	−11.2
17	−15.0	+5.0	−30.0	−22.0
18	−7.0	+19.4	−23.0	−9.4
19	−6.8	+20.3	−25.6	−14.1
20	−8.0	+17.6	−24.0	−11.2
21	−9.8	+14.4	−18.0	−0.4
22	−6.0	+21.2	−15.9	+3.4
23	−8.0	+17.6	−15.2	+4.6
24	–	–	−16.8	+1.8

Average temperature = −16.6°C (+2.1°F)
Average maximum temperature = −9.4°C (+15.2°F)
Average minimum temperature = −23.9°C (−11.1°F)
Highest temperature = −6.0°C (+21.2°F)
Lowest temperature = −30.0°C (−22.0°F)

daily rises and falls in air temperature is noted in the trace, particularly during periods of clear weather. Moderations in the daily maximum and minimum temperatures occur during periods of overcast skies and inclement weather, for example, on 8-9 June. The observed daily maximum and minimum temperatures (in degrees centigrade and degrees Fahrenheit) and the resultant averages for the period of record are given in Table I. The highest and lowest temperatures observed were −6.0°C and −30.0°C (+21.2°F and −22.0°F), respectively. The average maximum temperature was −9.4°C (+15.2°F), the average minimum temperature was −23.9°C (−11.1°F), and the overall average temperature was −16.6°C (+2.1°F). The latter three average temperatures, incidentally, agree closely with the estimated temperatures (+14°F, −7°F, and +4°F, respectively) derived for an area near Crete, Greenland, during June in a study by Bilello and Bates (1975, Table V, p. 14).

Wind speed and direction

The speed measuring capability of the wind equipment used is 1 to 50 knots with an approximate error of ± 2 knots at midrange. The wind speed is measured by an impeller-driven d-c generator, and is indicated on a calibrated meter on the instrument panel of the case. The impeller is oriented by the tail vane section which is attached to the main body of the generator housing. The wind direction is obtained by a potentiometer which is mounted on the shaft of the main body and provides an indication of the wind direction. The wind speed, and direction values which range from 0 to 360° (± 5°), are both read from a graduated scale on the wind speed meter. The wind measuring set is equipped with a detachable cable that can be used to place the sensor unit at an exposed location. During this field operation a 98-ft (30-m) cable was used.

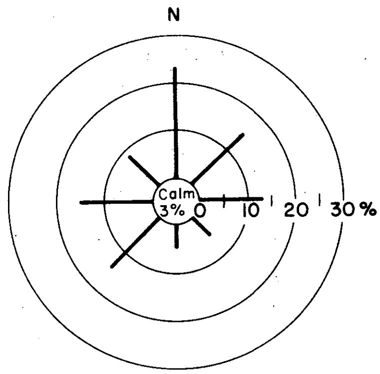

Figure 4. Wind rose, Crete Station, 5-24 June 1974.

The daily measurements of wind speed and direction are shown in Table II. The wind vane was positioned so that the wind directions read magnetic north. One hundred thirty five wind measurements were made from 5 to 24 June 1974. In four instances the wind was calm, and during the other observations the wind speed ranged from 2 knots to a maximum of 20 knots (on 23 June). The average wind speed over the period of record was 7.6 knots. Blowing snow was observed at wind speeds of 12 to 19 knots, but this phenomenon did not necessarily always occur at these wind speeds. This inconsistency may be attributed to the variation in the physical characteristics and texture of the surface snow at Crete Station during June.

An indication of the prevailing wind direction observed during June 1974 was obtained by constructing a wind rose (Fig. 4). The diagram shows that the most dominant wind was north (23% of the time), and that no dominant secondary wind direction occurred. The infrequency of periods of calm and directions from the south and southeast is, however, significant.

Atmospheric pressure

The atmospheric pressure is measured by an aneroid barometer connected to a link, lever and gear system. The barometer is sealed in its own container and records through a range in scale of 18.90 to 31.60 (± 0.01) in. of mercury (640 to 1070 mb). The indicating unit covers two complete revolutions to provide greater readability in scale. Proper precautions, including closing the barometer valve screw, were taken to protect the instrument during transit. Since there was no backup equipment, such as a mercurial barometer at Crete Station, it was not possible to check or recalibrate the aneroid barometer. However, reference with other sources, such as the U.S. Standard Atmosphere Pressure values at 10,400 ft (3,170 m) and altimeter readings from visiting aircraft, indicated that the observed values were within acceptable limits.

In accordance with the directions given in the operator's manual, a minor correction was applied to the data to compensate for the change in local pressure and temperature. The daily measurements of station pressure (in millibars and inches of mercury) plotted in Figure 5, therefore, are believed to be reasonably accurate. The passage of pressure troughs and ridges at Crete Station from 5 to 24 June 1974 is evident in the diagram; for example, when the events of snowfall were observed on 8 and 20 June (Table II), they were associated with notable decreases in atmospheric pressure. As will be noted later (p. 15), a marked decrease in atmospheric pressure was also recorded at Summit Station on 9 June.

Table II. Daily weather observations, Crete Station, Greenland, 5-24 June 1974.

Date	Time (LST)	Wind Dir	Wind Speed (knots)	Surface weather conditions*	Visibility* (miles)	Clouds Type*	Clouds (Amt†)	Base Height**
5	1200	S	9	PC	unl	Ci	2	200
	1500	WSW	7	PC	unl	Ci	1	200
	1800	SSW	3	PC	unl	Ci	1	200
	2100	WSW	3	Light fog	3	Unknown		
6	0900	ESE	9	Fog	1	St	10	0
	1200	SE	11	Fog	1	St	8	60
	1500	SSE	12	Clear	unl	Clear	0	–
	1800	SSE	9	PC	10	As	1	100
	2100	SSE	8	Fog	½	St	10	0
7	0900	SSE	16	Light BS	¾	St	10	5
	1200	SSE	15	Light BS	5	Cu	5	15
	1500	S	14	PC	3	Cu	6	15
	1800	S	10	GF, IC and solar halo	1	Unknown		
	2100	SSE	9	GF and rainbow around sun	½	Unknown		
8	0900	SW	13	Light GF	2	Cs	7	200
	1200	SW	12	Distant fog	7	Cc	4	200
	1500	SW	16	Distant fog	5	Cc	6	200
	1800	SW	13	GF, LS	½	St	10	20
	2100	SW	8	GF, LS	¼	St	10	20
	2400	W	7	GF	1/10	St	10	0
9	0300	W	10	Light GF	2	St	10	4
	0600	N	12	GF	½	St	3	10
	0900	N	13	Light GF	1	St	6	20
	1200	N	15	Distant fog	5	Cu	5	15
	1600	N	16	Light GF	2	Cu	9	15
	1800	N	14	PC	unl	Cc	4	200
	2100	N	12	GF	¼	St	8	10
	2400	NE	9	Distant GF	unl	Clear	0	–
10	0300	E	9	GF	¼	Clear	0	–
	0600	E	8	GF	¼	Ci	1	200
	0900	E	10	GF	½	Clear	0	–
	1200	E	12	Fog	½	Clear	0	–
	1500	E	10	GF	½	Ci	5	200
	1800	E	6	GF	½	Ci	3	200
	2100	E	5	Light GF	3	Ci	1	200
	2400	E	4	Light GF	1	Ci	3	200
11	0300	ENE	4	Light GF	5	Ci	1	200
	0600	ENE	4	Light GF	5	Cs	6	200
	0900	ENE	3	PC	10	Ci	2	200
	1200	E	5	PC	unl	Ci	2	200
	1500	E	5	PC	unl	Ci	2	200
	1800	ENE	2	PC	unl	Ci	2	200
	2100	NE	3	GF	1	Ci	1	200
	2400	ENE	2	GF	¼	Ci	1	200
12	0300	Calm	0	GF	¼	Clear	0	–
	0600	ENE	3	GF	1	Clear	0	–
	0900	ENE	4	Clear	unl	Clear	0	–
	1200	ENE	3	Clear	unl	Clear	0	–
	1500	ENE	3	Clear	unl	Clear	0	–
	1800	NNE	3	Clear	10	Clear	0	–
	2100	NE	4	GF	2	Clear	0	–
	2400	NE	4	GF	2	Clear	0	–
13	0300	NE	3	GF	2	Clear	0	–
	0600	NE	2	Clear	unl	Clear	0	–
	0900	ENE	4	Clear	unl	Clear	0	–
	1200	ENE	4	Clear	unl	Clear	0	–
	1500	ENE	2	PC	unl	Ci	1	200

Table II (cont'd).

Date	Time (LST)	Wind Dir	Wind Speed (knots)	Surface weather conditions*	Visibility* (miles)	Type*	Clouds (Amt†)	Base Height**
13	1800	Calm	0	Distant haze	5	Clear	0	–
(cont'd)	2100	NE	3	Clear	5	Clear	0	–
	2400	Calm	0	GF	1/10	Unknown		
14	0300	NE	3	GF	1/10	Unknown		
	0600	ENE	6	GF	½	Unknown		
	0900	ENE	2	Clear	unl	Clear	0	–
	1200	ENE	3	Clear	unl	Clear	0	–
	1500	E	5	Clear	unl	Clear	0	–
	1800	NE	5	Clear	unl	Clear	0	–
	2100	NE	6	Clear	unl	Clear	0	–
	2400	NE	6	Clear	unl	Clear	0	–
15	0300	NNE	4	GF	½	Clear	0	–
	0600	N	6	Clear	unl	Clear	0	–
	0900	N	10	PC	5	Ci	1	200
	1200	NNW	13	Clear	unl	Clear	0	–
	1500	NNW	14	PC	unl	Ci	1	200
	1800	NW	11	Light GF	5	Ci	2	200
	2100	WSW	9	IC	unl	Ci	2	200
	2400	WSW	8	IC	2	St	1	5
16	0300	NNW	3	Clear	unl	Clear	0	–
	0600	NNW	5	Light fog	5	Clear	0	–
	0900	N	7	Clear	unl	Clear	0	–
	1200	NNE	6	Clear	unl	Clear	0	–
	1500	N	8	Clear	unl	Clear	0	–
	1800	N	3	Clear	unl	Clear	0	–
	2100	N	4	Clear	unl	Clear	0	–
	2400	N	5	Clear	unl	Clear	0	–
17	0300	N	5	Distant fog	5	Clear	0	–
	0600	N	5	Clear	unl	Clear	0	–
	0900	NNW	13	Haze	2	Cs	9	200
	1200	NNW	13	PC	5	Ci	3	200
	1800	N	6	PC	5	Ci	2	200
	2100	NNW	7	Clear	unl	Clear	0	–
	2400	NNW	8	GF	3	St	9	50
18	0300	NNW	4	Light GF and IC	1	Unknown		
	0600	N	5	IC	unl	Ci	1	200
	0900	N	12	Clear	unl	Clear	0	–
	1200	N	13	Clear	unl	Clear	0	–
	1800	N	6	PC	unl	Ci	2	200
	2100	N	8	PC	unl	Sc	1	50
	2400	N	5	GF	½	Sc	4	50
19	0600	N	5	PC	unl	Ci	5	200
	0900	NW	5	PC	unl	Ci	3	200
	1200	WNW	2	PC	10	Ci	1	200
	1500	W	5	PC	unl	Ci	1	200
	1800	WNW	3	PC	5	As	2	100
	2000	W	3	PC	5	As	2	80
	2400	SSW	3	GF	¼	As	1	80
20	0300	SSW	4	Rime frost	unl	Sc	3	50
	0600	SSW	3	Cloudy	unl	Ci	8	200
	0900	W	8	Haze	1	Sc	10	30
	1200	WSW	8	Haze	1	Sc	10	50
	1800	WSW	9	Haze	1	Sc	9	50
	2400	WSW	15	Snow	0	St	10	0
21	0300	W	12	PC	5	St	1	50
	0600	W	12	Light fog	1	St	1	50
	0900	W	14	BS	1	St	10	50

Table II (cont'd).

Date	Time (LST)	Wind Dir	Wind Speed (knots)	Surface weather conditions*	Visibility* (miles)	Type*	Clouds (Amt†)	Base Height**
21	1200	W	13	BS	1	St	10	50
(cont'd)	1500	W	14	BS	2	Cu	4	15
	1800	W	12	BS	1/2	St	4	50
	2100	W	14	BS	1/5	St	10	50
	2400	W	16	BS	1/10	St	10	50
22	0300	WSW	3	PC	unl	Sc	1	50
	0600	WSW	7	GF	1	St	1	50
	0900	SW	7	GF	2	St	10	50
	1200	WSW	12	BS	2	St	9	50
	1800	SSW	7	PC	5	St	5	60
	2100	SSW	10	WO	0	St	10	0
	2400	SSW	7	Haze	1/2	St	5	50
23	0730	WNW	7	PC	5	St	5	60
	0900	NW	8	PC	10	St	1	60
	1200	WNW	16	GF	1/2	St	1	60
	1500	NNW	19	BS-GF	1/10	St	9	50
	1800	NNW	20	Fog	1/10	St	7	50
	2100	NNW	14	PC	1	Sc	5	50
24	0600	Calm	0	Clear	unl	Clear	0	–
	0900	SSE	3	Clear	unl	Clear	0	–
	1200	SSE	5	Clear	unl	Clear	0	–

* Abbreviations:

PC - Partly cloudy
BS - Blowing snow
GF - Ground fog
LS - Light snow
IC - Ice crystals
WO - Whiteout
Unl - Unlimited

Ci - Cirrus
Cs - Cirro-stratus
Cc - Cirro-cumulus
As - Alto-stratus
St - Stratus
Sc - Strato-cumulus
Cu - Cumulus

† In tenths.

** Estimated in 100's of ft.

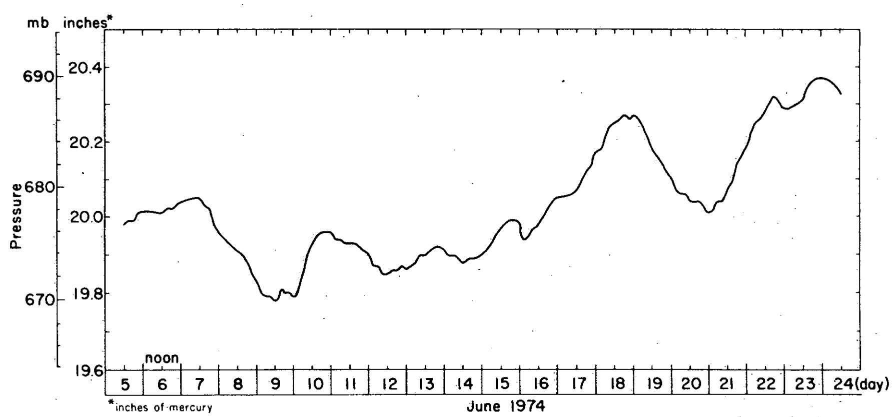

Figure 5. Atmospheric pressure, Crete Station, 5-24 June 1974.

Dew-point temperature

The following discussion, which describes the system and function of the dew-point temperature equipment, was obtained from the U.S. Army Electronics Command Draft Technical Manual DTM 11-6660-236-35-1 (USAEC 1973a). The instrument includes a fan, a sensor motor assembly, and the temperature dew-point sensing elements. The fan draws air in from the atmosphere through an air duct and directs it past the sensing elements. When dew point is being measured, the incoming air is drawn past a mirror surface which is thermally bonded to a small thermoelectric cooling module. This module, when charged with direct current of proper polarity, removes heat from the mirror and lowers the temperature of the mirror surface. As the mirror temperature reaches the dew point, a film (caused by the condensed moisture) begins to form on the mirror surface.

The presence of the film of moisture on the mirror surface causes the light reflection characteristics of the mirror to change. The mirror surface is illuminated by a light source, so that the change in reflectivity is detected by photocells, which develop a difference in voltage that is detected at the hygrometer control amplifier. The output signal of the amplifier (the difference in voltage developed at the photocells), in turn, controls the direct current supplied to the thermoelectric cooling module in direct proportion to the signal received by the incoming air. Using this proportional direct current to excite the cooler in a negative sense, that is, causing the mirror to become cooler when a decrease in the film of moisture occurs, the system stabilizes when a particular layer of moisture thickness is reached. A measurement of the mirror temperature under stabilized conditions is a measurement of dew point. The mirror temperature is measured by the dew-point thermistor embedded inside the mirror. The dew-point thermistor senses temperature as a resistance, and since the thermistor forms one leg of the null bridge (a standard Wheatstone bridge), a resistance change causes a deflection of the null meter needle located on an indicator panel.

Dew-point temperature measurements were attempted from 5 to 16 June at Crete Station despite the many difficulties that were experienced. After 16 June the equipment became completely inoperable and observations were terminated. No attempt was made to determine the reason for the failure, and analysis of the data collected warranted further suspicion of the equipment's reliability; for example, in 12 of the 49 measurements taken, the dew-point temperature was higher (warmer) than the concurrent air temperature. In numerous other instances, no dew-point temperatures were recorded by the observers because the null meter needle could not be balanced.

Serious doubts regarding the accuracy of the dew-point values obtained with the equipment therefore prompted the decision to omit the collected data. The large differences in relative humidity obtained on adjacent readings, the repetitive dew-point temperatures observed and the other problems experienced with the equipment were discussed with Mr. George Jossart, Instrument Calibration Specialist, at USAEC, White Sands Missile Range, New Mexico. Consequently, the dew-point equipment of the USAEC AN/TMQ-22(XE-4) measuring set was checked and calibrated at the White Sands laboratory using a quartz thermometer as a reference instrument. The results are shown in Figure 6. Excellent agreement between both instruments was observed at air temperatures above +15.6°C (+60°F), and good agreement from +10°C to +15.6°C (+50°F to +60°F). However, below air temperatures of +10°C (+50°F), the two instruments showed a gradual increase in disagreement between corresponding dew-point temperatures. A maximum difference was noted at an air temperature of −12.2°C (+10°F), when the quartz thermometer showed a dew-point temperature of −13.3°C (+8°F) and the AN/TMQ-22(XE-4) instrument showed a dew-point temperature of

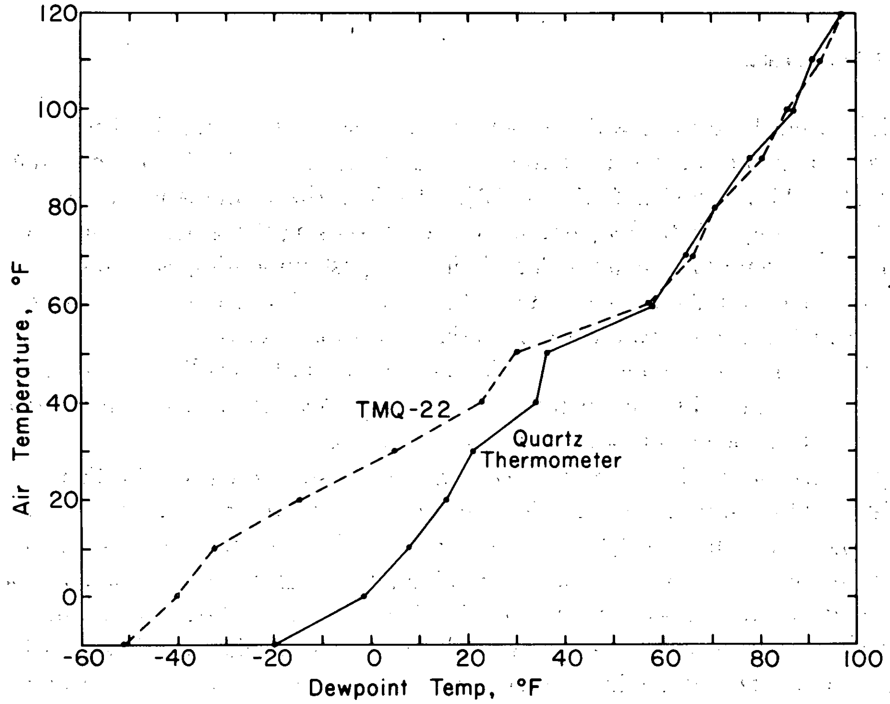

Figure 6. USAEC calibration of AN/TMQ-22(XE-4) dew-point temperature equipment with quartz thermometer.

−35.6°C (−32.0°F). The temperatures at which this maximum difference in dew-point recordings occurred were close to the average air temperature (−16.6°C) observed at Crete Station during the observation period; this further justified omission of the data.

Weather conditions

A sample of the Weather Log forms provided with the AN/TMQ-22(XE-4) meteorological measuring set is shown in Figure 7. Included on this form are blocks in which to insert visual observations of the weather conditions, such as surface conditions, snow, visibility and cloudiness.

During the period 5-24 June at Crete Station, the observers kept careful accounts of these weather elements, as shown in Table II. A cursory examination of this information shows that fog and ground fog were relatively common at this site, occurring about 40% of the time. Inclement weather, such as blowing snow, snowfall and whiteout, occurred about 17% of the time. Snowfall amounts on 8 June were not recorded; but between 2400 on 20 June and 0300 on 21 June, 2 cm of snowfall was recorded.

Visibility (Table II) ranged from zero during periods of snow and whiteout to unlimited when it was not foggy and the sky was clear or partly cloudy. Poor visibility, i.e. under 1-mile distance, was observed quite frequently (about 21% of the time) mostly because of the high frequency of fog and ground fog.

The observations of cloud types and base heights appeared to be reasonably accurate and reliable (Table II). Some minor changes in cloud heights had to be made in order to conform with the internationally accepted classification of cloud families and genera (Berry et al. 1945).

Overcast skies (cloud amount 10 tenths) were observed about 13% of the time, and during most of these instances, the clouds were the low stratus type. During about 17% of the time in June, 5 to 9 tenths cloudiness of various types and heights were observed. During the

WEATHER LOG
MET. MEAS. SET AN/TMQ-22

DATE______________ STATION IDENT. Crete

TIME	0900	1200	1500	1800	2100	2400
PRESSURE, in	20.03	20.03	20.04	20.04	20.05	
TEMP, °C	-20.5	-17.0	-16.1	-20.5	-27.9	
DEW POINT, °C	-16.5	-26.5	-26.7	-35.5	-26.6	
WIND SPEED, kt	9	11	12	9	8-9	
WIND DIR MAG NO. (360°)	115°	140°	160°	150°	150°	
SURF. COND.	Fog	Fog	Clear	Clear	Fog	
VISIBILITY (mi.)	1	1	unl	10	½	
CLOUD COVER, %	10	8	0	1	10	
CLOUD TYPE	–	Strat.		Alto-strat.		
CLOUD HT., ft	0	6000	–	10,000	0	
MIN TEMP, °F	-15.5	8.0	10	10	-7	
MAX TEMP, °F	8.0	10	12	14	9	

Taken from AMSEL-RD FORM 122(OT) 1 AUG 66 ESC-FM 4029-66

Figure 7. Example of Weather Log form.

rest of the time, clear skies (4 tenths or less of high cloudiness) were observed. These extended periods of few clouds and good weather, however, were accompanied by intervals of light fog, ground fog and other weather conditions which reduced horizontal visibility on the ice sheet's surface.

Summary of Crete Station data

Daily weather observations were made at Crete Station on the Greenland ice sheet using the experimental USAEC AN/TMQ-22(XE-4) portable meteorological measuring set. Except for the dew-point temperatures, the kit provided reliable data on the important meteorological elements, such as air temperature, atmospheric pressure, wind speed and direction.

The average air temperature at Crete Station from 5 to 24 June 1974 was −16.6°C (+2.1°F); temperatures ranged from a minimum of −30.0°C (−22°F) to a maximum of

−6.0°C (+21.2°F). The wind speed during this same period averaged 7.6 knots and was predominantly from the north. Few periods of calm were observed and winds from the south and southeast were infrequent. Station pressure, that is, the readings obtained at Crete's elevation of 10,405 ft ranged from almost 19.80 in. (670.5 mb) to almost 20.35 in. of mercury (689.1 mb). Extended periods of clear or partly cloudy weather were observed, although simultaneously ground fogs with reduced surface visibility occurred. During apparent passages of low pressure troughs across the area, light snow, blowing snow and whiteout were observed; at these times the visibility became quite limited.

Although this meteorological summary for Crete Station covers only one month of one year, it is hoped that the complete lack of such data for this remote area of Greenland will make these results useful.

SUMMIT STATION OBSERVATIONS

From 6 to 15 June another group of Greenland Ice Sheet Program personnel were engaged in performing geophysical studies and in obtaining ice cores from shallow depths at Summit Station (72°17'N, 37°59'W), 133 km north of Crete Station. This station was higher than Crete Station (by an as yet unknown amount) and was very close to the true summit of the ice sheet. Synoptic observations were not part of the program at Summit Station, but certain daily meteorological observations were made from 7 to 14 June (by S. Mock) primarily to provide current meteorological conditions for aircraft operations. Equipment available included a standard sling psychrometer, a hand-held wind velocity meter and an aneroid barometer.

Although only simple observations were made at Summit Station, they are of some interest, since many were made concurrently with those at Crete Station. Not only was this the first time that meteorological observations were made at the summit of the ice sheet, but it was the first time that two stations were operating simultaneously along the crest of the ice sheet.

Air temperature

The maximum temperature recorded at Summit Station was −13°C (+8.6°F) compared with a −6°C (+21.2°F) maximum during the same period at Crete Station. Recorded minimum temperatures during the period were −27°C (−16.6°F) and −30°C (−22°F) at Summit and Crete Stations, respectively. Since observations at Summit Station were normally not made during the warmest part of the day (1400-1500 hours), nor during the coldest (~ 0300 hours), the true extremes were undoubtedly greater than these.

Figures 8a, b and c compare Summit Station observations with concurrent or nearly concurrent observations at Crete Station. The temperatures (Fig. 8a) at the two stations are rather interesting in that they not only show the generally lower temperatures at the higher elevation, Summit Station, but the two different temperature regimes occurring during the period. On 8 and 9 June both stations experienced moderate winds with a probable change in air mass over both stations. For the concurrent data during this period, Summit Station averaged about 1°C (1.8°F) colder than Crete Station. Beginning 11 June a period of calm prevailed at Summit Station and light winds at Crete Station. For this period Summit Station averaged nearly 5°C (9°F) colder than Crete Station. During this period diurnal fluctuations at Crete Station had their greatest amplitude, averaging nearly 20°C (36°F) with high temperatures near −8°C (+17.6°F). At Summit Station, on the other hand, although no formal measurements were recorded, the impression from several "temperature checks" was that the daytime high temperatures seldom if ever exceeded −15°C (+5°F).

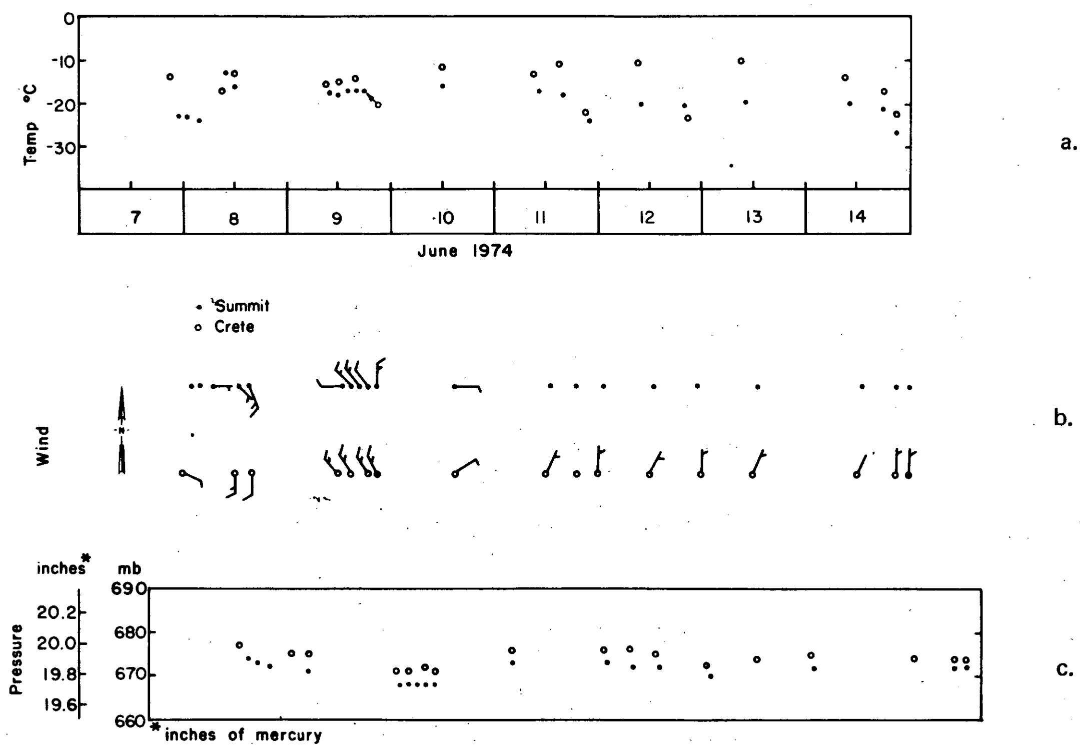

Figure 8. Comparison of daily observations of a) air temperature, b) wind direction and c) atmospheric pressure between Crete and Summit Stations.

One possible explanation for the colder temperatures at Summit Station involves the stability of the surface inversion. Under the clear conditions during the night hours, inversions were probably formed at both sites. Since Summit Station was continuously calm beginning 11 June, radiational cooling probably caused the formation of a thicker inversion layer there than at Crete Station. During the daylight hours the light winds promoted some mixing of the air near the surface at Crete Station, which along with the lesser thickness of the inversion layer, promoted the breakdown of the layer. At Summit Station the inversion layer probably persisted longer, or possibly, was not destroyed at all. Thus, slightly lower minimum temperatures would be expected at Summit Station than at Crete Station and markedly lower maximum temperatures.

Wind speed and direction

Surface winds at Summit and at Crete Stations are shown in Table III and are graphically shown in Figure 8b. The veering winds experienced at both stations from 7 to 9 June resulted from a low pressure system which moved northward along the west coast of Greenland. By 9 June the low had filled and winds at both stations were responding to a low pressure area centered over Iceland.

From 11 to 14 June winds were calm at Summit Station and light north or northeasterly at Crete Station. Since calm prevailed at Summit Station, it can be concluded that the winds experienced at Crete Station during this period were purely local gravity or katabatic winds.

Table III. Comparison of weather observations for Summit and Crete Stations, 7-14 June 1974.

Summit

Date	Time	Wind Dir	Wind Speed (knots)	Air temp (°C)	Air temp (°F)	Atmos. pressure (mb)	Weather-Clouds*
7	2300	E	1-2	−23	− 9.4	674	
8	0100	E	3	−23	− 9.4	673	
	0400	E	4	−24	−11.2	672	
	1000	SE	6	−13	+ 8.6		High broken
	1200	SSE	13	−16	+ 3.2	671	High broken
9	1000	W	9	−17	+ 1.4	668	Thin broken
	1200	NW	16	−18	− 0.4	668	Scattered $^{1}/_{10}$
	1400	NW	15	−17	+ 1.4	668	Scattered $^{5}/_{10}$
	1600	NW	11	−17	+ 1.4	668	Thin scattered $^{6}/_{10}$
	1800	N	14	−17	+ 1.4	668	Thin overcast
10	1200	E	9	−16	+ 3.2	673	High thin $^{3}/_{10}$
11	1000	Calm		−17	+ 1.4	673	Clear
	1600	Calm		−18	− 0.4	672	Clear
	2200	Calm		−24	−11.2	672	Clear w/GF
12	1000	Calm		−20	− 4.0	670	Clear
	2000	Calm		−20	− 4.0	—	Clear
13	1000	Calm		−20	− 4.0	672	Clear
14	1000	Calm		−20	− 4.0	—	Clear
	1800	Calm		−21	− 5.8	672	Clear
	2100	Calm		−27	−16.6	672	Clear

Crete

Date	Time	Wind Dir	Wind Speed (knots)	Air temp (°C)	Air temp (°F)	Atmos. pressure (mb)	Weather-Clouds*
7	2100	SSE	9	−19	− 2.2	677	GF
8	0900	SW	13	−21.5	− 6.8	675	Light GF, Cs $^{7}/_{10}$
	1200	SW	12	−18	− 0.4	675	Ci-Cu $^{4}/_{10}$
9	0900	N	13	−20.5	− 4.9	671	Light GF, St $^{6}/_{10}$
	1200	N	15	−20	− 4	671	Cu $^{5}/_{10}$
	1600	N	16	−19	− 2.2	672	Light GF, Cc $^{9}/_{10}$
	1800	N	14	−22	− 7.6	671	Ci-Cu $^{4}/_{10}$
10	1200	E	12	−16.5	+ 2.3	676	Fog, clear above
11	0900	ENE	3	−18	− 0.4	676	Ci $^{2}/_{10}$
	1500	E	5	−16	− 3.2	676	Ci $^{2}/_{10}$
	2100	NE	3	−27	−16.6	675	GF, Ci $^{1}/_{10}$
12	0900	ENE	4	−15.5	+ 4.1	673	Clear
	2100	NE	4	−28	−18.4	674	GF
13	0900	ENE	4	−15	+ 5	675	Clear
14	0900	ENE	2	−19	− 2.2	674	Clear
	1800	NE	5	−22	− 7.6	674	Clear
	2100	NE	6	−27.5	−17.5	674	Clear

* Abbreviations and amounts are defined in Table II.

Atmospheric pressure

Station atmospheric pressures are given in Table III and shown graphically in Figure 8c along with those recorded at Crete Station. Pressure at Summit Station throughout the observation period averaged 3 mb lower than that at Crete Station, again reflecting the higher elevation of Summit Station. This implies that Summit Station was approximately 32 m higher than Crete Station, but uncertainties in the aneroid barometers used at both stations make this figure only an estimate.

Both stations recorded the passage of a low pressure system on 7-9 June. Station pressure during this period dropped 9 mb over a 45-hour period at Crete. The pressure at Summit Station had started falling before the first measurements were recorded; nevertheless, a pressure drop of 6 mb in a 37-hour period was still recorded.

Summary of Summit Station data

Weather observations made at Summit Station are chiefly of interest for the comparison they provide with those made at Crete Station, on the crest some 133 km to the south. Observations made when both stations were operational indicate that calm conditions are more prevalent at Summit Station, whereas light katabatic winds occur at Crete Station. During these conditions Summit Station has lower air temperatures than Crete Station.

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