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QUARTERMASTER RESEARCH & ENGINEERING COMMAND
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TECHNICAL REPORT EP-139

MACRO- AND MICROCLIMATOLOGY OF THE ARCTIC SLOPE OF ALASKA

728700

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

OCTOBER 1960 NATICK, MASSACHUSETTS

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Tables of temperature, insolation, wind, and vapor pressure deficit are given.

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John H. Conover

Project Reference:
7X83-01-008

October 1960

FOREWORD

This report presents the results of the climatological portion of a study conducted on the Arctic Slope of Alaska by the Boston University Physical Research Laboratories, under contract AF33 (103)-15615 with the United States Air Force. At the time of the study the author was on the staff of the Harvard University Blue Hill Meteorological Observatory, and received the cooperation of that institution in preparation of the report. Mr. Conover is now with the Geophysics Research Directorate, Air Force Cambridge Research Center, L. G. Hanscom Field, Bedford, Massachusetts.

Because the study provides quantitative information concerning a little-known part of the Arctic, the Quartermaster Corps felt that it would be valuable to scientists throughout the Department of Defense. Therefore the report is published here as part of the Quartermaster series in microclimatology.

AUSTIN HENSCHEL, Ph.D.
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ABSTRACT

The tundra of the Arctic Slope is characterized in summer by cool maritime winds, much cloudiness, light precipitation, and frequent drizzle. In winter, cloudiness decreases and very cold katabatic winds prevail inland while easterlies continue along the coast. By mid-September a snow cover is generally established; this builds up to depths of 14 to 28 inches in March and April and finally melts in June or July.

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MACRO- AND MICROCLIMATOLOGY OF THE ARCTIC SLOPE OF ALASKA

1. INTRODUCTION

THE MACRO- AND MICROCLIMATOLOGY OF THE ARCTIC SLOPE OF ALASKA WERE OBSERVED DURING SELECTED PERIODS FROM 1952 THROUGH 1954 IN CONNECTION WITH A COORDINATED GEOLOGICAL, ECOLOGICAL, AND SOIL STUDY OF THE REGION.*

THIS LARGE TUNDRA-COVERED AREA IS FLANKED BY THE ARCTIC OCEAN ON THE NORTH AND THE BROOKS RANGE ON THE SOUTH. FIGURE 1 IS A MAP SHOWING PLACE NAMES AND THE GENERAL TOPOGRAPHY. NORTH OF APPROXIMATELY LATITUDE 70° THE LAND IS VERY FLAT AND INTERSPERSED WITH A GREAT MANY LAKES, BOGS, AND RIVERS. SOUTH OF THIS LATITUDE LIES A BROAD ZONE OF ROLLING FOOTHILLS, WHICH IN TURN GIVE WAY TO THE MOUNTAINS OF THE BROOKS RANGE. THE RANGE PRESENTS A BARRIER ROUGHLY 2000 FEET HIGH IN THE WEST, WITH PEAKS REACHING CONSIDERABLY HIGHER, AND 4000 FEET HIGH IN THE EAST, WITH NUMEROUS PEAKS RISING ABOVE 7000 FEET.

METEOROLOGICAL EQUIPMENT WAS ORIGINALLY SET UP IN THE UMIAT AREA BY THE AUTHOR IN JUNE 1952 AND OPERATED UNTIL SEPTEMBER 1952. ESSENTIALLY THE SAME OBSERVATION SITES WERE REOCCUPIED IN JUNE 1953, WHILE DURING JULY AND AUGUST ADDITIONAL STATIONS WERE OPERATED NORTH OF UMIAT, ALONG THE COLVILLE RIVER, AND IN THE FOOTHILLS SOUTH OF UMIAT. WINTER DATA WERE OBTAINED FROM THE UMIAT AREA IN 1953-54 AND CONTINUOUSLY NEAR BARROW FROM LATE 1953 THROUGH 1954 WITH ONE STATION CONTINUING UNTIL MID-1956.

2. INSTRUMENTATION

MANY OF THE INSTRUMENTS WERE ASSEMBLED ESPECIALLY FOR THIS STUDY FROM STANDARD INDUSTRIAL EQUIPMENT.

AIR AND GROUND TEMPERATURES WERE RECORDED ON 3-PEN, FOXBORO WEEKLY SPRING-DRIVEN RECORDERS. SENSING ELEMENTS CONSISTED OF GAS-FILLED BULBS AT THE ENDS OF 6-FOOT COMPENSATED CAPILLARY TUBES. AT THE UMIAT BASE STATION, WHERE POWER WAS AVAILABLE, A 12-POINT BROWN ELECTRONIC RECORDER MEASURED TEMPERATURES IN THE AIR AND SOIL BY MEANS OF THERMOCOUPLES IN REFERENCE TO A CONSTANT HOT TEMPERATURE.

WIND SPEED WAS MEASURED BY 3-CUP ANEMOMETERS AND RECORDED ON THE FOXBORO WEEKLY RECORDERS.

*SEE: TEDROW AND HILL (1955); DREW AND TEDROW (1956); BLISS (1956); BLISS AND CANTLON (1957); CANTLON AND GILLIS (1957); AND TEDROW, DREW, HILL, AND DOUGLAS (1958).

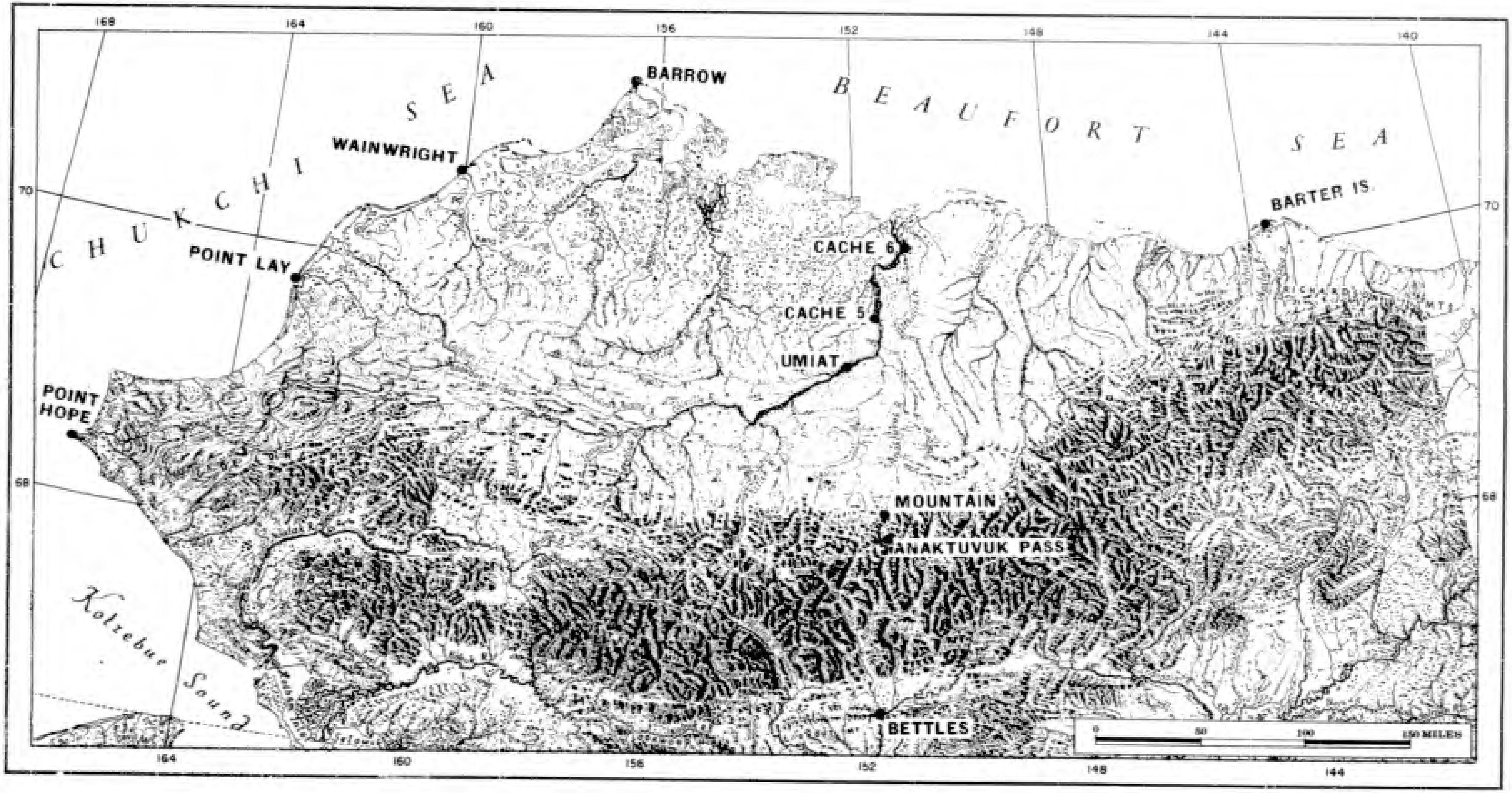

FIGURE 1. ARCTIC SLOPE OF ALASKA

Insolation was measured by an Eppley pyrheliometer and recorded on the Brown recorder.

Vapor pressure was recorded by a Foxboro Dewcel, and evaporation was measured in summer at weekly intervals by means of Livingston atmometers.

3. Observation sites

Microclimatic sites set up for the study consisted of clusters of stations in the Umiat and Barrow areas, one isolated station in the foothills of Brooks Range, and two stations along the Colville River between Umiat and the ocean.

a. Umiat area

Sites in the Umiat area are shown on the sketch map (Fig. 2). Sites 1 through 5 lay along a 3/8-mile transect running south-north over the first range of hills north of Umiat. The stations ranged in elevation from about 425 to 600 feet above sea level. They are described below:

Umiat Base station: Elevation 337 feet, several hundred feet from the landing strip and the U.S. Weather Bureau - U.S. Air Force weather station. Temperature measurements were made vertically near the southern side of a small isolated clump of 5-foot alders which were growing on a slightly depressed center polygon about 8 feet in diameter. This site was known as Umiat Base Polygon (Fig. 3). Temperatures 4 inches below a grass-covered surface and inside a standard thermometer shelter known as Umiat Base, were made about 22 feet WSW of this site. Low grass covered the ground between isolated alder clumps.

Site 1: Elevation about 425 feet, in a gully on a 20-degree south slope. Eight- to 12-foot willows and alders grew in the gully; dead leaves covered the ground.

Site 1A: Elevation about 525 feet, on a south-facing knob between the gullys on the south slope. Nine inches of soil covered the bedrock, and the site was dominated by willow grass.

Site 2: Elevation about 530 feet. The instruments were mounted above a narrow grass-covered shelf on a 40-degree south slope directly above site 1. Eight- to 10-foot willows and alders grew above and below the shelf. A snowbank just above this site was one of the last to melt in the spring.

Site 3: Elevation about 600 feet, on top of an exposed ridge in a 3- to 6-inch tussock-heath community.

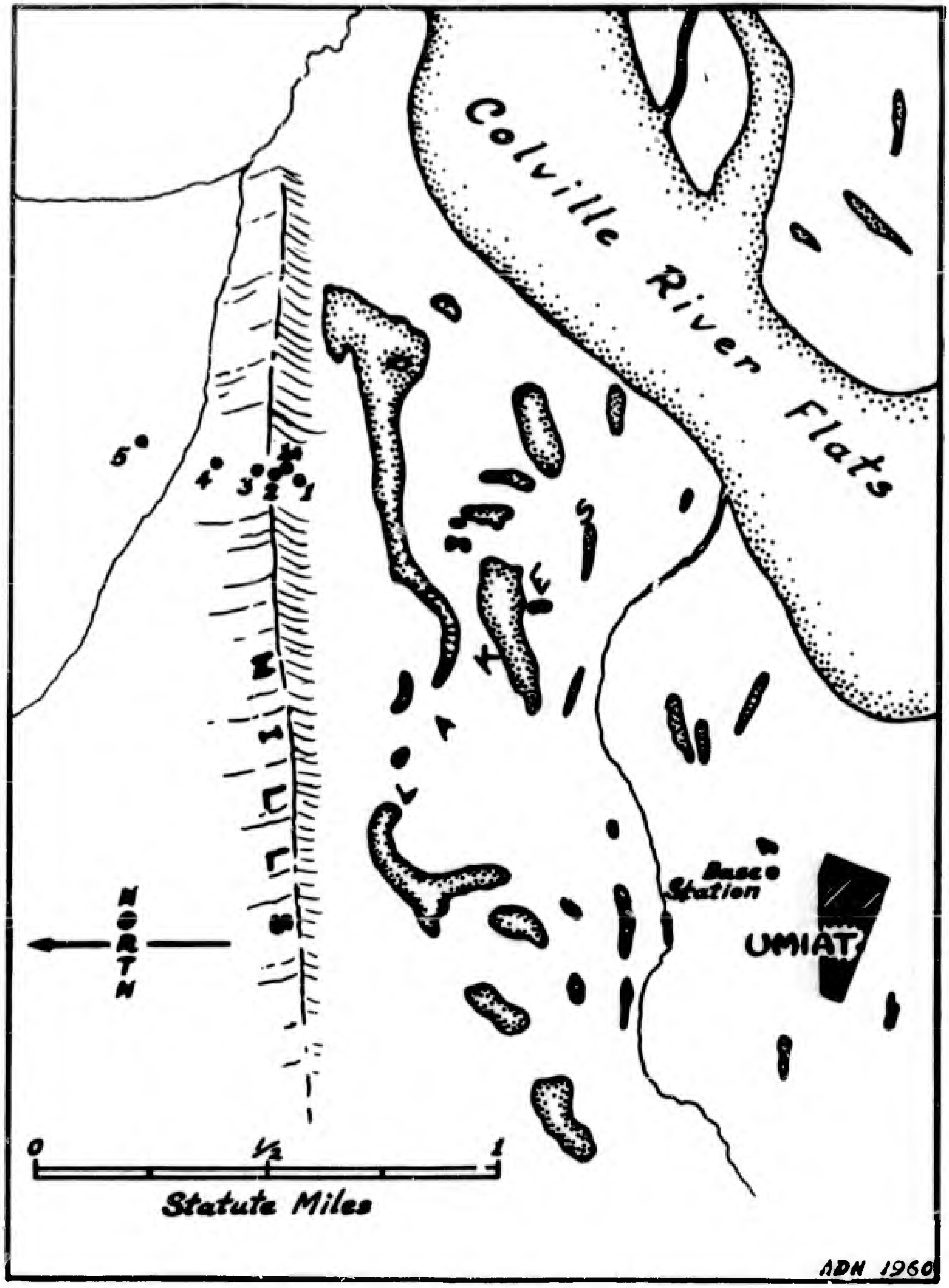

FIGURE 2. SKETCH MAP OF THE UMIAT AREA SHOWING THE SITE LOCATIONS.

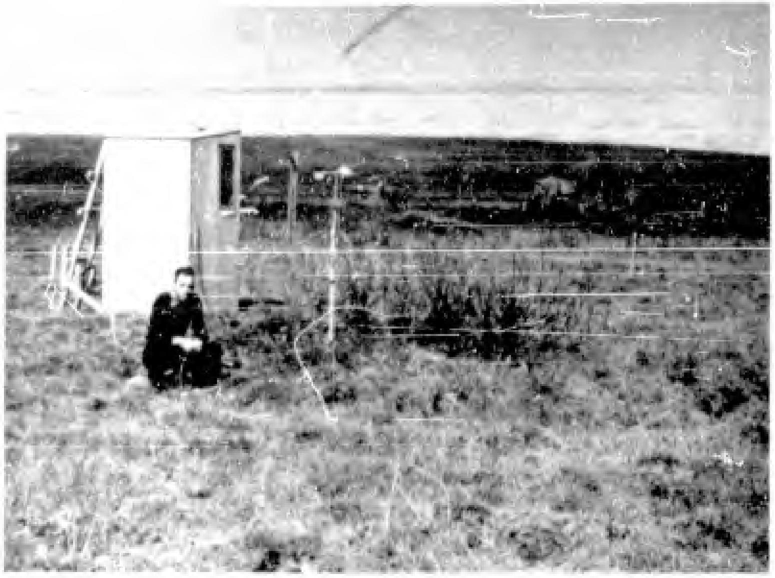

FIGURE 3. THE UMIAT BASE POLYGON SITE LOOKING NORTHWARD. THERMOCOUPLES ARE EXPOSED VERTICALLY ALONG THE ANEMOMETER SUPPORT. PYRHELIOMETER IS MOUNTED ON TOP OF THE RECORDER SHACK.

SITE 4: ELEVATION ABOUT 580 FEET, ON A 15-DEGREE SLOPE FACING NORTH IN A 5- TO 10-INCH TUSSOCK-HEATH COMMUNITY.

SITE 5: ELEVATION ABOUT 580 FEET, FACING SOUTH ON A 15-DEGREE SLOPE. THE TUSSOCK-HEATH COMMUNITY WAS SIMILAR TO THAT AT SITE 4 BUT SLIGHTLY SHORTER.

B. BARROW AREA

THE BARROW AREA SITES ARE SHOWN ON AN OUTLINE MAP (FIG. 4).

BARROW 1: ELEVATION ABOUT 10 FEET, 300 YARDS EAST-SOUTHEAST OF THE ARCTIC RESEARCH LABORATORY ON FLAT, GRASS-COVERED GROUND.

BARROW 2: ELEVATION ABOUT 30 FEET, ON AN OLD BEACH RIDGE ABOUT 20 FEET ABOVE THE LEVEL GROUND. THE GROUND WAS BARE AND GRAVELLY.

BARROW 3: ELEVATION ABOUT 3 FEET, IN 8- TO 10-INCH GRASS ABOUT 12 FEET FROM THE SHORE OF ELSON LAGOON.

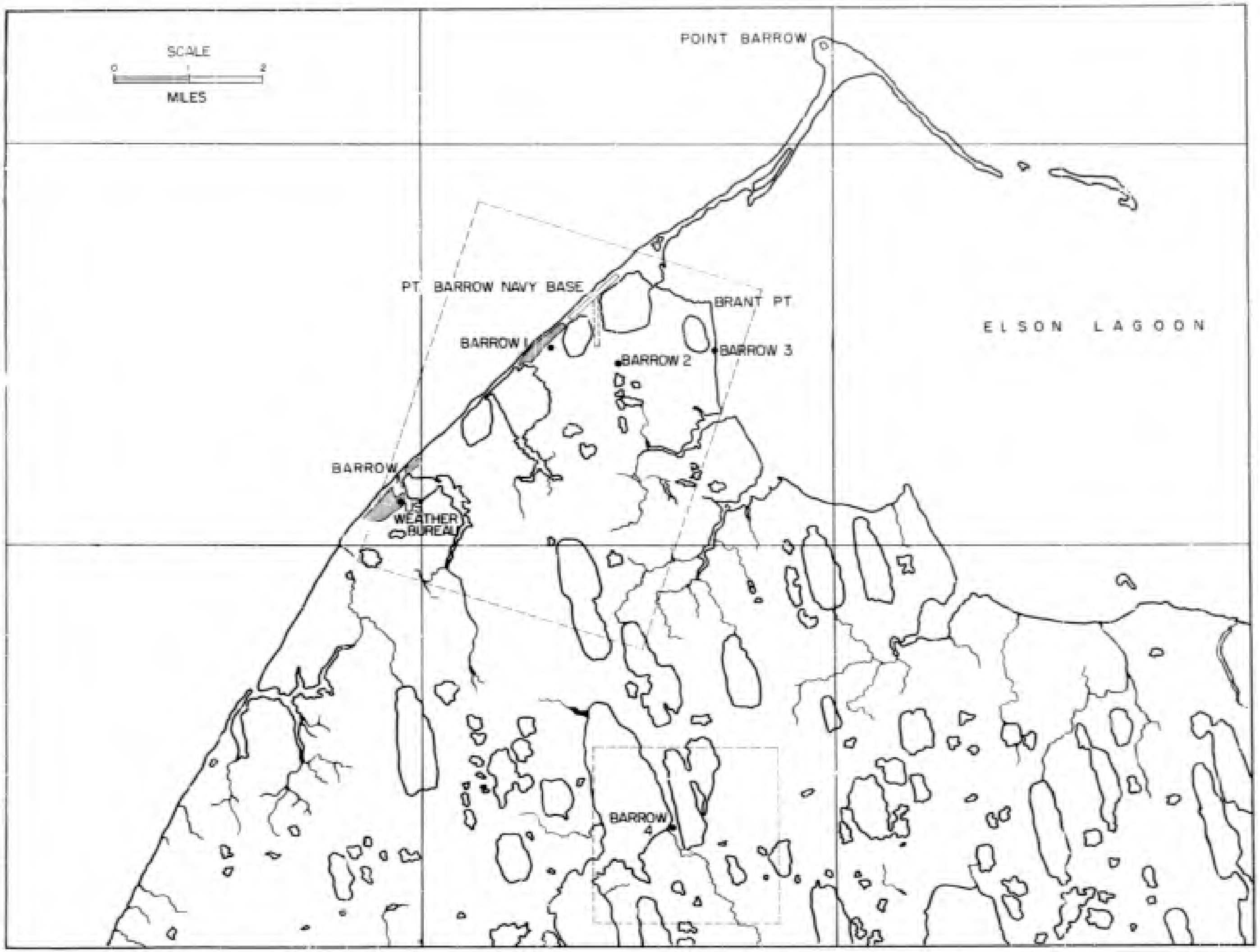

FIGURE 4. MAP OF BARROW AREA SHOWING SITE LOCATIONS.

BARROW 4: ELEVATION ABOUT 10 FEET. THIS STATION WAS THE FARTHEST INLAND OF THE BARROW GROUP. IT WAS SET UP ABOUT 150 FEET EAST OF A LAKE 2 MILES LONG (NORTH-SOUTH) AND 1 MILE WIDE.

c. ISOLATED SITES:

FIGURE 1 SHOWS SITE LOCATIONS.

MOUNTAIN: ELEVATION ABOUT 2500 FEET, ON A SLIGHTLY RAISED HEATH-MOSS-LICHEN COMMUNITY ABOUT 200 FEET SOUTH OF LAKE OKPIKRUARK. DEPRESSED WATER-FILLED POLYGONS COVERED THE AREA IMMEDIATELY TO THE SOUTHEAST AND SOUTHWARD. THE LAND WAS QUITE LEVEL BUT MOUNTAINS, ABOUT FOUR MILES TO THE SOUTH, ROSE 2000 FEET HIGHER. LOW HILLS SURROUNDED THE LAKE TO THE NORTHWEST AND NORTHEAST.

CACHE 5: ELEVATION ABOUT 400 FEET, IN AN UPLAND 5- TO 8-INCH HEATH-TUSSOCK COMMUNITY ON A SOUTH-FACING SLOPE ABOUT 30 FEET FROM THE CREST OF A HILL AND 3/4 MILE WEST OF THE COLVILLE RIVER. A FEW SHRUBS REACHED 1 FOOT IN HEIGHT.

CACHE 6: ELEVATION ABOUT 25 FEET, ABOUT 18 MILES FROM THE BEAUFORT SEA, 300 FEET EAST OF THE COLVILLE RIVER AND 150 FEET NORTH OF A SMALL CHANNEL WHICH ENTERS THE RIVER. THE AREA WAS GENERALLY COVERED WITH DEPRESSED CENTER POLYGONS CONTAINING 1 TO 3 FEET OF WATER, BUT WITH RAISED EDGES ABOUT 1 FOOT HIGH. THE EDGES SUPPORTED TUSSOCKS AND A FEW WILLOWS UP TO 2 FEET HIGH.

4. THE MACROCLIMATE

THE ATMOSPHERIC PRESSURE PATTERN OF THE ARCTIC SLOPE IS CHARACTERIZED BY A HIGH TO THE NORTH OR NORTHEAST AND A LOW TO THE SOUTH OR SOUTHWEST. THIS PATTERN CAUSES A GRADIENT WIND FLOW, OR THAT FOUND ABOUT 3000 FEET ABOVE SEA LEVEL, FROM THE EAST OR SOUTHEAST OVER THE AREA.

IN SUMMER, THE SEA TO THE NORTH IS MOSTLY ICE-COVERED, AND ITS SURFACE IS ONLY SLIGHTLY WARMED BY INSOLATION; THEREFORE, IT TENDS TO COOL THE AIR NEXT TO IT, PROVIDING A SOURCE FOR COLD AIR. THE VERTICAL CROSS-SECTION OF AVERAGE SUMMER TEMPERATURE FROM FAIRBANKS TO BARROW IS SHOWN IN FIGURE 5.

THE AVERAGE POSITION OF THE "POLAR FRONT", WHICH MARKS THE BOUNDARY BETWEEN THE COLD SURFACE AIR OVER THE ARCTIC OCEAN AND THE WARMER AIR TO THE SOUTH, IS BETWEEN 1000 AND 2000 FEET OVER BARROW AND AT THE GROUND ABOUT HALFWAY BETWEEN BARROW AND UMIAT. NORTH OF THE FRONT, THE SURFACE AIR IS DAMP AS A RESULT OF ITS PASSAGE OVER THE ICE-COVERED OR PARTLY OPEN SEA; THEREFORE, IT CONTAINS MUCH FOG AND CLOUD. THE POLAR FRONT OSCILLATES NORTH AND SOUTH. FREQUENTLY IT ADVANCES INLAND AGAINST THE

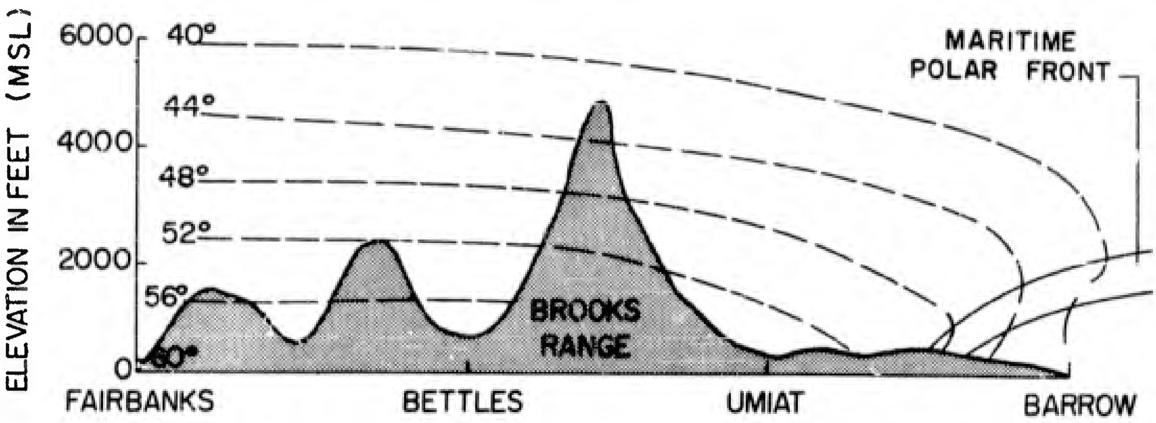

FIGURE 5. CROSS SECTION SHOWING AVERAGE JULY ISOTHERMS (°F) BETWEEN FAIRBANKS AND BARROW.

MOUNTAINS, SO THAT THE WHOLE ARCTIC SLOPE BECOMES COLD. WHEN THE COLD AIR ADVANCES FROM THE NORTH IT TENDS TO FLOW UP THE RIVER VALLEYS; OFTEN 300- TO 500-FOOT HILLTOPS ARE NO COLDER THAN THE ADJACENT VALLEYS. RATHER INFREQUENTLY THE FRONT RETREATS OVER THE SEA AND THE ENTIRE AREA IS WARMED BY LAND WINDS.

GRADUAL NON-FRONTAL SHIFTS IN WIND FROM AN EASTERLY DIRECTION TO SOUTHERLY AND WESTERLY ARE COMMON INLAND WHEN THE POLAR FRONT LIES TO THE NORTH. THESE WIND SHIFTS ARE ASSOCIATED WITH AN EASTWARD MOVEMENT OF PRESSURE TROUGHS AT HIGH LEVELS. LESS FREQUENTLY, ABOUT FOUR TIMES A MONTH IN SUMMER, A WEAK MIGRATORY LOW-PRESSURE CENTER PASSES EASTWARD NORTH OF THE ARCTIC SLOPE REGION. UNDER THESE CONDITIONS, A WARM FRONT PASSES NORTHWARD, AND THE WINDS BECOME SOUTHERLY. THIS IS SOON FOLLOWED, HOWEVER, BY A COLD FRONT PASSAGE AND RETURN TO COLD, DAMP AIR. MOST OF THE MIDDLE- AND HIGH-LEVEL CLOUDINESS AND RAIN ARE ASSOCIATED WITH THE PASSAGE OF HIGH-LEVEL PRESSURE TROUGHS.

IN WINTER, THE AVERAGE PRESSURE PATTERN IS ABOUT THE SAME AS IN SUMMER, BUT THE ENTIRE SLOPE IS NORMALLY COVERED WITH COLD ARCTIC AIR TO A DEPTH OF ABOUT 4000 FEET, AS SHOWN IN THE CROSS SECTION IN FIGURE 6.

IN SPITE OF THE OVER-ALL SIMILARITY OF THE PRESSURE PATTERNS BETWEEN SUMMER AND WINTER, AN ENTIRELY DIFFERENT PATTERN OF WIND AND TEMPERATURE DEVELOPS AT THE SURFACE. AS THE NIGHTS LENGTHEN IN THE FALL, THE HEAT LOST IN OUTGOING RADIATION INCREASES WHILE HEAT GAINED BY INSOLATION DECREASES; THUS LOSSES SOON EXCEED GAINS. THE COOLING EFFECT ON THE LOWEST LAYERS OF THE ATMOSPHERE IS PRONOUNCED, ESPECIALLY SINCE THE LAND

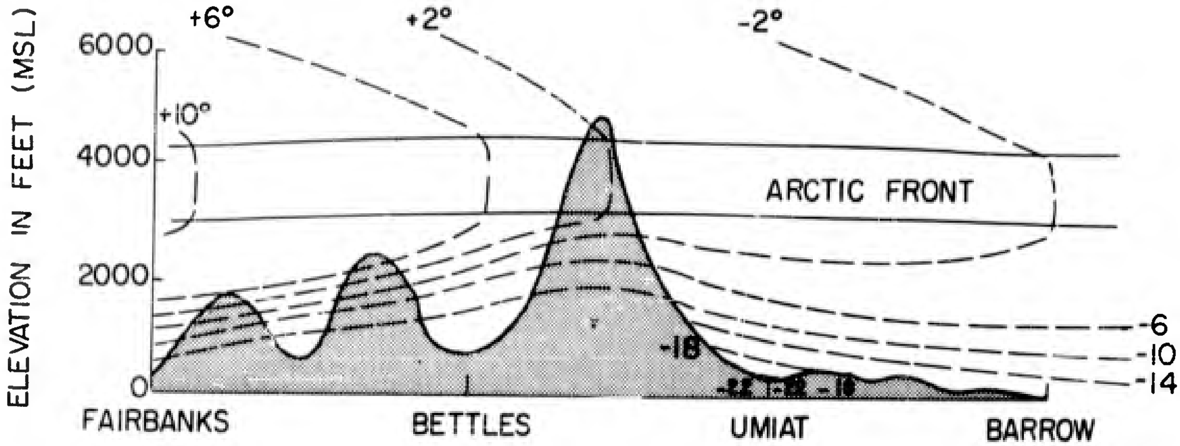

Figure 6. Cross section showing average January isotherms (°F) between Fairbanks and Barrow.

is usually snow-covered by mid-September. By October, a surface inversion of temperature exists more than half the time. The dense, cold air near the surface flows downhill toward the sea, sometimes directly opposed to the gradient level flow.

At Umiat, the katabatic wind--the cold air drainage--has an average depth of 700 feet, although it occasionally builds up to about 1700 feet, and blows at 5 to 12 miles per hour for prolonged periods. At this time the prevailing wind at Umiat changes from east (the upslope wind at Umiat) to west (downslope), and the mean temperature falls below that at Barrow. Winds remain northeasterly at the coast line.

Surface frontal passages are rare during the winter. The winds of invading storms are much warmer than the air near the surface, therefore they cannot displace the cold air easily. Unless the pressure gradients are strong, they ride aloft over the surface layers. Temperature changes therefore depend largely on radiation conditions and not on airmass changes.

A. Wind

The regime of wind from month to month is shown in the form of wind roses for two coastal stations, Barrow and Barter Island, and one inland station, Umiat, in Figure 7. This diagram shows the frequency of winds from 16 points of the compass as well as the frequency of their strength as light, moderate, or strong. The Barrow wind roses show predominant easterlies throughout the year. The winds there are seldom calm, and yet speeds above 32 mph are infrequent.

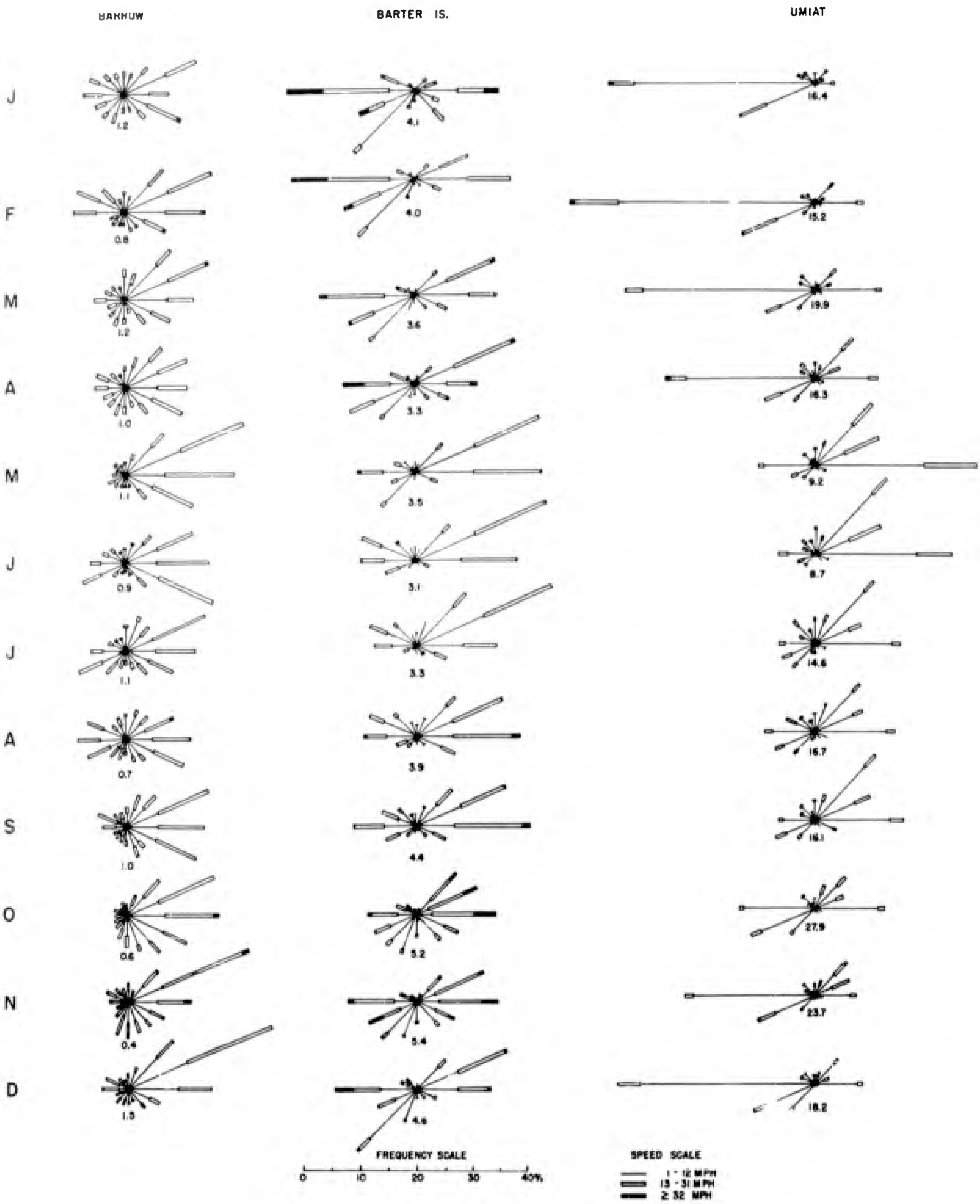

FIGURE 7. MONTHLY WIND ROSES FOR BARROW, BARTER ISLAND, AND UMIAT. THE LENGTH OF A LINE IS PROPORTIONAL TO THE FREQUENCY OF OCCURRENCE. A LINE EXTENDING UPWARD FROM THE CENTER REPRESENTS A NORTH WIND, ONE EXTENDING TO THE RIGHT, AN EAST WIND, ETC. NUMBERS DENOTE PERCENTAGE OF CALMS.

Barter Island, although a coastal station, does not experience the same winds as Barrow because of the nearby high mountains to the south. Calms are observed 3 to 5 percent of the time, but speeds average higher than at Barrow. The mountains tend to narrow the passageway for the winds, causing them to blow faster than would normally be experienced without the land barrier. This is especially true when a storm north of the area moves eastward. The resulting convergence causes frequent westerlies exceeding 32 mph, with a maximum near 100 mph once reported under these conditions.

Umiat, which lies in a shallow west-east inland valley, experiences frequent easterlies during the summer, but in winter, as already noted, katabatic winds prevail; in this case they blow down the valley from the west. The addition of an occasional general gradient flow from the west in winter results in stronger westerlies at Umiat. Calms at Umiat are frequent in winter. They occur when the general gradient favoring an easterly wind is just strong enough to counteract the local gradient favoring westerly katabatic wind.

Wind observations in other sections are scarce, but winds generally are northeasterly along the northwest coast throughout the year. When the gradient wind becomes moderate from the southeast, south, or southwest, strong southerly winds, sometimes carrying sand or dust, blow through the mountain passes.

B. Temperature

Mean monthly temperatures for the period 1947 to 1953 are shown in Table I. Due to the large anomalies which often occur in this region, all stations must be reduced to a common time-interval for comparison. The interval beginning with 1947 was chosen because two of the key stations, Umiat and Barter Island, were opened at that time. Some of the data were derived from shorter records adjusted to the full 7-year period. This was done by way of comparison with other stations over simultaneous months or years or from values at + 4 inches adjusted to shelter level according to the differences discussed later.

The pattern of isotherms at the thermometer-shelter level for July is shown in Figure 8. Along the northeast coast, temperatures average 40°F, due to frequent, cool, on-shore winds. Inland temperatures average higher, due to the warming of the land by insolation and the less frequent presence of the arctic airmass.

The 50° isotherm was located in areas away from the weather stations by using the alder and poplar as index plants. Dr. John Cantlon aided the author in doing this; all possible allowance was made for compensating factors which operate to permit plants to grow in slightly cooler areas

TABLE I. NORMAL MONTHLY AND ANNUAL (1947-1953) TEMPERATURES (°F) AT THERMOMETER-SHELTER LEVEL

STATION	DETERMINED FROM YEARS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	AN.
ANAKTUVUK PASS	AUG 53-OCT 56	-10.9	- 6.1	- 3.0	6.5	27.0	44.6	52.4	44.7	33.0	11.7	3.4	- 8.5	16.2
BARROW (USWB)	1947-53	-16.4	-19.6	-13.6	-0.4	17.5	31.9	40.1	38.8	30.7	17.2	5.2	-12.4	9.9
BARROW NO. 1	1954							40						
BARROW NO. 2	1954	(-17)						41						
BARROW NO. 3	1954	(-18)						39						
BARROW NO. 4	1954	(-18)												
BARTER IS.	NOV 47-DEC 53	-16	-21.5	-13	0.5	19.5	34	40	39.5	31	18	6	-12.5	10.5
BETTLES (YUKON VALLEY)	1947-53	-15.3	- 7.8	3.4	20.1	41.2	54.9	58.1	51.1	40.2	20.7	6.7	- 7.3	22.2
CACHE 5	1953							51.5	45.3					
CACHE 6	1953							49.1	43.7					
HERSCHEL IS. NWT	1901-16	-13.3	-19.6	-13.3	2.7	17.5	31.5	45.9	44.3	31.8	18.8	5.9	-12.2	11.7
MOUNTAIN STAT.	1953							51.2	44.3					
NOME (BERING SEA)	1947-53	1.2	3.6	7.0	20.5	34.9	45.6	50.0	48.6	42.2	29.8	19.5	7.3	25.8
POINT HOPE	1946-52	- 6.5	- 5.0	- 3.6	8.6	23.0	35.4	45.2	43.9	38.2	26.6	16.6	- 5.3	18.1
POINT LAY	1945-53	-15.0	-18.4	-11.9	2.4	21.3	36.9	45.6	44.2	34.6	21.2	7.7	-10.9	13.1
UMIAT	1947-53	-22.2	-26.9	-17.3	-0.9	20.6	43.1	53.2	46.9	32.5	12.6	-0.3	-20.4	10.1
WAINWRIGHT	1945-52	-16.2	-19.4	-13.4	0.8	19.6	34.6	43.3	41.6	33.2	18.9	6.0	-11.5	11.5

( ) = ROUGH ESTIMATE

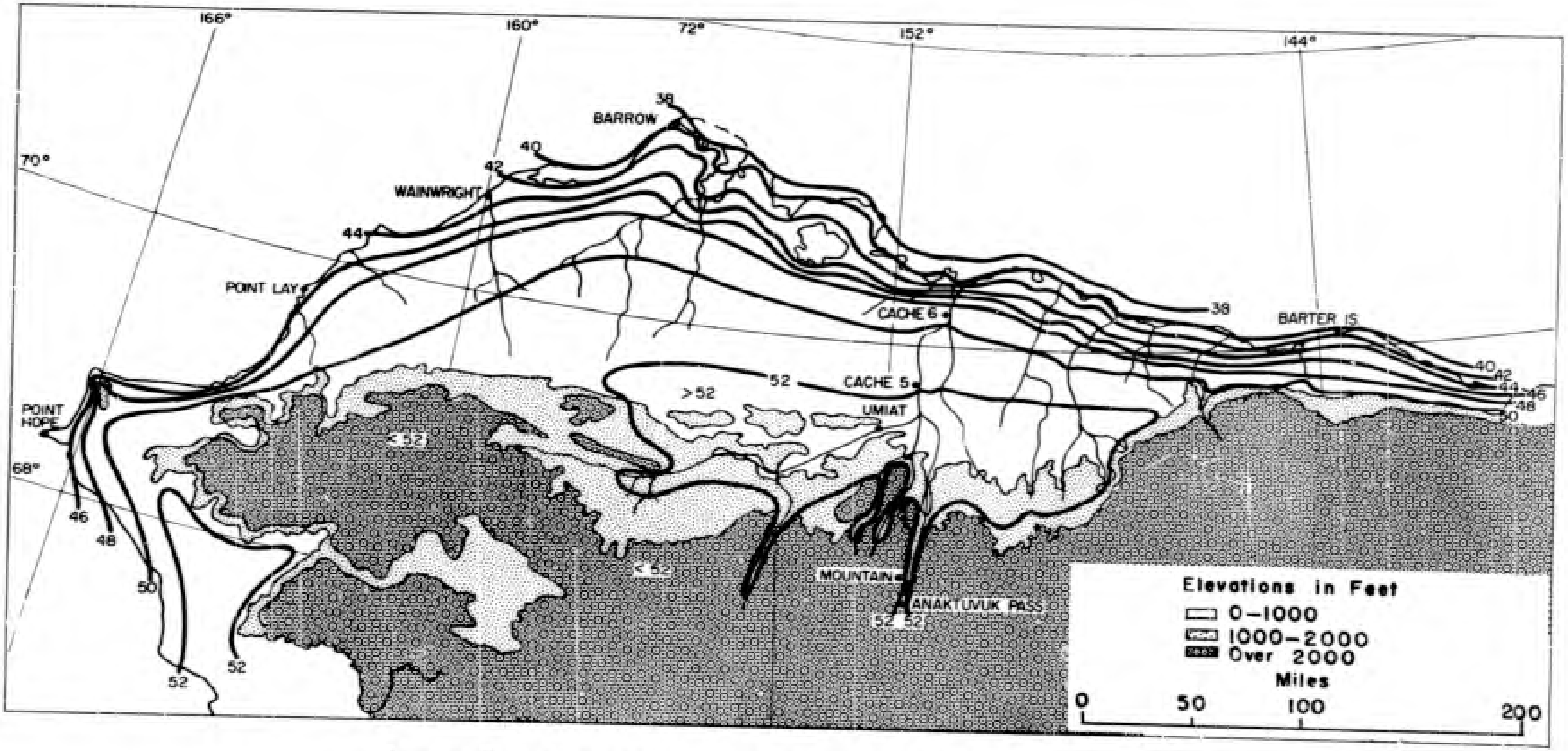

FIGURE 8. JULY NORMAL TEMPERATURE IN °F (1947 TO 1953)

or restrict them from otherwise suitable areas. Temperatures in the valleys east of the Hulahula River are unknown, but they may well be appreciably warmer than shown by the smoothed isotherms.

Temperatures at the 2000-foot level along the north slope average about 2F° lower than those at Umiat. This decrease of temperature with elevation southward is smaller than would normally be expected, because the higher slopes are in the polar airmass less frequently than the lower slopes. Isotherms above the 2000-foot level have not been drawn in Figure 9; however, south of this level the average temperature decrease along the mountain front is about 4 F° per 1000 feet. Monthly extremes of temperature and the average diurnal ranges at Barrow, Barter Island, and Umiat are given in Table II.

The maritime effects in summer are shown by small ranges at Barrow and Barter Island compared with Umiat. The inland station experiences higher maxima in summer. When the cool easterlies weaken or cease temporarily, temperatures rise rapidly, sometimes exceeding 80°F at shelter level. At these times, tundra surface temperatures may reach 105°F. Low summer extremes occur along the coast because these stations are nearer the cooling influence of permanent ice.

In winter (Fig. 9), the average January isotherm pattern is much different from that in summer. The vast area to the north of the Colville Valley, stretching to the coast, averages about -17°F. To the south, upslope, the temperature rises; the average is about -10°F at Anaktuvuk Pass (elevation 2000 feet). In general, average temperatures above 2000 feet along the Arctic Slope (south of the -10° isotherm in Fig. 9) rise to a maximum of about -1°F around 4000 feet and then decrease above this level. The mountain tops and passes are not always this warm; however, sometimes strong winds force the cold air in the valleys upward and through the passes.

The lowest average temperatures appear in the central Colville Valley, although it is possible that the topography of parts of the upper valley would permit still lower temperatures. A minimum of -78°F occurred in January of 1955 at Umiat (verbal communication by Lt. Col. William M. Thompson, U.S. Air Force, Anchorage, Alaska). This was the lowest observed there in 10 years of record and according to Wexler (1948) was only 3F° above the North American record set at Snag, Yukon Territory, on 3 February 1947. There may be cold, calm pockets in the western part of the Brooks Range where the minimum winter temperatures are lower than those found elsewhere on the continent.

Thawing indices (degree-days above 32°F at the shelter height of 5 feet) range from about 500 at Barrow to 1500 in the Colville Valley near Umiat. Values near 1200 are found at the 2000-foot level along the north slope.

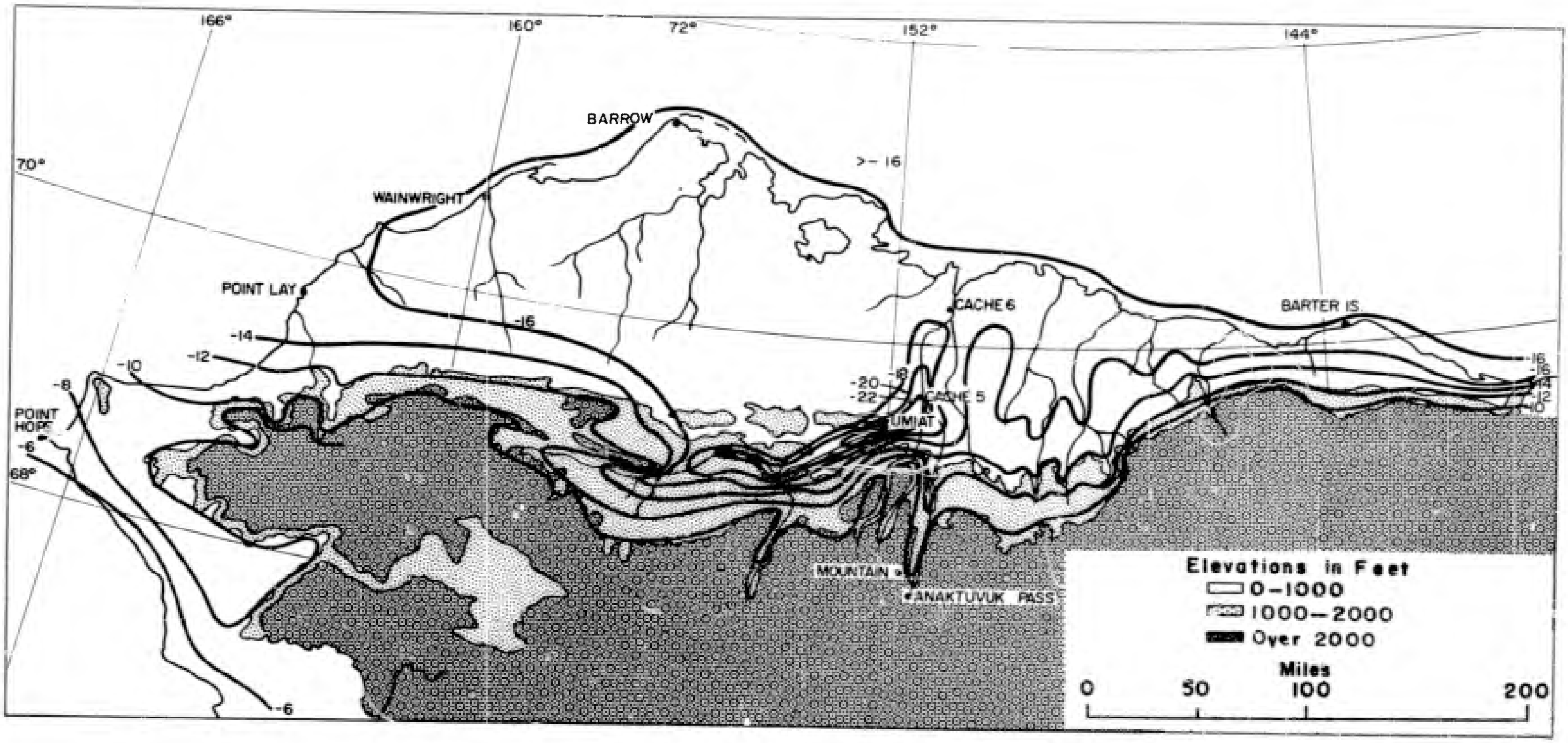

FIGURE 9. JANUARY NORMAL TEMPERATURE IN °F (1947 TO 1953).

TABLE 11. MONTHLY TEMPERATURE EXTREMES AND AVERAGE DIURNAL RANGES (°F) BY MONTHS AT BARROW, BARTER ISLAND, AND UMIAT

		J	F	M	A	M	J	J	A	S	O	N	D	AN.
BARROW (1921-53)	MAX.	33	31	30	42	45	70	78	73	59	40	39	34	78
	MIN.	-53	-56	-52	-42	-18	8	22	20	4	-19	-40	-55	-56
	DIUR. RANGE	13	13	14	15	11	10	13	11	7	10	12	12	12
BARTER IS. (1947-53)	MAX.	31	25	31	35	39	61	71	63	65	41	37	31	71
	MIN.	-51	-59	-39	-37	-15	20	26	24	12	-17	-51	-49	-59
	DIUR. RANGE	14	13	14	17	11	8	10	9	6	10	10	9	11
UMIAT (1947-54)	MAX.	30	28	35	40	55	74	85	77	63	45	43	31	85
	MIN.	-62	-63*	-50	-46	-22	20	30	24	-6	-27	-53	-56	-63*
	DIUR. RANGE	17	16	18	22	24	16	20	23	13	15	16	14	17

*-78 UNOFFICIALLY REPORTED 15 JANUARY 1955.

Freezing indices, or degree-days below a mean of 32°F at shelter height, range from about 9300 within the area enclosed by the -20° isotherm in Figure 9 to about 6000 at Point Hope. Values of 8400 occur along the coast from Barrow to Barter Island. At the 2000-foot level along the mountain front (Anaktuvuk Pass), the freezing index is approximately 7500.

c. Precipitation

Precipitation data for the slope are scarce and probably inaccurate. The efficiency of gage catch depends on the gage size, type of windshield, the wind speed at the gage orifice, and particle size and density. Black (1954) concludes from water equivalents of the snow cover that the actual Barrow precipitation is 2 to 4 times the amount caught in the standard 8-inch precipitation gage.

Warnick (1956), in wind tunnel tests, has determined collection efficiencies for different gage types, sizes, and shields vs. wind speed. Conservative interpolation of his curves between zero wind and the lowest tunnel speeds (about 12 mph) indicate that an 8-inch standard unshielded gage is about 60 percent efficient during snow and a wind speed of 10 mph. This is the orifice-level wind at Barrow as computed from measurements at 6 and 33 feet with due allowance for stronger-than-average wind during measureable precipitation. The collection efficiency is probably lower during the fall of small, dense snow crystals, as experienced during most of the arctic winter. Collection efficiencies of drizzle as low as 40 percent during a 15-mph orifice wind have been found by Conover (1951) during gage comparisons at Blue Hill. Therefore, it seems reasonable to estimate that the annual Barrow catch is only 60 to 70 percent efficient. Similar reasoning indicates that the annual Barter Island catch is about 50 to 60 percent efficient. Due to much lower winds at Umiat and a higher frequency of relatively large raindrop sizes in summer, the annual gage efficiency at Umiat is estimated to be 85 to 95 percent. The addition of an Alter shield, described by the U.S. Weather Bureau (1951), at Barrow, in October 1954 should have raised the efficiency only slightly, since its greatest effect takes place at higher wind speeds.

Monthly measured amounts for the period 1947-53 are given in Table III. Amounts are lowest in spring, when the large-scale storms are farthest to the south, and highest in the summer. Secondary monthly maxima, in October and November, which are found at Barter Island and Point Hope, are caused by additional snowfall resulting from the passage of cold winds over relatively warm water. This phenomenon, often referred to as "lee-shore snowfall", is common near the Great Lakes in the fall.

The geographical distribution of measured annual precipitation is shown in Figure 10. Precipitation totals, after allowance is made for gage catch efficiencies, probably are about 6 inches over the extreme northern

TABLE III. NORMAL MEASURED MONTHLY AND ANNUAL PRECIPITATION (INCHES), 1947 TO 1953

STATION	J	F	M	A	M	J	J	A	S	O	N	D	AN.
ANAKTUVUK PASS[1]	1.75	1.25	2.13	0.88	1.21	1.77	0.95	1.28	1.35	1.07	1.28	1.12	16.04
BARROW	0.19	0.15	0.08	0.17	0.10	0.25	0.75	1.05	0.52	0.43	0.29	0.15	4.13
BARTER ISLAND	0.42	0.14	0.15	0.19	0.27	0.63	0.81	1.08	0.55	1.01	0.68	0.35	6.28
BETTLES	0.73	0.50	0.85	0.35	0.55	1.36	1.48	2.56	1.93	0.82	0.71	0.51	12.35
KOTZEBUE	0.35	0.39	0.32	0.42	0.35	0.65	1.71	2.58	1.10	0.48	0.66	0.45	9.46
POINT LAY[2]	0.25	0.21	0.16	0.28	0.12	0.37	1.26	1.56	0.48	0.40	0.17	0.19	5.45
POINT HOPE[3]	0.46	0.53	0.33	0.93	0.54	0.55	0.81	2.23	1.11	1.02	1.57	0.67	10.75
UMIAT	0.23	0.22	0.14	0.30	0.08	0.56	0.79	1.74	0.51	0.47	0.42	0.38	5.84
WAINWRIGHT[4]	0.08	0.05	0.08	0.21	0.12	0.18	0.86	1.00	0.48	0.50	0.27	0.08	3.91

[1] ADJUSTED FROM SMOOTHED RATIOS OF ANAKTUVUK PASS/BETTLES DURING 1953-1956.

[2] BROKEN RECORD, FROM 3 TO 7 VALUES FOR INDIVIDUAL MONTHS.

[3] BROKEN RECORD, AVERAGE OF 5 VALUES FOR INDIVIDUAL MONTHS.

[4] 6 SCATTERED MONTHS MISSING.

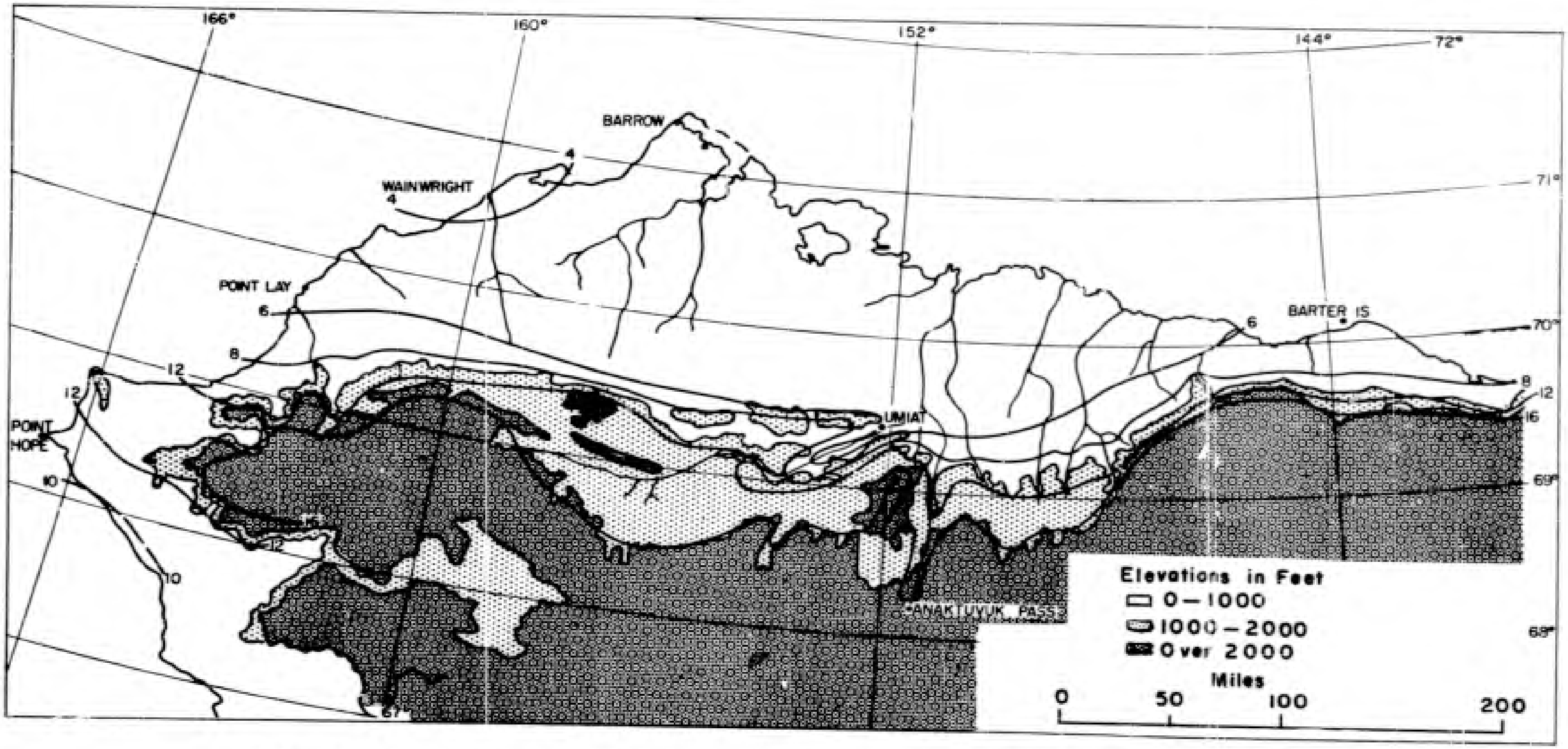

FIGURE 10. NORMAL MEASURED ANNUAL PRECIPITATION IN INCHES (1947 TO 1953).

COAST AND CENTRAL PART OF THE SLOPE, ABOUT 12 INCHES AT 1000 FEET, AND ABOUT 18 INCHES AT 2000 FEET ALONG THE CENTRAL PART OF THE SLOPE. ALONG THE EASTERN AND WESTERN PORTIONS OF THE SLOPE, AMOUNTS APPEAR TO BE HIGHER.

MONTHLY FREQUENCIES OF DIFFERENT DAILY PRECIPITATION AMOUNTS AT BARROW, BARTER ISLAND, AND UMIAT ARE SHOWN IN FIGURE 11. PRECIPITATION OCCURS FREQUENTLY BUT THE DAILY TOTALS ARE SMALL. EVEN IN SUMMER THE CHANCE OF 0.5 INCH OF RAIN IN ONE DAY IS ONLY ABOUT 1 IN 100 ALONG THE COAST AND INLAND ABOUT 3 IN 100. AT BARROW AND UMIAT THE SPRING MONTHS HAVE THE LOWEST TOTALS, BUT THEY ARE NOT THE LEAST LIKELY TO EXPERIENCE DAILY PRECIPITATION. HIGH FREQUENCIES OF LOW AMOUNTS IN WINTER AT UMIAT ARE CAUSED BY THE FREQUENT PERIODS OF ICE-CRYSTAL FORMATION, PROBABLY AT LOW LEVELS, AND FALLOUT.

HOARFROST, WHICH ERRONEOUSLY HAS NOT BEEN INCLUDED IN PRECIPITATION MEASUREMENTS, IS FREQUENT INLAND. DEPOSITS A FEW MILLIMETERS THICK OFTEN BUILD UP DURING DAYS OF CALM WEATHER.

SNOWFALL DATA ARE SUBJECT TO CONSIDERABLE ERROR DUE TO DRIFTING. HOWEVER, AVERAGES HAVE BEEN COMPUTED FROM ALL AVAILABLE DATA AND ARE PRESENTED IN TABLE IV. IN NEARLY ALL CASES THESE DATA REVEAL A FALL MAXIMUM. THIS MAY BE EXPLAINED AS THE RESULT OF TEMPERATURES BECOMING LOW ENOUGH FOR SNOW WHILE ATMOSPHERIC MOISTURE IS STILL APPRECIABLE AND BEFORE THE BELT OF LARGE-SCALE STORM SYSTEMS HAS RETREATED SOUTHWARD. THE "LEE-SHORE EFFECT", DISCUSSED EARLIER, IS PRESENT AT BARROW, BARTER ISLAND, WAINWRIGHT, POINT HOPE, AND ESPECIALLY AT CAPE LISBURNE. HOWEVER, THIS DOES NOT EXTEND AS FAR INLAND AS UMIAT.

THE GEOGRAPHICAL DISTRIBUTION OF AVERAGE ANNUAL SNOWFALL IS SHOWN IN FIGURE 12. THE EFFECTS OF ELEVATION ARE PRONOUNCED; IN GENERAL THE AMOUNTS AT SEA LEVEL, FAR FROM THE MOUNTAINS, AVERAGE 22 INCHES; AT 1000 FEET THEY AVERAGE ABOUT 46, AND AT 2000 FEET, ABOUT 71.

MONTHLY FREQUENCIES OF DIFFERENT DAILY SNOWFALLS AT BARROW, BARTER ISLAND, AND UMIAT ARE SHOWN IN FIGURE 13. ALTHOUGH NO MONTH IS NECESSARILY FREE OF SNOW, FALLS OF OVER 3 1/2 INCHES ARE NEARLY NON-EXISTENT. OF THE THREE STATIONS, BARTER ISLAND RECEIVES THE MOST FREQUENT MEASURABLE AMOUNTS; THIS RESULTS FROM THE CONVERGENCE AND LIFTING OF AIR NEAR THE MOUNTAINS.

D. SNOW COVER

MONTHLY FREQUENCIES OF DAILY AMOUNTS OF SNOW COVER FOR BARROW, BARTER ISLAND, AND UMIAT ARE SHOWN IN FIGURE 14. A CONTINUOUS SNOW COVER HAS GENERALLY FORMED THROUGHOUT THE AREA BY MID-SEPTEMBER. THE COVER CLEARS AWAY ABOUT MID-JUNE INLAND AND ABOUT A WEEK LATER ALONG THE COAST. SNOW DEPTHS BUILD UP SLOWLY BUT STEADILY TO A MAXIMUM, IN LATE MARCH OR EARLY APRIL, OF ABOUT 14 INCHES AT BARROW, 22 INCHES AT BARTER ISLAND, 15 INCHES AT UMIAT, AND (JUDGING FROM MEAGER DATA) ABOUT 28 INCHES AT ANAKTUVUK PASS.

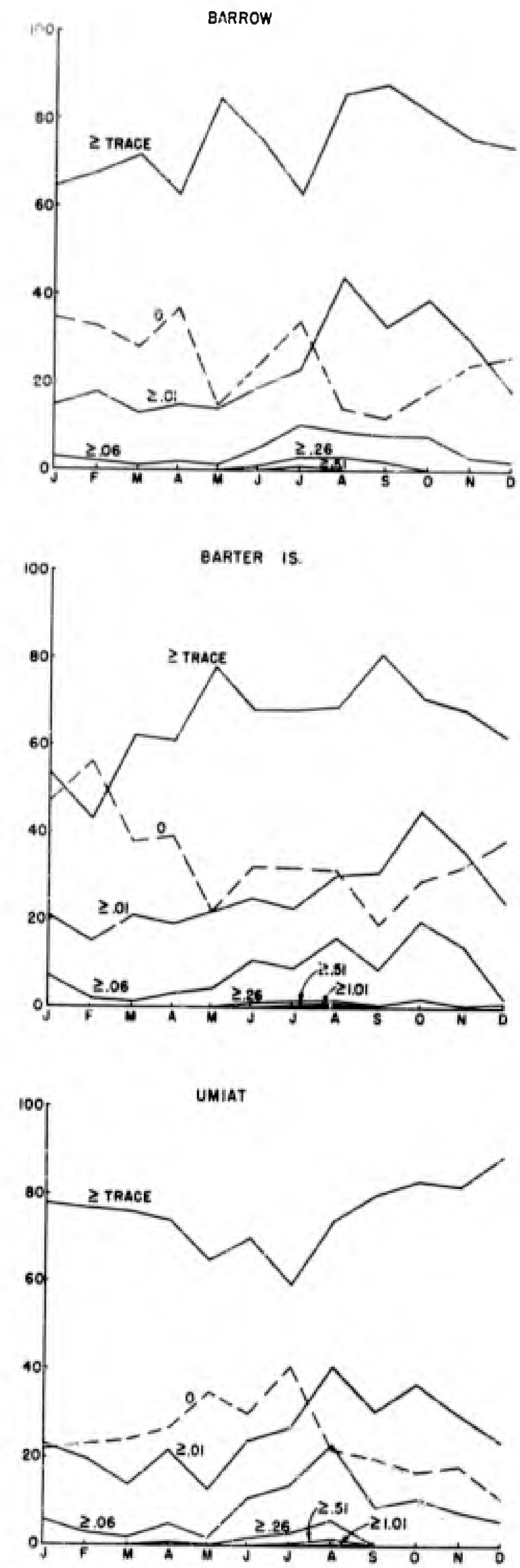

FIGURE 11. MONTHLY PERCENTAGE OF DAILY PRECIPITATION AMOUNTS IN INCHES AT BARROW (9 YEARS), BARTER ISLAND (5 1/2 YEARS), AND UMIAT (8 YEARS).

TABLE IV. NORMAL MONTHLY AND ANNUAL SNOWFALL (INCHES), 1947 - 1953

Station	Period	J	F	M	A	M	J	J	A	S	O	N	D	An.
Anaktuvuk Pass	Jul 1953-Jun 1956	5.2	6.8	10.9	3.8	6.0	0.7	T	1.0	10.2	9.6	9.2	7.1	70.5
Barrow	1947-1953	2.1	2.0	1.1	2.4	1.3	0.3	0.2	0.2	2.3	4.9	3.6	1.8	22.2
Barter Is.	1947-1953	4.2	1.4	1.5	2.1	2.4	2.2	T	1.4	3.4	10.5	6.5	3.4	39.0
Cape Lisburne	Feb 1954-Jun 1956	13.0	3.0	8.1	1.8	1.6	T	0	3.3	2.4	11.6	19.8	8.4	73.0
Kotzebue	1947-1953	3.7	4.4	3.9	4.4	1.5	T	0	T	0.1	4.0	8.6	6.1	36.7
Point Lay	1946-1955[A]	1.9	2.2	0.8	2.9	2.7	T	0	0.1	T	5.6	2.0	1.9	20.1
Point Hope	1946-1954[B]	3.9	3.0	1.0	3.0	2.3	1.0	0.1	T	1.9	3.7	10.9	5.1	35.9
Umiat	1947-1953	3.6	2.0	1.7	3.2	1.5	0.5	T	0.8	2.0	6.0	5.5	4.0	30.8
Wainwright	1946-1955[C]	2.9	0.9	0.9	1.2	1.3	T	0	T	0.7	5.8	2.3	0.9	16.9

[A] From 4 to 8 values for individual months.

[B] From 3 to 6 values for individual months.

[C] From 3 to 8 values for individual months.

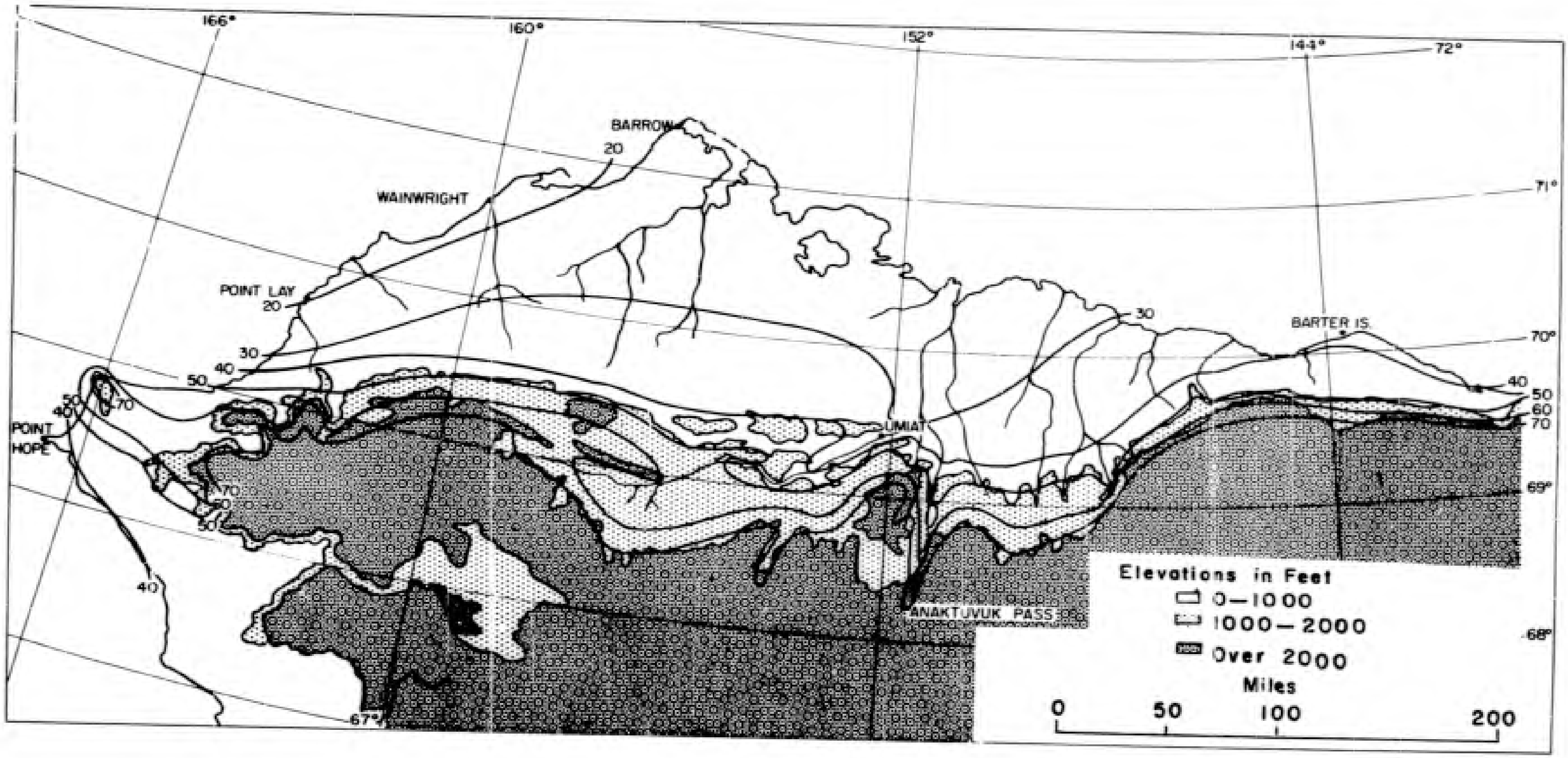

FIGURE 12. NORMAL ANNUAL SNOWFALL (1947 TO 1953).

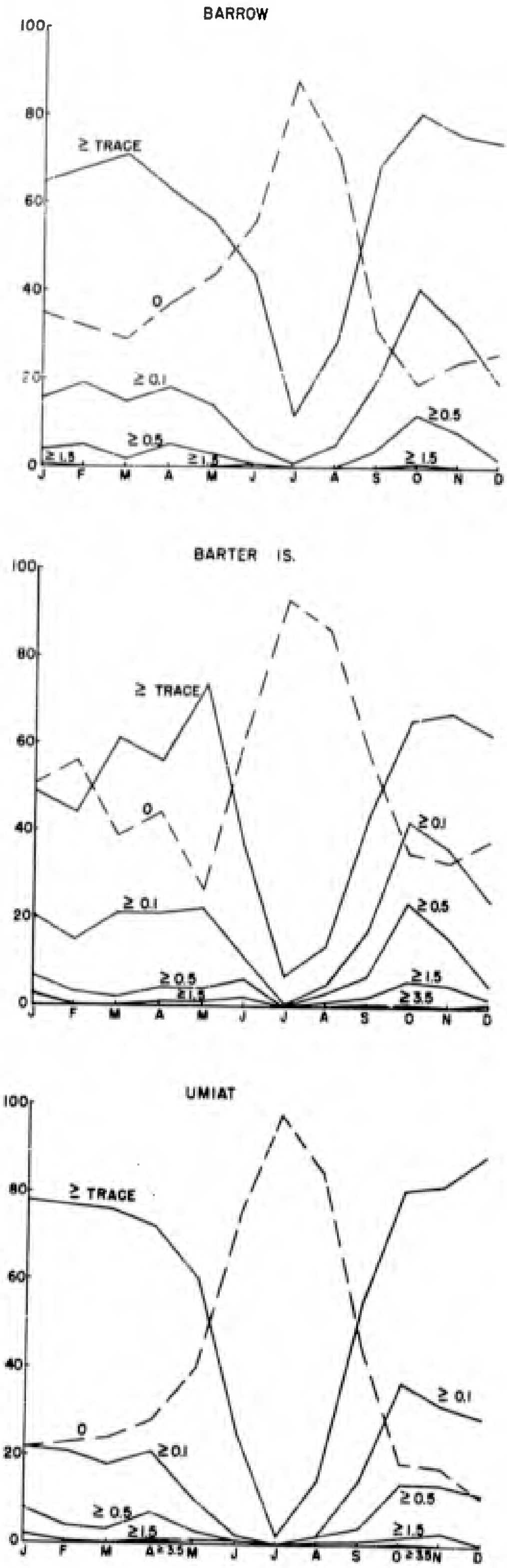

FIGURE 13. MONTHLY PERCENTAGE FREQUENCIES OF DAILY SNOWFALL DEPTHS IN INCHES AT BARROW (9 YEARS), BARTER ISLAND (5 1/2 YEARS), AND UMIAT (8 YEARS).

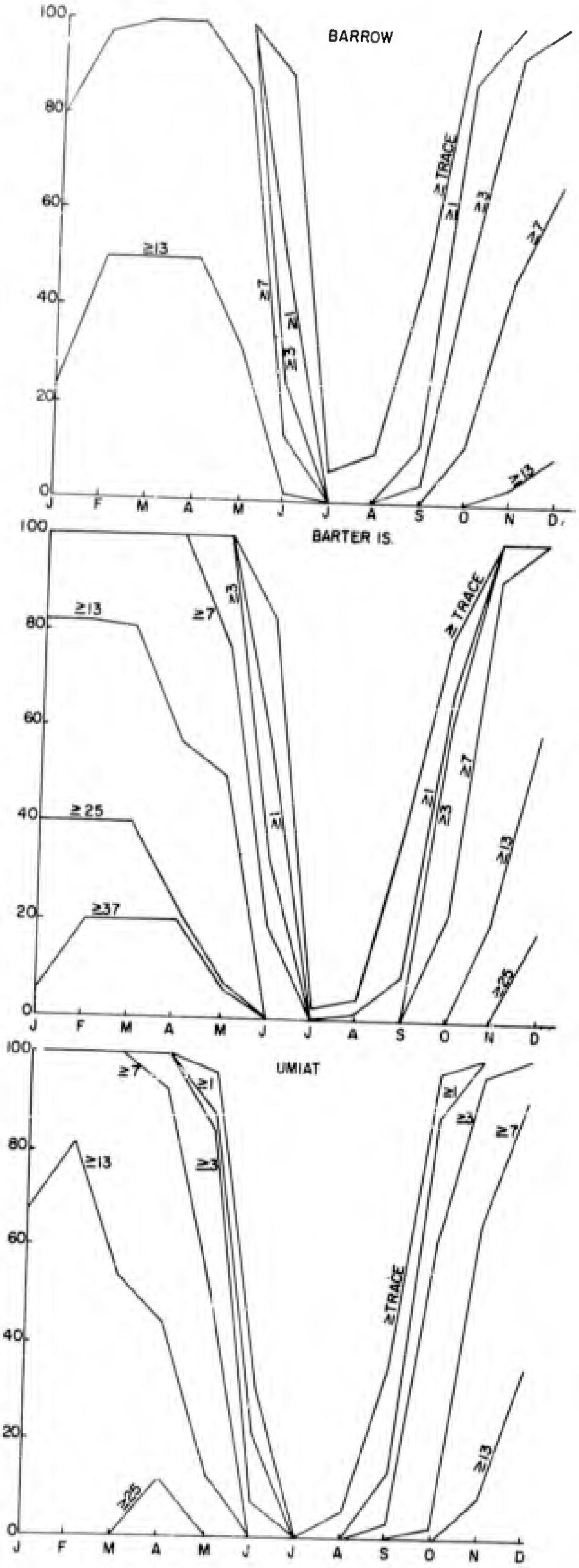

FIGURE 14. MONTHLY PERCENTAGE FREQUENCIES OF SNOW COVER DEPTHS IN INCHES AT BARROW, BARTER ISLAND, AND UMIAT (EACH 6 YEARS).

Single maximums range from 22 inches at Umiat to 40 inches at Barter Island. Undoubtedly, greater depths are found in the foothills than in the Colville Valley. In late May of 1955, following a season of above-average snowfall, 48 inches of snow lay on the ground in Anaktuvuk Pass. During January, February, and March, covers are never less than 7 inches at Barter Island and Umiat, and never less than 4 inches at Barrow.

e. Weather

The occurrence of thunderstorms, rain or drizzle, freezing rain, snow or sleet, and hail is summarized in Table V. The near absence of thunderstorms and related hail is due to the lack of warm, humid days and large-scale cyclonic storms such as occur in temperate latitudes. Thunderstorms, which have formed over or south of the mountains, occasionally drift northward, but they soon dissipate over the North Slope. The relatively high frequency of freezing rain is caused by the predominance of cold surface air while temperatures aloft are often above freezing during precipitation. This causes the rain to freeze when it strikes the surface. The hazard to flying aircraft is obvious. In summer the total time during which precipitation is falling drops to 13 to 16 percent, but in December it rises to 50 percent at Umiat.

f. Sky cover

The frequencies of occurrence of different amounts of sky cover for each month at Barrow, Barter Island, and Umiat are shown in Figure 15. The winter months average the least cloudy. The sky is usually either clear or completely covered. During summer and fall, overcast skies (10/10) are very frequent. Cloudiness over the foothills probably averages a little above that at Umiat. In winter the approach and presence of a cloud sheet over the Arctic Slope is invariably marked by a rise in temperature, and clearing is quickly followed by a fall in temperature. If a katabatic wind is blowing before the clouds arrive, it will usually diminish as cloudiness increases. The temperature may rise 5 or 6F° before the clouds appear, and 15 or 20° after they arrive. This feature has long been used by arctic natives to forecast storms.

g. Ceiling

Ceiling is defined as the level at which more than half the sky is obscured. Frequencies of the occurrence of different ceilings for each month at Barrow, Barter Island, and Umiat are shown in Figure 16. Ceiling height is not only of special importance in planning operations of aircraft but also indicates the type of clouds present. In winter, low ceilings are rare inland but are common from May to October, especially near the coast. During this period, fog or low clouds form over the sea and drift inland with the easterlies. Inland, insolation warms the land, as compared with

TABLE V. PERCENTAGE FREQUENCY OF OCCURRENCE OF PRECIPITATION TYPES (FROM HOURLY OBSERVATIONS) AT BARROW, BARTER ISLAND, AND UMIAT

STATION	MONTH	THUNDER-STORMS	RAIN AND/OR DRIZZLE	FREEZING RAIN	SNOW AND/OR SLEET	HAIL	TOTAL
BARROW (9 YEARS DATA)	J	0	0	0.9	27.8	0	28.7
	F	0	0	0	31.5	0	31.5
	M	0.1	0	0.1	29.0	0	29.2
	A	0	0.1	0.2	29.4	0	29.7
	M	0	0.6	2.8	38.0	0	41.4
	J	0	10.0	1.4	11.9	0	23.3
	J	0.1	13.8	0.5	2.5	0	16.9
	A	0.1	22.1	0.6	8.6	0	31.4
	S	0	12.2	2.1	25.7	0	40.0
	O	0	0.4	1.9	39.1	0	41.4
	N	0	0.1	0.5	41.1	0	41.7
	D	0	0	0	37.4	0	37.4
	YEAR	0	4.9	0.9	26.8	0	32.6
BARTER ISLAND (6 YEARS DATA)	J	0	0	0	18.6	0	18.6
	F	0	0	0	16.3	0	16.3
	M	0	0	0	19.3	0	19.3
	A	0	0.2	0.2	23.8	0	24.2
	M	0	1.9	2.9	30.4	0	35.2
	J	0	8.2	2.1	8.4	0	18.7
	J	0	15.1	0.3	1.2	0	16.6
	A	0	18.1	0.3	4.0	0	22.4
	S	0	13.4	1.7	14.1	0	29.2
	O	0	0.6	3.9	28.2	0	32.7
	N	0	0.3	0.6	28.9	0	29.8
	D	0	0	0	27.6	0	27.6
	YEAR	0	4.8	1.2	18.4	0	24.4
UMIAT (8 1/4 YR. DATA)	J	0	0.1	0.3	35.5	0	35.9
	F	0.1	0	0	37.9	0	38.0
	M	0	0	0	34.6	0.1	34.7
	A	0.1	0.3	0.2	30.0	0	30.6
	M	0	1.3	1.5	21.8	0	24.6
	J	0	13.4	0.3	6.1	0	19.8
	J	0.2	12.5	0	0.1	0	12.8
	A	0	18.8	0.2	4.7	0	23.7
	S	0	10.5	1.2	22.3	0	34.0
	O	0	0.5	1.3	37.7	0	39.5
	N	0	0	0.5	47.3	0	47.8
	D	0	0	0.2	50.5	0	50.7
	YEAR	0	4.8	0.5	27.4	0	32.7

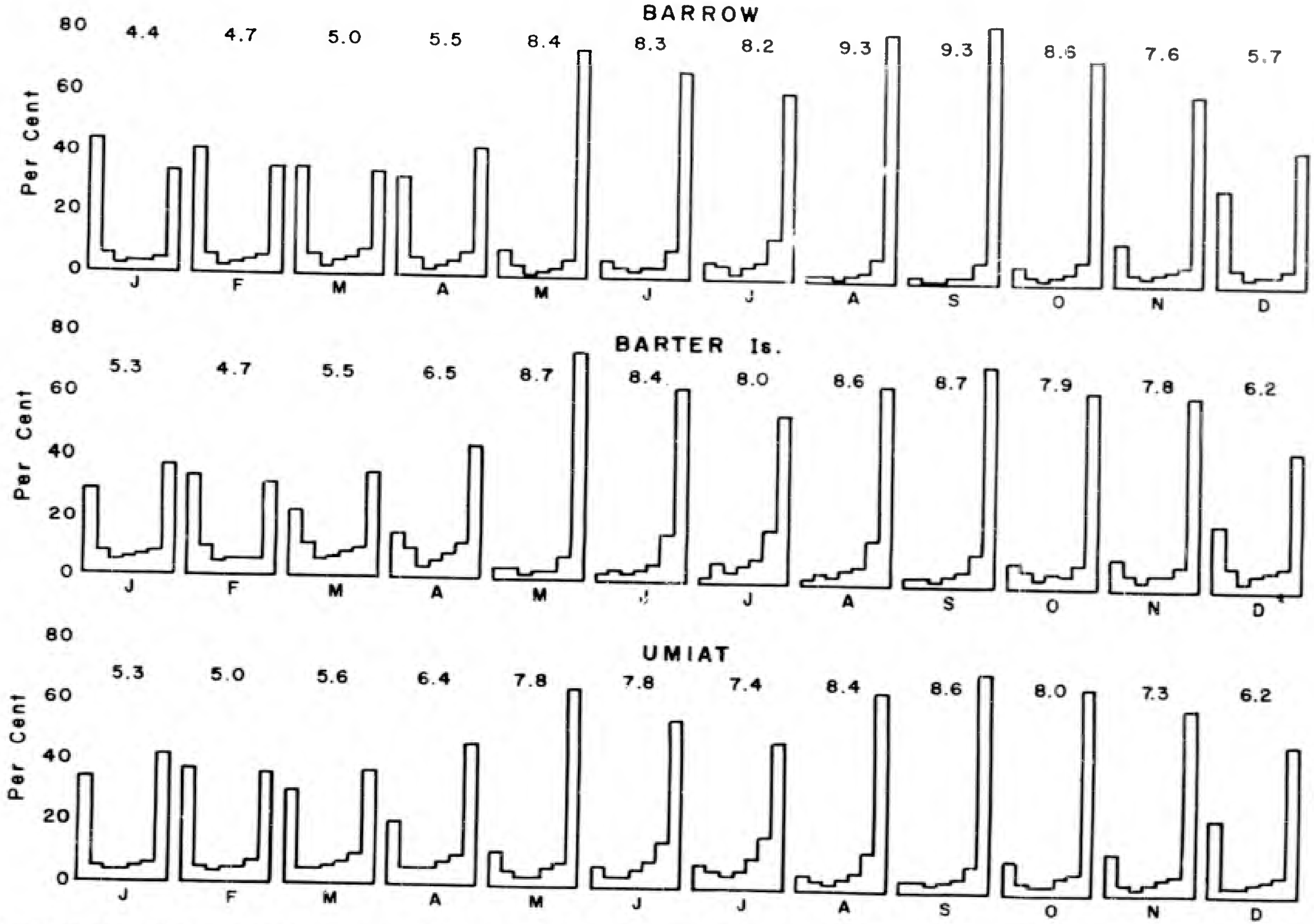

FIGURE 15. MONTHLY PERCENTAGE FREQUENCIES OF HOURLY SKY COVER IN TENTHS BY CLASS INTERVALS OF: 0, 1-2, 3, 4-5, 6-7, 8-9 AND 10 (LEFT TO RIGHT). AVERAGE MONTHLY SKY COVERS, IN TENTHS, UPPER FIGURE.

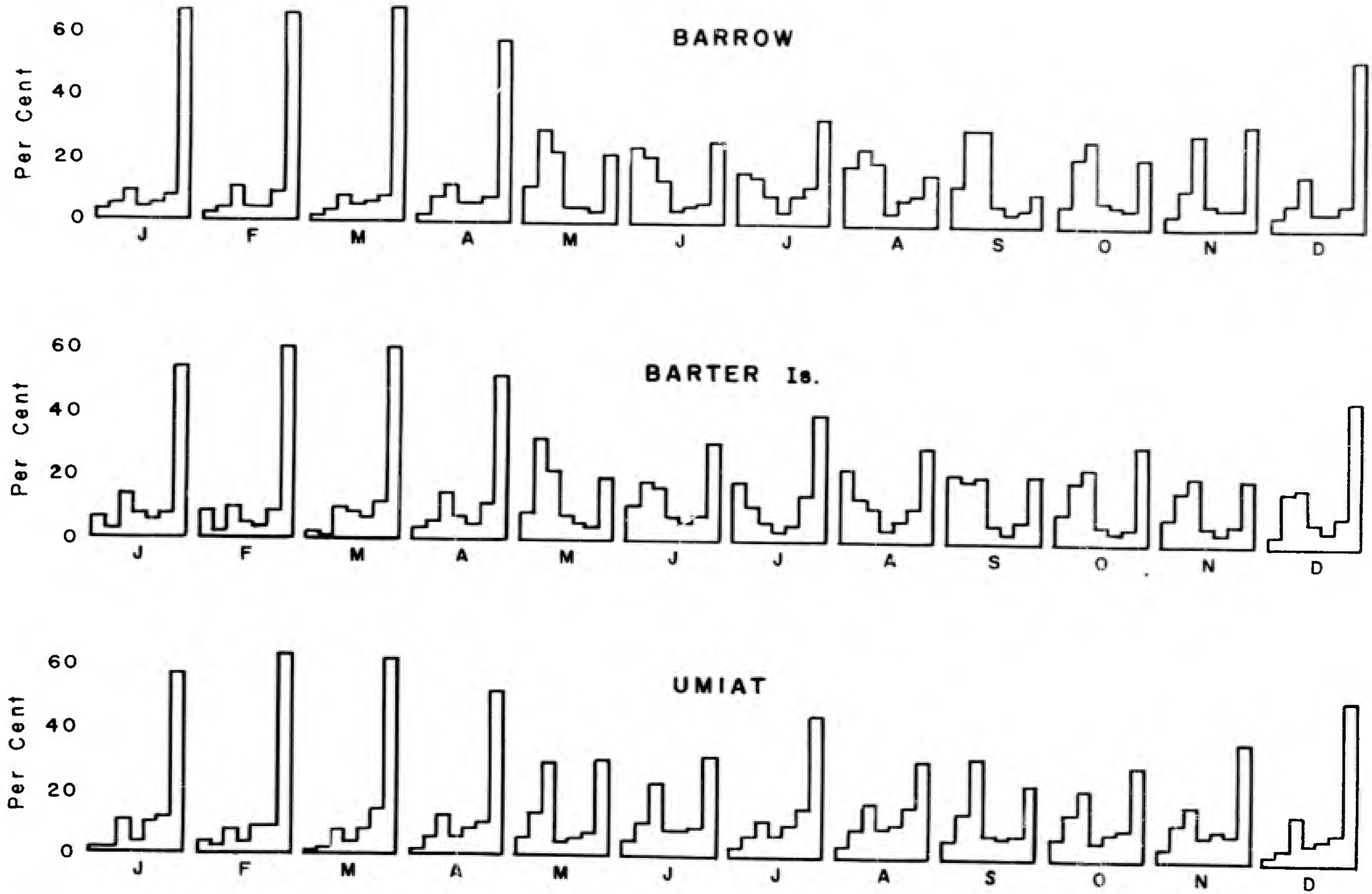

FIGURE 16. MONTHLY PERCENTAGE FREQUENCIES OF HOURLY CEILING HEIGHT (FEET) BY CLASS INTERVALS OF: 0-400, 500-900, 1000-2000, 2100-3000, 3100-5000, 5500-9500 AND 10,000 AND ABOVE (LEFT TO RIGHT).

THE LITTLE WARMING OF THE ONLY PARTLY ICE-FREE SEA. AS THE LAND WARMS THE AIR, THE RELATIVE HUMIDITY IS LOWERED, AND THERMAL CONVECTION DEVELOPS. THE WARMING OF THE AIR EVAPORATES THE SURFACE PORTION OF ANY FOG, CONVERTING IT INTO STRATUS CLOUD. THE ONSET OF CONVECTION CHANGES THE STRATUS TO STRATOCUMULUS. INLAND, IN SUMMER, CEILINGS ARE GENERALLY HIGHEST FROM 1000 TO 2200 HOURS. CEILINGS ON THE COAST RISE SLIGHTLY NEAR MIDDAY. IN WINTER, A SLIGHT RISE OCCURS NEAR MIDNIGHT.

H. VISIBILITY

VISIBILITY IS IMPORTANT NOT ONLY FOR AIRCRAFT OPERATIONS BUT, IN THIS REGION, FOR LAND TRAVEL ALSO. PERCENTAGE FREQUENCIES OF DIFFERENT VISIBILITIES AT BARROW, BARTER ISLAND, AND UMIAT ARE SHOWN IN FIGURE 17. AGAIN, THE POOREST CONDITIONS EXIST IN THE BARTER ISLAND REGION. AT UMIAT, THE VISIBILITY HAS NEVER BEEN REPORTED AS POOR IN JUNE AND JULY. INTERMEDIATE VISIBILITIES, WHICH ARE THE MOST FREQUENT CLASS IN TEMPERATE LATITUDES, ARE INFREQUENT AND CAUSED ONLY BY PRECIPITATION ON THE ARCTIC SLOPE. SMOKE AND HAZE PRACTICALLY NEVER OCCUR OVER THE SLOPE. BETWEEN 22 AND 27 JUNE 1952, DURING EAST WINDS, SEVERAL DUST COUNTS WERE ATTEMPTED BY THE AUTHOR WHILE AT UMIAT, USING AN OWENS COUNTER. AFTER 180 PUMPING STROKES ON THE INSTRUMENT, NO DUST WAS DETECTED.

TABLE VI LISTS THE PERCENTAGE FREQUENCIES OF VISIBILITIES UNDER 1 MILE AND THEIR CAUSE. THE TABLE SHOWS THAT LOW VISIBILITIES DUE TO BLOWING SNOW ARE COMMON, ESPECIALLY AT BARTER ISLAND. OTHER OBSERVATIONS SHOW THAT AT TIMES THE VISIBILITY IS REDUCED ALMOST TO ZERO FOR DAYS BY WINDS OF ONLY 15 TO 20 MPH AND VERY LIGHT SNOW. MANY OF THE WINTER CASES OF LOW VISIBILITIES DUE TO FOG WERE CAUSED BY ICE FOG. IN SUMMER, THE LOWEST VISIBILITIES ARE NORMALLY FOUND DURING THE "NIGHTTIME" HOURS. IN WINTER, THERE IS A SLIGHT TENDENCY FOR THE LOWEST VISIBILITIES TO OCCUR NEAR MIDDAY.

I. INSOLATION

DURING THE SUMMER, SOLAR RADIATION ON A HORIZONTAL SURFACE, AS MEASURED BY AN EPPLEY PYRHELIOMETER, IS SURPRISINGLY HIGH, ESPECIALLY IN VIEW OF THE CONSIDERABLE CLOUDINESS. AVERAGES AT BARROW, OBTAINED FROM ALMOST FOUR YEARS OF NEARLY CONTINUOUS OBSERVATION, SHOW A SKEWED SOLAR RADIATION CURVE (FIG. 18). THE MAXIMUM OCCURS NEAR 4 JUNE RATHER THAN AT THE SOLSTICE. AVERAGE DAILY RADIATION IN LANGLEYS (1 LANGLEY = 1 GM-CAL/CM^2) IN MAY IS ABOUT 538, AND IN AUGUST, 255. DATA BASED ON TWO SUMMERS AND ONE AUTUMN INDICATE THAT THE DISTRIBUTION OF RADIATION IS ABOUT THE SAME AT BOTH BARROW AND UMIAT.

THE HIGH INSOLATION VALUES IN MAY AND EARLY JUNE, THE SEASON WHEN A SNOW COVER IS STILL PRESENT, CAN BE ATTRIBUTED TO WHAT GEIGER (1950, P.164) AND OTHERS CALL THE "LIGHT CLIMATE" ABOVE THE SNOW. AT THIS TIME, PART OF

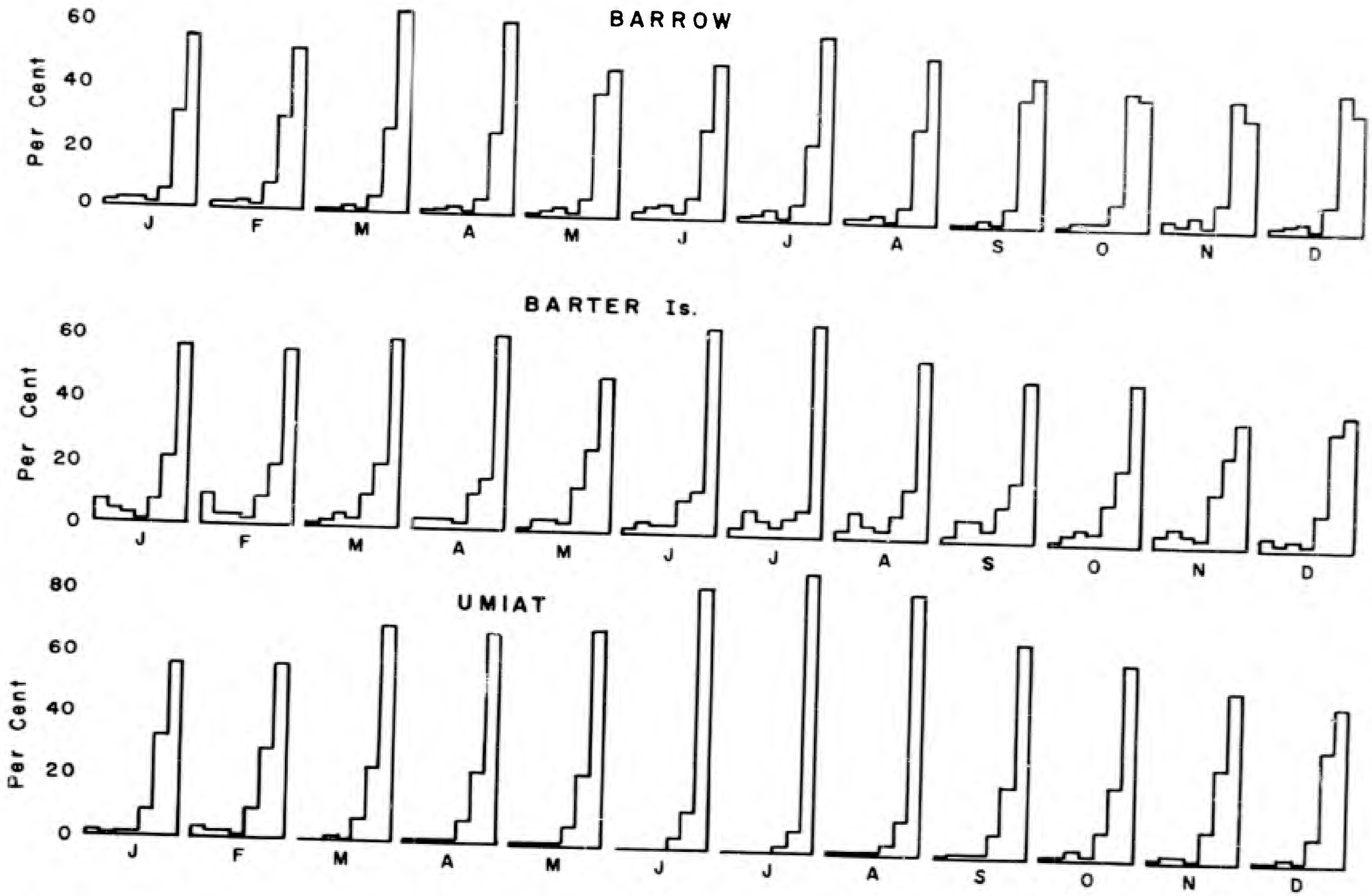

Figure 17. Monthly percentage frequencies of hourly visibilities (miles) by class intervals of: 0-1/8, 3/16-1/4, 5/16-1/2, 5/8-3/4, 1-2 1/2, 3-9 and 10 (left to right).

TABLE VI. PERCENTAGE FREQUENCY OF OCCURRENCE OF VISIBILITIES UNDER 1 MILE AND THEIR CAUSE (FROM HOURLY OBSERVATIONS) AT BARROW, BARTER ISLAND, AND UMIAT

		CAUSE OF LOW VISIBILITY				
STATION	MONTH	FOG	SMOKE AND/OR HAZE	BLOWING SNOW	PRECIP.	TOTAL
BARROW (9 YEARS)	J	3.5	0.1	4.1	0.2	7.9
	F	1.8	0	6.6	0.3	8.7
	M	1.0	0	2.5	0.3	3.8
	A	3.0	0	2.7	0.6	6.3
	M	6.1	0	0.3	0.3	6.7
	J	12.4	0	0.1	0.1	12.6
	J	9.4	0	0	0	9.4
	A	8.3	0	0	0.1	8.4
	S	3.7	0	0.1	0.3	4.1
	O	3.4	0	1.7	1.0	6.1
	N	3.6	0	6.8	0.5	10.9
	D	2.5	0	5.2	0	7.7
	YEAR	4.9	0	2.5	0.3	7.7
BARTER ISLAND (6 YEARS)	J	2.0	0	12.4	0.8	15.2
	F	3.0	0	14.5	0.4	17.9
	M	5.3	0	4.8	0	10.1
	A	3.3	0	6.7	1.6	11.6
	M	10.7	0	0.3	0.3	11.3
	J	10.7	0	0	0.4	11.1
	J	18.7	0	0	0	18.7
	A	19.8	0	0	0.2	20.0
	S	18.8	0	0.5	0.5	19.8
	O	8.8	0	2.4	1.5	12.7
	N	7.8	0	6.9	1.2	15.9
	D	3.2	0	6.1	1.6	10.9
	YEAR	9.3	0	4.6	0.7	14.6
UMIAT (8 1/4 YEARS)	J	1.1	0	2.0	0.8	3.9
	F	2.3	0	4.8	0.5	7.6
	M	1.4	0	0.3	0.2	1.9
	A	1.9	0	1.1	0.6	3.6
	M	2.5	0	0.1	0.1	2.7
	J	1.5	0	0	0.1	1.6
	J	1.4	0.1	0	0	1.5
	A	2.1	0	0	0.3	2.4
	S	2.8	0	0.1	0.2	3.1
	O	4.7	0	0.3	0.6	5.6
	N	3.9	0	1.6	0.6	6.1
	D	2.3	0	1.7	0.3	4.3
	YEAR	2.3	0	1.0	0.4	3.7

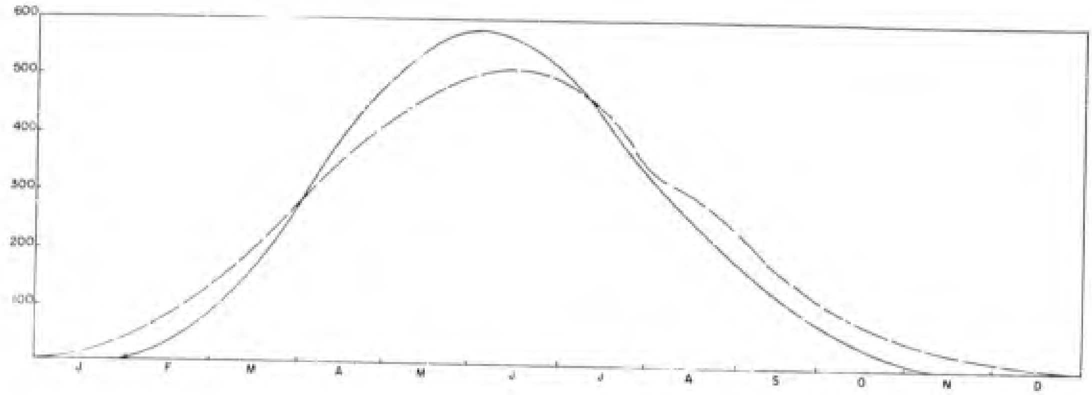

FIGURE 18. AVERAGE DAILY INSOLATION ON A HORIZONTAL SURFACE IN LANGLEYS AT BARROW (SOLID LINE) 1951 TO 1954 AND FAIRBANKS (DASHED LINE) 1933 TO 1949.

THE SOLAR RADIATION, AFTER PASSING THROUGH A CLOUD LAYER TO REACH THE SURFACE OF THE EARTH, IS REFLECTED FROM THE SNOW TO THE CLOUDS AND BACK AGAIN. ALTHOUGH THE SNOW COVER, BY REFLECTING THE SOLAR RADIATION, REDUCES THE AMOUNT RECEIVED BY THE SURFACE AS A WHOLE, IT EFFECTIVELY INCREASES THE RADIATION RECEIVED AT THE PYRHELIOMETER.

THE ANNUAL INSOLATION CURVE SUGGESTS THAT THE ORIGINAL INSOLATION RECEIVED AT THE PYRHELIOMETER IS INCREASED BY A FACTOR OF ABOUT 1.5 IN MID-MAY AND 1.4 IN EARLY JUNE BECAUSE OF REFLECTION FROM THE SNOW TO THE CLOUDS AND BACK. THESE FACTORS ARE PROBABLY LOW BECAUSE, ACCORDING TO FUQUAY AND BUETTNER (1957), THE EPPLEY PYRHELIOMETER READS LOW DURING PERIODS OF LOW SUN AND REFLECTION FROM BELOW INTO THE INSTRUMENT. FURTHERMORE, THE TREND TOWARD HIGHER AMBIENT TEMPERATURES FROM DAY TO DAY DURING THIS TIME OF THE YEAR ALSO LOWERS THE OUTPUT OF THE PYRHELIOMETER FOR GIVEN AMOUNTS OF RADIATION. AFTER THE SNOW COVER IS GONE, THE HIGH PERCENTAGE OF CLOUDINESS CAUSES AN INCREASE OF ONLY ABOUT 1.1 IN THE ORIGINAL INSOLATION RECEIVED AT THE PYRHELIOMETER. THUS, THE HIGH INSOLATION VALUES OBSERVED AT THE PYRHELIOMETER FROM APRIL TO MID-JUNE DO LITTLE TOWARD WARMING THE SURFACE. HOWEVER, IF PART OF THE RADIATION WERE TRAPPED IN A GREENHOUSE OR SIMILAR DEVICE, IT WOULD BE USEFUL TO MAN.

EVEN IN LATE JUNE AND EARLY JULY, WHEN THE SNOW COVER IS GONE, HEATING OF THE AIR IS STILL RETARDED BECAUSE MUCH OF THE INSOLATION IS USED IN THAWING A FEW INCHES OF FROZEN SOIL. DURING THE LATTER PART OF JULY, SOLAR RADIATION HEATS THE SURFACE LAYERS OF THE AIR MUCH AS IT DOES IN THE SOUTHERN LATITUDES. INSOLATION OVER THE SLOPE IN AUGUST IS ABOUT 20 PERCENT LOWER THAN AT FAIRBANKS AND IT IS ABOUT THE SAME AS IN LATE OCTOBER AT BLUE HILL OBSERVATORY IN EASTERN MASSACHUSETTS. IN SEPTEMBER, IT AVERAGES BELOW ANY WINTER VALUES AT BLUE HILL.

J. POTENTIAL EVAPO-TRANSPIRATION

According to Thornthwaite's moisture index (1948), Umiat and Barrow are semiarid. Calculation of potential evapo-transpiration indicates that Umiat is micro-thermal and Barrow is tundra. The moisture index based on measured precipitation amounts is -30, or semiarid, at Umiat and Barrow; however, when the estimated corrected precipitation amounts are used, the index becomes -26, or semiarid at Umiat and -14, or dry subhumid at Barrow. These classifications appear to have little meaning except where the active layer is deep (i.e., greater than 3 or 4 feet) and drainage conditions are good. Elsewhere, the nearness of the permafrost to the surface keeps the moisture content of the soil high. A few measurements indicate that the water content of soils at the microclimatic stations generally ranges from 25 to 35 percent.

K. FREEZE AND BREAK-UP

At Umiat, the Colville River normally breaks up about 24 May. In five years the maximum plus and minus deviations from this date were 12 days. The average date on which it becomes safe for a man to walk on the ice is 18 October; the average date on which it becomes unsafe is 17 May. At Barrow, the average safe date is 4 October and the average unsafe date is 22 July.

Very complete climatological tables of additional frequencies of occurrence and averages pertaining to the sections discussed above for Barrow, Umiat, and Barter Island have been prepared by the U.S. Air Force (no date). If data are desired in these forms, reference should be made to these publications.

5. CLIMATIC TRENDS

When the climate of an area is described mostly in terms of averages and extremes over a short time as it has been in this case, it is helpful to know something of the climate in the past and what the trends have been. For this we must rely on Point Barrow's fairly homogeneous record, the longest in the area, which extends back to 1921. The sequency of 10-year "floating" means shows a downward trend of July and August temperatures, combined, of about 1F° from the 1920's to the late 1940's. Since then, it has recovered about 3/4F°, although the summers of 1955 and 1956 were the coldest on record with averages of 35.2°F. The sum of the July and August precipitation declined from about 2 inches to 1 inch in the middle of the record and then increased to 1 3/4 inches toward the end.

The average of the December, January, and February temperatures show a marked rise of 3F° from the 1920's to, roughly, 1939, then a fall of 5F° in the 10-year period ending with 1955-56.

A comparison of the complete Barrow record with the 1947-1953 normal period used in the above discussions shows that the 7-year period averaged

1F° COLDER IN THE WINTER AND 1F° WARMER IN THE SUMMER WITH ONLY A 0.2F° DIFFERENCE BETWEEN ANNUAL AVERAGES.

DIFFERENCES BETWEEN THE COMPLETE RECORD OF PRECIPITATION AND THE 7-YEAR PERIOD WERE INSIGNIFICANT.

THE NORTHERN SLOPE IS SUBJECT TO LARGE MONTHLY TEMPERATURE AND PRECIPITATION ANOMALIES. OVER THE 1947-54 PERIOD THE WINTER MONTHS OF DECEMBER, JANUARY, AND FEBRUARY HAVE AN ABSOLUTE RANGE OF MONTHLY MEAN TEMPERATURE OF AS MUCH AS 35F° AT UMIAT AND 25F° AT BARROW. THE TEMPERATURE ANOMALIES ARE LARGER INLAND IN WINTER AND ABOUT THE SAME INLAND AS ON THE COAST IN SUMMER. DURING THE WINTER MONTHS, PRECIPITATION IS USUALLY HEAVIER WITH HIGHER MEAN TEMPERATURE.

TEMPERATURE TRENDS PRIOR TO THE PERIOD OF ACTUAL RECORDS HAVE BEEN DEDUCED IN OTHER PARTS OF THE WORLD, FROM THE TEMPERATURE GRADIENTS FOUND IN DEEP MINES OR DRILL HOLES. SIMILAR DATA TO A DEPTH OF 1,432 FEET ARE AVAILABLE FROM PARTS OF THE NORTH SLOPE, AND LACHENBRUCH* IS PRESENTLY ENGAGED IN STUDYING THESE DATA TO SHOW THE EFFECTS OF THE DRILLING DISTURBANCE, THE NEARBY OCEAN, AND SECULAR TEMPERATURE CHANGES. HOWEVER, THE WORK HAS NOT YET ADVANCED TO A STAGE WHERE SPECIFIC RESULTS CAN BE GIVEN.

6. THE MICROCLIMATE

IN GENERAL, GROUND TEMPERATURE IS DIRECTLY RELATED TO SURFACE TEMPERATURE. THAT IS, WARM GROUND TEMPERATURES TEND TO BE FOUND BELOW WARM SURFACE TEMPERATURES AND VICE VERSA. THEREFORE, IN ESTIMATING GROUND TEMPERATURE IT IS USUALLY BEST TO ESTIMATE THE SURFACE TEMPERATURE FIRST. SURFACE TEMPERATURES ON THE ARCTIC SLOPE, WHEN THE GROUND IS BARE OF SNOW, FOLLOW CHANGES IN INSOLATION MORE CLOSELY THAN THEY DO IN TEMPERATE LATITUDES, WHERE THE OVER-LYING AIRMASSES CHANGE MORE FREQUENTLY.

THE MOST IMPORTANT FACTORS THAT AFFECT SURFACE TEMPERATURES, OTHER THAN INSOLATION, ARE VEGETATION, DEPTH AND DENSITY OF SNOW COVER, AIR TEMPERATURE, PRECIPITATION, WIND, EVAPORATION, CONDENSATION, AND, OVER THE ARCTIC SLOPE, THE PROXIMITY AND MOISTURE CONTENT OF THE FROZEN LAYER. THE CHIEF EFFECT OF VEGETATION IS IN SCREENING THE SURFACE FROM INSOLATION. TALL VEGETATION RETARDS THE WIND AND HINDERS ITS CONTACT WITH THE SURFACE. A SNOW COVER ALWAYS TENDS TO INHIBIT SUDDEN TEMPERATURE CHANGES FROM THE AIR TO THE GROUND SURFACE. THE WHITE OF A SNOW SURFACE REFLECTS MOST OF THE SOLAR RADIATION; ON THE AVERAGE, ONLY 20 TO 50 PERCENT IS ABSORBED AS COMPARED WITH ALMOST 70 TO 80 PERCENT WITHOUT A SNOW COVER. THE SNOW ACTS ALSO AS AN INSULATOR; THE LOWER ITS DENSITY THE BETTER ARE ITS INSULATING

*VERBAL COMMUNICATION FROM ARTHUR H. LACHENBRUCH, GEOLOGICAL SURVEY, 4 HOMEWOOD PL., MENLO PARK, CALIFORNIA.

PROPERTIES, AND THE GREATER ITS DEPTH, THE MORE EFFECTIVE IS THIS PROPERTY. PRECIPITATION TENDS TO MODIFY THE SURFACE TEMPERATURES TOWARD THE TEMPERATURE OF THE PRECIPITATION. USUALLY THE RESULT IS TO COOL THE SURFACE. A LACK OF WIND ALLOWS STRONG SOLAR OR OUTGOING RADIATION TO HAVE A MAXIMUM EFFECT ON THE SURFACE TEMPERATURE. WIND DECREASES THESE EFFECTS BY REMOVING OR ADDING HEAT THROUGH TURBULENCE. EVAPORATION IS A COOLING PROCESS; ITS EFFECT MAY BE PRONOUNCED, AS IN THE CASE OF WET MOSS DURING A DRY DAY. THE EVAPORATION OF RAINWATER ALSO COOLS THE SURFACE. CONDENSATION LIBERATES HEAT, BUT THE AMOUNT OF HEAT ADDED TO THE SURFACE BY THIS PROCESS IS BELIEVED TO BE RELATIVELY SMALL. DURING THE THAWING PROCESS, ADDITIONAL HEAT IS REQUIRED TO CONVERT ICE TO WATER. THE HIGHER THE MOISTURE CONTENT OF FROZEN SOIL, THE MORE ICE IT CONTAINS. CONSEQUENTLY, MORE HEAT IS REQUIRED TO THAW IT. THE FREEZING PROCESS OPERATES IN THE SAME WAY EXCEPT THAT HEAT MUST BE REMOVED. WHEN THE LEVEL OF FROZEN GROUND IS NEAR THE SURFACE IT, THEREFORE, TENDS TO "REFRIGERATE" THE SURFACE.

ALTHOUGH THE TEMPERATURE IN THE GROUND BELOW THE SURFACE TENDS TO FOLLOW THAT AT THE SURFACE, THE LAG VARIES WITH THE THERMAL PROPERTIES OF THE SOIL. IN GENERAL, THE HIGHEST ANNUAL GROUND TEMPERATURES (UPPER 2 TO 4 FEET) ARE FOUND IN GRAVELLY, WELL-DRAINED, AND THEREFORE, DRY BARE SOILS. IN SUMMER THE GROUND IS WARMED LEAST IN THE POORLY DRAINED, WET AREAS THAT ARE HEAVILY VEGETATED (MOSS). A LARGE ICE CONTENT SLOWS THE WARMING PROCESS BECAUSE OF THE HEAT REQUIRED TO THAW THE ICE.

AN UNUSUALLY COMPLETE DISCUSSION OF GROUND TEMPERATURES AND ASSEMBLAGE OF DATA, INCLUDING A LARGE BIBLIOGRAPHY, HAS BEEN PREPARED BY CHANG (1958).

A. TEMPERATURE

THE GENERALITIES REGARDING THE THERMAL PROPERTIES OF THE GROUND AND THE HEAT FLOW THROUGH IT ARE ILLUSTRATED IN FIGURE 19 BY THE TIME-HEIGHT CROSS SECTION OF TEMPERATURES OBSERVED ON A SUNNY DAY AT UMIAT BASE. THE SURFACE ON 19 JUNE WAS DRY AND THE THIN LAYER OF DEAD GRASS PROVIDED A GOOD INSULATOR WHICH RETARDED THE FLOW OF HEAT INTO THE SOIL. AS SOLAR RADIATION INCREASED, THE AIR TEMPERATURE AT THE SITE ROSE FIRST AT THE 2-INCH TO 6-FOOT LEVELS. THIS WAS BECAUSE THE IMMEDIATE SURROUNDING GRASS AND SHRUBS "TRAPPED" THE NOCTURNALLY-COOLED AIR NEXT TO THE GROUND; THE WARMER AIR WAS WAFTED OVER AND ABOVE FROM WARMER REGIONS. HOWEVER, BY 1000 THE COOL LAYER WAS COMPLETELY ERADICATED AND THE SURFACE WAS THE WARMEST LEVEL. FROM 1100 TO 1400, THE SURFACE TEMPERATURE AVERAGED 91°F; MUCH OF THE HEAT WENT INTO WARMING THE AIR, HOWEVER, AS SHOWN BY THE RISING 60° AND 70° ISOTHERMS.

BELOW THE SURFACE, THE HEAT WAS TRANSFERRED DOWNWARD MORE SLOWLY IN THE EARLY MORNING HOURS THAN IN THE EARLY AFTERNOON HOURS AFTER THE SURFACE HAD BECOME HOT. BETWEEN 1900 AND 2000, THE INCOMING RADIATION HAD DIMINISHED TO AN AMOUNT INSUFFICIENT TO MAINTAIN A SURFACE WARMER THAN THE AIR NEXT TO IT. AT THIS TIME THE SURFACE TEMPERATURE FELL BELOW THE AIR TEM-

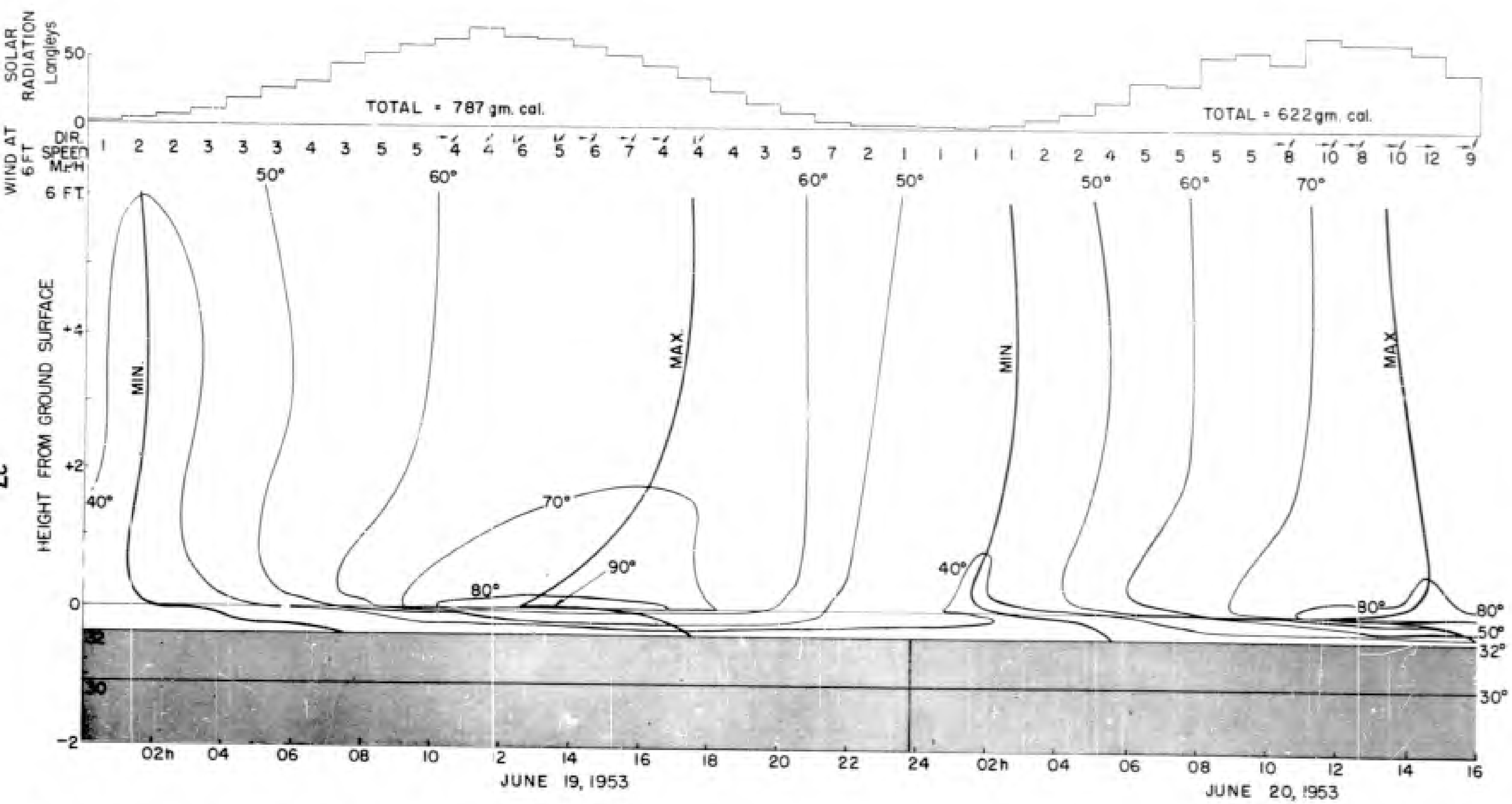

FIGURE 19. A TIME-HEIGHT CROSS SECTION OF TEMPERATURE (°F), WIND, AND SOLAR RADIATION ON SUNNY DAYS AT UMIAT BASE. THE STIPPLED LAYER IS FROZEN.

PERATURE, AND AN INVERSION WAS SET UP. BY ABOUT 2400, FURTHER COOLING OF THE SURFACE HAD LOWERED ITS TEMPERATURE BELOW THAT OF THE SOIL IMMEDIATELY UNDERNEATH. AT 0200 THE SURFACE MINIMUM WAS REACHED, AND SUCCESSIVE MINIMUMS OCCURRED AT -1 INCH 1 HOUR LATER, AT -2 INCHES 2 1/2 HOURS LATER, AND AT -4 INCHES 3 HOURS LATER. THE FROST WAS MELTED SLIGHTLY AS THE HEAT WAVE REACHED IT, BUT, DUE TO THE FACT THAT 80 CALORIES ARE REQUIRED TO THAW 1.1 CM3 OF ICE, IT IS CLEAR THAT THE HEAT IS QUICKLY SPENT IN CONVERTING FROZEN SOIL AT 32°F TO MUD AT 32°F. THE FOLLOWING DAY EXHIBITED A SIMILAR PATTERN ALTHOUGH THERE WAS 15 PERCENT LESS SOLAR RADIATION UNTIL NOON, AND STRONGER WINDS PERMITTED ONLY A 52F° RISE OF THE SURFACE TEMPERATURE, AS COMPARED WITH 58F° ON THE PREVIOUS DAY.

THESE PROCESSES ARE STILL WORKING IN WINTER, BUT THE PICTURE IS QUITE DIFFERENT, AS SHOWN BY THE 4 OCTOBER DATA IN FIGURE 20. THE IMPORTANT DIFFERENCE BETWEEN THIS AND THE SUMMER EXAMPLE IS THE 3-INCH SNOW COVER. UNFORTUNATELY, NO THERMOCOUPLE WAS PLACED AT THE SNOW SURFACE, THEREFORE, THE ISOTHERMS HAVE BEEN ESTIMATED THROUGH THIS ZONE. VERY LIGHT SNOW AMOUNTING TO ONLY A TRACE FELL THROUGH MOST OF THE HOURS OF DARKNESS, CONSEQUENTLY, THE SURFACE DID NOT COOL AS MUCH AS IT WOULD HAVE DURING A CLEAR NIGHT. HOWEVER, IT WAS CLEAR AND CALM DURING THE DAY AND THE PYRHELIOMETER RECEIVED 94 LANGLEYS BY NOON. ASSUMING AN ALBEDO OF 80 PERCENT FOR FRESHLY FALLEN SNOW, THIS LEAVES ONLY ABOUT 19 LANGLEYS FOR HEATING THE SNOW SURFACE UNTIL NOON. ACCORDING TO GEIGER (1950, P. 166) 50 PERCENT OF THE RADIATION THAT GETS THROUGH THE SNOW SURFACE PENETRATES 10 CM., OR IN THIS CASE, DOWN TO THE SOIL SURFACE. THIS WAS BORNE OUT BY THE DATA FROM THE GROUND SURFACE AND +2-INCH LEVELS WHICH ROSE 7 AND 10F°, RESPECTIVELY. AT THE SURFACE A RISE OF BETWEEN 20 AND 25F° PROBABLY OCCURRED; A MEASURED RISE OF 17F° OCCURRED AT THE +24-INCH LEVEL.

IN THIS CASE, THE DATA INDICATE A SLIGHT DOWNWARD MOVEMENT OF THE 32° ISOTHERM (FREEZING) DURING THE MORNING, TO BE FOLLOWED BY AN UPWARD MOVEMENT (THAWING FROM BELOW) AS THE GRADIENT RELAXED IN THE AFTERNOON. THE MOTION OF THE MAXIMUM TEMPERATURE WAVE DOWNWARD INDICATES THE RATE OF HEAT PENETRATION THROUGH SNOW OR SOILS OF DIFFERENT THERMAL PROPERTIES. THE RATE IS LOW WHERE SNOW IS THE LEAST DENSE, BUT INCREASES NEAR THE GROUND AS THE DENSITY INCREASES. WITHIN THE FROZEN GROUND, THE LAG IS LESS THAN IN THE THAWED GROUND OF SUMMER.

IN ORDER TO COMPARE THE DATA GATHERED, MEANS AND EXTREMES HAVE BEEN COMPUTED. THE MORE SIGNIFICANT OF THESE ARE PRESENTED IN THE FOLLOWING SECTIONS, WHILE COMPLETE TABLES OF WEEKLY AVERAGE SOIL AND AIR TEMPERATURES WILL BE FOUND IN TABLES I AND II OF THE APPENDIX.

AVERAGE TEMPERATURES, COMPUTED FROM HOURLY AVERAGE VALUES, AT THE SITES FOR THE SEASON, 27 JUNE TO 28 AUGUST 1953, ARE GIVEN IN TABLE VII.

EQUAL AVERAGE TEMPERATURES AT +4 AND -4 INCHES AT SITE 1A ARE APPARENTLY CHARACTERISTIC OF A STEEP, SOUTH-FACING, POORLY-VENTILATED SLOPE WHERE THE

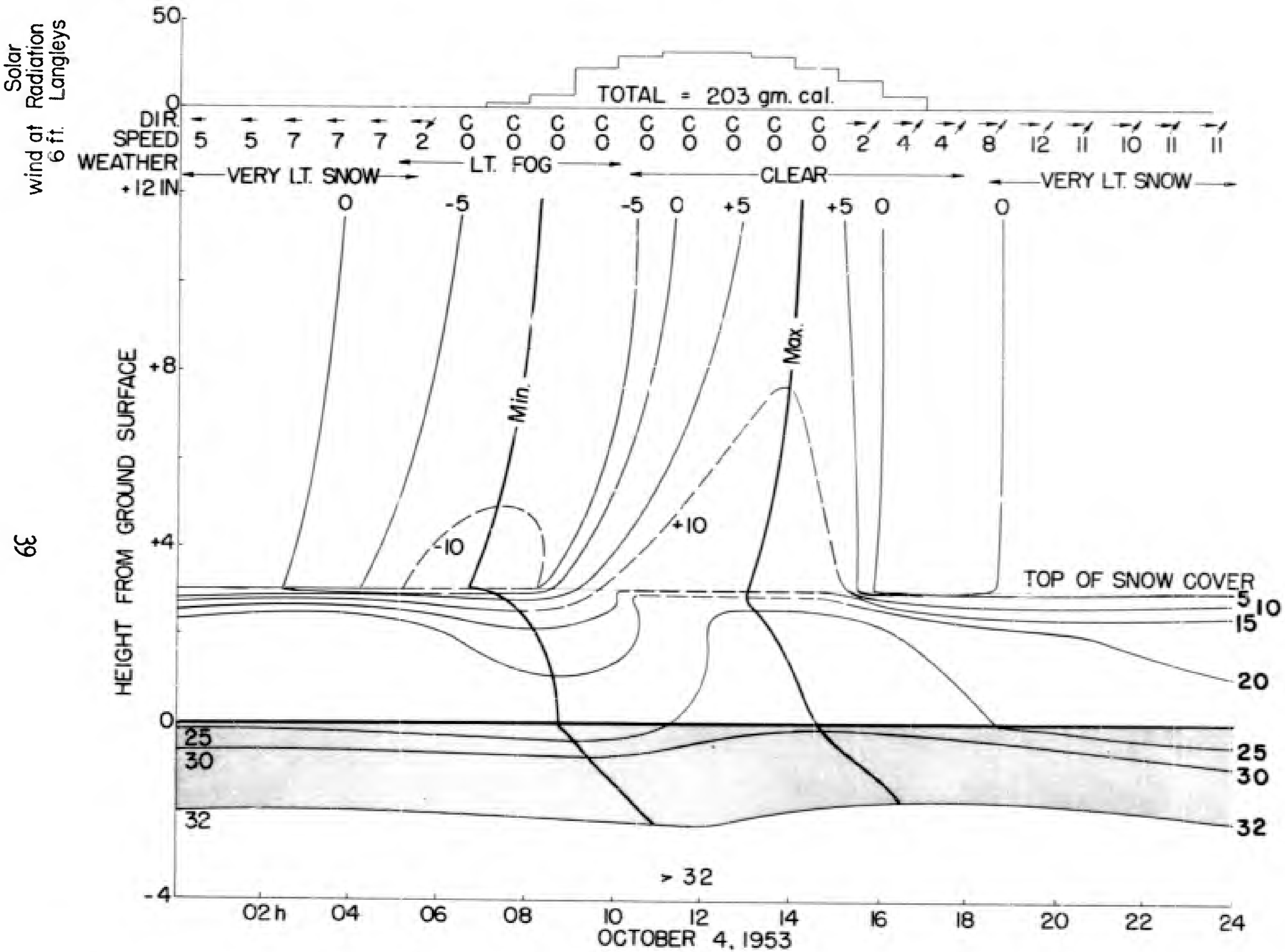

Figure 20. A time-height cross section of temperature (°F), wind, weather, and solar radiation during an early winter day at Umiat Base. The stippled layer is frozen.

TABLE VII. AVERAGE TEMPERATURES (°F) AT THE +4- AND -4-INCH LEVELS FROM 27 JUNE TO 28 AUGUST 1953

SITE AND DESCRIPTION	+4 IN.	-4 IN.	DIFF.
UMIAT BASE POLYGON IN COLVILLE VALLEY - ALDER CLUMP.	47.8	39.0	8.8
UMIAT BASE - LOW TUSSOCKS, 22 FT. WSW OF ABOVE SITE.		39.2	
UMIAT 1 - S SLOPE, CLOSELY PACKED 10-FT. ALDERS.		40.0*	
UMIAT 1A - STEEP S SLOPE, BOULDERY SOIL PARTIALLY BARE, LOW GRASSES, BEDROCK AT 9 INCHES.	49.0	49.2	-0.2
UMIAT 2 - STEEP S SLOPE, CLOSELY PACKED 8-FT. ALDERS.		40.0*	
UMIAT 3 - RIDGE TOP, SCATTERED (3-6 IN.) TUSSOCKS.	47.4	41.2	6.2
UMIAT 4 - SLIGHT N SLOPE, MEDIUM (10 IN.) TUSSOCK-HEATH.	47.1	39.7	7.4
UMIAT 5 - SLIGHT S SLOPE, MEDIUM (5-8 IN.) TUSSOCK-HEATH.	48.8	42.2	6.6
CACHE 5 - SLIGHT ESE SLOPE, CLOSE HEATH TUSSOCK (5-8 IN.)	45.8	40.6	5.2
CACHE 6 - ON RAISED EDGE OF FLOODED POLYGONS.	43.8		
MOUNTAIN - FLAT, LOW HEATH-MOSS-LICHEN, APPROX. 2500 FT. MSL.	42.1	37.9	4.2

*ADJUSTED TO THE 1953 SEASON FROM 1952 DATA.

ACTIVE LAYER IS DEEP. THE LACK OF WATER AND ICE IN THE ROCK, AS WELL AS THE ROCK'S HIGHER CONDUCTIVITY ALLOW IT AND THE LAYER OF SOIL ABOVE IT TO WARM RAPIDLY. THE GREATEST DIFFERENCE BETWEEN +4-AND -4-INCH TEMPERATURES WAS FOUND IN THE DEPRESSED CENTER POLYGON AT UMIAT BASE WHERE THE GROUND WAS SOMEWHAT SHADED AND MANY ICE LENSES WERE PRESENT JUST BELOW THE SURFACE, CAUSING A STEEP THERMAL GRADIENT. LOW AIR AND GROUND TEMPERATURES AT THE MOUNTAIN STATION ARE APPARENTLY LARGE-SCALE PHENOMENA SINCE THE EXPOSURE IS SIMILAR TO THAT AT UMIAT BASE. AIR TEMPERATURES AT CACHES 5 AND 6 WERE FOUND TO BE LOWER THAN THOSE AT UMIAT DUE TO THE PROXIMITY OF THE SEA.

THE DIFFERENCES OF SOIL TEMPERATURES FOUND ALONG THE UMIAT TRANSECT ARE LARGELY A RESULT OF EXPOSURE AND GROUND COVER. STATIONS 1 AND 2, ALTHOUGH HAVING NEARLY THE SAME EXPOSURE AS 1A, EXPERIENCE COLDER GROUND TEMPERATURES BECAUSE OF THE TALL TREES. THE +4-INCH AVERAGES GIVEN ABOVE ARE ABOUT 3 1/2F° BELOW THE 7-YEAR NORMALS, WITH THE EXCEPTION OF THE MOUNTAIN STATION, WHICH WAS ABOUT 2F° BELOW NORMAL. THIS IS ESTIMATED FROM THE FACT THAT THE SHELTER TEMPERATURES FOR THAT PERIOD DEPARTED BY THESE AMOUNTS FROM THE 7-YEAR NORMAL.

AVERAGE VERTICAL TEMPERATURE PROFILES AT UMIAT BASE FOR WEEKS IN EARLY SUMMER. MIDSUMMER, EARLY FALL, AND MIDWINTER AT FOUR SELECTED HOURS ARE SHOWN IN FIGURE 21. DURING MIDSUMMER, A SLIGHT INVERSION IN THE AIR USUALLY OCCURS NEAR MIDNIGHT. AT THIS TIME, THE SOIL IS WARMEST ABOUT 1 INCH BELOW THE SURFACE. UNDER IDEAL CONDITIONS FOR SURFACE HEATING, MID-DAY SURFACE TEMPERATURES AVERAGE 90°F WHILE THE -2-INCH AND -4-INCH TEMPERATURES AVERAGE 57° AND 42°F, RESPECTIVELY. BY MID-AUGUST, THE HIGH SURFACE TEMPERATURES CHARACTERISTIC OF MIDSUMMER ARE FOUND ONLY ON THE 1200 TO 1300 PROFILE. WITH THE APPROACH OF FALL, THE DURATION OF A WARM SURFACE DECREASES WHILE THE DURATION OF A MAXIMUM BELOW THE SURFACE INCREASES. PROFILES FOR MIDWINTER ARE ALSO SHOWN. VALUES NEAR THE SNOW SURFACE WERE ESTIMATED. NOTE THE LACK OF DIURNAL CHANGE DURING THIS SUNLESS PERIOD.

A SERIES OF CURVES SHOWING THE AVERAGE HOURLY TEMPERATURES, THE MAXIMUM AND MINIMUM VALUES FOR EACH HOUR, AND SIMILAR TYPE OF DIURNAL COURSE OF SOLAR RADIATION FOR SELECTED WEEKS ARE SHOWN IN FIGURE 22A, B, C, AND D. THE REDUCTIONS IN INSOLATION AND AIR TEMPERATURES JUST AFTER NOON DURING THE WEEK OF 13 TO 19 JUNE RESULT FROM AN INCREASE IN CLOUDINESS AT THAT TIME. AFTER THE FOLIAGE CAME OUT, THE GROUND WAS PARTIALLY SHADED BETWEEN 1300 AND 1600. THIS EFFECT SHOWS IN THE SURFACE TO -2-INCH CURVES DURING THE WEEK OF 25 TO 31 JULY. UNTIL ABOUT MID-AUGUST, THE SURFACE MAXIMUM OCCURS NEAR 1230 AND THE -4 INCH MAXIMUM LAGS ABOUT 5 1/4 HOURS. FROM MID-AUGUST UNTIL THE TIME OF SNOW COVER, THE SURFACE MAXIMUM OCCURS NEAR 1330 AND THE -4-INCH MAXIMUM ABOUT 4 1/4 HOURS LATER. THIS APPARENT CHANGE IN RATE OF PENETRATION IS DUE TO A CHANGE FROM A LARGE GRADIENT DURING THE FIRST PERIOD TO A MEDIUM ONE LATER. THE MAXIMUM AVERAGE SURFACE TEMPERATURE FOR ONE HOUR, 101°F, WAS RECORDED IN JULY. WITH THE APPROACH OF FALL, THE THIRD WEEK SHOWN, ALL AMPLITUDES DIMINISH AND IN MIDWINTER THE DIURNAL CHANGES ARE ALMOST ABSENT.

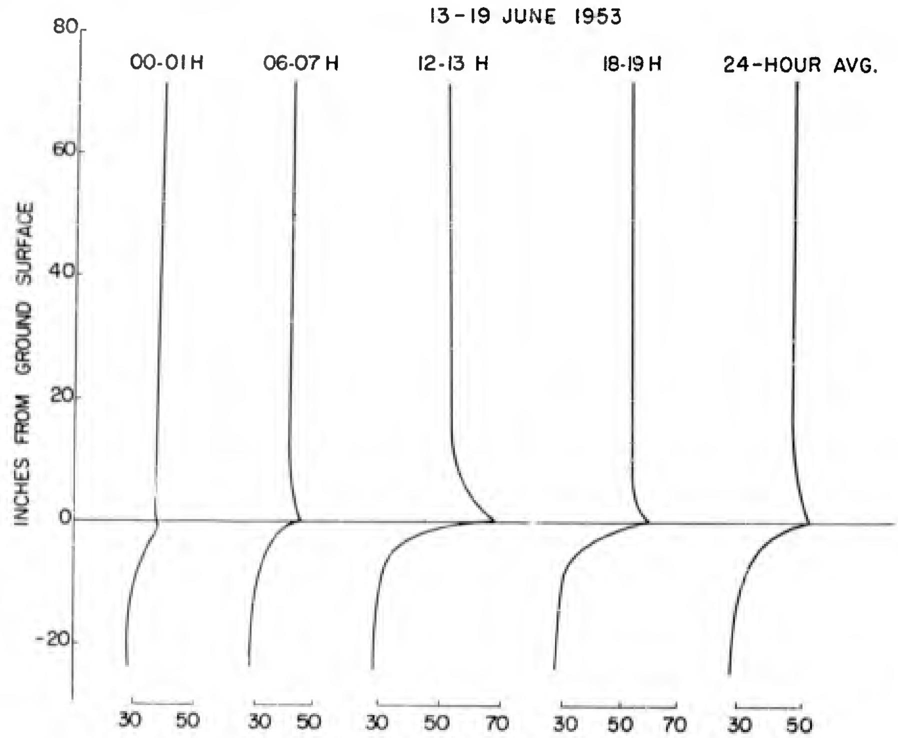

FIGURE 21A. 13-19 JUNE 1953

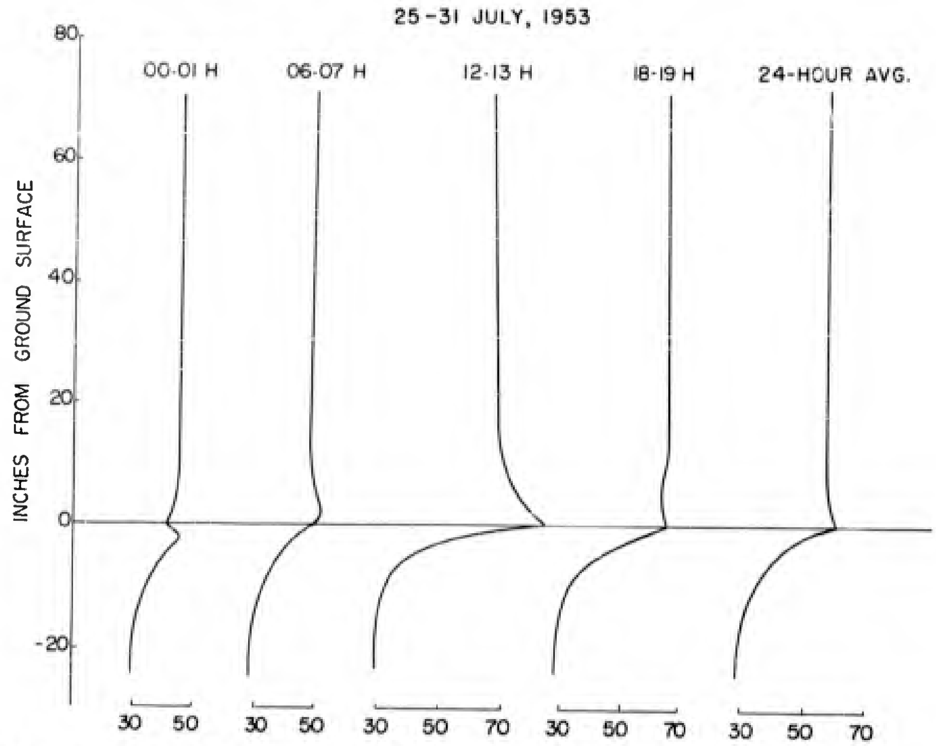

FIGURE 21B. 25-31 JUNE 1953

FIGURE 21. AVERAGE WEEKLY VERTICAL TEMPERATURE (°F) PROFILES AT UMIAT BASE, FROM 72 INCHES ABOVE TO 24 INCHES BELOW THE GROUND SURFACE AT FOUR SELECTED HOURS AND AVERAGES OF THE 24-HOUR PERIODS.

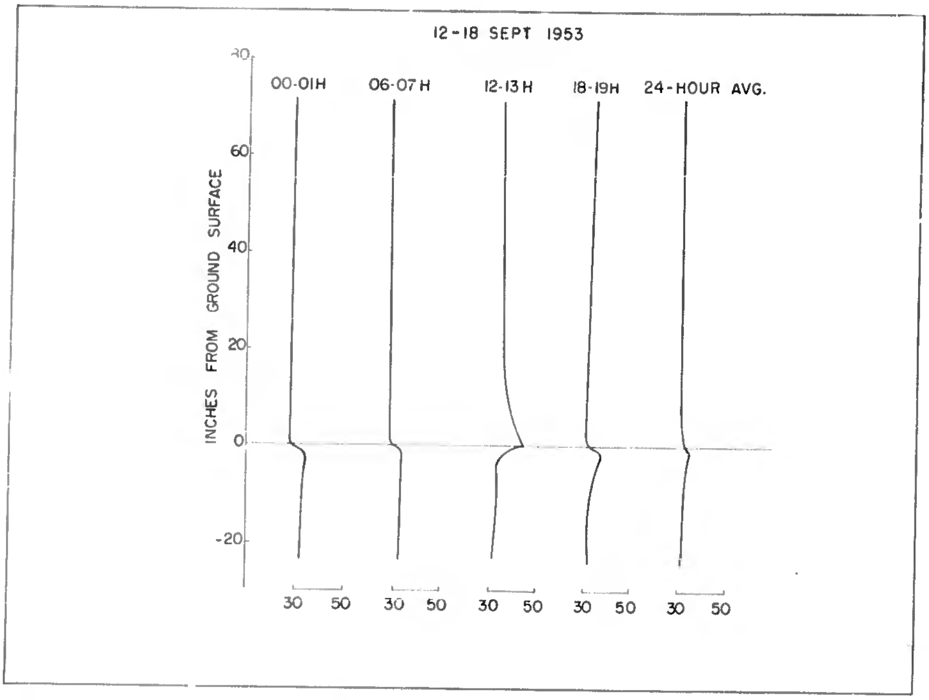

FIGURE 21C. 12-18 SEPTEMBER 1953

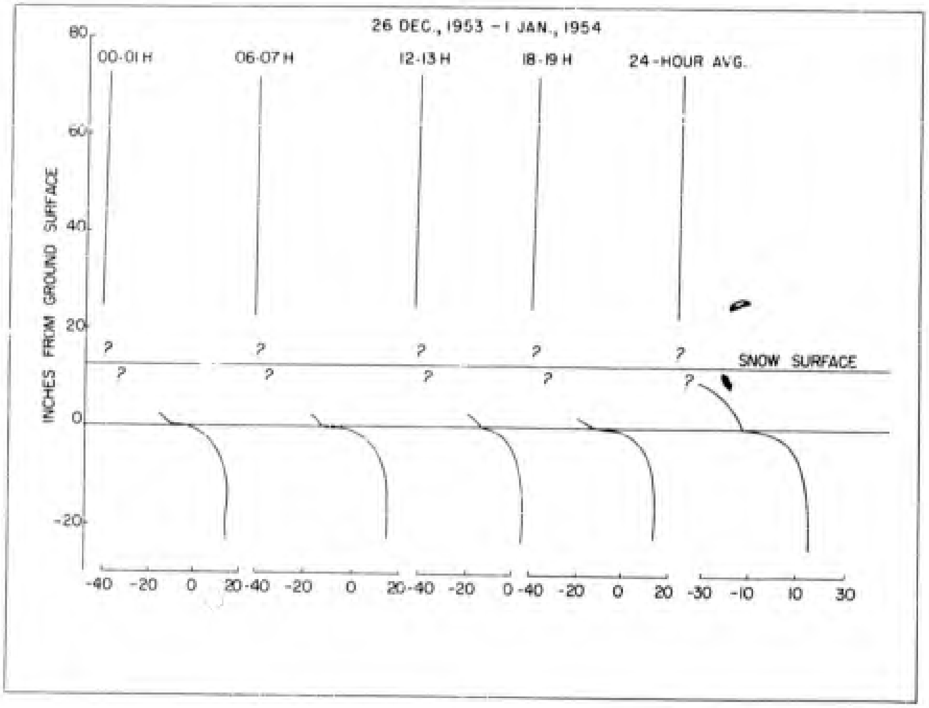

FIGURE 21D. 26 DECEMBER 1953-1 JANUARY 1954

13-19 JUNE, 1953

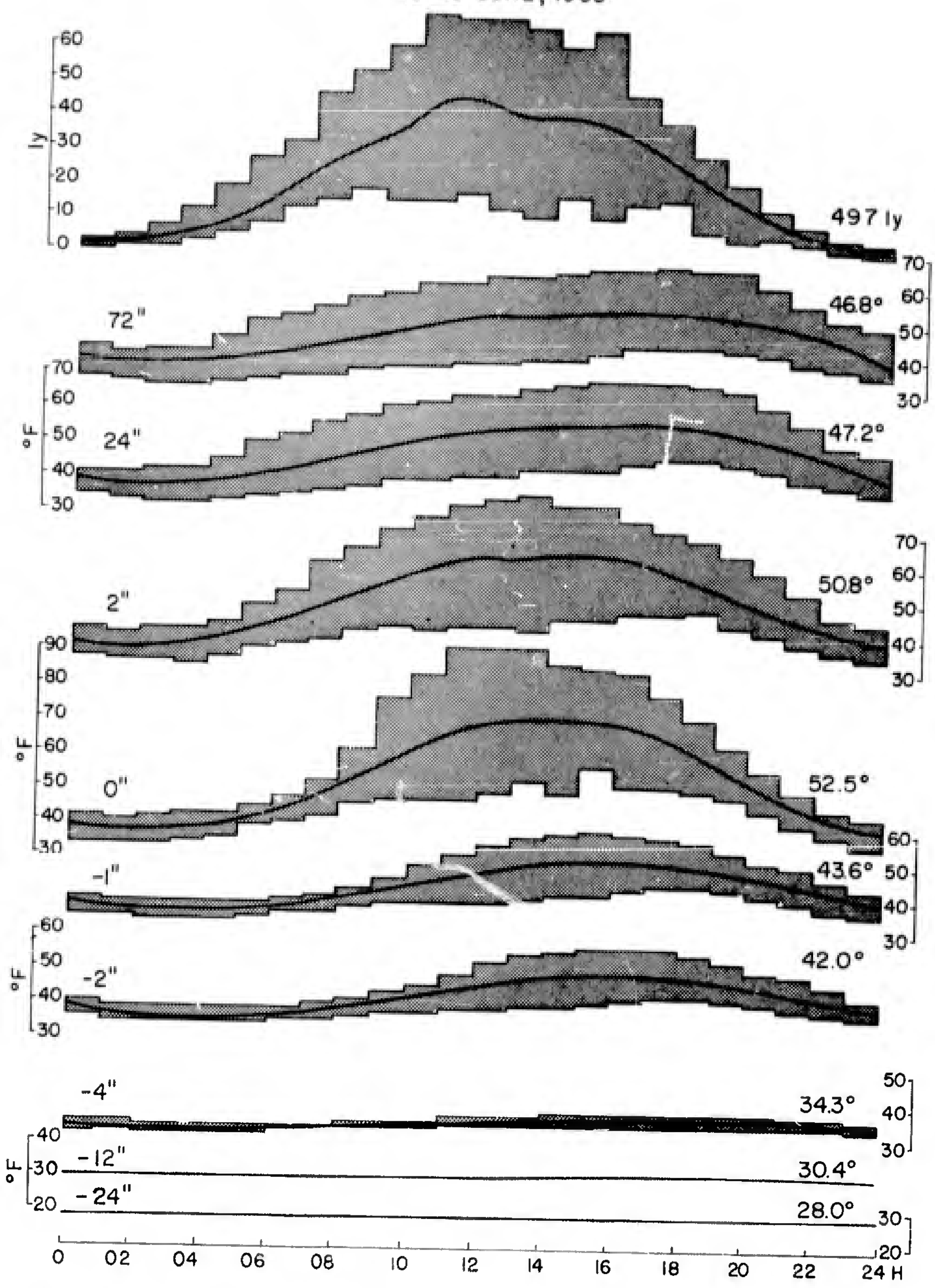

FIGURE 22A. AVERAGE HOURLY TEMPERATURES (°F) AT FIXED LEVELS ABOVE AND BELOW THE GROUND SURFACE, AND SOLAR RADIATION (TOP, IN LANGLEYS) DURING A WEEK IN JUNE 1953 AT UMIAT BASE. THE WEEKLY RANGE OF VALUES IS SHOWN BY THE STIPPLED AREAS. THE DAILY AVERAGES FOR THE WEEK ARE SHOWN ON THE RIGHT.

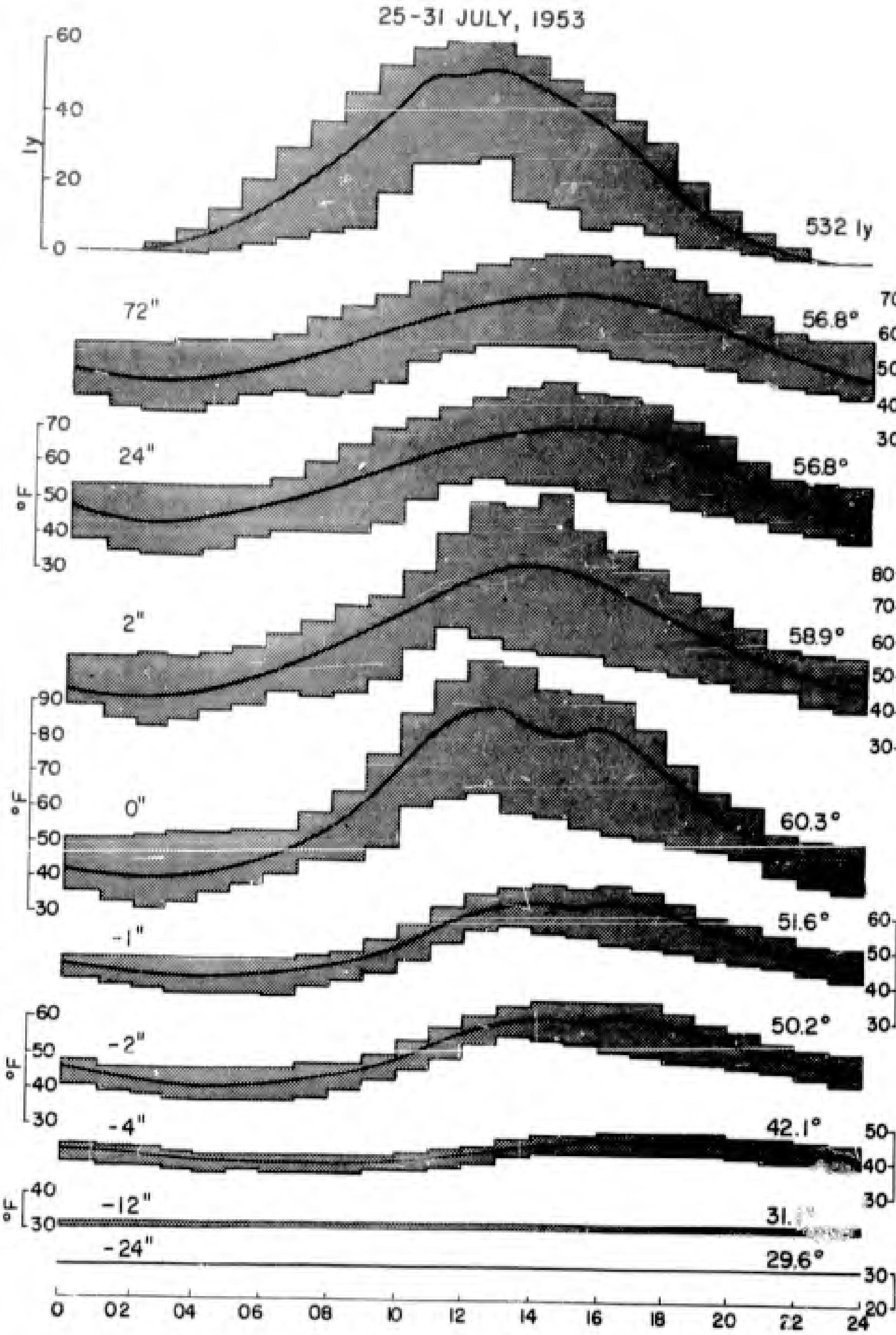

FIGURE 22B. AVERAGE HOURLY TEMPERATURES (°F) AT FIXED LEVELS ABOVE AND BELOW THE GROUND SURFACE, AND SOLAR RADIATION (TOP, IN LANGLEYS) DURING A WEEK IN JULY 1953 AT UMIAT BASE. THE WEEKLY RANGE OF VALUES IS SHOWN BY THE STIPPLED AREAS. THE DAILY AVERAGES FOR THE WEEK ARE SHOWN ON THE RIGHT.

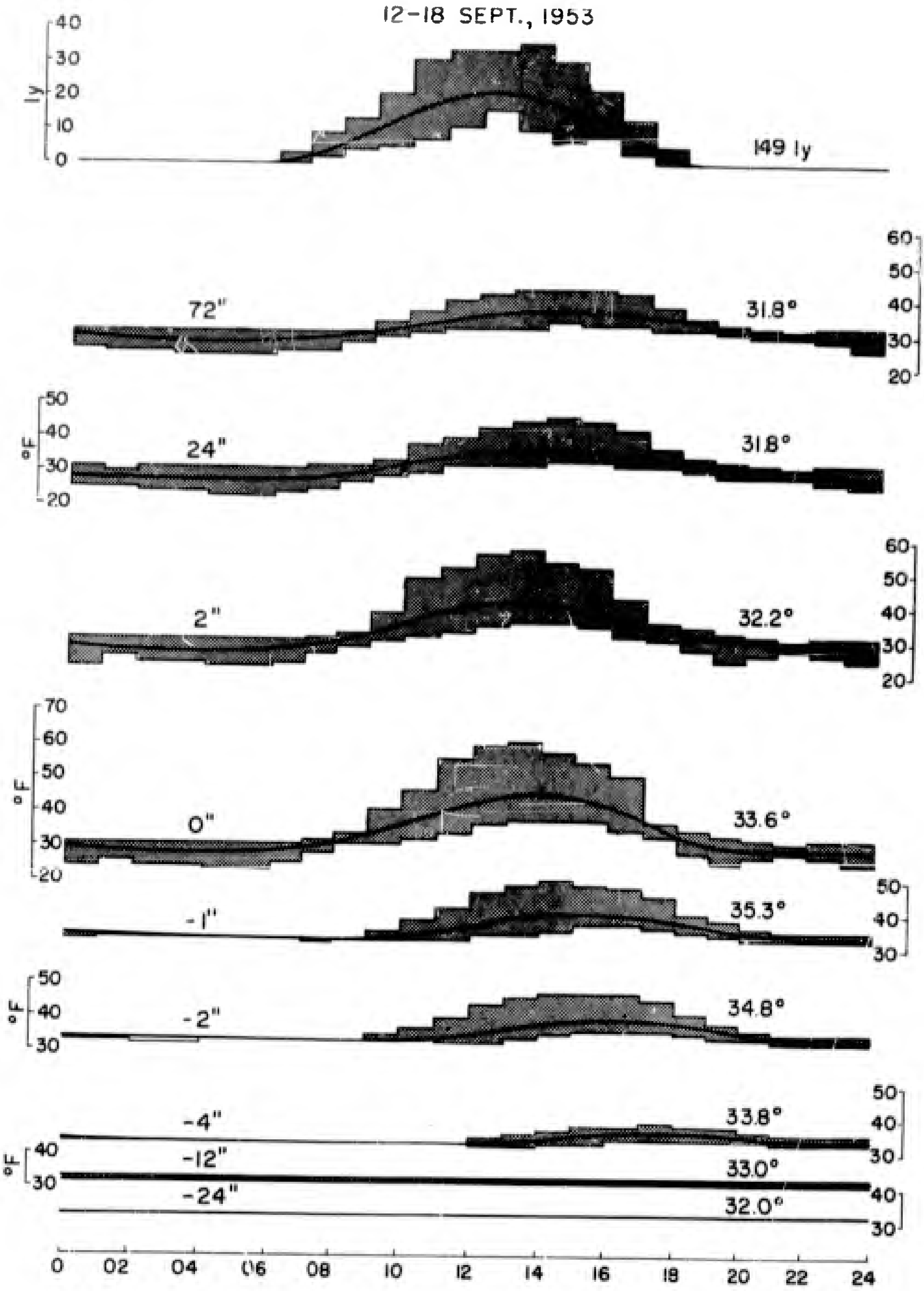

FIGURE 22C. AVERAGE HOURLY TEMPERATURES (°F) AT FIXED LEVELS ABOVE AND BELOW THE GROUND SURFACE, AND SOLAR RADIATION (TOP, IN LANGLEYS) DURING A WEEK IN SEPTEMBER 1953 AT UMIAT BASE. THE WEEKLY RANGE OF VALUES IS SHOWN BY THE STIPPLED AREAS. THE DAILY AVERAGES FOR THE WEEK ARE SHOWN ON THE RIGHT.

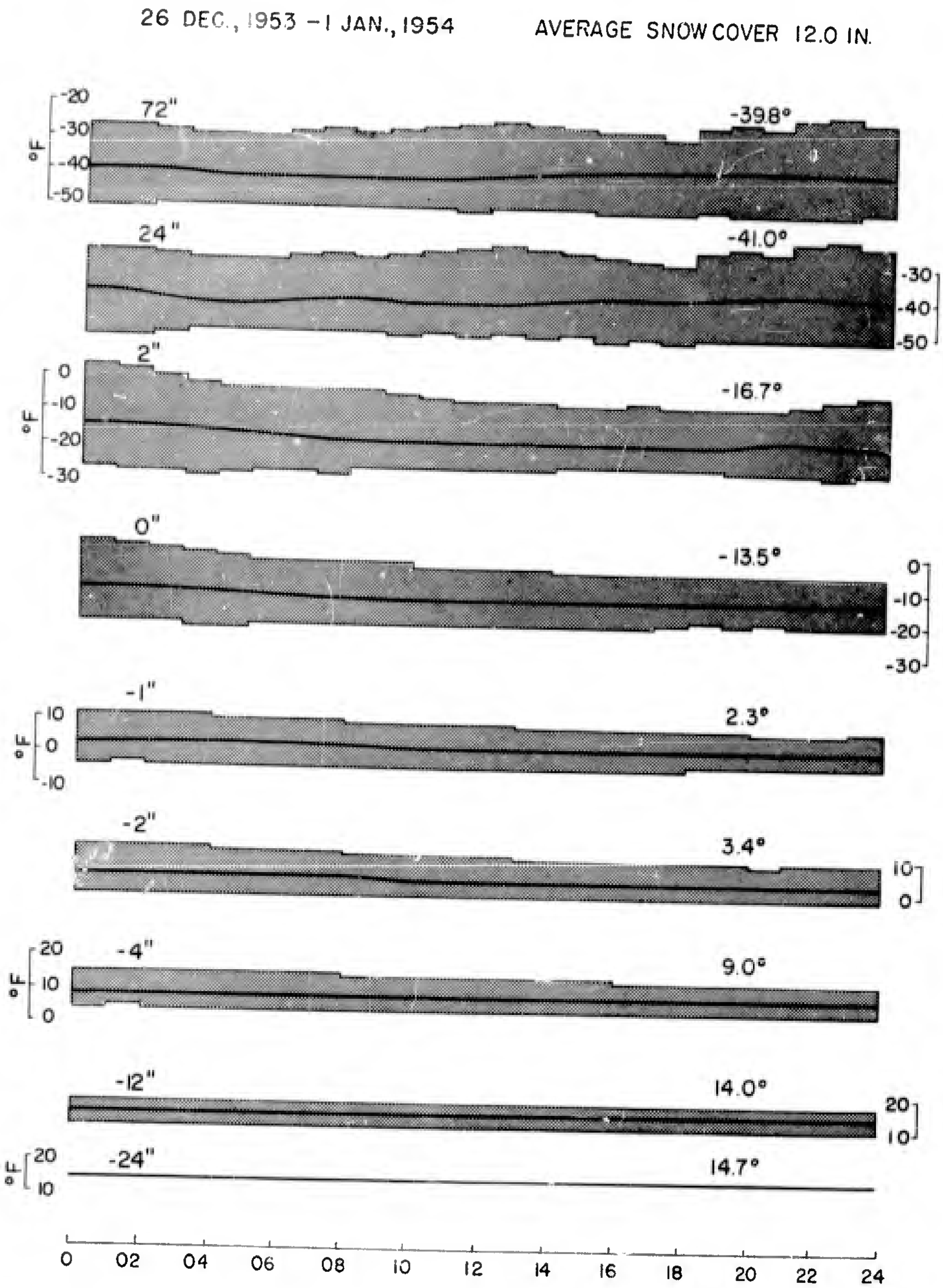

FIGURE 22D. AVERAGE HOURLY TEMPERATURES (°F) AT FIXED LEVELS ABOVE AND BELOW THE GROUND SURFACE DURING A WEEK IN DECEMBER 1953 AT UMIAT BASE. THE WEEKLY RANGE OF VALUES IS SHOWN BY THE STIPPLED AREAS. THE DAILY AVERAGES FOR THE WEEK ARE SHOWN ON THE RIGHT. (THERE IS NO SOLAR RADIATION IN DECEMBER AT UMIAT BASE.)

A table of approximate monthly temperatures, made up from weekly averages, for all of the levels at Umiat Base is given in the Appendix (Table I).

The mean diurnal range of temperature at the sites is shown in Table VIII. The correlation between diurnal ranges and total insolation is evident in spite of the exposure.

The uniformity of average range for the season among the flat, breezy stations, Site 3, Cache 5, and the mountain is striking. Larger ranges are found at Site 5 (gentle south slope) rather than 1A (steep southern slope). Examination of the hourly values shows that Site 5 experiences high ranges because of its cool nights. It is generally about 2F° colder than 1A at night presumably because cool surface air can accumulate easily and not slide into the valley. The station at 1A is on a convexity, or knob, part way down the slope, thus the cold air drains off toward the East, South, and West into a broad valley whose floor is nearly 200 feet lower. Only during excessive insolation does Site 5 warm to temperatures above the others.

The -4-inch diurnal temperature ranges, shown in Table IX, also indicate a good correlation with solar radiation.

The range correlates better with slope at this level than at the +4 inch level. Variations in thermal diffusivity are important when these ranges are considered. Such differences, for example, must account for the different range between Umiat Polygon (U-P) and Umiat Base (U-B).

Monthly average temperatures, computed from weekly averages, for the +4- and -4-inch levels also are given in the Appendix (Table I).

The +4-inch temperatures at four stations in the vicinity of Barrow, although incomplete, due to clock stoppages, etc., yield interesting results.

Comparisons of the +4-inch temperatures at the Barrow stations were made by selecting simultaneous periods of record when two or more stations were operative; in this way the averages and extremes which are given in Table X were compiled. Data from the U.S. Weather Bureau's shelter in Barrow, where the thermometers are 12 feet above the ground, are also included in the table.

Generally, temperature differences are small between sites, owing to the flat terrain and almost constant winds. This is especially true during the season when all bodies of water are ice-covered. During the warm week of 17 to 24 January 1954, the data show that the invading warm air had difficulty in penetrating cold surface layers only 20 feet lower.

TABLE VIII. MEAN DIURNAL RANGE OF TEMPERATURE (°F) AT +4 INCHES AT THE SITES, AND AVERAGE INSOLATION BY WEEKS AT UMIAT BASE, 1953

	Mean diurnal range of temperature at +4 inches						
Site:	1A	3	4	5	Cache 5	Mt.	Solar Radiation Average (lys.)
20-26 June	18	15	15				367
27 June-3 July	16	14	14				373
4-10 July	22	19	20	22	16	17	483
11-17 July	13	11	11	15	10	13	318
18-24 July	22	21	23	25	21	22	452
25-31 July	30	28	28	35	30	30	532
1-7 August	18	16	18	24	17	10	250
8-14 August	16	15	17	18	14	16	259
15-21 August	21	17	16	21	14	24	370
22-28 August	13	12	12	15	11	7	206
4 July-28 August	19	17	18	22	17	17	359

TABLE IX. MEAN DIURNAL RANGE OF TEMPERATURE (°F) AT -4 INCHES AT THE SITES, AND AVERAGE INSOLATION BY WEEKS AT UMIAT BASE, 1953

	Mean diurnal range of temperature at -4 inches								
Site:	U-P	U-B	1A	3	4	5	Cache 5	Mt.	Solar Radiation Average (lys.)
20-26 June	2	2	5	2	3				367
27 June-3 July	4	3	7	3	3	4	5		373
4-10 July	6	3	9	4	4	6	7	3	483
11-17 July	3	2	5	2	2	4	3	1	318
18-24 July	6	4	9	5	5	7	8	3	452
25-31 July	7	4	11	5	4	9	8	2	532
1-7 August	4	3	6	3	3	5	4	1	250
8-14 August	4	2	5	3	3	5	3	1	259
15-21 August	5	2	9	3	3	5	3	2	370
22-28 August	3		5	3	2	4	4	1	206
4 July-28 August	5	3	7	4	4	6	5	2	359

TABLE X. AVERAGE DAILY MAXIMUM, AVERAGE DAILY, AND AVERAGE DAILY MINIMUM TEMPERATURE (°F) 4 INCHES ABOVE THE SURFACE IN THE BARROW AREA

	U.S. Weather Bureau Barrow Village (12 ft above ground)			Barrow-1			Barrow-2			Barrow-3			Barrow-4		
	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
18-24 Dec. 1953	-11	-17	-23	-10	-16	-22							-10	-15	-20
25-31 Dec. 1953	-17	-22	-26				-16	-20	-23	-17	-21	-24	-18	-21	-24
17-24 Jan. 1954	14	1	-11	12	- 1	-14	13	0	-12	12	0	-12	12	- 1	-13
25-29 Jan. 1954	-12	-18	24				-12	-21	-31	-13	-22	-32	-13	-21	-29
21-31 Mar. 1954	14	7	0				14	6	- 1	16	6	- 3			
15-20, 23-30 April 1954	16	5	- 5				20	7	6	16	4	- 7			
1-7, 9-31 May 1954	22	16	10				25	18	11	25	17	10	17	5	- 6
2-7 June 1954	33	30	27	35	32	28	34	31	28	34	31	29	26	18	11
1-8, 16-31 July 1954	46	40	33	49	42	36	49	43	36	46	41	35	37	33	29
1-8, 10, 15-17 Aug. 1954	55	47	40	57	50	42	59	51	42	55	49	43			
1-10 Sept. 1954	50	44	38	50	44	38	52	45	38	50	45	39			
21-29 Sept. 1954	32	28	23	33	27	21	34	28	22	32	27	22			
13-24 Oct. 1954	20	17	15	21	18	15	20	18	15	21	18	16			
9-22 Nov. 1954	2	- 3	- 7				1	- 3	- 6	1	- 2	- 6			
Extremes:															
Winter (beg. Dec. 17, 1953) min.		-48			-48			-55			-57				
Summer (1954) max.		71			71			77			74				

Under average winter conditions, slightly higher temperatures were measured at B-2 than at B-3 and B-4, indicating the characteristic increase of temperature with height during the cold season.

The higher winter minimum of -48°F at B-1, compared with -55°F at outlying stations, which occurred during a light NW wind, was partly due to the heating effect of the village. The tempering influence of the ocean, even though frozen, was also undoubtedly a factor in keeping the B-1 station warmer than the others during light NW winds.

Differences between the Barrow sites were smallest in the spring period when the ground was still snow-covered. Over the period 2 to 7 June, the summer continental effects were beginning to show in the form of higher temperatures at B-4, the inland station. This occurred while winds blew strongly from the NE and across 6 miles of partly bare ground before reaching the station. During July and August the effects of the cold sea are most pronounced, with B-3, the Lagoon Beach Station, averaging 2F° cooler than B-2, the ridge station 1 1/2 miles inland. At the same time B-1, near the west shore, averaged 1F° cooler than B-2. This temperature pattern continued until the end of September. A summer maximum of 77°F was observed at B-2, while maximums of only 71 and 74°F occurred at the coastal stations.

In late September, the effects of chilling by the sea and warming by the land have disappeared and temperatures are virtually the same at all the stations.

Temperature differences between the +4-inch and +12-foot levels at Barrow were obtained over the period April 1955 to July 1956, by using the U.S. Weather Bureau's thermometer inside a standard shelter and the project's shielded recording thermometer set up nearby at +4 inches. The latter was kept adjusted to 4 inches above the snow surface. Results of the comparison are shown in Figure 23. The curve was sketched from averages, shown as horizontal lines, which were obtained for the different periods of time covered by each line. Variations of the differences from year to year may be as much as 2F°, therefore, this curve must be used with caution. The abrupt positive increase of differences at Barrow in June is associated with the end of snow cover which occurred on 21 June. Differences at Umiat Base Polygon are also shown; small differences are caused by the vegetation and partial shading of the 4-inch level.

B. Frost Effects

Sigafoos (1951) and others have emphasized the effects of frost action on vegetation, and there is no doubt that solifluction, or the downhill movement of soil, is a prominent feature of the North Slope. However, congeliturbation, resulting from surface freezing and thawing, is slight over this area. At three stations in the vicinity of Barrow,

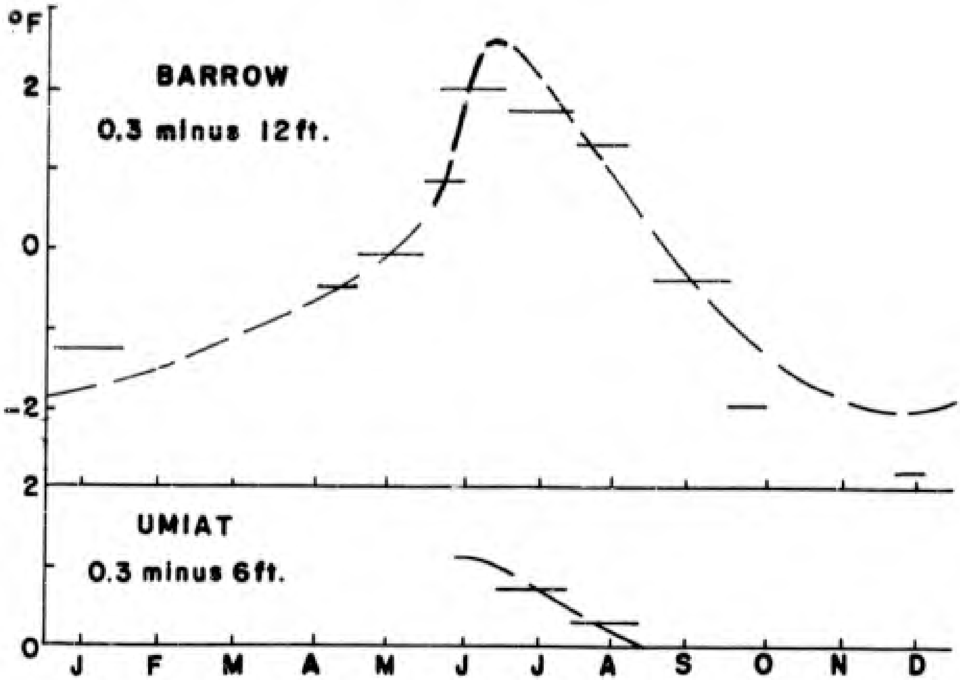

FIGURE 23. AVERAGE CHANGE OF TEMPERATURE (°F) WITH HEIGHT AT BARROW AND UMIAT.

THE SURFACE THERMOGRAPHS SHOWED A TOTAL OF 6 TO 14 THAWS AND FREEZES THROUGH THE SPRING AND FALL SEASONS COMBINED. THIS COMPARES WITH A FIGURE OF ABOUT 92 AT BLUE HILL, MILTON, MASSACHUSETTS, FOR ONE SPRING PERIOD, OR APPROXIMATELY 180 PER YEAR. FROM THIS IT IS OBVIOUS THAT THE SURFACE DOES NOT SUFFER DIRECTLY FROM FREEZING AND THAWING; IT DOES, HOWEVER, EXPAND AND CONTRACT CONSIDERABLY WHEN THE SNOW COVER IS ABSENT OR VERY THIN. FOR EXAMPLE, AT ONE STATION THE SURFACE TEMPERATURE WHEN COVERED WITH 1 INCH OF SNOW CHANGED 29F° IN THREE DAYS. DURING ANOTHER EXTREME CASE, A 38F° RISE IN THE 4-INCH AIR TEMPERATURE CAUSED A 10F° RISE AT THE SOIL SURFACE WHEN IT WAS COVERED WITH 8 INCHES OF SNOW.

IT APPEARS THAT THE SOURCE OF THE MORE IMPORTANT FROST EFFECTS IS AT THE LEVEL WITHIN THE GROUND AT THE TOP OF THE FROZEN LAYER. A SMALL AMOUNT OF THAWING AND FREEZING OCCURS AT THIS LEVEL DAILY AS THE DIURNAL TEMPERATURE WAVES REACH IT. THE AMOUNT OF THAW AND FREEZE IS LARGEST IMMEDIATELY AFTER THE SURFACE THAWS AND IT DIMINISHES AS THE DEPTH OF THAWED GROUND (ACTIVE LAYER) INCREASES, DUE TO ABSORPTION OF THE DIURNAL HEAT WAVE. A CALCULATION BASED ON THE TEMPERATURES OBSERVED DURING A very sunny day (17 June 1953) showed that about 18 calories were delivered at the frost level, -4 inches at that time, as a result of downward heat flux. This amount of heat will thaw about 0.1 inch of ice, or if ice makes up 50 percent of the soil volume, about 0.3 inch of frozen soil. A factor of three, rather than two, applies because of the low specific heat of soil compared to ice. With the relaxation of the heat wave, the direction of heat flux is reversed and a small amount of soil is refrozen. This change is not necessarily one detectable by thermometric means because the liquid and solid states may both remain at 32°F. However, Bryson*, from large numbers of frequent probings in approximate 1 m^2 areas, has detected diurnal oscillations of the frost level when the thawed layer was at least 6 inches deep. It is obvious that the amplitude of this cycle varies under different conditions.

It is therefore postulated that this effect, working inside the ground, may be related to the strange soil patterns often found side by side but in zones where the thermal properties of the soil or the solar radiation reaching and penetrating the surface differ. Furthermore, this action makes the idea of solifluction more realistic. Rather than assuming that a mass of soil simply slides on a lubricated frozen layer (viscous flow), the motion is more likely helped by daily freezing and lifting perpendicular to the frozen layer followed by vertical sinking during the thaw. In this way the mass is pushed, and gravity alone is not the propelling force.

c. Wind

The windiness and lack of tall vegetation over the area results in relatively high averages at the 6-foot level. Average wind speeds measured over comparable periods in 1953 and 1954 are shown in Table XI.

The adjusted 6-foot-level winds have been obtained from the extrapolation of curves drawn for winter and summer at Umiat and Barrow in which the wind speed is related to height through the expression given in Geiger (1950 p. 103): $v_2 = v_1 \times z^A$, where v_2 signifies the speed in m/sec. at the height z in meters, v_1 is the speed at 1 meter, and A is an exponent whose value changes primarily with the temperature lapse rate.

The pattern is clear-cut; easterlies, especially in summer, are felt most at the exposed lagoon station near Barrow. Inland they weaken in summer, as shown by the Cache 5 and 6 values, with the lowest values at 1A, on the protected slope. In winter the winds continue strong; in fact, these speeds make travel in the open very uncomfortable. The ridge-top winds are strongest in winter but even the valleys experience considerable

*Oral communication from Reid A. Bryson, University of Wisconsin.

TABLE XI. AVERAGE WIND SPEEDS (IN MILES PER HOUR)

	Summer (July and August) at 6 ft.	Summer (July and August) at 2 ft.	Winter (Dec.-Feb. approx.) at 6 ft.	Winter (Dec.-Feb. approx.) at 2 ft.
Barrow No. 1 (near Arctic Res. Lab.)	7.2		7.6	
Barrow No. 2 (old beach ridge)	9.1		8.8	
Barrow No. 3 (shore Elson Lagoon)	9.4		8.7	
Umiat Base (raised polygon)	4.3		5.1	
U-1A (steep south slope)	3.1*	2.0	7.0*	5.0
U-3 (ridge top)	6.6*	4.8	9.0*	6.7
U-4 (slight north slope)	4.2*	2.9	8.6*	6.0
U-5 (slight south slope)	4.0*	2.7	6.0*	4.2
Cache 5 (ridge)	5.6*	4.4		
Cache 6 (flat)	6.8*	5.0		
Mountain (flat)	4.8*	3.6		

*Height adjusted to 6 feet (see text).

wind, mostly of katabatic origin. In the Umiat area, it is interesting that the shrubs lean from the E and NE which is the prevailing wind (42 percent of the total time) during the growing season. In winter the winds are westerly. At exposed sites, such as U-3, it was apparent that the preceding season's growth, which protruded about 4 inches above the general level of the frost boils and apparently above the early snow cover, had been winter-killed. A short distance away, near U-1A, willows which grow 10 to 12 feet high in a gully were most likely covered with drift snow during the winter.

D. Snow cover and depth of thaw

Since the snowfall over the area is fairly uniform, the depth of snow on the ground is largely dependent on the wind and topography. Large changes of depth occur in midwinter or spring when strong winds may remove a foot of snow from one spot and add it to another. Usually these storms are characterized by westerly winds and therefore the depth pattern can be deduced reasonably well for a small area from its exposure.

During the winter period when sun crusts do not develop, the hardness of the snow cover depends on the wind speed; in general, the higher the wind the greater the hardness. The duration of drift also lengthens with the wind speed. These relations have been generalized by the U.S. Air Force (1954).

In the Barrow region during the winter of 1953-54, snow covers at B-2 and B-3 averaged about the same, reaching a maximum of 8 inches, while at the more sheltered station, B-1, the depth averaged near 16 inches for 2 months. Average ground-surface temperatures, under the snow cover (read from a large thermometer in contact with the soil or grass), did not vary more than a few degrees between stations. Weekly measurements of the depth of thaw showed maximum values of 22 inches at B-1, 33 inches at B-2, and 18 inches at B-3. Since the July and August air temperatures were, respectively, 50°, 49°, and 46°F at these stations, it is obvious that the depth of thaw is not necessarily proportional to the surface temperature. The reason for the greater thaw at B-2, the old beach ridge composed mostly of sand and pea-size pebbles, is its dryness and, therefore, lower heat capacity owing to better drainage than at B-1 and B-3. The fact that dry soil is a poorer heat conductor than wet soil, is not as important as the fact that, when frozen, less heat is required to thaw it. Well-drained coarse soils having a water table so low that water will not be drawn into the upper layers during freezing, thaw to depths greater than wet soils.

This contrast is well illustrated in Figure 24A where the measurements of Dr. Larry C. Bliss have been plotted to show isochrones of the retreating frost level through a frost boil. Here the well-drained central portion thaws rapidly not only because it is dry but also because its bare surface is warmer than that of the adjacent plant-covered sides. When the ground is raised similarily but covered with vegetation (such as a large tussock, Figure 24B), the thaw is greater under the tussock than under adjacent areas early in the season but the tussock's effect is lost at depths below about 30 cm. When higher vegetation grows around and over an old, dry, depressed center polygon such as at Umiat Base (Fig. 24C and D), the center thaws the least while the outer sides of the polygon thaw to the greatest depth on the south and west and the least on the north and east. It is also interesting that measurable freezing from the bottom upward occurred at all the sites over the last week of observation.

The effects of slope on the depth of thaw under similar soil and vegetation conditions is shown by maxima at Umiat site 4, the gentle north slope, of 44 cm (17 1/2 in.) and at site 5, the gentle south slope, 49 cm (19 1/2 in.).

In general the depth of thawed soil below shallow, calm bodies of water is about the same as under soil covered with vegetation. Under deeper water, i.e., 1 foot, the amount of thawed ground increases. The thaw also increases where the water bottom is gravelly, and especially if the water is flowing or stirred by the wind.

Details for adjusting shelter-level freezing and thawing indices to the ground surface and their use in determining the depth of thaw or freeze in different soils are given by the U.S. Army (1954).

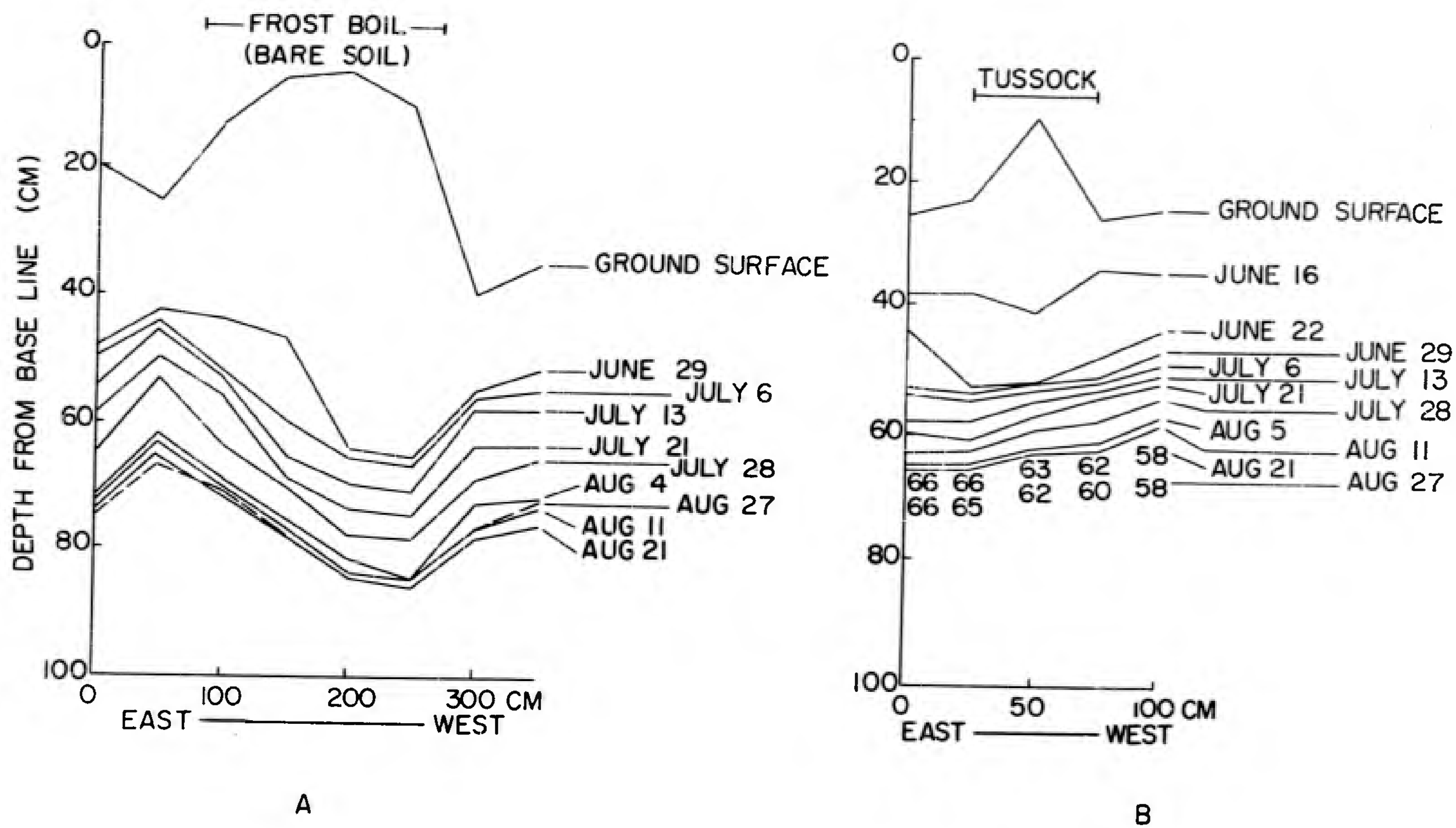

FIGURE 24 A-B. PROFILE OF GROUND SURFACE AND ISOCHRONES OF THE DEPTH OF THAWED GROUND NEAR UMIAT SITE 3.

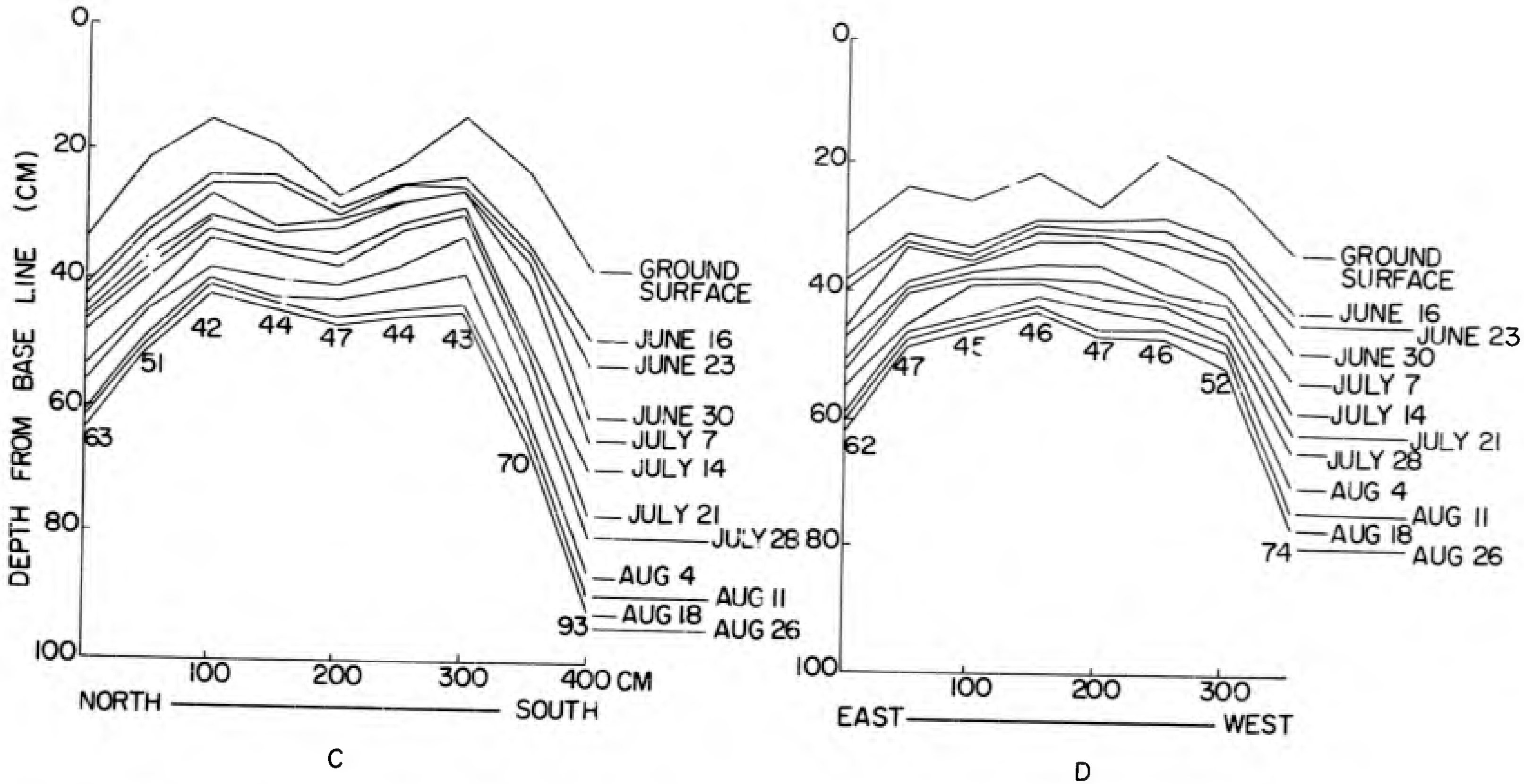

FIGURE 24 C-D. PROFILE OF GROUND SURFACE AND ISOCHRONES OF THE DEPTH OF THAWED GROUND THROUGH THE DEPRESSED CENTER POLYGON ALDER CLUMP AT UMIAT BASE.

E. HUMIDITY

HUMIDITY WAS MEASURED AT UMIAT BASE BY A DEW-POINT RECORDER (THE FOXBORO DEWCEL). THE DATA ARE REPRESENTED HERE AS THE VAPOR PRESSURE DEFICIT, OR THE DIFFERENCE BETWEEN THE SATURATION VAPOR PRESSURE AND THE ACTUAL VAPOR PRESSURE. IN THIS CASE, ACTUAL VAPOR PRESSURES WERE RECORDED AT 4 INCHES AT UMIAT BASE AND THE SATURATION VAPOR PRESSURES WERE COMPUTED FOR THE TEMPERATURES AT 2 INCHES. OWING TO IMPROPER SETTING OF THE DEW-POINT RECORDER SCALE, ABSOLUTE VALUES CANNOT BE GIVEN, BUT FIGURE 25 SHOWS THE DIURNAL RANGES OF MAXIMUM, AVERAGE, AND MINIMUM VAPOR PRESSURE DEFICITS.* IF THE VALUES NEAR 2400 ARE ASSUMED TO BE ZERO OR SLIGHTLY NEGATIVE (THE TIME OF FOG OR FORMATION OF DEW), THEN VALUES EARLY IN THE SEASON REACH 13 MB (1 MB = .75MM) DURING MIDDAY; LATER IN THE SEASON, DURING THE HOT WEEK OF 25 TO 31 JULY, THEY AVERAGE UP TO ABOUT 23 MB. BY LATE AUGUST THEY REACH ONLY 5 MB, ON THE AVERAGE, WITH AN EXTREME OF 9 MB. AVERAGE WEEKLY VAPOR PRESSURE DEFICITS FOR THE ENTIRE SEASON ARE GIVEN IN THE APPENDIX, TABLE I.

ATMOMETER DATA WERE OBTAINED FOR THE UMIAT STATIONS THROUGH MOST OF ONE SUMMER. THE TOTAL EVAPORATED WATER DURING THE EARLY PART OF THE SEASON FROM LIVINGSTON ATMOMETERS MOUNTED 13 TO 15 INCHES ABOVE THE GROUND IS SUMMARIZED IN TABLE XII.

TABLE XII. TOTAL EVAPORATED WATER IN CM^3 FROM LIVINGSTON ATMOMETERS, 29 JUNE TO 28 JULY 1953

UMIAT BASE	UMIAT 1A	UMIAT 3	UMIAT 4	UMIAT 5
872	778	916	747	807

DURING THIS PERIOD THE AVERAGE DAILY VAPOR-PRESSURE DEFICIT AT UMIAT BASE WAS 109 MB.

7. CONCLUSIONS

THE TUNDRA OF THE ARCTIC SLOPE, WHICH IS ENTIRELY UNDERLAIN WITH DEEP PERMAFROST, IS A REGION DOMINATED IN SUMMER BY COOL MARITIME WINDS,

*AN ERROR IN THE SCALE ZERO ALSO INTRODUCES AN ERROR IN THE RELATIVE VALUE OF VAPOR PRESSURE DEFICIT BECAUSE OF THE NON-LINEAR RELATIONSHIP OF DEW-POINT TO VAPOR PRESSURE.

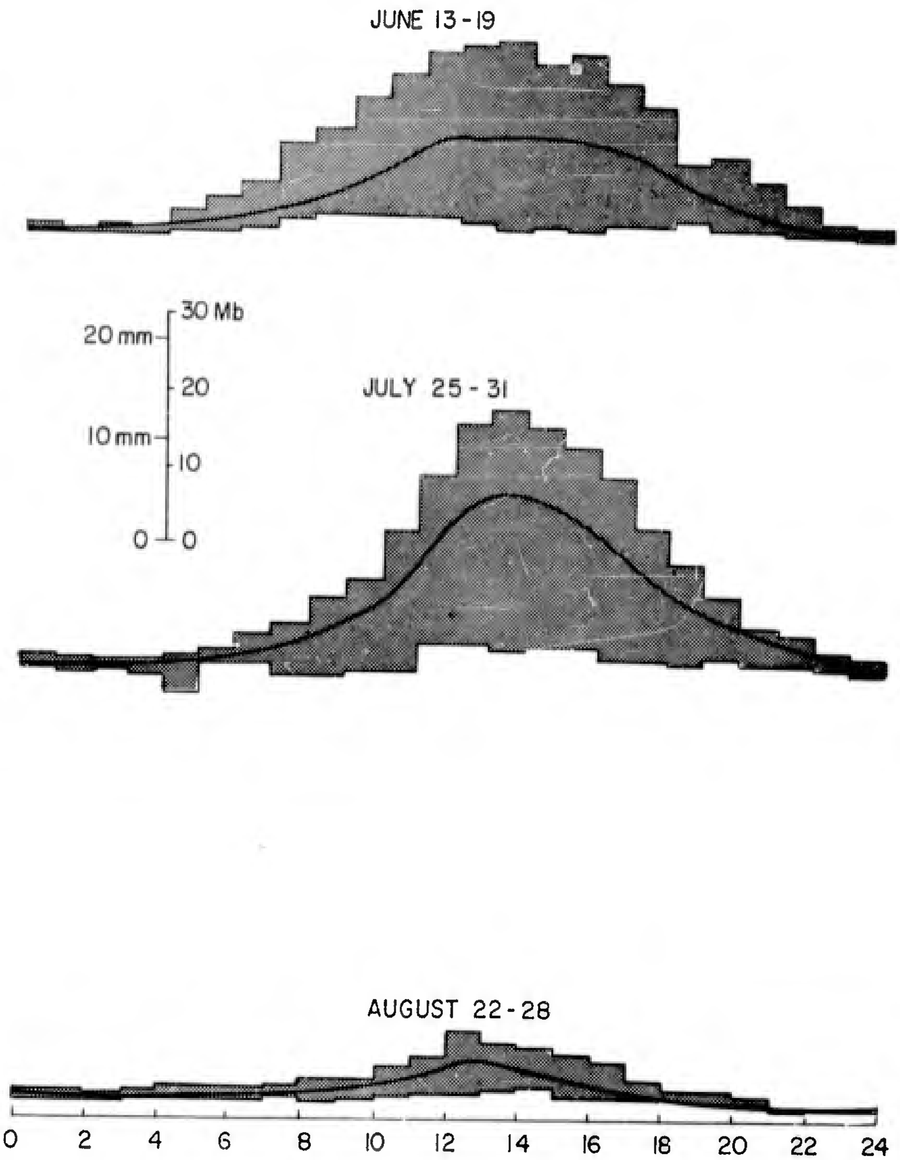

FIGURE 25. THE DIURNAL MARCH OF VAPOR PRESSURE DEFICIT AT THE 14-INCH LEVEL FOR THREE SELECTED WEEKS IN 1953 AT UMIAT BASE. MAXIMUM, AVERAGE, AND MINIMUM HOURLY VALUES.

MUCH CLOUDINESS, LIGHT PRECIPITATION, AND FREQUENT DRIZZLE. JULY NORMAL TEMPERATURES RANGE FROM 40°F ON THE NORTHEAST COAST TO 52°F WELL INLAND. IN WINTER, CLOUDINESS DECREASES AND KATABATIC WINDS PREVAIL INLAND, WHILE EASTERLIES CONTINUE ALONG THE COAST. TEMPERATURE IN JANUARY AVERAGES -16°F NEAR THE COAST, -22°F IN THE CENTRAL COLVILLE VALLEY, AND -10°F NEAR 2000 FEET ALONG THE SLOPE OF THE MOUNTAINS. ANNUAL PRECIPITATION TOTALS ABOUT 6 INCHES OVER THE EXTREME NORTHERN COAST AND CENTRAL SLOPE, ABOUT 12 INCHES AT 1000 FEET, AND ABOUT 18 INCHES AT 2000 FEET. THE LAND IS GENERALLY SNOW-COVERED FROM MID-SEPTEMBER TO MID-JUNE. DURING THE WINTER, THE SNOW IS BLOWN ABOUT ALMOST CONSTANTLY, CREATING A RELATIVELY SMOOTH SURFACE WITH AVERAGE DEPTHS RANGING FROM ABOUT 14 INCHES AT BARROW TO 28 INCHES AT ANAKTUVUK PASS. THE STRENGTH OF THE WINTER WINDS IS GOVERNED BY THE COMBINATION OF THE GRADIENT AND KATABATIC COMPONENTS. THE STRONGEST WINDS BLOW FROM THE WEST AND OCCUR IN THE NORTHEAST SECTION IN COMBINATION WITH A STORM PASSAGE ON THE NORTH AND CONVERGENCE INDUCED BY THE NEARBY MOUNTAIN BARRIER ON THE SOUTH. FREEZING DRIZZLE OR RAIN IS RELATIVELY FREQUENT FROM MAY TO OCTOBER.

SUMMER TEMPERATURE TRENDS, AS SHOWN BY 10-YEAR FLOATING MEANS, AT BARROW SINCE 1921 WERE DOWNWARD UNTIL THE LATE 40'S AND SLIGHTLY UPWARD THEREAFTER. WINTER TRENDS WERE UPWARD 3F° TO ABOUT 1939, THEN DOWNWARD ABOUT 3F° TO 1956.

MICROCLIMATIC MEASUREMENTS, INCLUDING WIND SPEEDS, TEMPERATURES ABOVE AND BELOW THE GROUND SURFACE, AND DEPTH OF THAW PROFILES, WERE MADE NEAR THE COAST, IN THE COLVILLE VALLEY, ON NEARBY SLOPES, AND IN THE FOOTHILLS OF THE BROOKS RANGE. VAPOR PRESSURE AND SOLAR RADIATION WERE RECORDED AT THE UMIAT BASE STATION. SUMMER GROUND-SURFACE TEMPERATURES GENERALLY AVERAGED IN THE LOW 50'S; EXTREMES OF 100°F OCCURRED WHILE SOIL WAS FROZEN 10 TO 15 INCHES BELOW THE SURFACE. TEMPERATURE LAPSE-RATES IN AIR ABOVE ABOUT 6 INCHES WERE USUALLY ISOTHERMAL. THE DEPTHS OF SUMMER THAWING AVERAGED ABOUT 2 FEET. THE SOILS THAT WARM QUICKEST ARE THE WELL-DRAINED ONES; THESE AREAS ARE USUALLY BARE, ALLOWING THE SURFACE TO WARM RAPIDLY, AND THE RELATIVE LACK OF ICE IN THEM DOES NOT REQUIRE LARGE AMOUNTS OF HEAT TO ACCOMPLISH THAWING. SUCH AREAS MAY THAW 5 FEET. THE LEAST THAWING, AS LITTLE AS A FEW INCHES, IS FOUND IN THE WET, GENERALLY MOSS-COVERED, POORLY DRAINED AREAS. MOST OF THE SOILS OF GENTLE SLOPE ARE SOMEWHERE <u>BETWEEN</u> FIELD CAPACITY AND SATURATION IN THE LEVEL <u>BELOW</u> THE TUSSOCKS AND PROBABLY <u>NEAR</u> FIELD CAPACITY <u>IN</u> THE TUSSOCKS. ON MORE STEEPLY-SLOPING SURFACES, THE UPPER LAYERS ARE MOSTLY BETWEEN WILTING PERCENT AND FIELD CAPACITY. DRIER SOILS MAKE UP A SMALL PERCENTAGE OF THE AREA.

THE FREQUENCY OF SURFACE THAWS AND FREEZES WAS FOUND TO BE LOW, AVERAGING ABOUT 15 PER YEAR. IN WINTER THE VEGETATION THAT IS NOT PROTECTED BY SNOW FROM THE DESICCATING COLD WIND, IS GENERALLY KILLED. FREEZING-INDICES ARE GREATEST IN THE VALLEYS. THE HIGHEST INDICES ARE FOUND INLAND ON THE SOUTH SLOPES WHILE THE LOWEST OCCUR ALONG THE COAST.

8. Acknowledgements

The reporting and recording of information presented in this report would not have been possible without the cooperation of many people. Mr. Charles Matthews, Dr. Franklin Erickson, and the late Mr. Theodore Wood of Boston University worked out the logistics and took observations after the author set up the equipment and commenced the observations in the summer of 1952. Dr. John Cantlon, Dr. Larry Bliss, and Mr. Paul Swenson set up and ran the stations under the author's direction the second summer, while U.S. Air Force observers, Mr. John Merrick and Mr. David Butler, made observations throughout the following winter and the third summer. Credit is also due Mr. John Ingold, Mr. and Mrs. Harvey Isham, Mr. Harold Rice, and my wife, Ethel Conover, who spent many tedious hours reducing the data.

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APPENDIX

Table I. Average weekly temperature, solar radiation, vapor pressure deficit, and snow cover at Umiat Base

Table II. Average weekly temperatures (°F) at + 4 inches and -4 inches, at 8 Arctic Slope Stations

TABLE 1. AVERAGE WEEKLY TEMPERATURE, SOLAR RADIATION, VAPOR PRESSURE DEFICIT, AND SNOW COVER AT UMIAT BASE

Week 1953	Temperature (°F) at indicated inches from the ground surface +72	+24	+4*	+2	0	-1	-2	-4	-12	-24	Solar Rad. per Day (Lys.)	Aver. Daily Vapor Press. Deficit (mb.)	Snow Cover (in.)
June 13-19	46.8	47.2	49.2	50.8	52.5	43.6	42.0	34.3	30.4	27.9	497	144	0
20-26	56.0	56.0	56.5	56.6	55.4	47.3	45.8	37.0	31.0	28.4	367	107	0
27- 3	46.2	46.1	47.0	47.4	49.0	45.0	43.7	37.2	31.5	29.6	373	89	0
July 4-10	47.9	47.9	48.7	49.7	50.8	44.7	43.8	37.0	31.0	29.0	483	117	0
11-17	43.5	43.4	44.2	45.0	48.2	43.5	42.8	37.4	32.0	30.6	318	66	0
18-24	56.0	55.6	56.4	57.3	58.5	50.2	49.0	40.8	31.9	30.6	452	126	0
25-31	56.8	56.8	57.8	58.9	60.3	51.6	50.2	42.1	31.1	29.6	532	148	0
Aug. 1- 7	51.9	51.5	51.8	51.9	52.3	48.7	48.0	42.0	32.7	31.3	250	45	0
8-14	48.2	47.7	48.0	48.5	49.4	46.6	45.8	40.9	33.0	31.9	259	44	0
15-21	36.6	36.8	37.7	38.7	41.0	40.5	39.7	36.6	32.0	30.7	370	25	0
22-28	38.5	38.5	38.8	39.3	40.5	40.6	40.0	37.4	33.0	31.7	206	3	0
29- 4	36.3	35.9	36.5	36.6	37.5	37.5	37.1	34.9	32.0	31.0	199	---	0
Sept. 5-11	29.8	30.3	31.2	31.9	33.0	33.8	33.5	32.5	32.0	31.1	169	---	0
12-18	31.8	31.8	32.1	32.2	33.6	35.3	34.8	33.8	33.0	32.0	149	---	0
19-25	38.2	37.4	37.0	37.0	37.0	36.8	36.5	35.1	33.0	32.0	149	---	0
26- 2	24.6	23.9	----	28.2	30.3	33.2	33.1	33.3	33.1	32.7	91	---	2.0
Oct. 3- 9	15.4	14.8	----	26.3	27.8	31.6	32.0	33.0	33.0	32.7	89	---	3.2
10-16	19.6	19.2	----	27.0	28.0	32.0	31.8	32.0	32.0	32.4	60	---	4.3
17-23	14.0	13.6	----	24.8	26.3	30.8	31.0	32.0	32.0	32.4	36	---	5.0
24-31	-5.3	-6.2	----	16.8	22.4	28.8	29.0	31.0	32.0	31.6	28	---	6.0
Dec.26-Jan.1	-39.8	-41.0	----	-16.7	-13.5	2.3	3.4	9.0	14.0	14.7	0	---	12.0
Average temperature for periods of approximately one month													
July 4-31	51.0	50.9	51.8	52.7	54.4	47.5	46.4	39.3	31.5	30.0			
Aug. 1-28	43.8	43.6	44.1	44.6	45.8	44.1	43.4	39.2	32.7	31.4			
Aug. 29-Oct.2	32.1	31.9	----	33.2	34.3	35.3	35.0	33.9	32.6	31.8			
Oct. 3-31	10.9	10.4	----	23.7	26.1	30.8	31.0	32.0	32.2	32.3			

*Interpolated from temperature profiles.

APPENDIX (CONT'D)

TABLE 11. AVERAGE WEEKLY TEMPERATURES (°F) AT +4 INCHES AND -4 INCHES, AT 8 ARCTIC SLOPE STATIONS

Week 1953		Temperature at +4 inches: Umiat Base P	1A	3	4	5	Cache 5	Mt.	Temperature at -4 inches: Umiat Base P	Umiat Base*	1A	3	4	5	Cache 5	Mt.
May	16-22									26.7						
	23-29									28.7						
	30- 5									31.0						
June	6-12									32.0						
	13-19	49.2							34.3	33.8	46.8	36.7	33.8	39.0		
	20-26	56.5	56.5	55.3	55.3				37.0	37.0	49.9	40.2	38.5			
	27- 3	47.0	47.4	45.7	45.3				37.2	37.5	47.4	39.8	38.7	39.4	38.7	
July	4-10	48.7	50.8	49.0	49.4	49.4	47.3	45.3	37.0	38.3	48.3	40.2	39.3	41.2	41.1	35.4
	11-17	44.2	45.5	43.5	43.0	44.4	42.0	45.7	37.4	38.2	47.5	39.9	38.8	41.3	38.7	36.7
	18-24	56.4	57.4	56.2	56.5	57.2	55.5	53.9	40.8	40.9	52.6	43.8	42.6	46.8	46.0	39.5
	25-31	57.8	60.2	58.4	57.9	61.0	56.1	59.6	42.1	42.3	56.1	46.0	44.1	49.2	46.1	42.9
Aug.	1- 7	51.8	52.9	51.4	51.3	52.0	49.8	51.1	42.0	41.6	53.0	44.7	42.4	44.7	44.0	40.4
	8-14	48.0	48.6	47.1	47.0	48.0	46.3	44.3	40.9	40.3	50.4	42.6	40.3	42.4	41.5	39.5
	15-21	37.7	38.6	36.9	35.8	38.3	35.0	38.9	36.6	36.0	44.3	36.8	34.7	37.3	34.5	34.9
	22-28	38.8	39.1	37.8	37.0	38.8	36.2	38.5	37.4	----	43.3	37.5	35.8	37.8	35.2	36.6
Average temperatures for periods of one month																
July	4-31	51.7	53.4	51.8	51.7	53.0	50.2	50.6	39.3	39.9	51.1	42.5	41.2	44.6	43.0	38.6
Aug.	1-28	44.1	44.8	43.3	42.8	44.3	41.8	43.2	39.2	----	47.8	40.4	38.3	40.6	38.8	37.8

*Umiat Base site was 22 feet WSW of Umiat Base P (polygon) and under 6 to 8 inch grass in a tussock community. The snow cover left this site about 4 June and the ground thawed at the -4 inch level between 4 and 11 June.

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QM R&E Field Evaluation Agency, U.S. Army
Airborne Systems Test Div.
Yuma Test Station
Yuma, Arizona

ARMY (Cont)

1 Commanding Officer
Cold Weather & Mountain Indoctrination
School
Fort Greeley, Alaska

1 Commanding Officer
Fort Greeley, Alaska
Attn: Post Library

AIR FORCE

2 Department of Air Force
Hqs., USAF, Wash 25, D. C.
(1 DC/S Material, 1 DC/S Dev.)

1 Director
Air University Library, Attn: 7575
Maxwell AFB, Alabama

2 Commandant
USAF School of Aviation Medicine
Randolph AF Base
Randolph Field, Texas

1 Commander, Arctic Aeromedical Lab
APO 731, Seattle, Washington

1 Commander
Air Res & Dev Command
Attn: RDSBTL (Hqs., Tech Lib. Br.)
Andrews AF Base, Washington 25, D.C.

1 Commander
Wright Air Development Center
Wright Patterson AF Base, Ohio
Attn: Tech Library

1 Commander
Strategic Air Command
Offutt AF Base, Nebraska

1 Chief, Nutrition Div.
Air Development Center
Aero-Medical Lab.
Wright Patterson AFB, Ohio
Attn: Dr. Harry C. Dyme

1 Commander
AF Cambridge Research Center
Air Research & Development Cmd.
Laurence G. Hanscom Field
Bedford, Mass.
Attn: CRTOTT-2

NAVY

1 Director
Naval Research Laboratory
4th & Chesapeake St., S. W.
Washington 25, D. C.

1 Chief, Bureau of Ordnance
Department of the Navy
Washington 25, D. C.
Attn: R&D Div.

1 Naval Medical Research Institute
National Naval Med. Res. Center
Bethesda, Md.

2 Chief of Naval Research
Washington 25, D. C.
Attn: Code 402S

1 Chief, Bureau of Ships
Department of the Navy
Washington 25, D. C.
Attn: Code 331

1 Chief, Bureau of Med. & Surgery
Dept. of the Navy, Wash 25, D. C.
Attn: Code 33

NAVY (Cont)

1 Commander, U. S. Naval Ord. Test
Station, China Lake, Calif.
Attn: Code 753

1 Chief, Bureau of Aeronautics
Dept. of the Navy, Wash 25, D. C.
Attn: Code AE 52

1 Chief, Bureau of Supplies & Accounts
Department of the Navy
Washington 25, D. C.

CONARC

1 C.G., U.S. Continental Army Command
Ft. Monroe, Va.

1 President
U. S. Army Artillery Bd.
Ft. Sill, Okla.
Attn: ATBA

1 President
US Army Armor Board
Ft. Knox, Ky.
Attn: ATBB

1 President
U. S. Army Infantry Bd.
Ft. Benning, Ga.
Attn: ATBC

1 President
U. S. Army Air Defense Bd.
Ft. Bliss, Texas
Attn: ATBD

1 President
U. S. Army Airborne and Electronics Bd.
Ft. Bragg, N. C.
Attn: ATBF

1 President
U. S. Army Aviation Bd.
Ft. Rucker, Ala.
Attn: ATBG

1 Commanding Officer
U. S. Army Arctic Test Board
Ft. Greely, Alaska
Attn: ATBE

BOARDS & COMMITTEES

1 Army Committee on Environment
Chief, Research & Development
Pentagon, Washington, D. C.

1 Armed Forces Pest Control Bd.
Walter Reed Army Med. Center
Forest Glen Annex
Main Bldg.
Forest Glen, Maryland

1 Army Research Committee
Chief, Research & Development
Pentagon, Washington, D. C.

MISCELLANEOUS

1 National Research Council
2101 Constitution Ave., Washington, D.C.
Attn: Advisory Bd. on QM R&D

10 Armed Services Technical Information Agency
Arlington Hall Station
Arlington 12, Va.
Attn: TIPDR

2 Gift and Exchange Division
Library of Congress
Washington 25, D. C.

1 U. S. Department of Commerce
Weather Bureau Library, Washington, D.C.

1 Central Intelligence Agency
Collection & Dissemination
Washington 25, D.C.

1 National Library of Medicine
Washington 25, D. C.

1 Generalintendanten
Standardiseringskontoret
Festningen
Oslo, Norway

1 Marine Corps Equipment Board
Marine Development Center
Marine Corps School
Quantico, Va.

1 Office of Technical Services
U. S. Department of Commerce
Washington 25, D.C.
Attn: Tech Rpts Sec (THRU OQMG)

1 U. S. Department of Agriculture Library
Washington 25, D. C.

1 Commandant
Industrial College of the Armed Forces
Ft. McNair, Washington 25, D. C.

1 QM Representative
Army Command and General Staff College
Department of the Infantry Div.
Ft. Leavenworth, Kansas

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