AD 636256

TECHNICAL REPORT
66-7-ES

YUMA WINTER MICROCLIMATE

by

Howard L. Ohman

and

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June 1966

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

U.S. ARMY MATERIEL COMMAND

Earth Sciences Division

ES-24

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Military Applications Branch

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Project Reference:
1V025001A129

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Natick, Massachusetts

FOREWORD

The microclimate of the soldier is represented by conditions in the layer of air from the surface of the ground to a height of about two meters. Greater differences in temperature may exist within this layer than in any other two meter thickness of the whole atmosphere. Standard observations, taken in an instrument shelter approximately five feet above the ground, represent this important layer inadequately. It is for this reason that the Army has conducted numerous microclimatic studies in various parts of the world.

This report highlights some of the microclimatic changes characterizing the lowest layer of the atmosphere during a typical winter season at Yuma Proving Ground (formerly Yuma Test Station), Yuma, Arizona. Together with its companion study, EP-120 "Yuma Summer Climate," it provides new and revealing information about the changing character of desert climate through the seasons.

The study was conducted under DA Project 1V025001A129, Task 02, Hot Environments.

L. W. TRUEBLOOD, Ph.D.
Chief
Earth Sciences Division

Approved:

DALE H. SIELING, Ph.D.
Scientific Director

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Colonel, USA
Commanding

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ABSTRACT

This study consists of an analysis of winter temperatures at and near the ground and wind velocities at standard heights, at three sites within Yuma Proving Ground. Two of the sites were selected for their representativeness of surface types characterizing the desert basins of southwestern United States. The third site was selected to represent the many low rocky mountain areas of the desert. The study develops information on the nature of diurnal temperature fluctuations, based on hourly records of temperature of January and February 1957, at ten levels ranging from 25 centimeters below the ground to 200 centimeters above the ground surface. In addition, hourly records of wind speed and direction at the standard shelter height were kept and analyzed.

Results show that the temperature regime at the ground level differs markedly from that for the "standard" or 200-centimeter level at all sites, particularly in diurnal range, both actual and average (at Desert Pavement the average temperature range is 37 F° at the surface and 22.4 F° at 200 centimeters). Some differences in temperature from site to site were also noted, the most significant being the higher nighttime temperatures at Laguna Top the most elevated station, as compared to those for the two lower stations, Sandy Plains and Desert Pavement (average over 6 F° at the surface and 7 F° at two meters). Strong radiational cooling and air drainage into low areas resulting in the formation of nighttime inversions account for the lower daily minimum temperatures at the two low-lying stations. Laguna Top, in contrast, is unaffected by the nighttime inversions because of its height. Another difference of note is the higher temperatures just below the ground surface during the afternoon at the Desert Pavement site (over 7 F°) as compared to the Sandy Plains site. At Sandy Plains the light colored sands with insulating air spaces absorb less incoming radiation during the day and store less heat in the ground than the weather darkened gravels of the Desert Pavement site.

The wind regimes of the two low-lying sites, Sandy Plains and Desert Pavement, were very comparable, wind speeds being strong during the day and weak at night. At Laguna Top, on the other hand, the winds were strong both day and night, even though speeds at night were somewhat below the daytime maximum.

YUMA WINTER MICROCLIMATE

1. Introduction

In a previous study (2), the microclimate of that layer of the atmosphere affecting the majority of operations conducted by the Army in desert environments was examined in some detail for a two-month period during the summer of 1956. The present study complements the first through analysis of similar data for a two-month period of the following winter season. Temperature extremes for the study year, ranging from the highest surface temperature recorded during the heat of the summer, to the lowest temperature recorded during the winter, are thereby covered by the two studies. Together they provide the basis for realistic judgments of the thermal conditions endured by the soldier while operating in desert areas analogous to those within and about Yuma Proving Ground.

2. Observational Program

In May 1956, three microclimatic stations were installed within Yuma Proving Ground and were operated continuously for a period of fourteen months. The site of each station was selected for its representativeness of a surface or terrain type characterizing the Yuma area. The first and primary station was erected on a sandy plain east of the main post area at an elevation of 420 feet above sea level. This site represents the many areas of sand and small gravel that abound in the Yuma area and impart to the desert its overall light tan color. The second station was located on a patch of desert pavement not far from the Ordnance Firing Range at an elevation of approximately 425 feet above sea level. This site represents the many weather-darkened "patinated" or "varnished" rock and large gravel surfaces of the south-western deserts. The third station was located on a rocky peak of the North Laguna Mountains at an elevation of 630 feet above sea level. This site represents the "patinated" bare rock slopes of the mountain ranges in the Yuma area. For reference convenience, the number one site will be referred to as "Sandy Plains," number two as "Desert Pavement," and number three as "Laguna Top" throughout the text. The location of the stations as well as some of the principal physical and cultural features of the Yuma Test Station is shown in Figure 1. Figures 2, 3, and 4 are photographs of the three stations.

At each of the sites, temperature measurements were made at 10 levels using thermocouples of 20 gauge wire placed at: (a) heights of 2.5, 7.5, 25, 50, and 200 centimeters above the surface of the ground; (b) depths of 2.5, 7.5, and 25 centimeters below the surface of the ground; and (c) the surface of the ground, where the thermocouple was kept lightly dusted. At all points above the surface of the ground, the thermocouples were shaded by special radiation shields, as shown in Figures 2, 3, and 4.

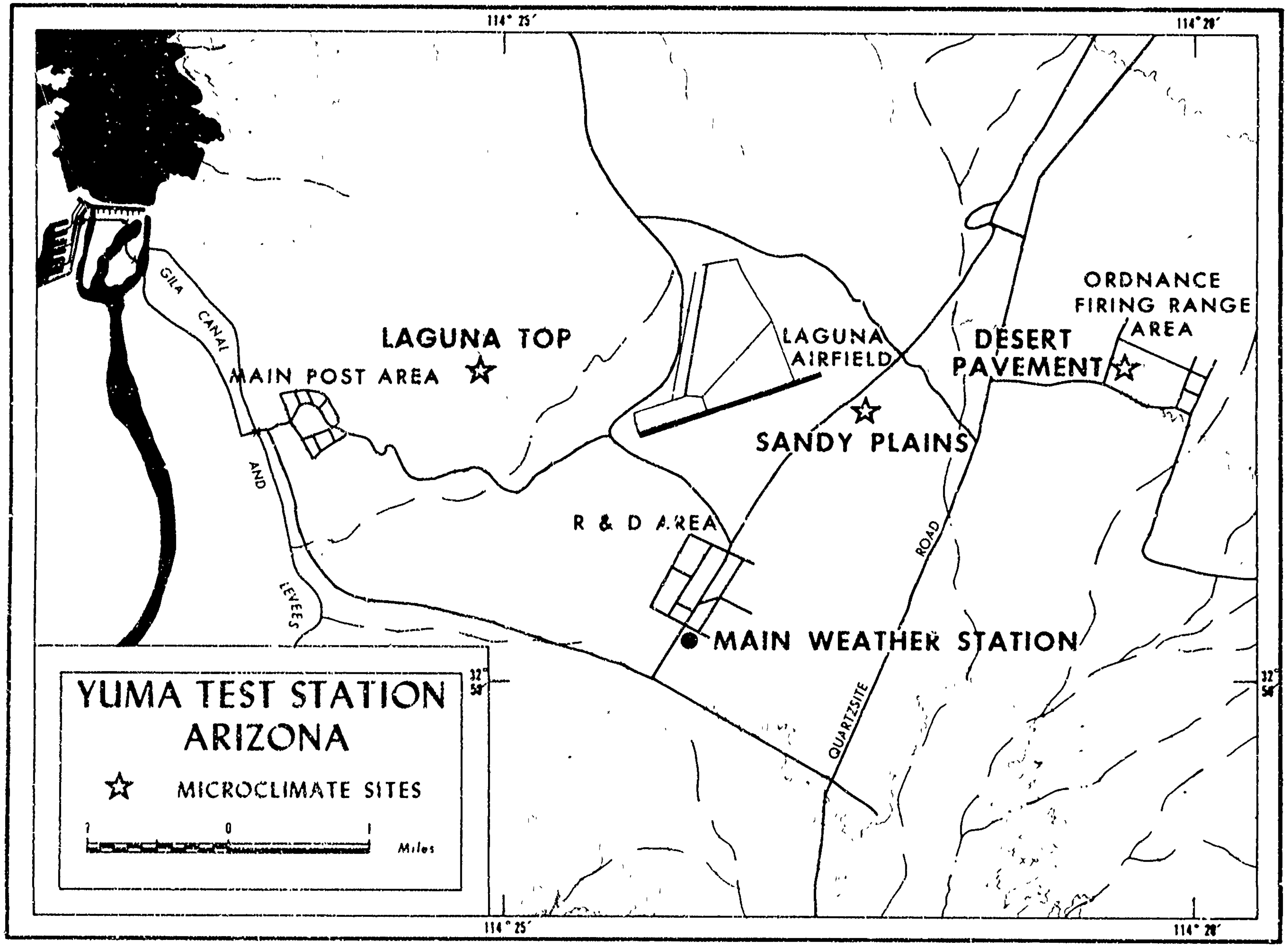
114° 25′
114° 20′
LAGUNA TOP
MAIN POST AREA
GILA CANAL
AND
LEVEES
LAGUNA AIRFIELD
SANDY PLAINS
DESERT PAVEMENT
ORDNANCE FIRING RANGE AREA
R & D AREA
MAIN WEATHER STATION
QUARTZSITE ROAD
32° 50′
YUMA TEST STATION
ARIZONA
MICROCLIMATE SITES
1
0
1
Miles

Figure 1

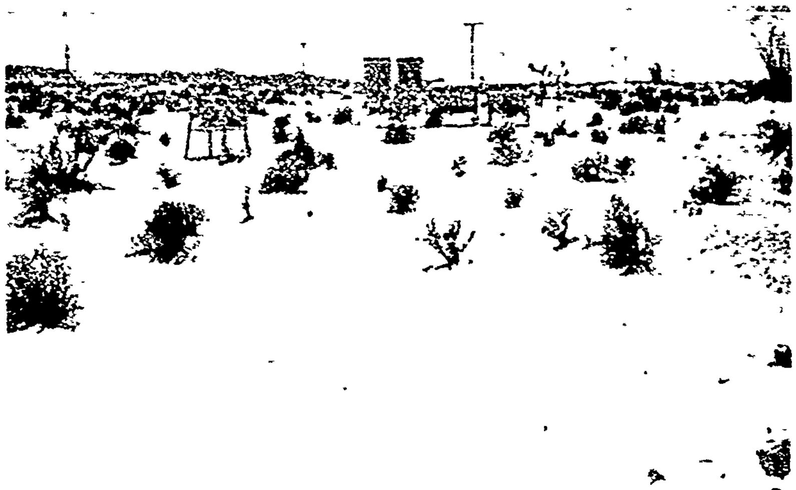

Figure 2

Sandy Plains

Figure 3

Desert Pavement

Figure 4

Laguna Top

The measurements were recorded on roll charts of a 12-point Brown Recorder at a rate of one measurement per minute. This meant that for each of the 10 points concerned, one temperature measurement was recorded every 12 minutes, the time required to complete the 12-point cycle. Continuous records of wind speed and direction were obtained at each site by special aerovane anemometers installed at a height of five feet above the surface of the ground.

The Army has operated a standard weather station at Yuma Proving Ground since 1951. The record for this station provides the means for determining the general weather conditions prevailing at any time during test periods, as well as a "standard" with which the microclimatic measurements may be compared.

3. Analysis of Data

From the fourteen months of record available for analysis, the months of January and February 1957 were selected as the two-month period most representative of winter weather conditions. These months not only included the coldest weather experienced during the winter of 1956-1957 but also had the lowest average temperatures of any two months of the fourteen months of observation. The data in Table I show the comparison of temperature and rainfall data for January and February 1957 with data of a fairly long period of record (1952-65). Mean daily maximum and minimum temperatures for January 1957 are almost the same as the 14-year values, but those for February 1957 are warmer than average by about 5 F°. The rainfall data indicate no significant difference between the short and long periods, though January 1957 has 3 more days with rain, and February 1957 somewhat less total rainfall than the average for the 14-year period. Data from the Yuma Weather Bureau Airport Station (13) indicate January and February 1957 received 21 and 11 percent less sunshine, respectively, than the average from 1952-1965 for the same months. Consequently, any microclimatic effects due to daytime solar heating are apt to be less pronounced in the two months selected for the study than might normally be expected.

From the Brown recorder charts for January and February 1957, values were read for hourly temperatures at each of the ten observational levels concerned and the data punched on cards. Hourly wind speeds and directions for each site were also punched. Using machine processing methods to sort, tabulate, and summarize, the data were subsequently prepared for analysis and presentation. The basic hourly data were first averaged and tabulated to produce mean hourly values. The mean hourly temperatures and windspeeds were then compared at the three sites. An analysis of the differences in average temperatures for the coldest night and warmest day were prepared for all sites, as well as lapse rate curves of temperature for representative cloudy and clear nights. Finally, the frequency distribution of temperatures for selected levels at each site were determined and graphed.

TABLE I

Comparison of Yuma Weather Records for January and February 1957 with Averages for 1952-1965

	Mean Max(°F)	Mean Min(°F)	Absolute Max(°F)	Absolute Min(°F)	Rain (in.)	No.Days w/Rain	% Possible Sunshine*
Jan (1952-65)	67.3	42.5	86	28	0.43	2	85
Jan 1957	65.1	42.5	74	35	0.52	5	64
Feb (1952-65)	72.1	46.2	94	24	0.34	2	90
Feb 1957	77.0	51.4	94	35	0.05	2	79

a. Mean Hourly Temperatures

Isotherms of mean temperature for the two-month study period were drawn against height and time for Sandy Plains site (Fig. 5), for the Desert Pavement site (Fig. 6), and for the Laguna Top site (Fig. 7). The graphs are based on mean hourly temperatures for the two-month period of January and February 1957 at the ten observational levels.** The graphs demonstrate some of the characteristic features of the microclimatic layer, and permit quantitative statements concerning the temperature regimes within and above the ground.

Diurnal temperature ranges are greatest at the ground surface and least at the -25 cm level at all stations. The Desert Pavement profile, for example (Fig. 5), shows an average ground surface temperature range from above 80°F during the heat of the day to less than 50°F during the coolest part of the night, a range greater than 30 F°.*** In contrast, mean maximum and minimum values at the -25 cm level are 65°F and 61°F, an average of about 4 F°.**** At the standard shelter level (2 meters) mean temperatures range from about 54° to 67°, a difference of approximately 13 F°. Both Laguna Top and Sandy Plains profiles show similar ranges.

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* Yuma Weather Bureau Airport Station data.

** Originally, the data for January and February were averaged separately, but since there was little difference in the temperature profiles for the two months, the original data were reaveraged and presented here as a two-month average.

*** During July and August 1956 this range was over 40F°. (Ref. 2).

**** During July and August 1956 this range was about 10F°. (Ref. 2).

MEAN HOURLY TEMPERATURE PROFILES FOR SANDY PLAINS SITE, YUMA, ARIZONA
(January & February 1957)

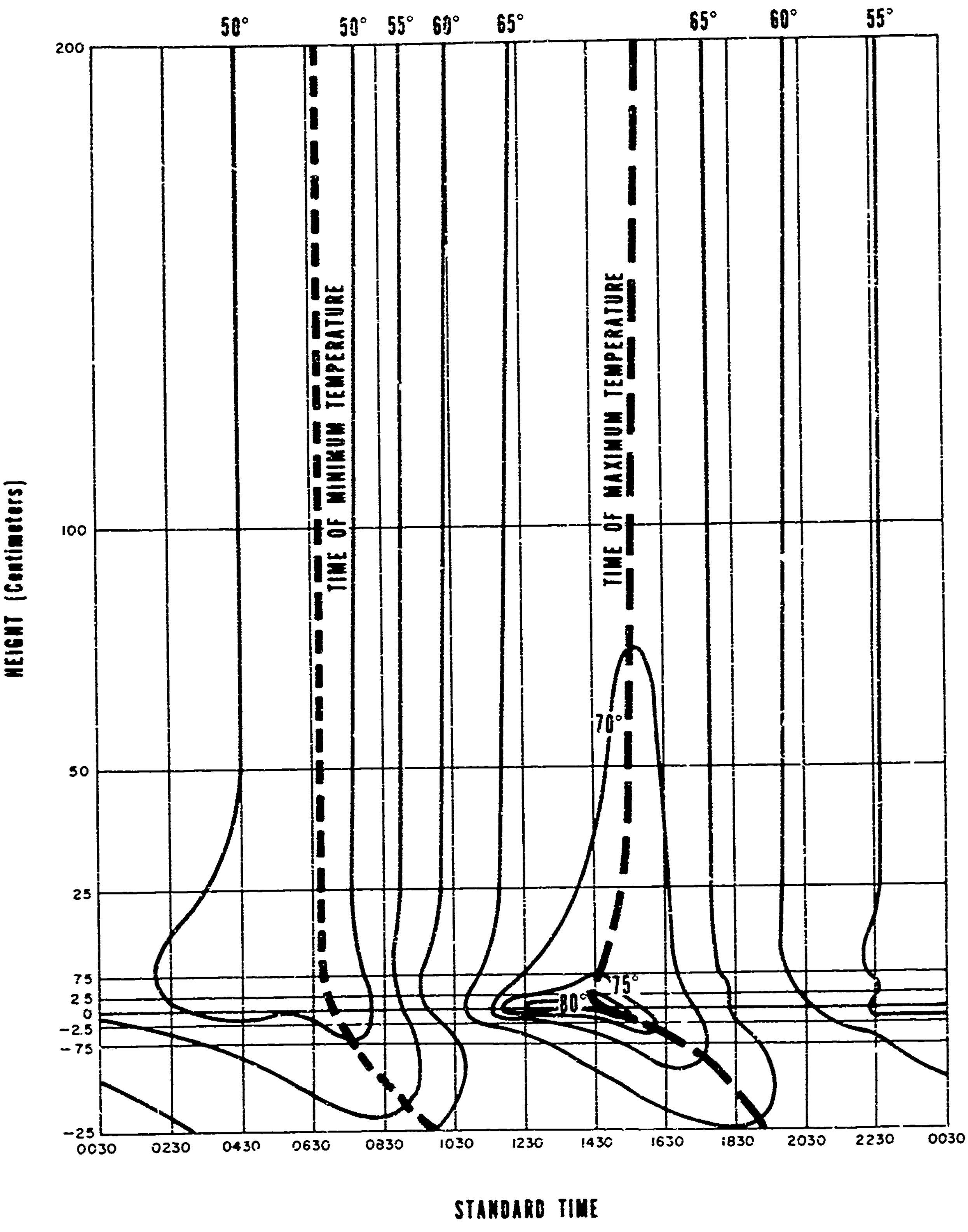

Figure 5

MEAN HOURLY TEMPERATURE PROFILES FOR DESERT PAVEMENT, YUMA TEST STATION, ARIZONA
(January & February 1957)

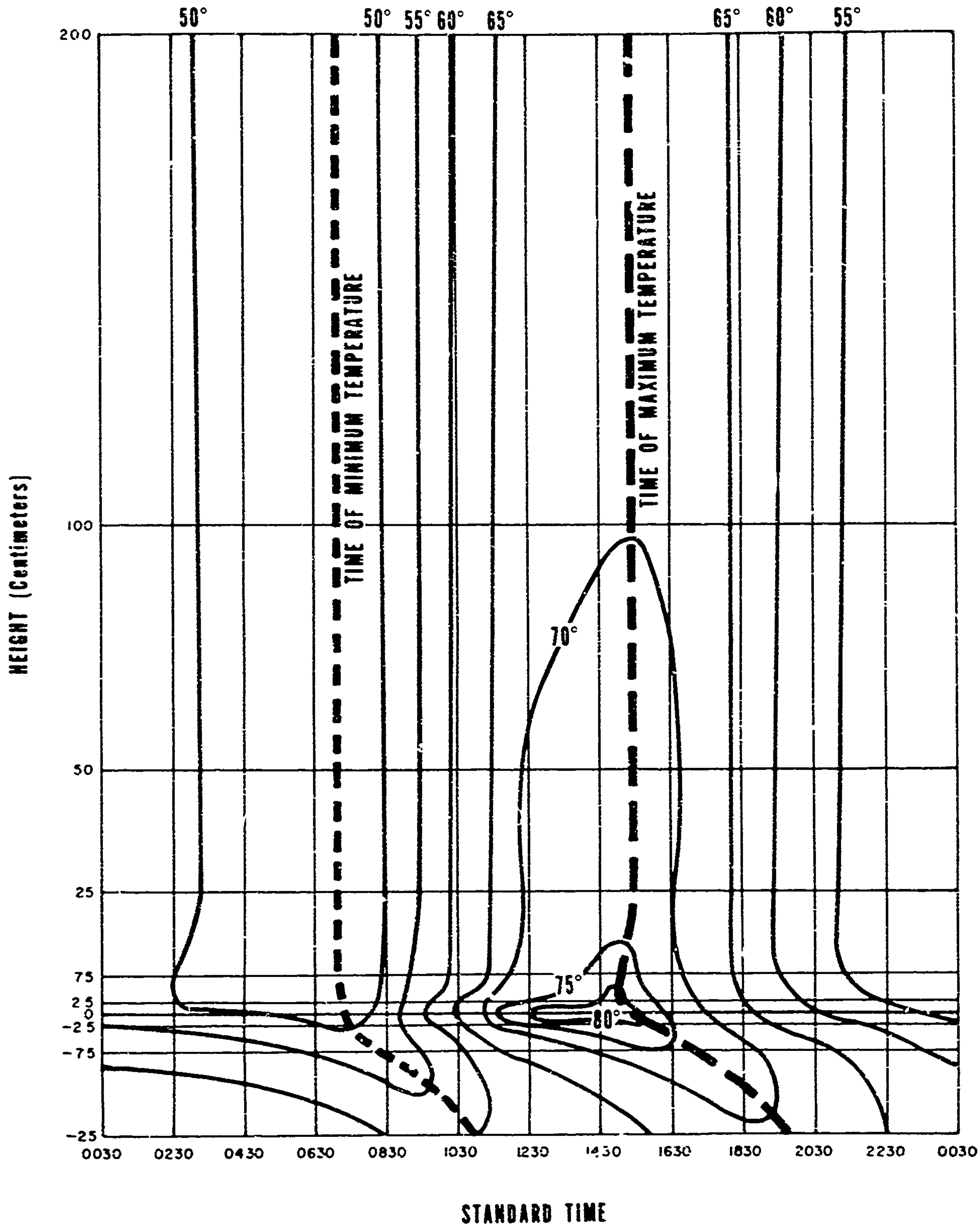

Figure 6

MEAN HOURLY TEMPERATURE PROFILES FOR LAGUNA TOP, YUMA TEST STATION, ARIZONA
(January & February 1957)

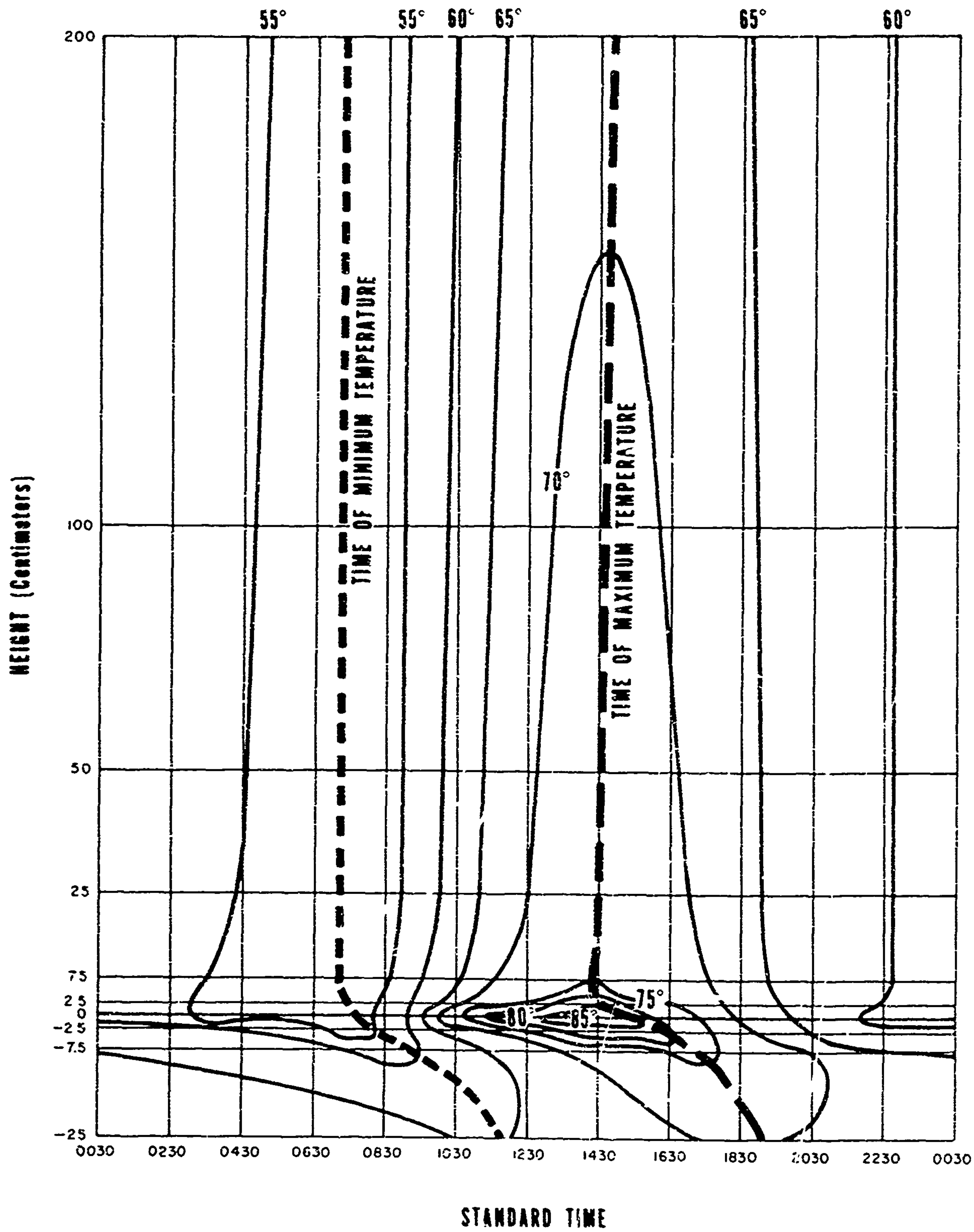

Figure 7

There is a decided lag in time between occurrences of the daily extremes at the surface and those at the subsurface levels. Between the surface and the -25 centimeter level, the lag amounts to about 5 hours, from approximately 1430 hours to 1930 hours in the case of maximum temperatures, and from approximately 0700 or 0730 hours to 1100 or 1130 hours in the case of the minimum temperatures. The highest mean hourly temperature computed, 89.3°F, is based on observations for Laguna Top station, occurring at the ground surface at 1430 hours. The lowest mean hourly temperature computed, 45.3°F, is based on observations for the Sandy Plains Station, occurring at the ground surface at 0730 hours.

Figures 8, 9, 10, and 11 are designed to show station-to-station differences in average temperature at the various levels. They demonstrate that the most elevated station, Laguna Top, is by far the warmest. When compared with Sandy Plains (Fig. 9), and with Desert Pavement (Fig. 10), Laguna Top is some 4 to 7 degrees warmer at most levels and hours. Only occasionally from late morning through early afternoon is the trend for higher temperatures at Laguna Top reversed, and then by a degree or two only and not at all levels. Perhaps this unusual situation can best be explained on the basis of differences in slope and exposure. The instruments at Laguna Top are located within a few feet of the crest on a south-facing slope of the mountain. Because of this orientation, the rock surfaces of the Laguna Top site face the low-angle sunlight of the winter season more directly than the horizontal surfaces of either of the other two sites. Consequently, both air and soil are heated more rapidly and the heat retained in the soil longer.

The temperature regimes of Sandy Plains and Desert Pavement (Fig. 11) are similar, showing few significant differences. One difference worthy of note, however, is the higher temperatures at the Desert Pavement site during the afternoon hours at the -2.5 centimeter level. At this first level below the ground surface, temperatures average 7 to 8 degrees higher than at Sandy Plains from 1100 hours to 1630 hours. This variation probably is caused by differences in the heat absorption of soils at the two sites. Measurements taken near these sites* show that about 65 percent of the solar radiation at midday is absorbed by light colored sandy soils of the Sandy Plains type, whereas about 85 percent is absorbed by the dark colored "patinated" gravels of the Desert Pavement type. More heat is thereby made available for transmission into

* Measurements taken at a height of about 300 feet with an Eppley Pyrheliometer attached to the underside of a helicopter and subsequently compared with the incoming radiation measurements at the standard weather station.

MEAN HOURLY GROUND SURFACE TEMPERATURES, FOR SANDY PLAINS, LAGUNA TOP, AND DESERT PAVEMENT, YUMA TEST STATION, ARIZONA
(January & February 1957)

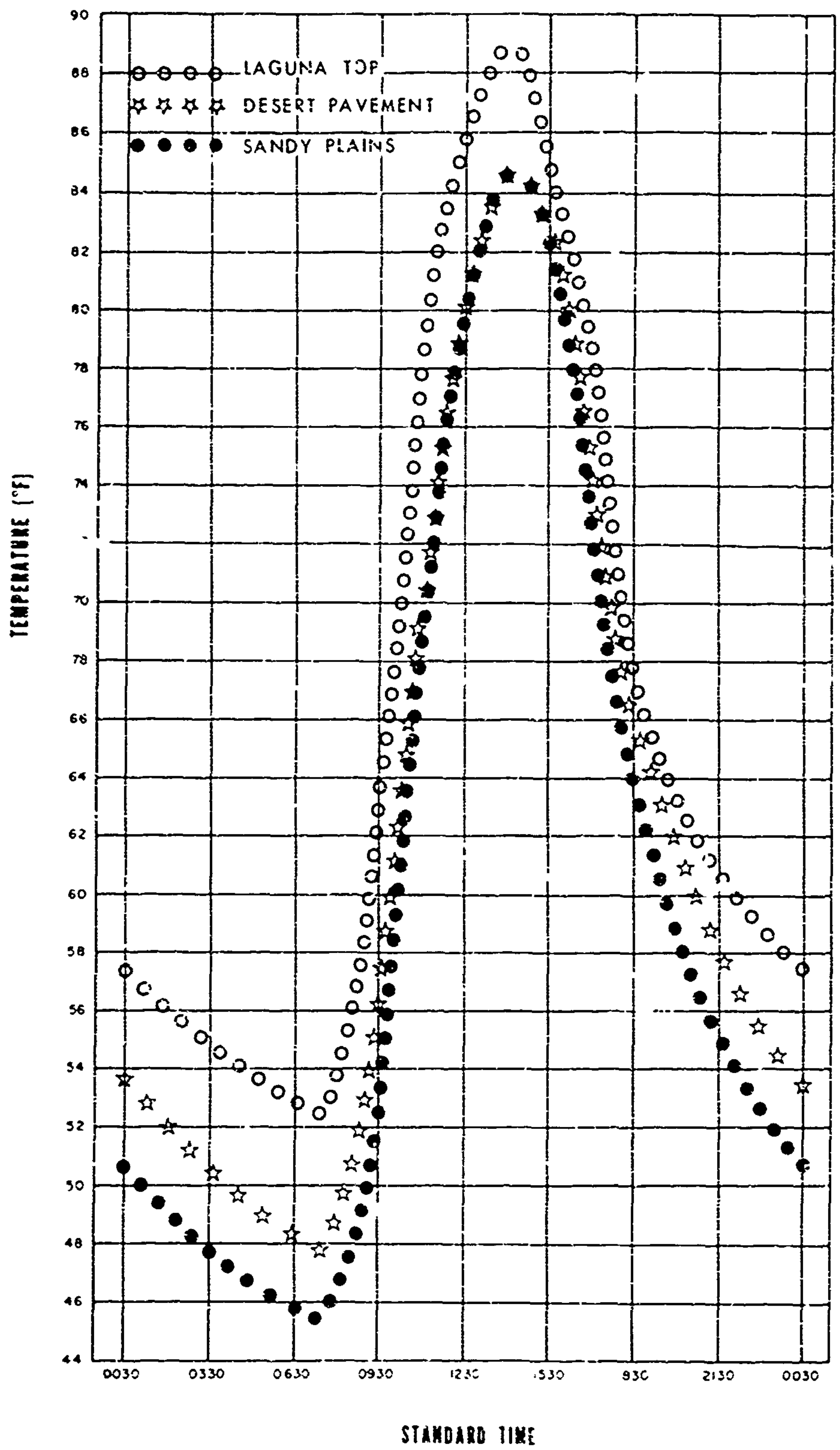

Figure 8

DIFFERENCES IN MEAN TEMPERATURES BETWEEN LAGUNA TOP AND SANDY PLAINS, YUMA TEST STATION, ARIZONA

HOURLY MEASUREMENTS (°F) AT EIGHT LEVELS FOR THE TWO MONTH PERIOD, JANUARY AND FEBRUARY, 1957

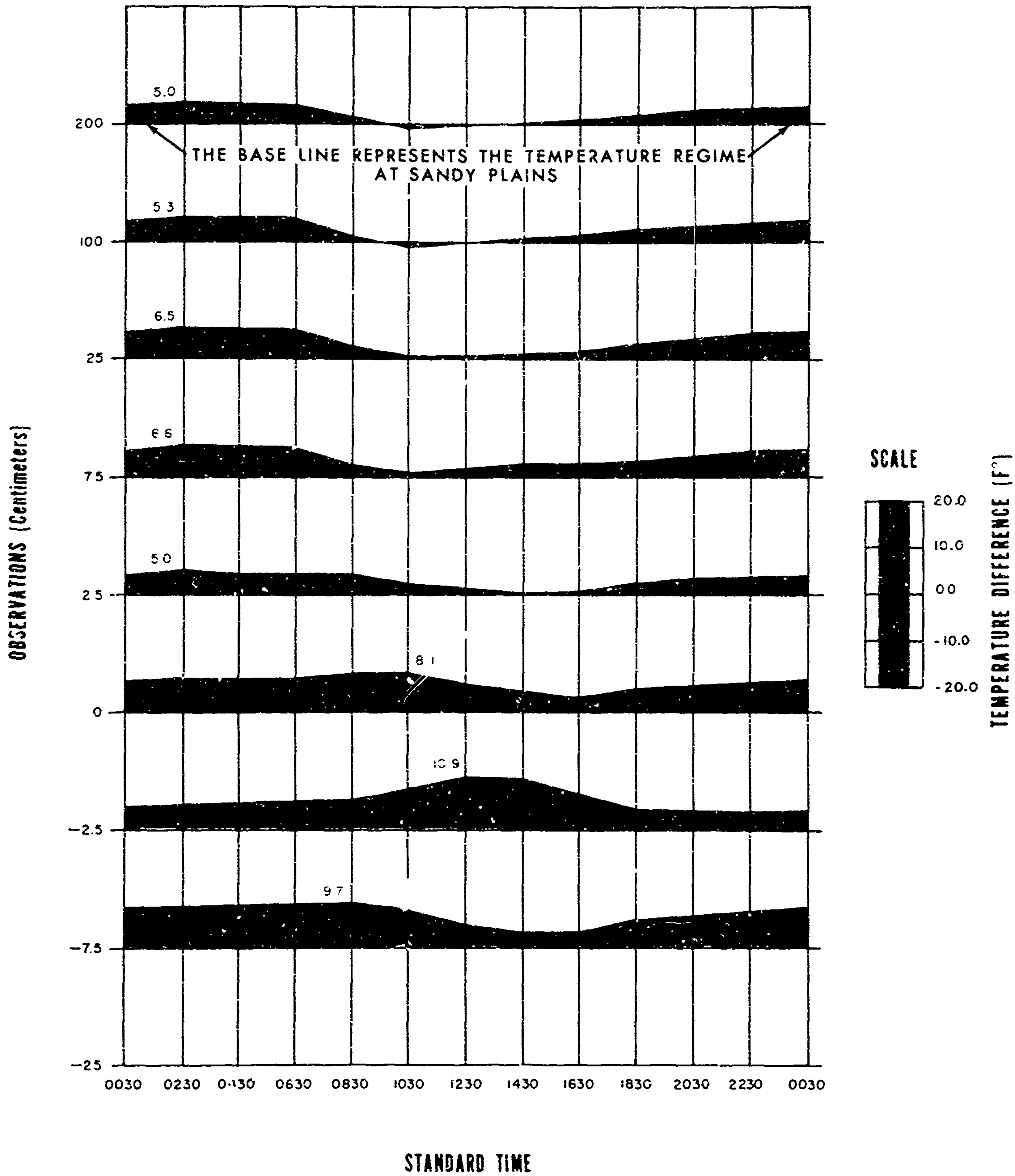

Figure 9

DIFFERENCES IN MEA'' TEMPERATURES BETWEEN LAGUNA TOP AND DESERT PAVEMENT, YUMA TEST STATION, ARIZONA

HOURLY MEASUREMENTS (°F) AT NINE LEVELS FOR THE TWO MONTH PERIOD, JANUARY AND FEBRUARY, 1957

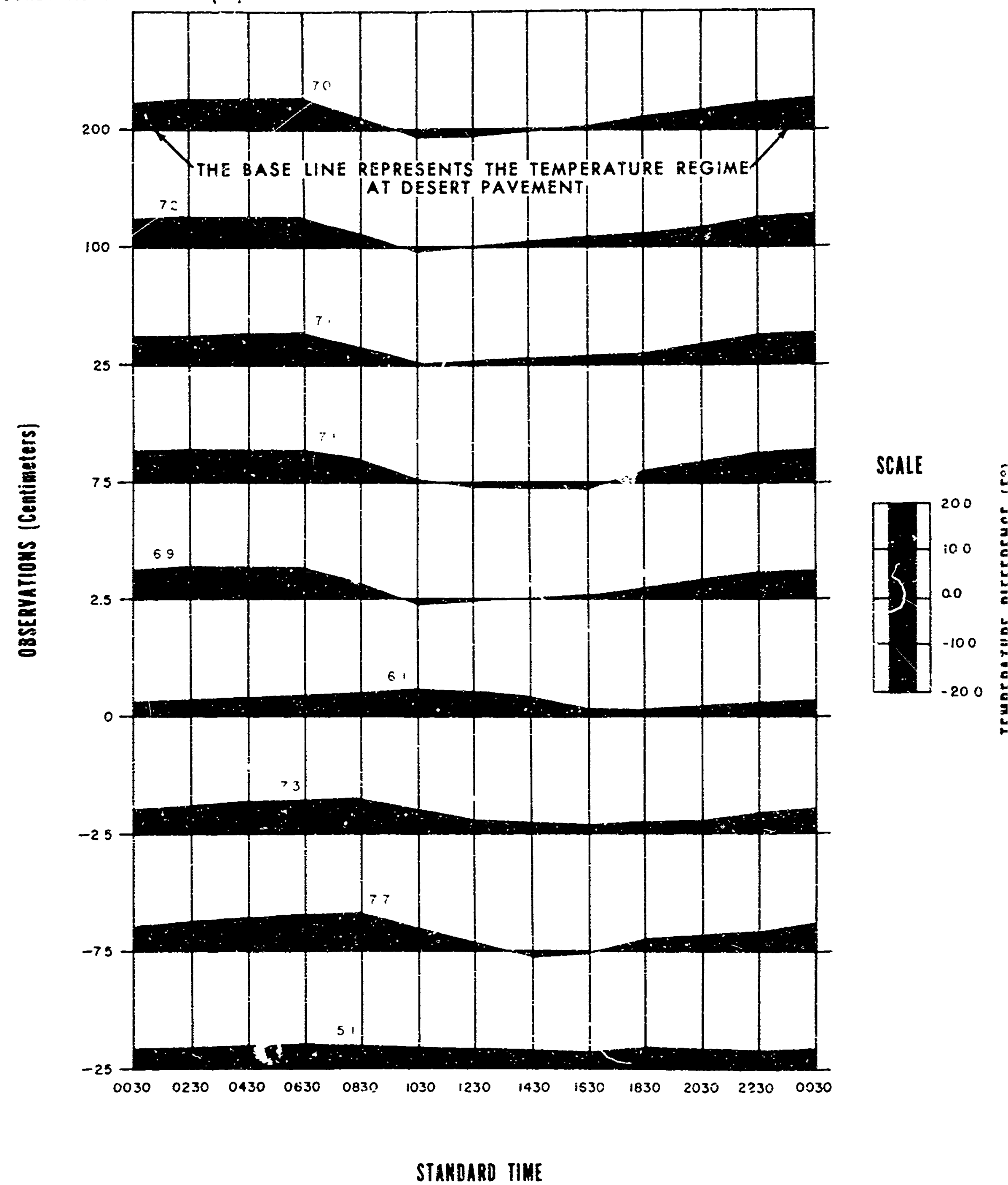

Figure 10

the ground at the Desert Pavement site. The amount of heat actually transmitted to the subsoils, however, is dependent on the thermal diffusivity of the soil - a term denoting interaction of conductivity, density, and specific heat. Dry sand of the Sandy Plains type is noted for its low thermal diffusivity (4). It can be concluded, therefore, that less heat is transmitted downward to subsurface levels at the Sandy Plains site.

Another significant comparison between the two sites should be pointed out. It might be assumed that the greater absorption of radiant energy by the dark-colored surface materials at Desert Pavement would produce higher ground surface temperatures during daylight hours; but, instead, slightly lower surface temperatures were measured during these hours at Desert Pavement. This is most likely explained by the same physical qualities of the materials involved, as described in the paragraph above. The low diffusivity of sand causes concentration in a thin layer near the surface of the sand of most of the heat generated by absorption of radiation from the sun and sky. This produces a greater increase in surface temperature at Sandy Plains than at Desert Pavement, where a greater amount of total heat is involved, but is spread through a considerably thicker depth of material.

b. Temperature Gradients

The temperature records for the various observational points provide a means for examining vertical temperature gradients immediately above and below the ground surface in somewhat greater detail than most earlier studies would permit. Since air and soil temperatures are characteristically different in their respective rates of heating and cooling, each is accorded separate treatment in the following discussion.

(1) Atmospheric Gradients

The layer of air between the ground surface and the two-meter level is a zone in which temperatures continuously change between limits fixed by the complex interaction of outgoing and incoming radiation, atmospheric conduction, convection and advection, the nature of the air mass involved, and the nature of the underlying ground surface. The possible variety of resulting lapse rates is extremely large, but commonly occuring types can be identified for certain periods of the day and certain weather conditions. The range of temperature differences likely to be found in winter in an environment similar to that of Yuma is fairly well covered in Figures 12, 13, and 14.

Figure 12 shows simultaneous lapse rates for Sandy Plains, Desert Pavement, and Laguna Top, constructed from records for the 0730

DIFFERENCES IN MEAN TEMPERATURES BETWEEN DESERT PAVEMENT AND SANDY PLAINS,
YUMA TEST STATION, ARIZONA

HOURLY MEASUREMENTS (°F) AT EIGHT LEVELS FOR THE TWO MONTH PERIOD OF JANUARY AND FEBRUARY, 1957

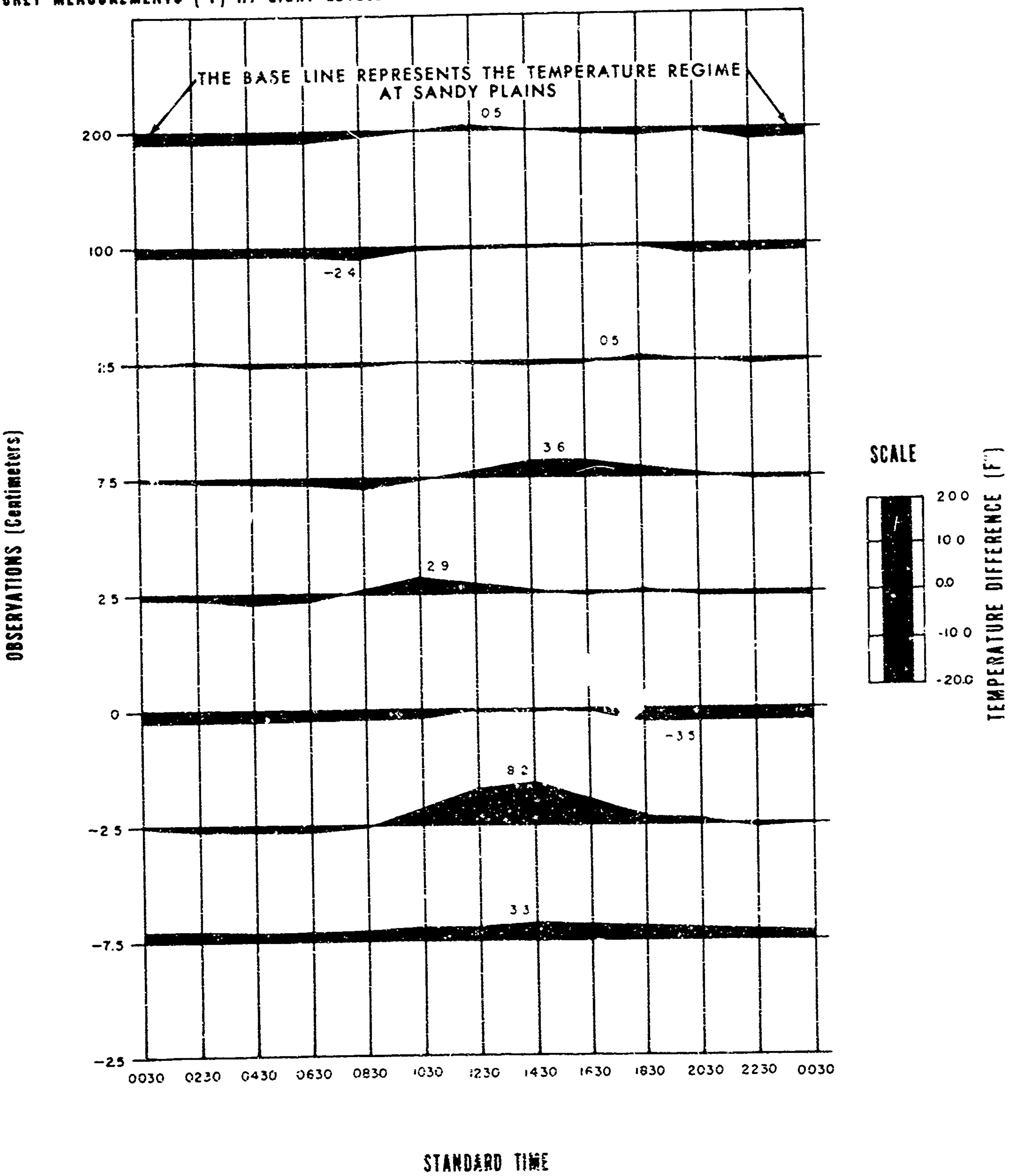

Figure 11

TEMPERATURE LAPSE RATES FOR SANDY PLAINS, DESERT PAVEMENT, AND LAGUNA TOP
(0730, 22 JANUARY, 1957)

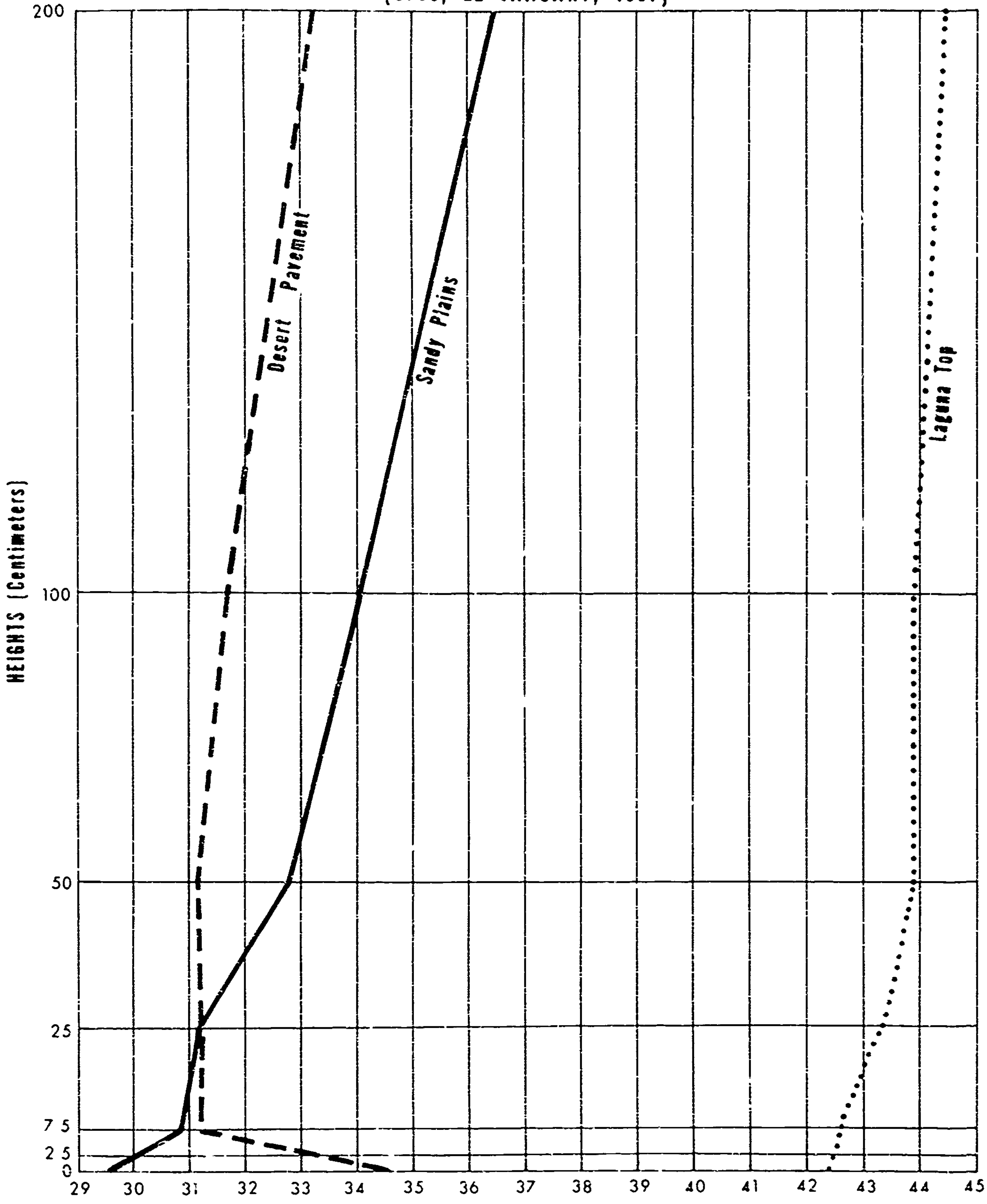

Figure 12

TEMPERATURE LAPSE RATES FOR SANDY PLAINS, DESERT PAVEMENT, AND LAGUNA TOP
(1430, 26 FEBRUARY, 1957)

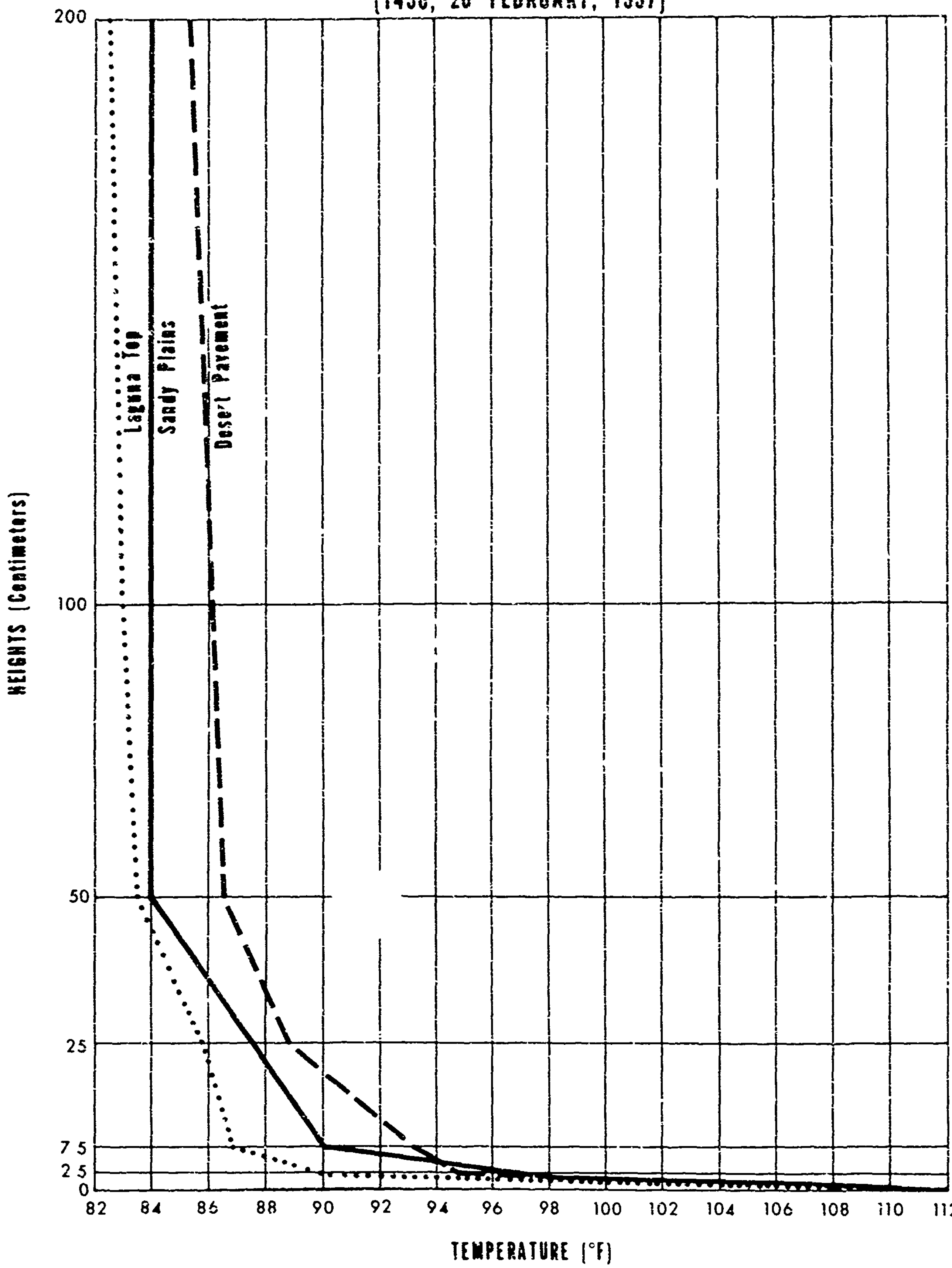

Figure 13

observation on 22 January 1957. At this time the temperature dropped to 29.5°F at Sandy Plains, the lowest temperature recorded at any site during January or February 1957. Below freezing temperatures were experienced on only eight nights of the study period, the total hourly duration of which amounted to 23 hours. The graph accentuates the higher temperatures of Laguna Top as compared to the inversion-reduced temperatures at the two low lying stations. The inversion appears to be best developed at Sandy Plains where the surface is about seven degrees cooler than that at the two-meter height. Average temperatures at Sandy Plains are higher than at Desert Pavement above the 25 cm. height (about three degrees at the two meter level). At the surface the temperature is about five degrees lower. Another interesting feature of this graph is the super-adiabatic lapse rate between the surface and the 7.5 cm. height at the Desert Pavement site. This is not an isolated example, for this super-adiabatic rate appears rather frequently in the records for the early morning hours at Desert Pavement. This temperature anomaly is probably caused by the difference in thermal diffusivity of the soils at Desert Pavement and Sandy Plains*, and the fact that more heat is initially made available for transmittal to subsurface levels during the day at Desert Pavement because of the weather-blackened gravels. The resulting reversal of the normal nighttime conditions, therefore, can be explained on the basis of a slight warming from beneath of the cool air draining into the area from the more elevated sandy areas surrounding the Desert Pavement site.

Figure 13 shows simultaneous lapse rates for the three stations drawn from records for the 1430 observation on 26 February 1957. At this time, the surface temperature at Sandy Plains reached 110.5°F, its maximum for the study months. At the same time temperatures were 110.9°F at Laguna Top and 110.3°F at Desert Pavement. Clear skies favoring maximum solar radiation and low wind speeds (highest, 8 mph at Sandy Plains) were other conditions helpful to the generation of extreme temperatures on the afternoon of 26 February. The outstanding feature of this graph is the extreme steepness of the lapse rates (super adiabatic) within the first 2.5 cm of the ground surface. This characteristic is caused by strong heating of the ground surface, and contrasts sharply with the inversion type of lapse rate featured in Figure 12. A comparison of Figures 12 and 13 reveals that the greatest change in temperature with time occurred at the surface level where, at Sandy Plains for example, a difference of 81F° has been experienced, as evidenced by a minimum temperature of 29.5°F reported for the coldest night of the study months, and a maximum temperature of 110.5°F for the warmest day.

* Thermal diffusivity of dry sand in cm^2/sec is 0.0013 while that for stone (granite) is 0.021.

AVERAGE LAPSE RATE COMPARED WITH ACTUAL LAPSE RATES ON A CLOUDY AND WINDY NIGHT AND A CLEAR AND CALM NIGHT

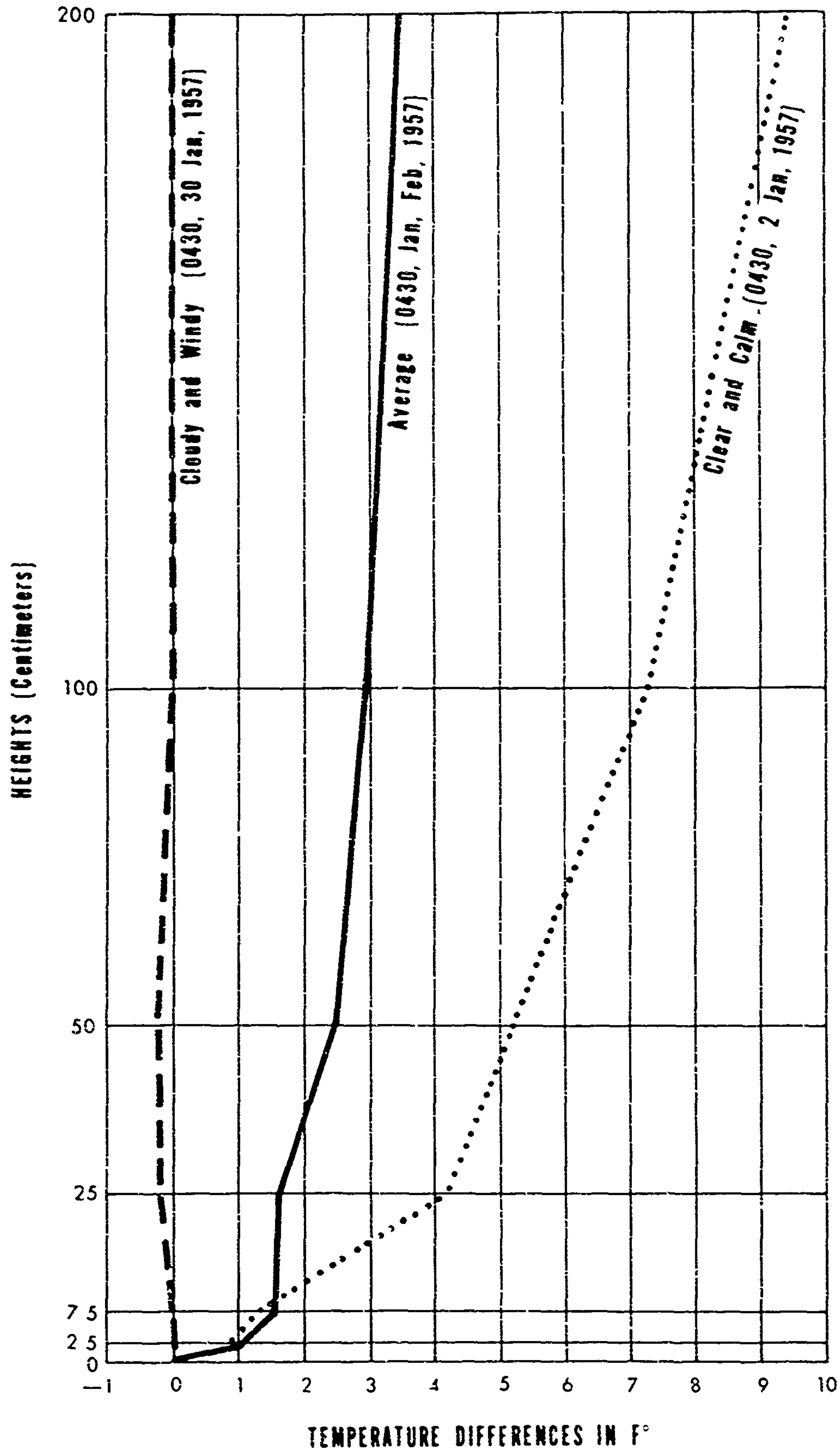

Figure 14

Figure 14 provides a measure of the possible range in actual lapse rates as compared to average lapse rate conditions at Sandy Plains as weather conditions vary. Using the 0430 surface level average for January and February 1957 as the zero or standard base, it shows deviations from that standard, expressed in Fahrenheit degrees, at each of the observational levels for (a) mean temperature for the two-month period of January and February 1957, (b) actual temperatures on a cloudy and windy night as represented by the 0430 temperatures on 30 January 1957, and (c) actual temperatures on a calm, clear night as represented by the 0430 temperatures on 2 January 1957. The differences clearly indicate the higher probability for inversion on calm clear nights. The 2 January curve of temperature differences shows a better than 9 F° increase from the surface to the two-meter height as compared to a comparative figure of zero for the 30 January curve.

Some idea of the ever-changing nature of temperature lapse rates near the surface can be gained from Figures 15 and 16.

Figure 15 shows the hourly progression of lapse rates at Desert Pavement during a six-hour period of rising temperatures (0730-1330) for 26 February 1957. The chart indicates that the rate of temperature rise at all points is greatest during the first hour or two after sunrise and the least as the heat peak for the day is approached. During this six-hour period, the temperature increase at the surface level was 57 F°; at the 7.5 cm level, 41 F°; at the 50 cm level, 33 F°; and at the 200 cm level, 30 F° (about 1/2 the surface temperature rise). The graph also provides further support for the argument advanced earlier that low level inversion development is retarded at the Desert Pavement site. Even at 0730, the time of the lowest temperature and greatest probability for inversion development, inversion is not apparent. Wind speed at the time of this observation was two miles per hour.

Figure 16 presents a bi-hourly progression of lapse rates as temperatures fall during the period from 1430 on 26 February to 0430 on the following morning of 27 February 1957. In keeping with the heating curve for the morning of the 26th, that for the following afternoon and night shows the greatest rate of heat loss just after sundown and the least during the following hours of late evening and early morning. Both Figures 15 and 16 show that the interface area between air and ground, as represented by the interval between the surface and the 2.5 cm level, is the zone of greatest temperature change and variability.

(2) Sub-Surface Gradients

Temperature profiles, based on average temperature values for the two-month period of January and February 1957 at four levels

MEAN TEMPERATURE NEAR THE GROUND DURING THE PERIOD OF RISING TEMPERATURES AT DESERT PAVEMENT, YUMA TEST STATION, ARIZONA
26 FEBRUARY 1957

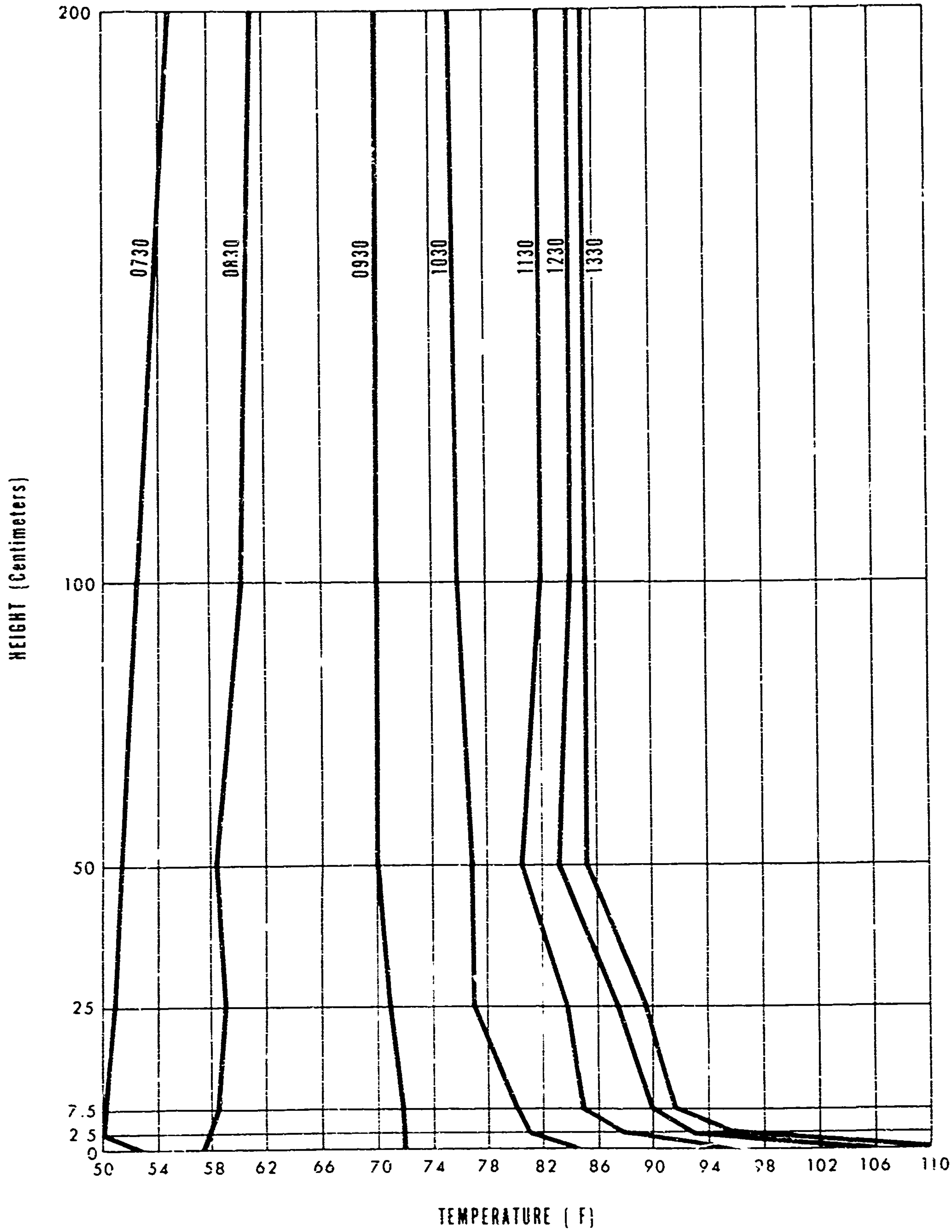

Figure 15

MEAN TEMPERATURE NEAR THE GROUND DURING THE PERIOD OF FALLING TEMPERATURES, DESERT PAVEMENT, YUMA TEST STATION, ARIZONA
26 AND 27 FEBRUARY

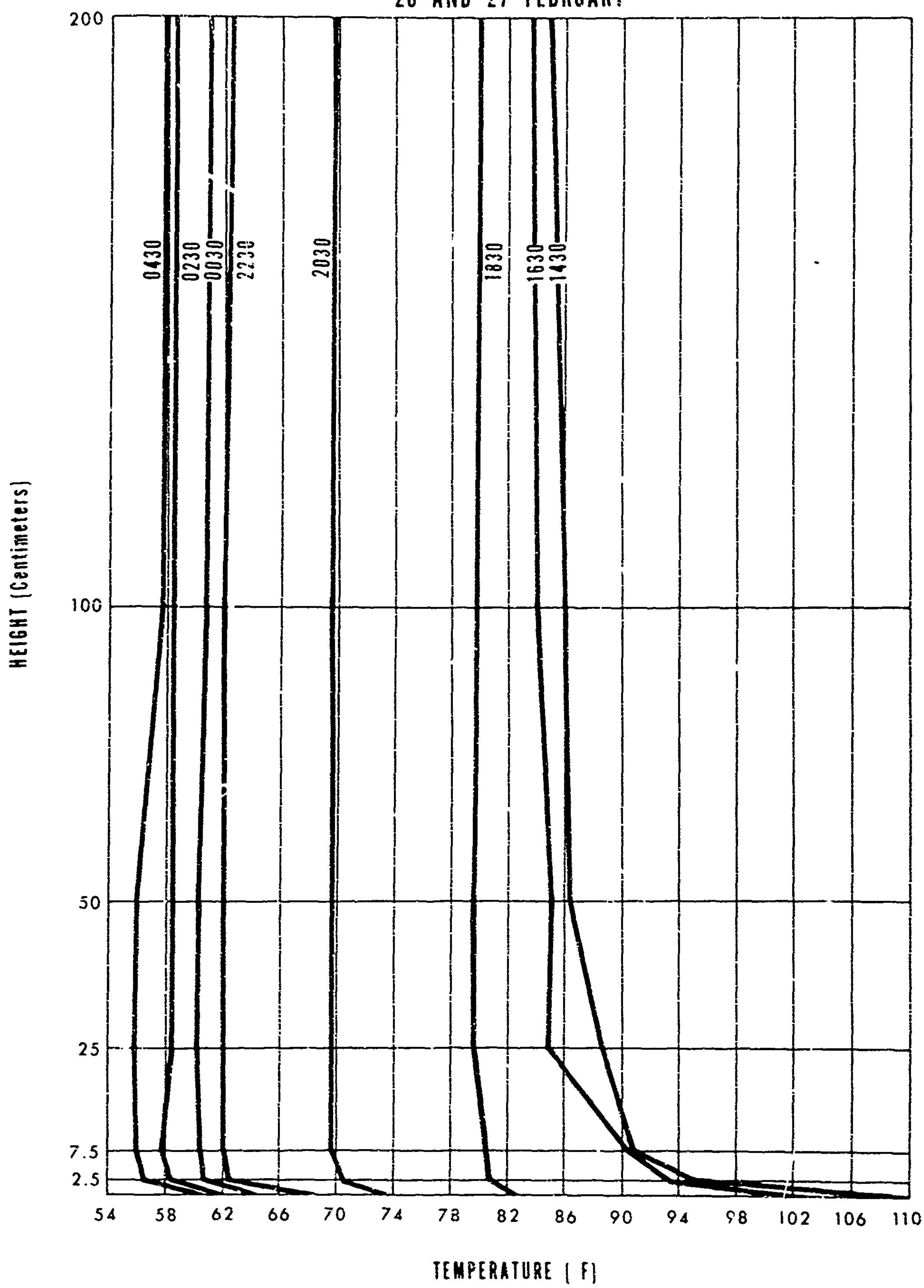

Figure 16

from the surface to the -25 cm depth, are shown for Laguna Top and Desert Pavement stations in Figures 17 and 18, respectively. A graph of the subsurface temperatures at Sandy Plains was not prepared since much of the data obtained at the -25 cm level at this station is known to be in error.

The graphs for Laguna Top and Desert Pavement both demonstrate some rather well known characteristics of soil temperatures, namely, that the diurnal range of temperature narrows rapidly downward from the surface, and that the times of occurrence of the subsurface daily extremes lag farther and farther behind their surface counterparts as depth increases. For example, at Laguna Top the lag between the time of occurrence of the daily maximum temperature at the surface and that for the -25 cm level amounts to about five hours, from 1430 (surface) to 1930 (-25 cm level). As for daily range, at Laguna Top there is a narrowing from about 37 F° at the surface (89.3°F average maximum and 52.3°F average minimum) to less than 5 F° at the -25 cm level (69.8°F average maximum and 65.3°F average minimum).

c. <u>Temperature Frequencies</u>

Temperature frequencies have often proved useful in planning military operations. For example, it is sometimes necessary to know for food storage purposes, what percent of the time temperatures can be expected to remain at or above some such critical level as 100°F, or, conversely, what percent of the time they can be expected to remain at or below the freezing point. To provide a means for making realistic estimates of such parameters, curves of temperature frequencies at four points (200 cm, 7.5 cm, surface, and -7.5 cm) are given in Figures 19, 20, and 21.

The graphs show that at all stations the highest temperatures occurred at the ground surface. The record high for any site during the two-month study period was 120.8°F at Laguna Top. Surface temperatures at or above 100°F were experienced small percentages of the time at all three stations, with Sandy Plains and Desert Pavement showing between two and three percent and Laguna Top nearly five percent. At the 7.5 cm level, temperatures were considerably lower, reaching 100°F at Laguna Top only, and there for something less than one percent of the time. At Desert Pavement the highest temperature reached at levels above 7.5 cm was 98°F, recorded at the 200 cm level. On the low side, freezing temperatures were experienced at Sandy Plains and Desert Pavement, but percentage occurrences were low, not exceeding two percent at either site. At the 200 cm level freezing temperatures were observed on one occasion only.

DESERT PAVEMENT

DIURNAL TEMPERATURE CURVES AT FOUR LEVELS
FROM THE GROUND SURFACE TO 25 CM. BELOW THE GROUND
(JANUARY AND FEBRUARY 1957)

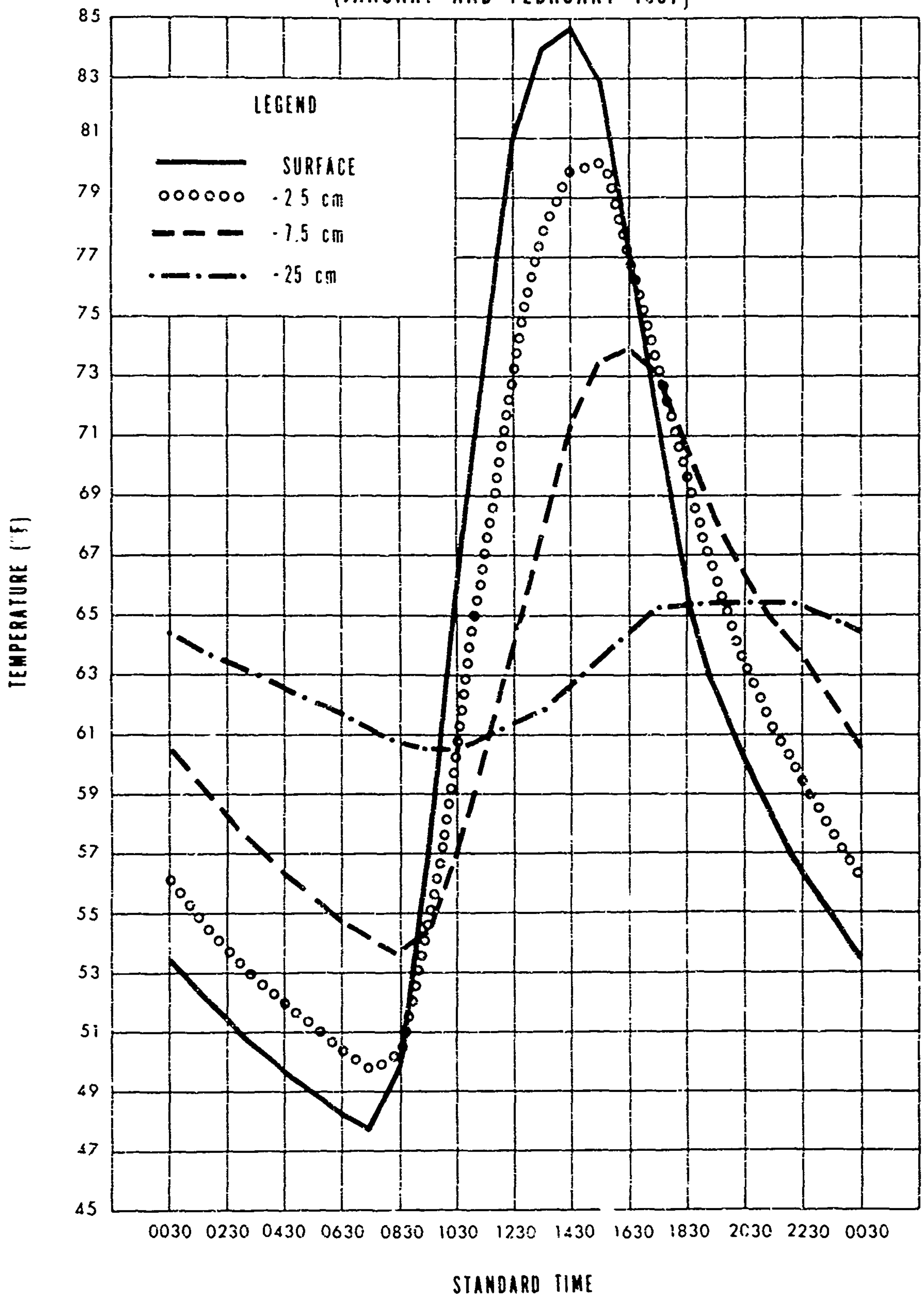

Figure 17

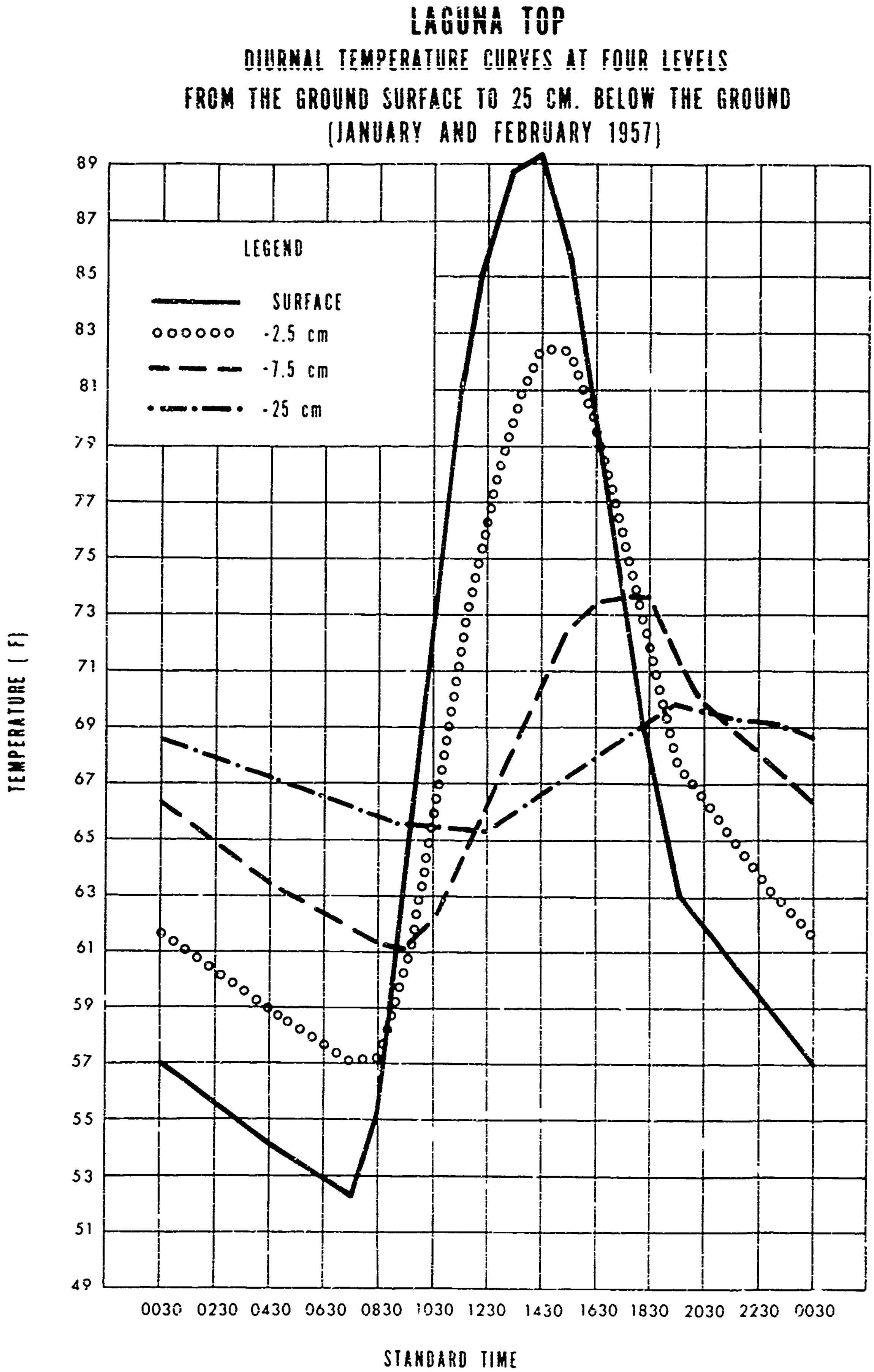
LAGUNA TOP
DIURNAL TEMPERATURE CURVES AT FOUR LEVELS
FROM THE GROUND SURFACE TO 25 CM. BELOW THE GROUND
(JANUARY AND FEBRUARY 1957)
LEGEND
SURFACE
-2.5 cm
-7.5 cm
-25 cm
TEMPERATURE (F)
89
87
85
83
81
79
77
75
73
71
69
67
65
63
61
59
57
55
53
51
49
0030 0230 0430 0630 0830 1030 1230 1430 1630 1830 2030 2230 0030
STANDARD TIME

Figure 18

CUMULATIVE TEMPERATURE FREQUENCIES AT SANDY PLAINS, ARIZONA

JANUARY AND FEBRUARY 1957

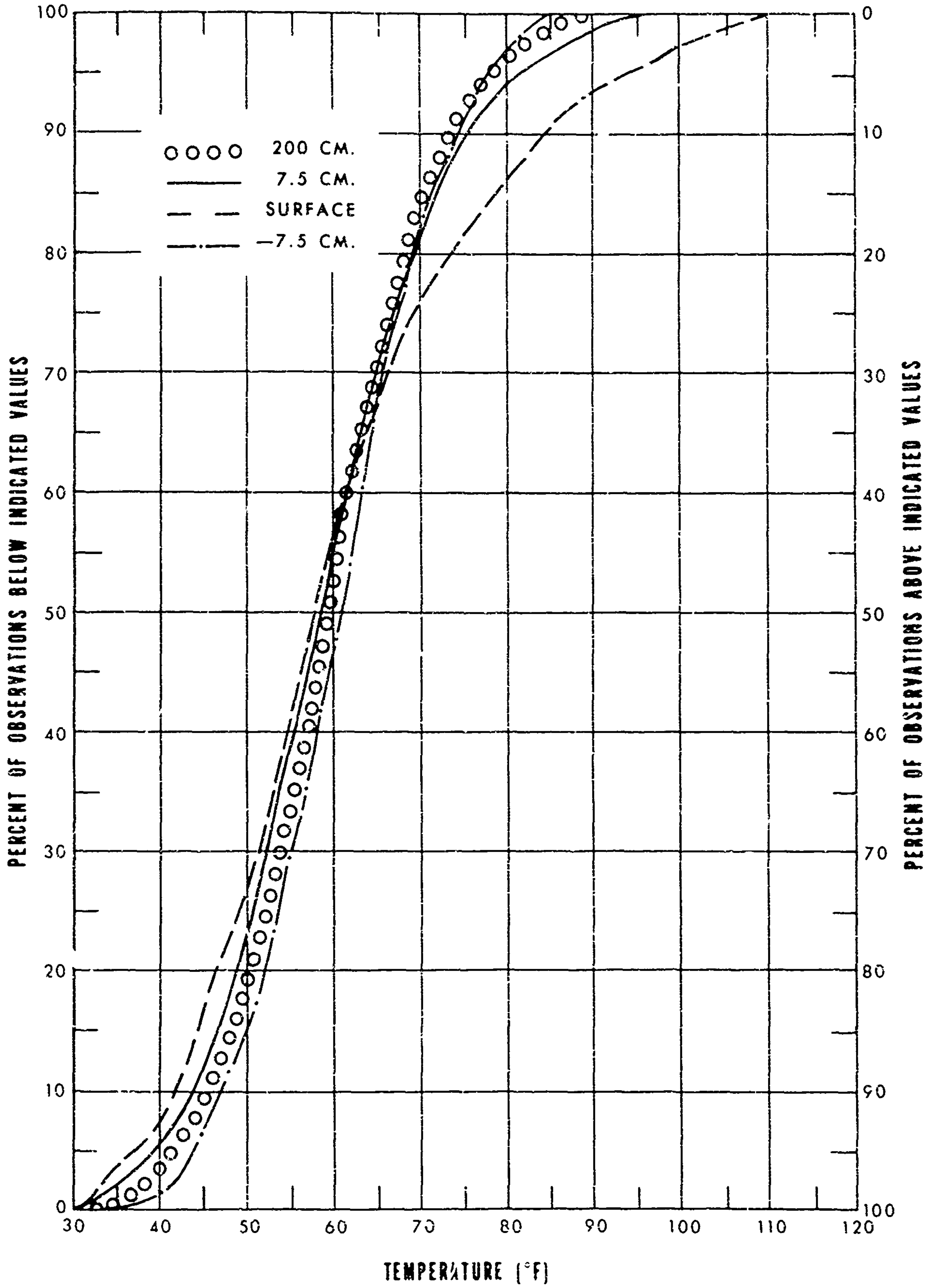

Figure 19

CUMULATIVE TEMPERATURE FREQUENCIES AT LAGUNA TOP, ARIZONA

JANUARY AND FEBRUARY 1957

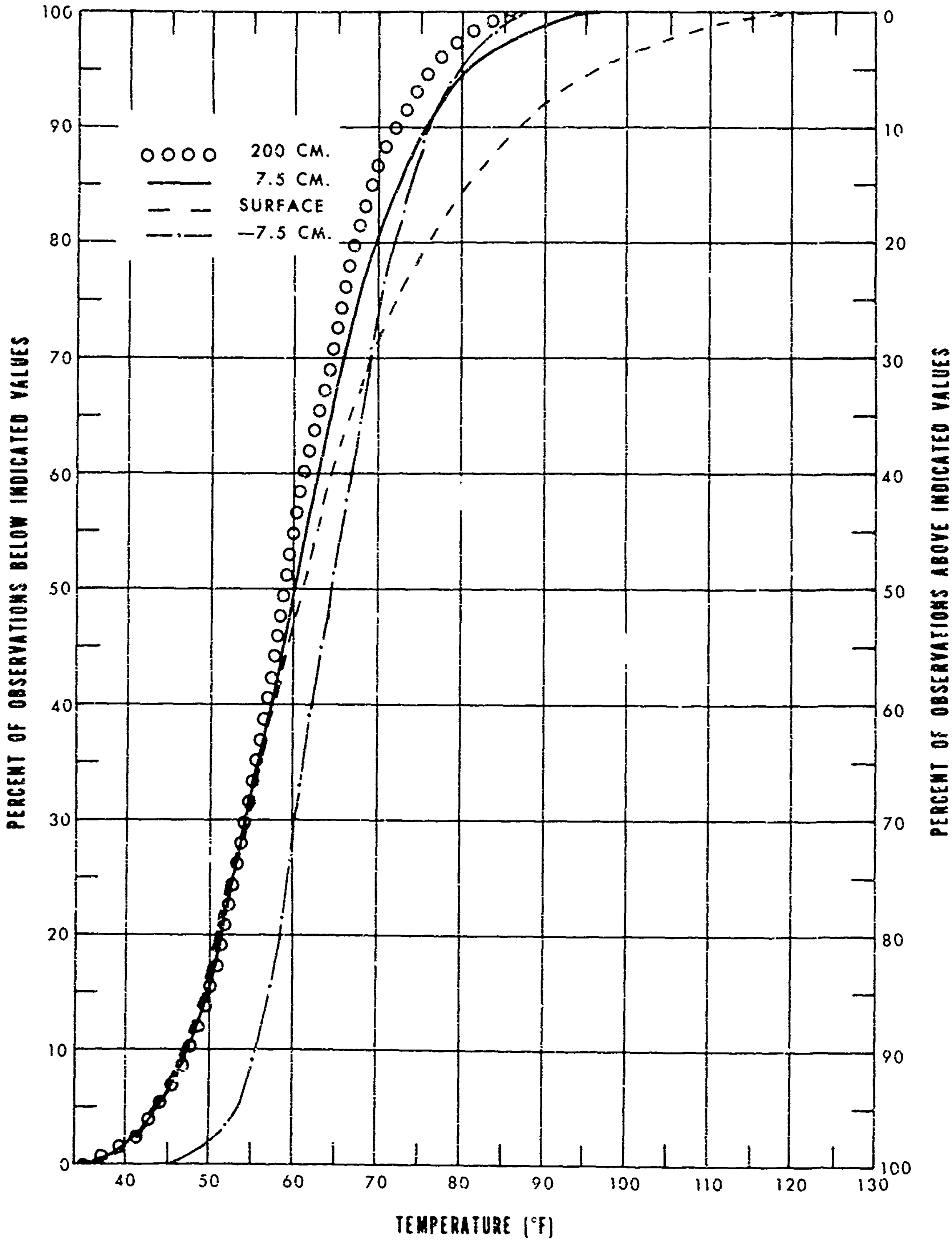

Figure 20

CUMULATIVE TEMPERATURE FREQUENCIES AT DESERT PAVEMENT, ARIZONA

JANUARY AND FEBRUARY 1957

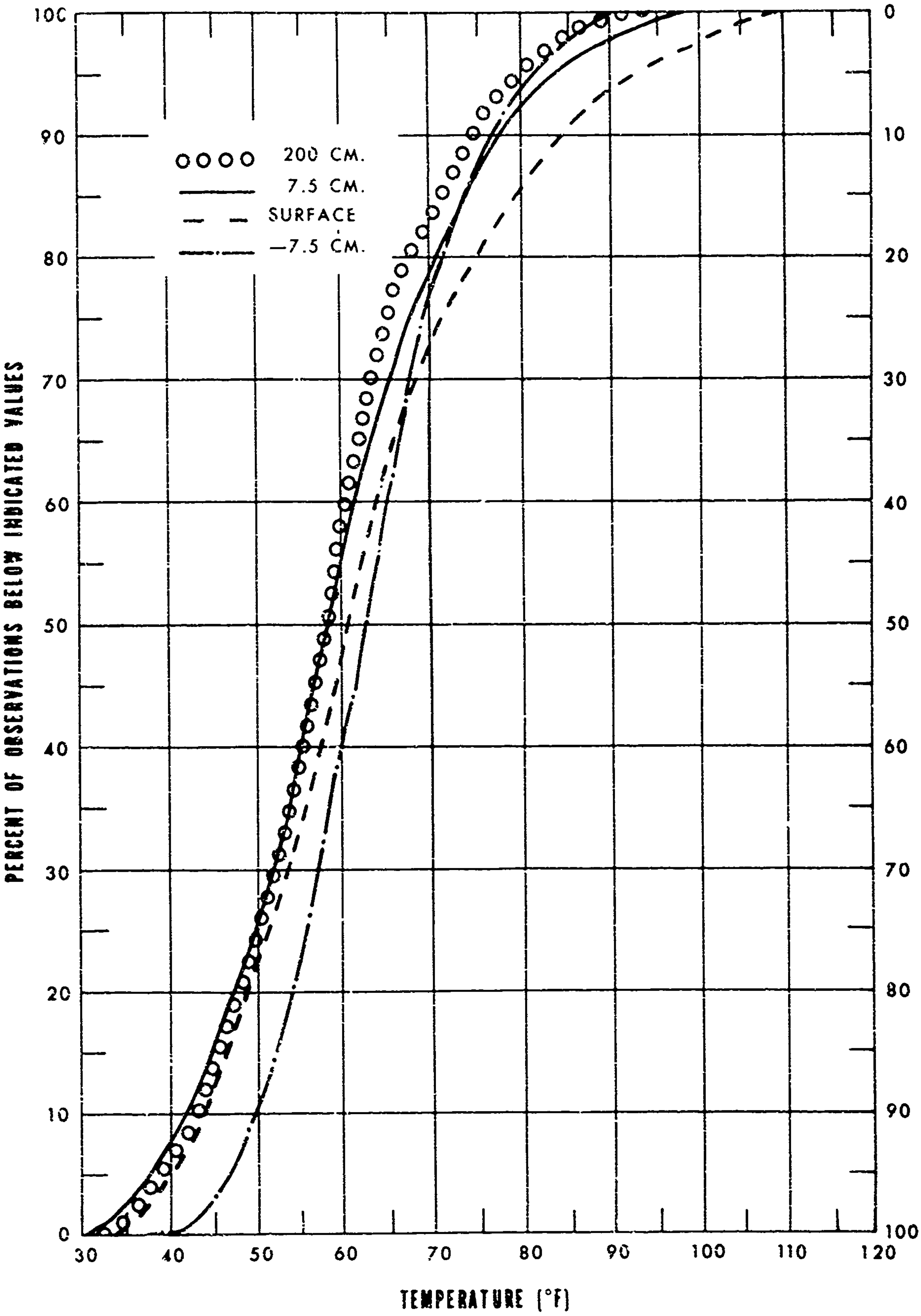

Figure 21

d. Wind Speed and Directions

Hourly winds at the standard weather station and the three microclimatic sites are graphed in Figure 22. A feature of this graph is the moderate strength and consistency of the winds at Laguna Top. Even at night the mountain winds remain above 6 mph on the average, a figure not too far removed from the highest average speeds of 8 to 9 mph reached during the heat of the day. The strength of the mountain winds during the hours of darkness indicates that the nighttime inversions that form in the valleys below do not deepen to the point of reaching the elevation of Laguna Top. The wind regimes of all three low-lying stations (standard, Sandy Plains, and Desert Pavement) are strikingly similar at all hours, showing strength throughout the day and weakness at night. From about 1800 in the evening to 0700 in the morning, the air has little or no motion, with winds averaging a scant one to two miles per hour during the period of the nighttime inversion. After sunrise, the winds pick up rapidly with averages climbing to 5 to 7 mph by 1000 hours, a level maintained throughout the remainder of the day.

Wind roses, drawn to show direction percentages during the warmth of the day (0930-1530) and the coolness of the night (0030-0630) are presented in Figure 23. The values given in the center of each rose represent the percent of time calms prevail. The mean windspeeds shown were computed from the hourly speeds for the concerned periods of the day and night. An examination of the roses strengthens the argument for nighttime inversions at the Sandy Plains and Desert Pavement sites. It can readily be seen that the requirement for little or no wind during inversions is more closely satisfied at the two low-lying sites than at Laguna Top. During the night, calms prevailed more than half the time and windspeeds were generally low during the remaining time at both Sandy Plains and Desert Pavement, as opposed to a mere 10 percent of the time for calms at Laguna Top which had average winds of 6.6 mph. The random directions of the nighttime wind roses for both low-lying stations further suggest light and variable winds. In contrast, the rose for Laguna Top exhibits a predominance of northwesterly winds; such persistence suggests moderate strength as well, an effective deterrent in itself to the formation of inversion. The daytime roses for all three sites show better development than those of nighttime, both as to strength and direction. Like the nighttime regime, the daytime wind system of Laguna Top shows higher speeds, a larger percent of northwesterly directions, and many fewer calms than either Sandy Plains or Desert Pavement.

HOURLY AVERAGE WIND SPEEDS AT FOUR STATIONS, YUMA TEST STATION

JANUARY AND FEBRUARY 1957

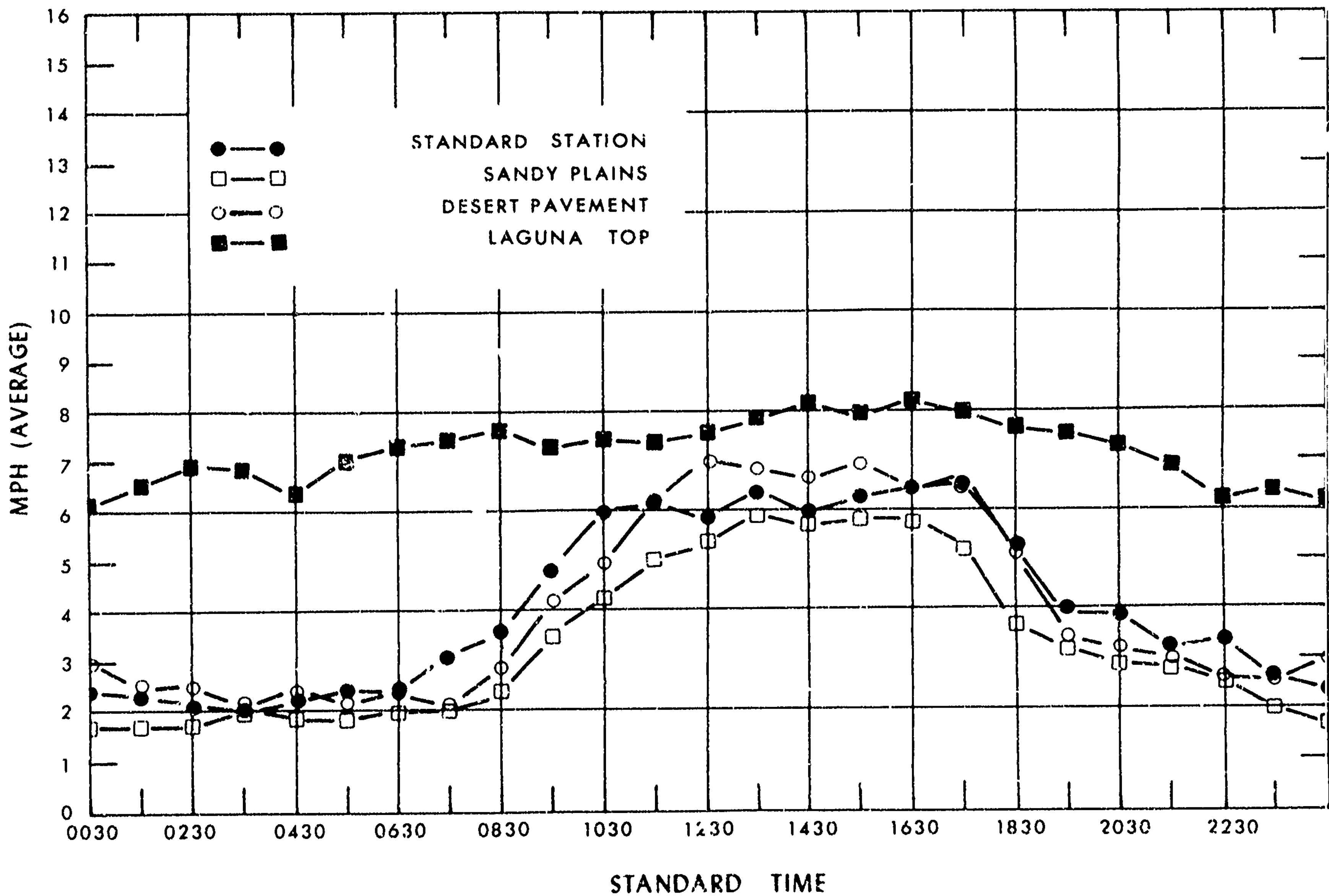

Figure 22

DAYTIME AND NIGHTTIME WIND ROSES, YUMA TEST STATION, ARIZONA

JANUARY AND FEBRUARY 1957

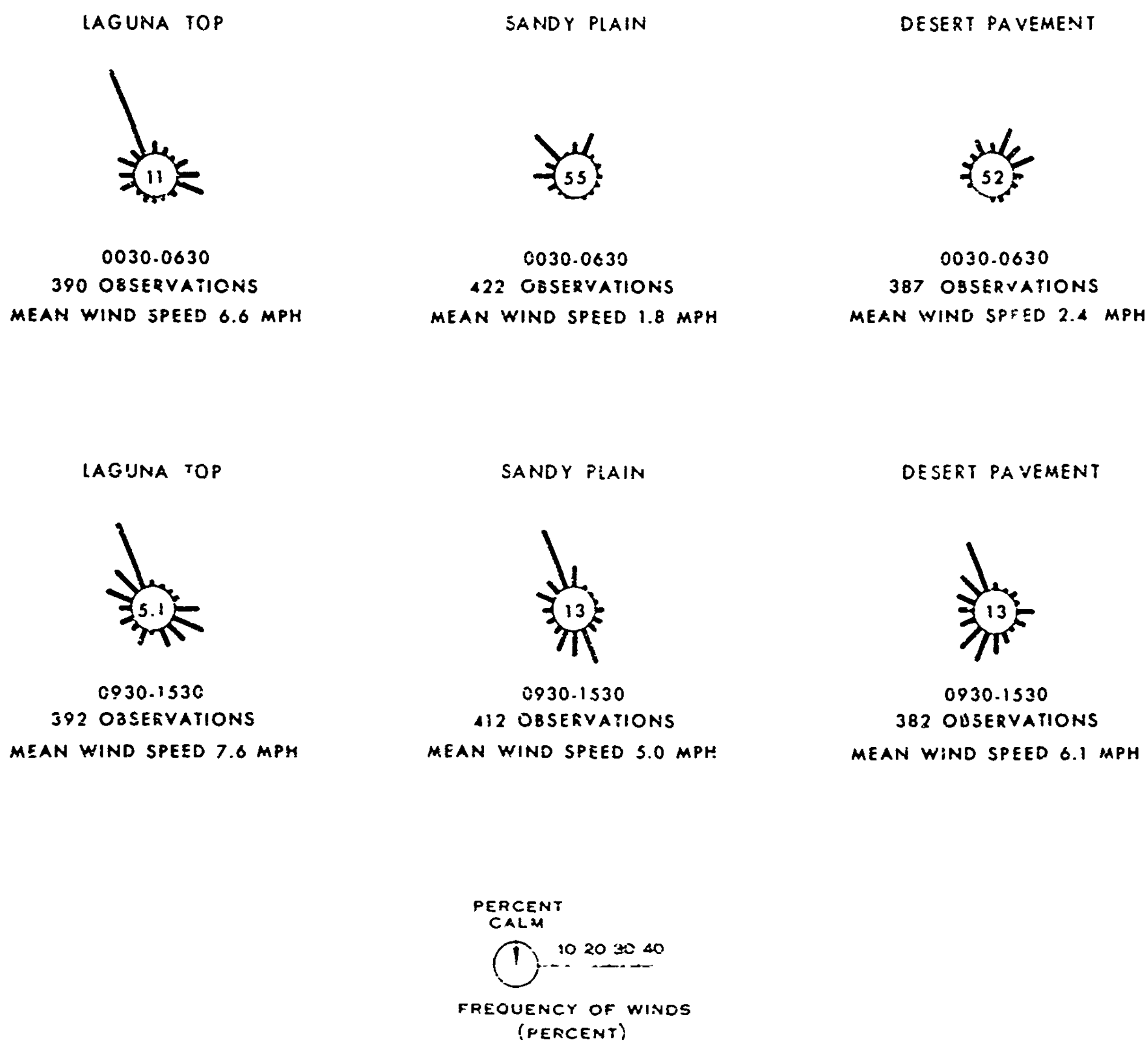

Figure 23

4. Conclusions

a. General

At all three stations the temperature regime at the standard observational height differs markedly from the regime at and close to the ground surface. From station to station there are also significant differences due primarily to differences in elevation, exposure, and the nature and configuration of the ground surface. Among these, the most notable contrast is the higher temperatures of Laguna Top, the most elevated station, as compared to those for Sandy Plains and Desert Pavement. This difference is great enough to warrant consideration of Laguna Top, or any similar slope, as a possible winter testing site, particularly in connection with those test programs requiring comparative freedom from frosts. Similarly, the Desert Pavement site offers more protection from frosts than does Sandy Plains where the light colored sand absorbs less incoming radiation and stores less heat than the weather-blackened gravels of Desert Pavement. This difference could have special connotations in planning tests involving contact with the ground surface.

b. Specific

From the various analyses of the January and February 1957 data for Yuma, the following conclusions may be drawn or inferred:

(1) The diurnal range of temperatures, both actual and average, is greater by far at the ground surface than at any other level, either sub-surface or supra-surface. At the surface level at Desert Pavement, for example, the average daily range is 37 F° as compared to 22.4 F° at the 200 cm level, and 4.9 F° at the -25 cm level.

(2) The daily temperature range decreases more rapidly below than above the ground surface level. For example, at the Desert Pavement site the average daily range at the -7.5 cm level was 20.3 F° while that for the 7.5 cm level was 30.5 F°.

(3) There is a lag behind air temperatures in the time of occurrence of the sub-surface daily extremes. At the -25 cm level, this lag amounts to about five hours for both the daily maximum and minimum temperatures.

(4) At Desert Pavement, temperatures during the warmest part of the day average about 8 F° higher just below the surface (-2.5 cm level) than at Sandy Plains due to the higher thermal diffusivity and greater radiation absorption rate of the dark colored gravels.

(5) Mean daily minimum temperatures at all levels were about six to eight degrees higher at Laguna Top than at either of the two lower lying sites.

(6) Mean daily maximum temperatures at the 200 cm level (standard shelter height) were very comparable, being within a degree of each other at all sites.

(7) There was a marked diurnal variation in average windspeeds at Sandy Plains and Desert Pavement; the winds were of moderate strength during the day (about 6 mph) and light at night (about 2 mph).

(8) At Laguna Top, there was little diurnal variation in average windspeed; the winds were moderate both day and night, though some diminution was apparent during the hours of darkness (day 7.6 mph; night 6.6 mph).

(9) At Desert Pavement the lowest nighttime air temperatures were recorded at the 7.5 cm level rather than at the ground surface. This departure from the normal condition was probably caused by a slight warming from beneath of cool air draining into the area from higher surrounding areas.

(10) At the valley stations, lapse rates of temperature near the ground are extremely stable (inversion type) on clear nights, and less stable (isothermal type) on cloudy nights.

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Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) U. S. Army Natick Laboratories Natick, Massachusetts	2a REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3 REPORT TITLE

YUMA WINTER MICROCLIMATE

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

5 AUTHOR(S) (Last name, first name, initial)

OHMAN, HOWARD L.
PRATT, RICHARD L.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
June 1966	33	13

8a CONTRACT OR GRANT NO b PROJECT NO 1V025001A129 c d	9a ORIGINATOR'S REPORT NUMBER(S) 66-7-ES 9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ES-24

10 AVAILABILITY/LIMITATION NOTICES

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
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13 ABSTRACT

This study consists of an analysis of winter temperatures at and near the ground and wind velocities at standard heights, at three sites within Yuma Proving Ground. Two of the sites were selected for their representativeness of surface types characterizing the desert basins of southwestern United States. The third site was selected to represent the many low rocky mountain areas of the desert. The study develops information on the nature of diurnal temperature fluctuations, based on hourly records of temperature of January and February 1957, at ten levels ranging from 25 centimeters below the ground to 200 centimeters above the ground surface. In addition, hourly records of wind speed and direction at the standard shelter height were kept and analyzed.

Results show that the temperature regime at the ground level differs markedly from that for the "standard" or 200-centimeter level at all sites, particularly in diurnal range, both actual and average (at Desert Pavement the average temperature range is 37 F° at the surface and 22.4 F° at 200 centimeters). Some differences in temperature from site to site were also noted, the most significant being the higher nighttime temperatures at Laguna Top the most elevated station, as compared to those for the two lower stations, Sandy Plains and Desert Pavement (average over 6 F° at the surface and 7 F° at two meters). Strong radiation cooling and air drainage into low areas resulting in the formation of nighttime inversions account for the lower daily minimum temperatures at the two low-lying stations.

DD FORM 1 JAN 64 1473

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13 ABSTRACT (Continued)

Laguna Top, in contrast, is uneffected by the nighttime inversions because of its height. Another difference of note is the higher temperatures just below the ground surface during the afternoon at the Desert Pavement site (over 7 F°) as compared to the Sandy Plains site. At Sandy Plains the light colored sands with insulating air spaces absorb less incoming radiation during the day and store less heat in the ground than the weather darkened gravels of the Desert Pavement site.

The wind regimes of the two low-lying sites, Sandy Plains and Desert Pavement, were very comparable, wind speeds being strong during the day and weak at night. At Laguna Top, on the other hand, the winds were strong both day and night, even though speeds at night were somewhat below the daytime maximum.

14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Diurnal variations	8		7		7	
Temperature	1,2		7			
Wind	1,2				7	
Winter	1,2		0		7	
Elevation			6		6	
Terrain			6		6	
Yuma Proving Ground	9		9		9	
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Deserts	4					
Day			6		6	
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