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HEADQUARTERS
QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND

TECHNICAL REPORT
EP-35

FC

THE DAYTIME INFLUENCE OF IRRIGATION UPON DESERT HUMIDITIES

QUARTERMASTER RESEARCH & DEVELOPMENT CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

MAY 1956 NATICK, MASSACHUSETTS

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Quartermaster Research & Development Center, U S Army
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

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THE DAYTIME INFLUENCE OF IRRIGATION UPON DESERT HUMIDITIES

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7-83-03-008A

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Foreword

In the past few years the study of desert environments has become of major concern to military planners. Experiences in North Africa during World War II have focused attention on world deserts as areas of possible military importance. At the same time, these experiences served as a strong reminder of the general inadequacy of environmental data available for use in planning desert operations. Some new knowledge of desert environments has been developed in recent studies, but much more climatic and geographic research remains to be done before logistical and tactical planning needs can be adequately met.

The purpose of this report is to further the understanding of desert environments through a study of the influence of local areas of moisture upon the surrounding desert during the heat of the day. Related to this is the more specific aim of determining the effect of the irrigated farmland in the Yuma area, Arizona, upon humidity conditions at Yuma Test Station, located in the desert area to the lee of the irrigated districts.

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Contents

Abstract

This report describes a study of daytime dew point distribution within and about the irrigated farmland near Yuma, Arizona. A comparison is made of the moisture content of the air before, during, and after passage over irrigated land, using data obtained during the course of a field investigation in the summer of 1954. The pattern of dew point distribution was sampled through observations taken within and about selected crop types in various stages of growth.

The results of the study indicate that evaporation and transpiration cause an average increase of 6 to 8 degrees (F), in the dew point of the air directly over an irrigated area, but that the lateral extent of this effect is limited to distances of 100 feet or less from the fields. The influence of irrigation agriculture upon humidities in the various testing sites within Yuma Test Station therefore is negligible.

THE DAYTIME INFLUENCE OF IRRIGATION UPON DESERT HUMIDITIES

1. Introduction

High humidity is generally not considered a desert problem. An important exception is provided by localized areas of moisture, such as oases or strips of river marsh, where high transpiration and evaporation rates during the heat of the day cause measurable increases in the moisture content of the air. This report is a study of the influence of a local moisture source, as represented by the irrigated farmland within and about Yuma, Arizona, upon humidity conditions in the surrounding desert. Of particular concern is the effect upon humidities at Yuma Test Station, an area set aside by the Department of the Army for desert and hot weather research and testing. The possibility of humidifying effects of an expanding agricultural landscape upon the natural desert environment of the test area is a chief reason for this investigation. Also involved is the general question of whether military operations in desert areas need to take into consideration the possibility of high humidity near oases.

Night conditions were not examined. It is conceivable, however, that the horizontal spread of air away from a moisture source is greater at night due to inversion effects associated with radiative cooling. The subject merits future attention.

a. Distribution of Irrigable Land

More than 100,000 acres of farmland are irrigated in the Yuma area, primarily along the lower Colorado River in southern Yuma County, Arizona (Fig. 1). Extending a distance of about 28 miles from Laguna Dam to the Mexican boundary, the agricultural districts border both sides of the river and include small sections of Imperial County on the California side. The Gila River Valley, from the confluence of the Gila with the Colorado near Yuma, provides a lengthy and in places a wide extension of the irrigable lands some 40 miles to the east and northeast. In Mexico the irrigation developments continue along both sides of the lower Colorado River, but in general are well to the southwest of the study area.

The agricultural districts are framed in a desert setting of low, bare mountains, badlands, and sand and gravel flats. In the south and southeast, the irrigated fields with few exceptions terminate at the escarpment of the Yuma Mesa, a low tableland of sand and gravel desert. To the north and northeast, the farmland is contained by an upland district of hills and low mountains with intervening patches of deeply

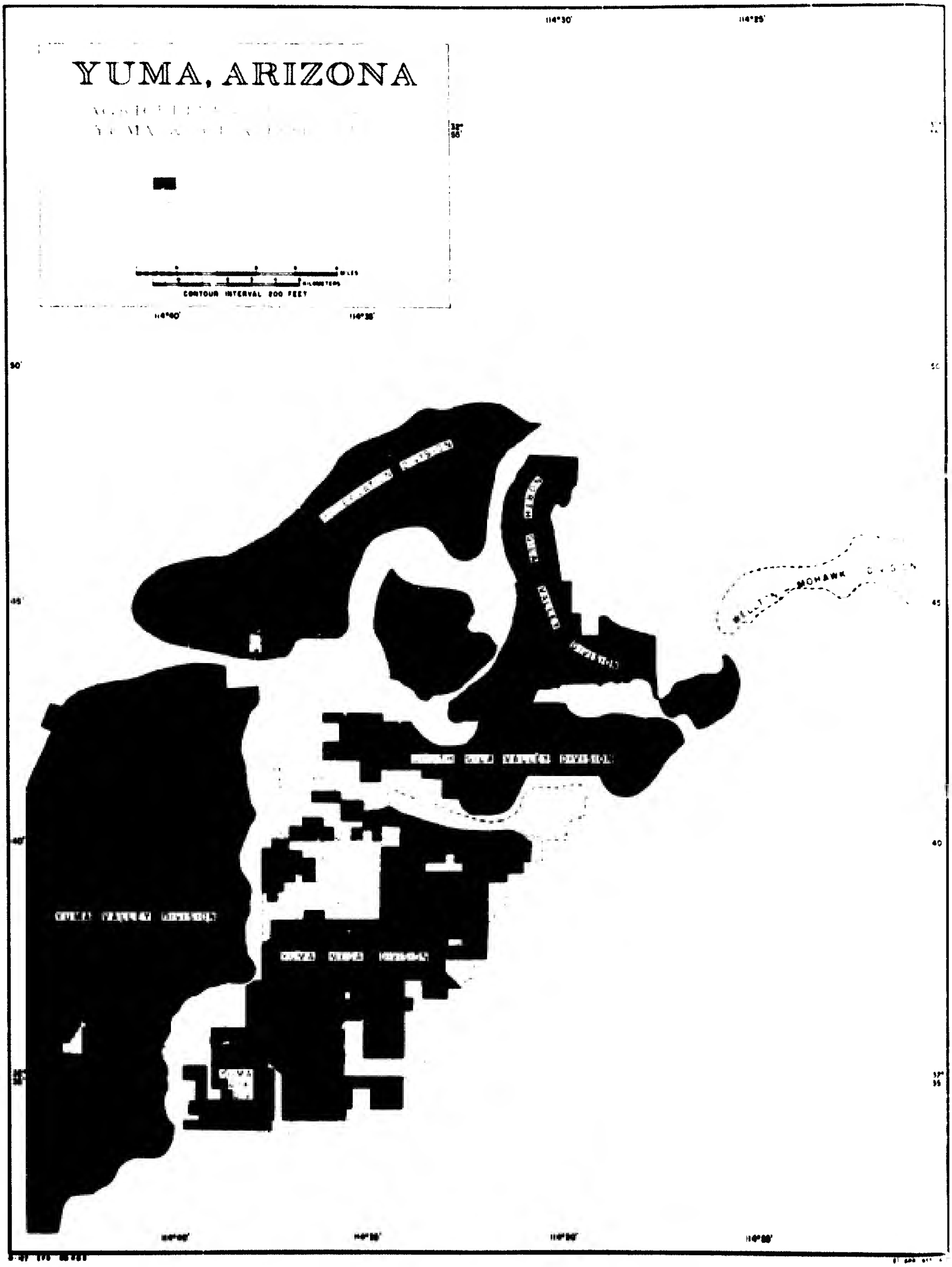

Figure 1

eroded badland. The valleys of the Colorado and Gila Rivers provide the only breaks in this irregular rim. West of the Colorado in California the landscape is dominated by the elongated outline of the Algodones Sand Hills, a series of interconnected sand ridges and mounds averaging 200 to 300 feet high. Throughout the Yuma area elevations are generally low: in the river bottom proper they vary from 80 to 160 feet above sea level, and the maximum elevation in the area is 1,662 feet in the Gila Mountains.

Most of the farmland in this area has been prepared for irrigation by the Bureau of Reclamation under the Yuma Reclamation Project. The project is served largely by Colorado River water diverted from the All-American Canal to the irrigation fields by a gravity feed system of canals and lateral ditches. The Valley and Reservation Divisions are the chief subdivisions of the project. The larger and more completely developed is the Valley Division, which in 1953 had about 47,000 acres (of a potential 52,000 acres) under irrigation. The irrigated valley soils are alluvial, fertile sandy loams. Some 14,000 acres of the Yuma Project lie on the California side of the Colorado River in the Reservation Division. Of this amount, about one-half has been allotted to the Yuma Indians, who occupy the district centered about the town of Bard. In 1953, approximately 5,000 acres of the Indian land were under irrigation, and 6,000 acres of non-Indian land. Some additional 2,300 acres of the project are located on the Mesa in the Yuma Auxiliary Project (Unit B). The surface of the Mesa is 70 to 75 feet higher in elevation than the Valley, and water must be pumped to the district from the gravity feed system of the Valley. Gravels and sands are the chief surface materials of the Mesa.

Water requirements in the Valley are generally less than one-half those of the Mesa. In 1953, for example, an average of 4.58 feet of irrigation water was used on Valley farms as compared to 10.9 feet for farms on the Mesa. There is a year-round requirement for water, but summer demands far exceed those of winter, as a monthly breakdown of the annual figures indicates. For example, farms in the Valley use an average of 0.69 foot of water during July as compared to 0.28 foot during January. On the Mesa, water requirements average 1.52 feet during July and 0.62 foot during January.

In 1947, a second irrigation development, the Gila Project, was authorized. Designed to bring Colorado River water to large sections of the Gila Valley and Yuma Mesa, the project will eventually add about 100,000 acres of irrigable land to the Yuma area. Development so far has been greatest in the sections of the Valley and Mesa closest to Yuma. The project's main divisions are the North Gila Valley district of about 6,000 acres, the South Gila Valley district of about 9,000 acres, the Yuma Mesa Division where some 14,000 acres are under irrigation, and the Wellton-Mohawk Division, a largely incomplete development extending eastward beyond the limits of the study area. Upon completion of the Wellton-Mohawk irrigation canal system about 75,000 additional acres will be available for agriculture. The project is supplied with water from the Colorado River channeled to the various sections via the Gila Main Canal and distributory canals. The system is chiefly gravity-fed, but pumping stations have been installed at critical points to raise the water to the higher lands of the Mesa and upper Gila Valley. In the South Gila Valley most farms draw their irrigation water from underground sources brought to the surface by pumping.

Northeast of Yuma is the Yuma Test Station, an area of some one million acres with its Headquarters approximately 30 miles by road from the city of Yuma. The southern and southwestern-most limits of the test station in places are within one mile of the irrigated farmland. This distance probably will be further reduced with completion of the scheduled irrigation, especially in parts of the Gila Valley.

b. Climate

Few places in the United States are as dry as Yuma. Clear skies, abundant sunshine, low relative humidity, and low rainfall characterize the weather at all seasons. Measurements taken at the Yuma County Airport indicate that annual rainfall averages only 3.4 inches, the lowest average for any city in the United States. Rainfall is erratic, ranging from a low of 0.31 inch in 1953 to a high of 11.4 inches in 1905. September, with 0.64 inch, is the month of greatest average rainfall. Winter, however, with nearly one-half the annual average, is the wettest season. Relative humidity is comparatively low at all seasons. September, the month of highest rainfall, has an average early morning relative humidity of 64% and an afternoon average of 27%. During midsummer, the moisture content of the air is higher than might be expected for a desert region. Dew point values during July and August generally range between 55°F and 65°F, as compared to values about 25 degrees (F.) lower in May and June, two of the driest months. Cloudiness records indicate that Yuma has sunny weather about 91% of all possible sunlight hours during the year, and June, the month of least cloudiness, has an average of 98% of possible sunlight.

Summer weather is hot at Yuma. July, the warmest month, has an average temperature of 94.6°F, and August with 93.7°F is nearly as hot. Average daily maximum temperatures for July and August are 107.7° and 106.1°F respectively. The highest temperature ever recorded at Yuma was 123°F on 1 September 1950, and the warmest day, with a mean temperature of 101.5°F, was recorded on 11 August 1933, and again on 1 September 1950.

Surface winds are generally light during summer, averaging 5 to 7 mph from a general southerly direction. Air movement is strongest during the heat of the day, and lightest during the early morning hours, the coolest part of the day. At night, winds are light and variable with calm conditions reported frequently. By 0800 hours a definite but light southerly flow of perhaps 2 to 4 mph velocity has established itself. Wind speeds pick up to an average of 4 to 6 mph by noon, and reach their highest average velocity of 8 to 12 mph during mid- and late afternoon. The day-to-day variance in wind direction is slight, being confined largely between southeast and southwest. Dust devils and winds associated with thunderstorms, of course, are exceptions to the general circulation pattern. Thunderstorms, when well developed, have a particularly disturbing effect, for accompanying winds have been known to reach gale force and are largely responsible for the dust storms sometimes reported in the area. By 2000 hours, air movement usually has subsided to an average of 2 to 4 mph, and by midnight there is hardly any movement.

The study of irrigation effects upon humidity conditions is complicated somewhat by a midsummer influx of moist air into the area. The added moisture content of the air is apparent through inspection of surface and upper air data and is generally present through the thunderstorm season, i.e., from mid-July to September. The weather at this time seems hotter than temperatures indicate, because of high humidity. The source of the added moisture is a matter of some controversy, but examination of weather maps indicates that the additional vapor content is usually associated with air originating in the Gulf of Mexico. The Gulf air moves northwestward towards a thermal trough of low pressure centering in Sonora, Southwestern California, and western Arizona. During its westward passage the Gulf air loses much of its original moisture through thunderstorm activity. This results from rising air caused either by heating at the surface or by forced ascent over the mountains of western Texas, New Mexico, and Arizona. Upon arrival at Yuma, the air has been considerably altered in its moisture characteristics, yet sufficient moisture remains to result in afternoon convective showers on days when the condensation level is at a sufficiently low level for strong surface heating to produce heavy clouds. The southerly winds may bring small additional amounts of moisture from passage over the Gulf of California. This midsummer increase in the moisture content of the air might be described as area-wide and should be clearly distinguished from humidity increases associated with irrigation. As will be demonstrated, effects of irrigation are purely local, and offer a set of study problems entirely alien to the broader regional problem.

The westward migration of Gulf air requires perhaps a full month to arrive at Yuma. By mid-June, the thermal low of the southwestern United States is approaching full development and the Atlantic High Cell (Bermuda High) has moved to its summer position off the coast of southern Florida, a synoptic situation favorable for the development of a westward flow of air. This flow is strongest when a lobe of the Bermuda High has developed in the eastern Gulf area and the pressure gradient from the Gulf to Arizona is steep and uninterrupted. Gulf air is first noted in western Texas in the latter part of June and is heralded by severe thunderstorms as the air is forced to rise over the mountains of New Mexico and western Texas. Its westward progress can be noted in synoptic analysis by humidity changes, cloud development, and thunderstorm activity. The moist air reaches the Tucson-Phoenix area of central Arizona about the first of July. Continuing westward, the Gulf air reaches Yuma about the middle of July, but with its thunderstorm potential greatly reduced after loss of much of its moisture. During migration, the leading edge or front of the Gulf air is sometimes characterized by a continuous line of thunderstorm activity, sometimes referred to as the cT-mT front, which marks the plane of contact between the dry air being displaced and the more moist Gulf air.

Modified Gulf air usually characterizes the midsummer period of increased humidity at Yuma. At infrequent times, however, the westward migration of air is interrupted or becomes weak because of unseasonal changes in the pressure pattern. During periods when the flow of moist air is prevented, the weather at Yuma is dry and clear.

2. Field Observations

To test the extent to which atmospheric humidities in the surface layer of the atmosphere are influenced by irrigation, a record of dew point distribution within and about the irrigable lands was compiled during the period 3 to 13 August 1954 through: (1) the operation of eight meteorological substations equipped with instruments to record wet- and dry-bulb temperatures and wind speed and direction at selected sites windward and leeward of the irrigated areas; (2) humidity surveys within representative crop types; (3) sampling methods of examining vertical and horizontal variance of humidity; and (4) comparison of Yuma weather data with data for other stations in the southwestern United States. Procedures followed for the first three are discussed below:

a. Substation Measurements

Moisture characteristics of air before and after passage over the irrigated fields were determined by means of eight meteorological substations. In general north-south alignment, the substations spanned a distance of approximately 20 miles from the open desert south of Yuma to Picacho Wash north of Yuma (Fig. 2). The two southernmost stations (Nos. 1 and 2) were exposed to dry southerly winds from the Mexican and southern Arizona deserts (Fig. 3); the two stations within the irrigated district (Nos. 3 and 4) were located on the north or leeward sides of cotton fields where air directly from the field could be sampled (Figs. 4 and 5); and the four northernmost stations (Nos. 5, 6, 7, and 8) were aligned along Picacho Wash for a distance of two and one-half miles from the All-American Canal in order to measure characteristics of air moving away from the crop land (Fig. 6). The three Picacho Wash stations nearest to the crop land (Nos. 5, 6, and 7) were spaced one-half mile apart, and No. 8, the farthest, was one mile beyond station No. 7. At each station, continuous records of wind speed, wind direction, and wet- and dry-bulb temperatures were kept with a Weksler recording psychrometer and a Beckman and Whitley Climate Survey System. The Weksler recording psychrometer was calibrated to readings from an Assman type electric-ventilated psychrometer at least once daily. Records are not complete for all stations. The wet-bulb record at Station No. 4 is incomplete due to inoperative instruments, and both wind and temperature records for Stations 1 and 2 are lacking for several hours on the 3rd and 4th of August, the result of instrument failure following a dust storm.

b. Observations in Crop Lands

The humidity surveys in agricultural crop lands, in one case a cotton field, in the other a citrus (grapefruit) grove, were carried out as part of an overall plan to examine humidity variance within the irrigated areas. During the summer, and perhaps throughout the entire year, the irrigated lands are not one vast uninterrupted area of vegetative growth, but rather a composite of fields planted to different crops in various stages of growth or preparation, appearing at any one time as a patchwork of browns, tans, and greens. Both citrus grove and cotton field offered good possibilities for examining changes in the moisture content of air during movement across a field under active irrigation. Both test crops were surrounded by farmland in an inactive stage of irrigation, the land either being readied for planting or in stubble. This bordering farmland, therefore, was essentially dry, and added little or no moisture to the air either before or after air passage over the field. The citrus grove and cotton field, on the other hand, were being irrigated every ten days to two weeks, and the soil therefore was moist. (No standing water was visible during the tests, however. Following irrigation, water is visible in a field for a period generally less than one hour.) Humidity distribution at both sites was determined from data obtained by 6-man observer teams equipped to take wet- and dry-bulb temperature readings within the crops according to a systematic plan for coverage. Measurements were taken simultaneously at both sites, on the morning and afternoon of 7 and 8 August 1954.

To survey humidity conditions in cotton, permission was obtained to use a field of cotton on the University of Arizona Experimental Farm located in the Valley Division at 8th and E Streets, Yuma, Arizona.*

* Figure 11.

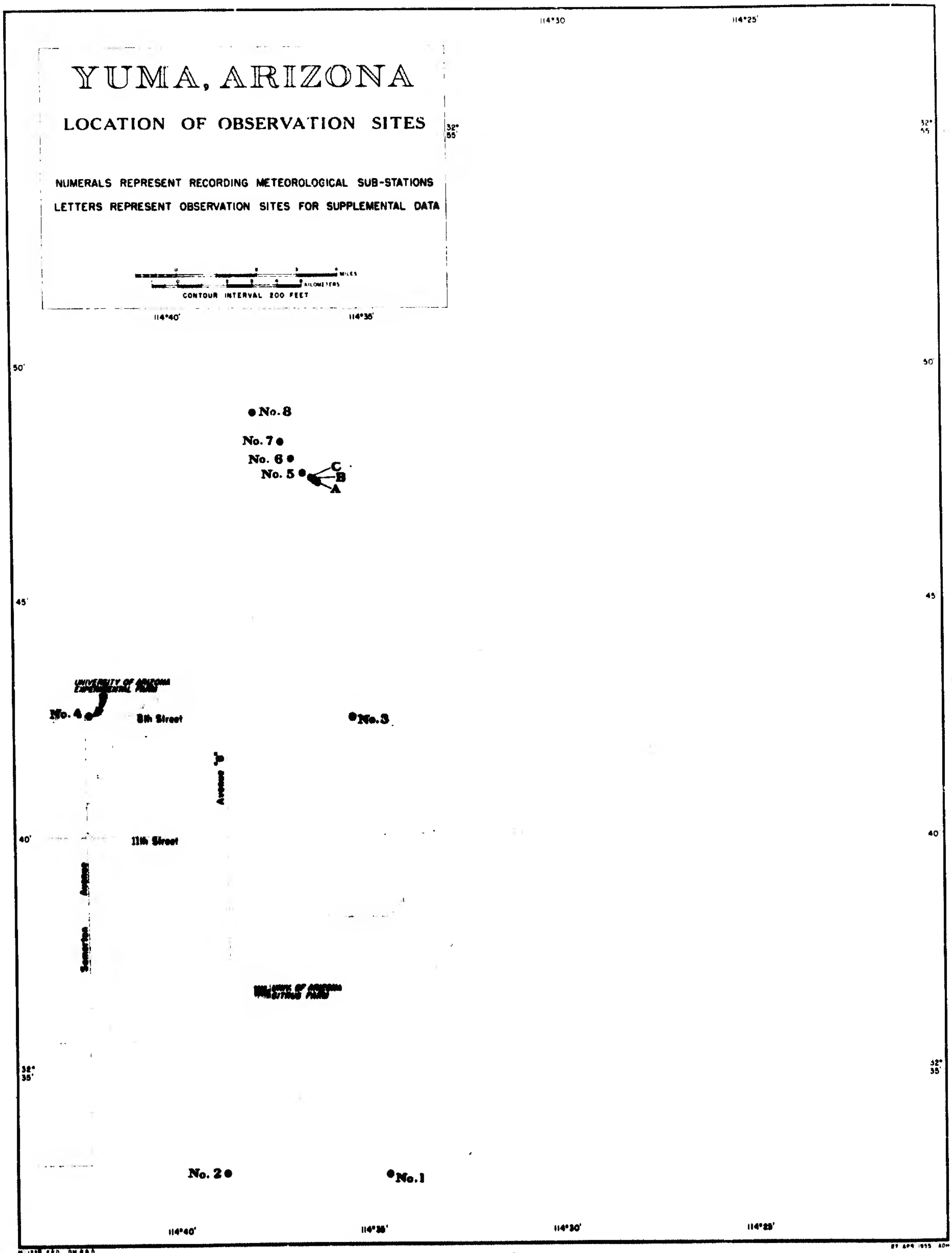
YUMA, ARIZONA
LOCATION OF OBSERVATION SITES
NUMERALS REPRESENT RECORDING METEOROLOGICAL SUB-STATIONS
LETTERS REPRESENT OBSERVATION SITES FOR SUPPLEMENTAL DATA
MILES
KILOMETERS
CONTOUR INTERVAL 200 FEET
No. 8
No. 7
No. 6
No. 5
C
B
A
No. 4
8th Street
No. 3
11th Street
No. 2
No. 1
114°40'
114°35'
114°30'
114°25'
50'
45'
40'
32° 35'
32° 55'

Figure 2

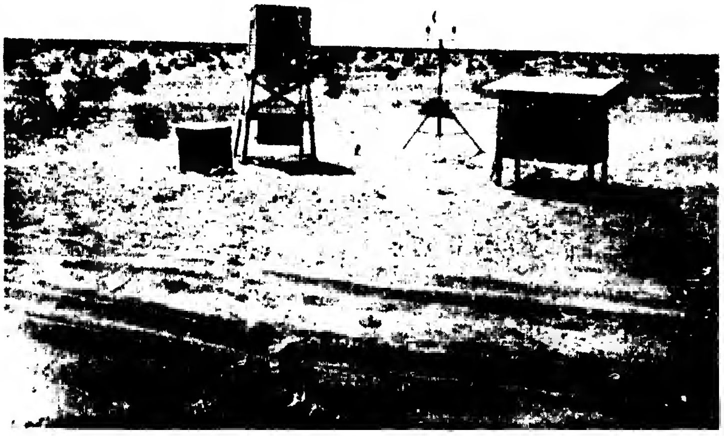

Figure 3. Substation No. 1, in the South Yuma Desert

Figure 4. Substation No. 4, on the north side of cotton field, South Gila farm site

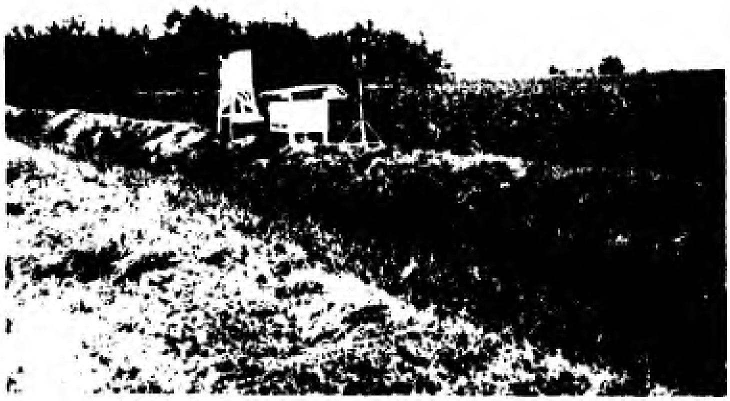

Figure 5. Substation No. 4, on the north side of a cotton field, University of Arizona Experimental Farm, 8th and E Streets

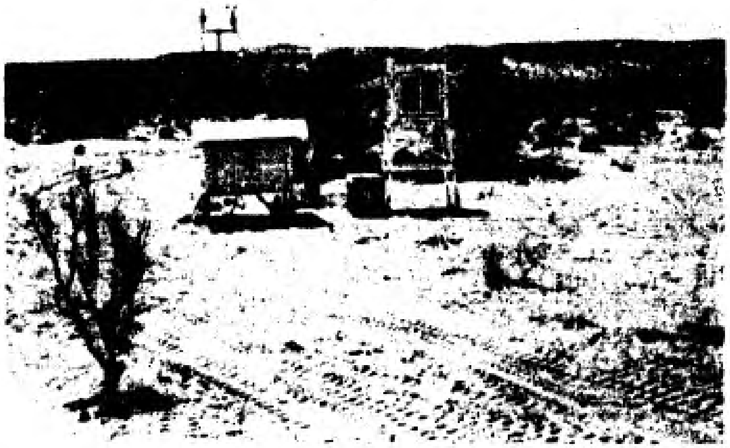

Figure 6. Substation No. 7, Picacho Wash about one and one-half miles north of the All-American Canal

The field was an eighth section measuring 1/4 by 1/2 mile and was entirely surrounded by fallow fields. The north side of the field faced 8th Street and the western side paralleled Somerton Avenue. The cotton was approaching maturity, standing just under 3 feet high, with dense foliage completely shading the ground. The field had been last irrigated about one week prior to the taking of the measurements and no standing water was apparent. Access to the center of the field was permitted along a north-south axis by way of a path bordering an irrigation ditch. Surveys were made twice daily on the 7th and 8th of August, observations starting at 1000 hours in the morning and at 1430 hours in the afternoon. About an hour was needed to complete each set of readings. Simultaneous readings at the 3-foot level were taken at the center point of each side of the field, and as rapidly as possible thereafter, at 10-foot intervals away from each side of the field for minimum distances of 100 feet. At the same time, observations were being made within the field along an irrigation ditch which bisected the field along its north-south axis. On the 7th of August, starting from the south end, readings were taken within the field at 15-foot intervals for a distance of 150 feet and at 50-foot intervals thereafter. On the 8th of August, observations within the field were taken in the same manner but terminated 1050 feet from the south end.

Another series of humidity surveys on the 7th and 8th of August was made in a grapefruit grove of the University of Arizona Experimental Citrus Farm located on the Yuma Mesa at Avenue A and 15th Street.* The grove measured 1/8 by 1/4 mile and was one of four groves contained within an eighth section, with open desert on all sides of the groves. The grove investigated was flanked on the west by another grapefruit grove of equal size, and on the east by a grove planted partly to grapefruit and partly to date palm. The grove was planted in north-south and east-west rows of trees 22 feet apart. All trees were mature fruit bearers averaging perhaps 25 feet in height and 18 to 20 feet in spread. The symmetrically planted trees touched or nearly touched each other about 2 to 3 feet from the ground where branching development was greatest. Throughout the summer, irrigation water was applied to the grove on the average of every 10 days and the soil, therefore, was in a moist condition. Each survey within the grove required about one hour to complete, and was made at the same time as a survey at the cotton field. Each survey commenced at the center of the grove with all members of the team making wet- and dry-bulb measurements for calibration purposes. Measurements were made every 22 feet along transects to the north, east, south, and west away from the center point of the field. While the transects were being run, measurements of wind as well as wet- and dry-bulb temperatures were made every five minutes at the center point. The northern transect (the longest of the transects) was run a distance of approximately 1,000 feet beyond the northern boundary of the grove. This was done to insure an adequate

* Figure 12.

amount of data for determining the limits of leeward transport away from the grove. To the west, the transect carried through the adjacent grove and some 100 feet into the desert beyond. The shortest of the transects carried eastward through the test grove and some 50 feet into the palm grove beyond. The southern or windward series of observations carried across 15th Street and through a patch of desert approximately 200 feet in width terminating at a line of trees marking the northern limits of another irrigation section planted to field crops.

c. Other Measurements

To further test the variance of humidity from place to place within the irrigated district, a 20-mile cross-section of wet- and dry-bulb temperature readings taken at half-mile intervals was run on the 8th of August from the desert south of the Yuma irrigated area to the All-American Canal on the north.* Proceeding by car from one observation point to the next, the transect was completed in approximately one hour and thirty minutes, from 1100 to 1230 hours. At each observation post, notes on the surrounding crop types, landscape characteristics, and estimates of wind speed and direction were made for later evaluation. Observations of wet- and dry-bulb temperature were also taken intermittently throughout the test period at points to the leeward of several crop types to provide a full sampling of humidity distribution under various conditions of irrigation.

Three sets of measurements of the vertical distribution of temperature and humidity over field crops were made. On the 9th of August, a vertical sampling of wet- and dry-bulb temperatures above and below crop-height levels was taken, first at the ground level and thereafter at levels from 1 foot to 7 feet (as high as could be conveniently reached), in a cotton field in the Gila Valley about noon using an Assman type aspirating psychrometer. Irrigation of this particular field had taken place earlier the same morning, and standing water remained between the rows. Later, on the 10th of August, and again on the 12th of August, similar observations were made in a cotton field on the University of Arizona Experimental Farm** but with measurements extended to the 12-foot level through use of a folding ladder. Though periodically irrigated about every 10 days, this field had not been irrigated immediately prior to either test, and no standing water was apparent anywhere in the field.

Additionally, a fairly complete survey of humidity conditions along the lower Colorado River was made available for certain days of the period 2 to 12 August through the courtesy of the International Boundary and Water Commission, whose river control observers took

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* Figure 14
** Figure 13

wet- and dry-bulb temperature readings at their regular control points between Yuma and the Mexican border.*

3. Analysis of Data

Of the several forms of expressing humidity, the dew point temperature is one of the most suitable for comparing the moisture content of the air at one place with that of another. Its advantages lie primarily in its conservative properties, that is, the stability of dew point values in respect to fluctuating air temperatures. Unlike relative humidity, whose values change rapidly with varying temperature, dew point is not affected by the rise or fall of air temperature. Defined as the temperature to which air must be cooled in order to reach saturation, the dew point is affected only by the addition of water vapor to the air, or by the removal of moisture from the air. Furthermore, dew point temperature can be translated easily into terms of vapor pressure, another conservative measurement for humidity used frequently in environmental analysis by physiologists in determining the thermal equilibrium of the body. Dew point, therefore, as computed from the wet- and dry-bulb temperatures obtained in the field, is used exclusively within this study as a basis for examining humidity variance associated with irrigation.

a. Comparison of Substation Records

Comparisons of dew points for the substation sites show little or no change before and after passage of the air over the irrigated district. Data for nearly all days of the test period show at a given time a tendency toward high dew points in the farmland and relatively low values at desert sites both leeward and windward of the irrigated district. Comparisons for 1100 hours on 7 August and 1430 hours on 8 August are shown in Table I.

TABLE I: CROSS SECTION OF DEW POINTS (°F)

	Windward South Yuma Desert		Irrigated Farmland		Leeward Lower Picacho Wash				Leeward Picacho Wash		
	1	2	3	4	A	B	C	5	6	7	8
7 Aug 54, 1100	60	62	71	73	67	63	61	61	62	61	63
8 Aug 54, 1430	60	63	73	74	74	61	62	59	59	58	57

(Stations and positions are underlined.)

* See Figure 15

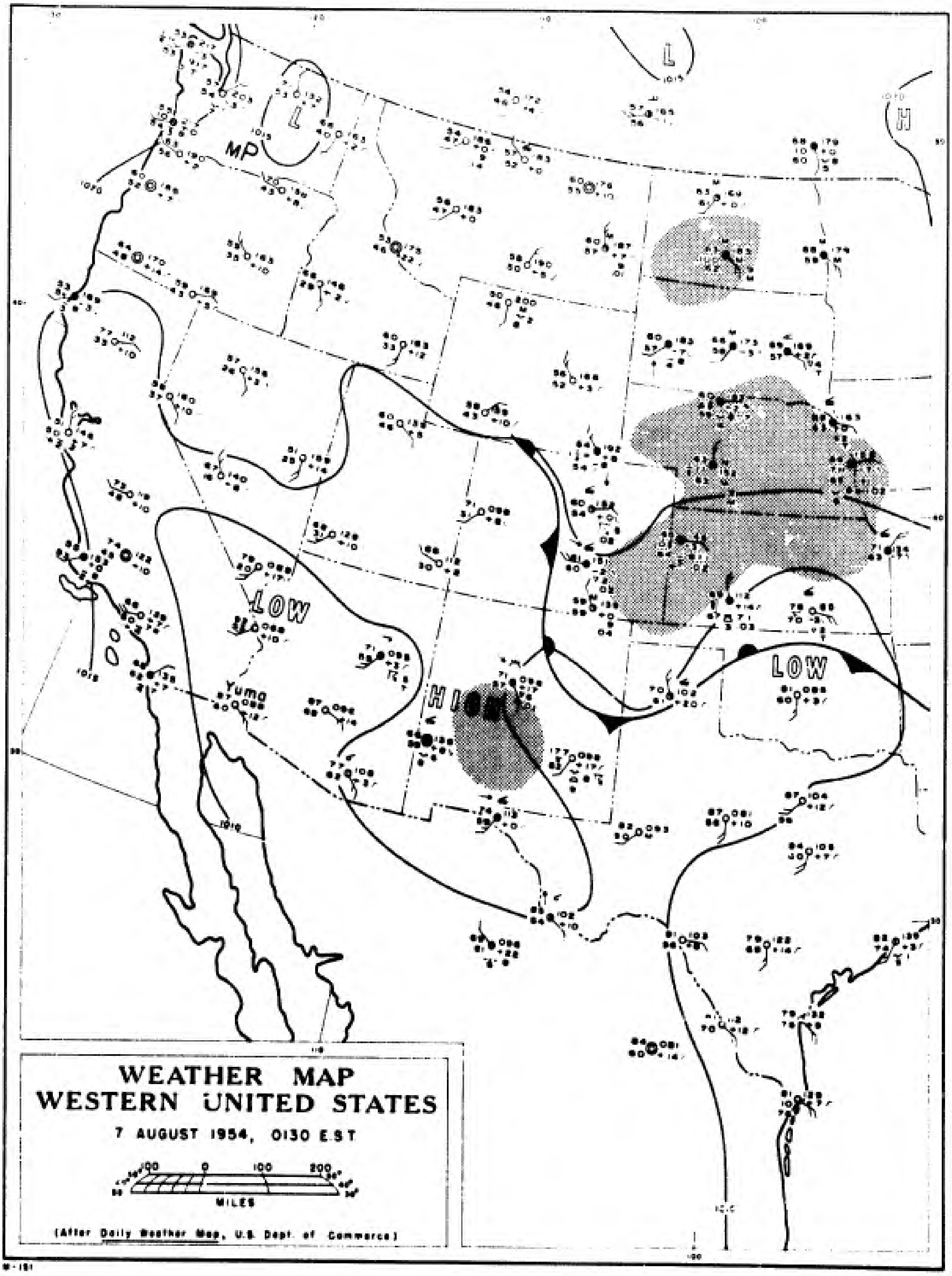
On the 7th and 8th of August the southerly pattern of air flow was well established as shown by the synoptic map for 0130 EST on the 7th of August (Fig. 7), and the pseudo-adiabatic chart for 0800 MST, 8 August at Yuma Test Station (Fig. 8), which establishes southerly flow at all upper air levels to 25,000 feet. The data comparisons for the 7th and 8th of August were selected not only for their representativeness of dew point distribution in general, but also because additional data were available for those days. Supplemental data in the form of sling psychrometer readings were taken at positions A, B, and C as indicated in Figure 2. These data help to complete the cross section of humidity distribution by providing measurements near the lower end of Picacho Wash, south of the All-American Canal (Fig. 9). The wash crosses the canal by means of a siphon just to the south of substation No. 5, and continues for a distance of about 300 yards before terminating at the edge of the irrigated land (Fig. 10). Positions A, B, and C were spaced approximately 100 yards apart in the lower wash with position A located within 6 feet of the northern edge of a cotton field. It is interesting to note that measurements taken at position A approximate the higher values for substations 3 and 4 within the irrigated area, and that measurements at position B, only 100 yards from A, are very close to those for substations 1, 2, 5, 6, 7, and 8, all in desert areas outside the farmland proper. It is apparent from Table 1 that the horisontal transport of the higher humidity originating with the crop land is limited to distances of 100 yards from the source.

There is some evidence that carry-off is limited to a few feet, and then only when the wind is blowing. The observations for August, for example, taken every 15 minutes, suggest that carry-off on that day was associated with gustiness, with higher values being recorded at position A, located six feet from the northern edge of a cotton field, during moments when the southerly wind was blowing. A portion of the record for 8 August, comparing measurements at position A with those at position B, 100 yards north of A, is given in Table II below.

TABLE II: CONSECUTIVE OBSERVATIONS OF DEW POINT (°F), 8 August 1954 AT VARIOUS TIMES (MST)

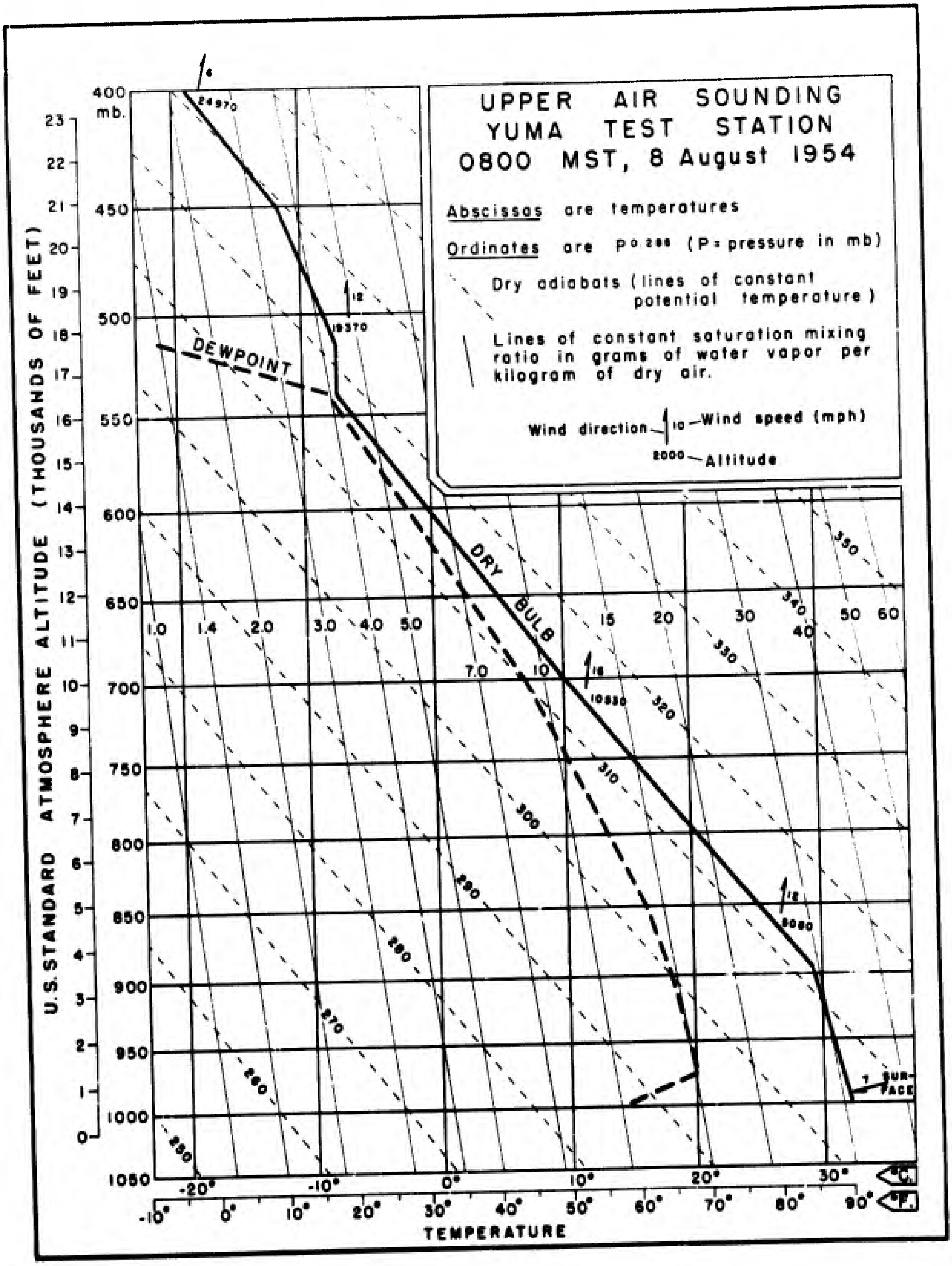
	1200	1215	1230	1245	1300	1315	1330	1345	1400	1415	1430	1445	1500
Position A	76	78	72	64	63	72	69	60	59	62	66	74	72
Position B	61	60	60	59	57	60	59	59	57	61	52	50	60

Though the data contain little evidence that the surface layer of air in the surrounding desert is materially affected by irrigation, the



WEATHER MAP
WESTERN UNITED STATES
7 AUGUST 1954, 0130 E.S.T
MILES
(After Daily Weather Map, U.S. Dept. of Commerce)
LOW
HIGH
LOW
Yuma
MP

Figure 7



C-183

Figure 8

Figure 9. Terminal area of Picacho Wash, South of the All-American Canal

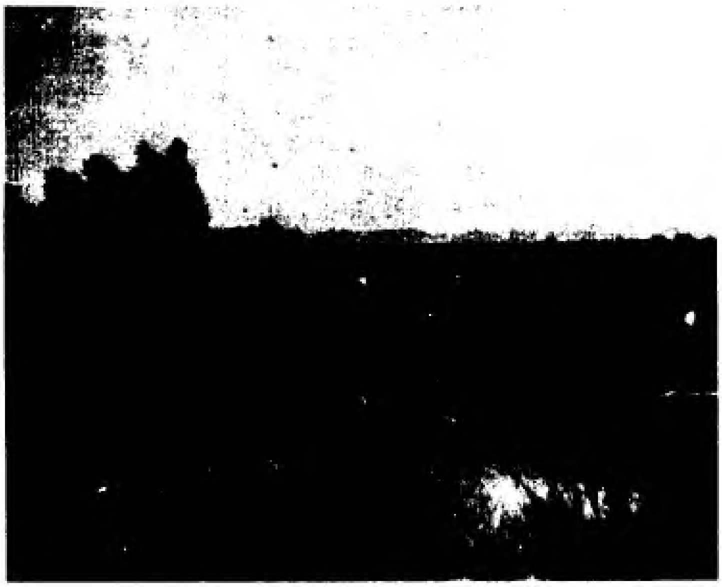


Figure 10. Northern limit of the irrigated farmland near the All-American Canal

higher dew points recorded within the farmland itself indicate that substantial amounts of moisture were being added to the air immediately above the fields, to be carried aloft by vertical mixing. A rough estimate has been made of the rate at which the water vapor content increases, based on Thornthwaite's figures* of maximum evapotranspiration for typical June days at Riverside, California, and Miami, Florida. Using evapotranspirometers to measure amounts of moisture being transferred to the air, Thornthwaite set the maximum hourly rate, in centimeters of water, at 0.065 for Riverside and 0.061 for Miami. These figures apply only at mid-day, between the hours of 1200 and 1300 when the most solar radiant energy is available. It was assumed in applying the Thornthwaite figures to Yuma, that 100% of the agricultural area was under active irrigation and that air passing from south to north over the district would travel a distance of 20 miles at a rate of 10 miles per hour. Thus, in passing over the area, a column of air would be increasing its vapor content at a uniform rate for a period of two hours. If the maximum rate of evapotranspiration computed for Riverside is used, 0.065 centimeters of water would be entering the air each hour, an average increase during passage of 0.13 grams for a column of air one square centimeter in base area. This would amount to 1,300 grams of water vapor for a column of air one square meter in basal area. If it is further assumed that this moisture is uniformly distributed within the column to heights of 1,000 meters, an average increase of 1.3 grams of water vapor would be added to every cubic meter of air within the column. In terms of dew point, this amount of additional water vapor would cause an increase of approximately 3 degrees (F) when dew point is in the range of 60°F, a representative midsummer value. Such an increase of dew point at all significant levels could be sufficient to cause considerably more thunderstorm activity if a sufficient volume of air were affected. Considering, however, that the 100,000 acres of irrigation comprise less than one percent of the total acreage of southern Arizona and that only a small proportion of the land is under irrigation at any given time, the effect on the total volume of air must be very local indeed, and is considered an inconsequential factor in altering the air mass characteristics for the region.

b. <u>Dew Point Distribution within Selected Crop Types</u>

When plotted and graphed, the data accumulated during the course of the crop surveys on the 7th and 8th of August show distinct patterns for dew point and air temperature. For both the grapefruit grove and cotton field, dew points were higher and dry-bulb temperatures lower at a height of 3 feet than equivalent measurements taken in the drier lands surrounding the test fields, as shown by data from the afternoon surveys of 7 August, in Figures 11 and 12. As indicated by the data, the effect of irrigation upon dew point is to raise values

* See No. 10, Bibliography.

by an average of 6 to 8 degrees (F), and upon air temperature, to lower values by an average of 4 to 6 degrees (F). The absolute difference may be as high as 14 degrees (F) with respect to dew point, and 10 degrees (F) with respect to air temperature. Compared with conditions in surrounding dry areas, these influences are limited. The change from higher to lower values of dew point at the edge of the field is especially sharp in the case of the grapefruit grove, where the northern or leeward limit of the grove is well marked by the contrast in values. This lack of leeward transport is perhaps caused by the impeding effects of a tree cover upon low-level wind flow. Measurements of wind speed at points within the grove indicate calm or nearly calm conditions during the test periods, whereas winds at points surrounding the grove averaged between 3 and 8 mph from a southerly direction. In the case of the cotton field, where winds are unimpeded above levels of 3 to 4 feet, some carry-off was noticeable within limited distances. In general, however, the leeward transport is limited to distances within 100 feet of the field, and then largely to the first 40 feet. In order to arrive at some index of evaluating humidity distribution at distances farther from the field, a comparison of dew points to the windward and leeward of the field was made by averaging the observation values on both days for points within 100 to 300 feet away from either end of the field. The dew point observations within 100 to 300 feet of the leeward end averaged 0.6 degrees (F) higher than the observations 100 to 300 feet from the windward end of the field. A statistical test (the Man-Whitney non-parametric test) indicates that this difference is of no statistical importance.

Typical distributions of dew point and air temperature within the cotton field and citrus grove are shown for the afternoon surveys (1400 to 1500 hours) on the 7th of August in Figures 11 and 12.

c. Vertical Distribution of Dew Point

The three surveys of low-level humidity variance within cotton fields indicate a concentration of moisture content beneath crop height levels. Above the cotton, there is a decrease of dew point values with elevation to at least 12 feet, the level where measurements terminated. Air temperature, on the other hand, changes but little with elevation, though there is a trend toward inversion at levels below the height of the cotton. At low levels the higher moisture content and lower temperature are no doubt partly the result of reduced ventilation caused by the effect of a vegetative cover upon air flow. Representative gradients in the vertical distribution of dew point and air temperature are shown graphically in Figure 13.

The first measurements of vertical gradients were made on the 8th of August in a field of cotton in the South Gila Valley District. Observations were taken over a 7-minute period starting at 1306 hours at

AIR TEMPERATURE & DEW POINT SURVEY
COTTON FIELD, U. OF ARIZONA EXPERIMENTAL FARM
(1430 - 1530 HOURS, 7 AUGUST 1954)

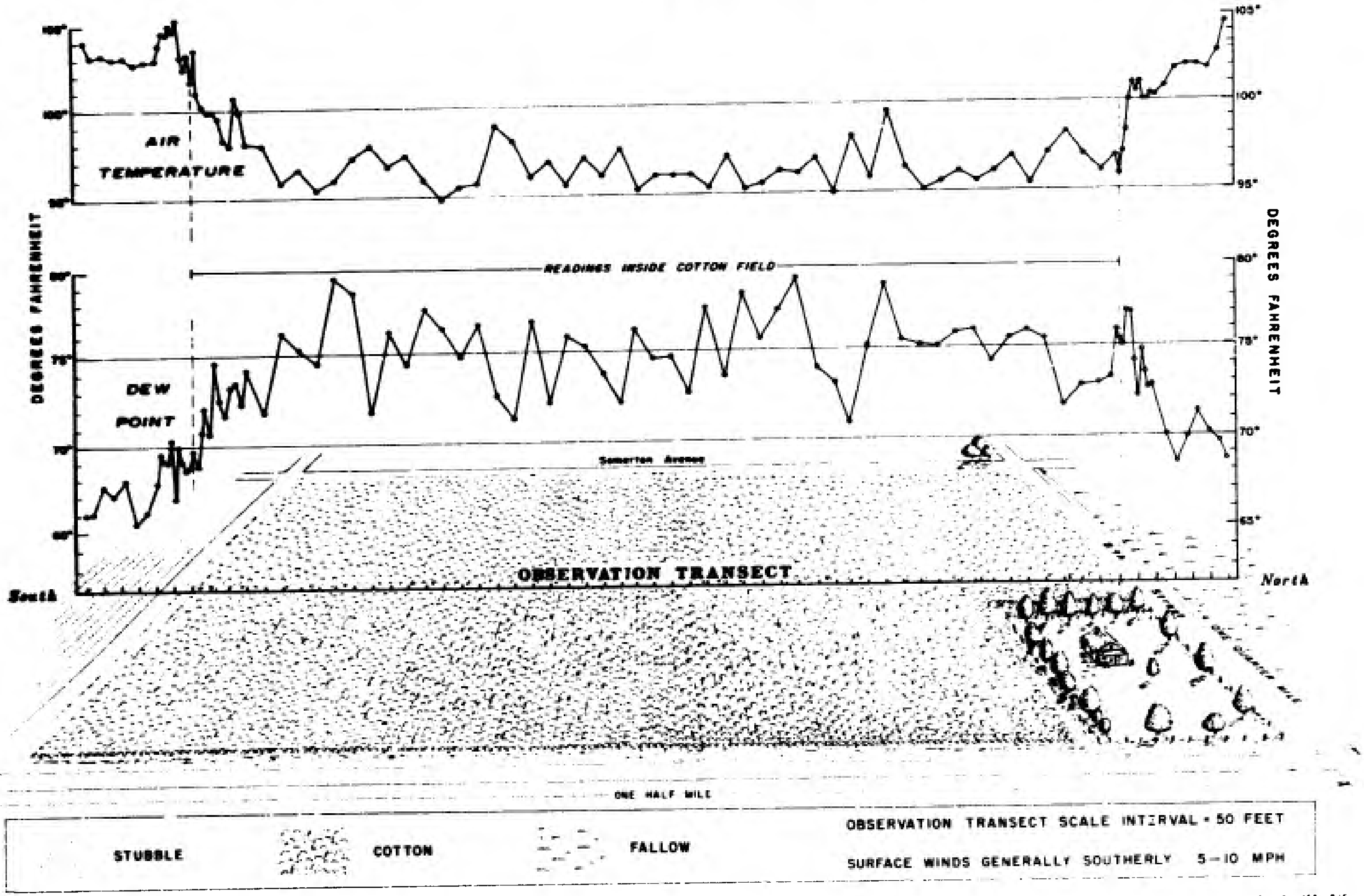
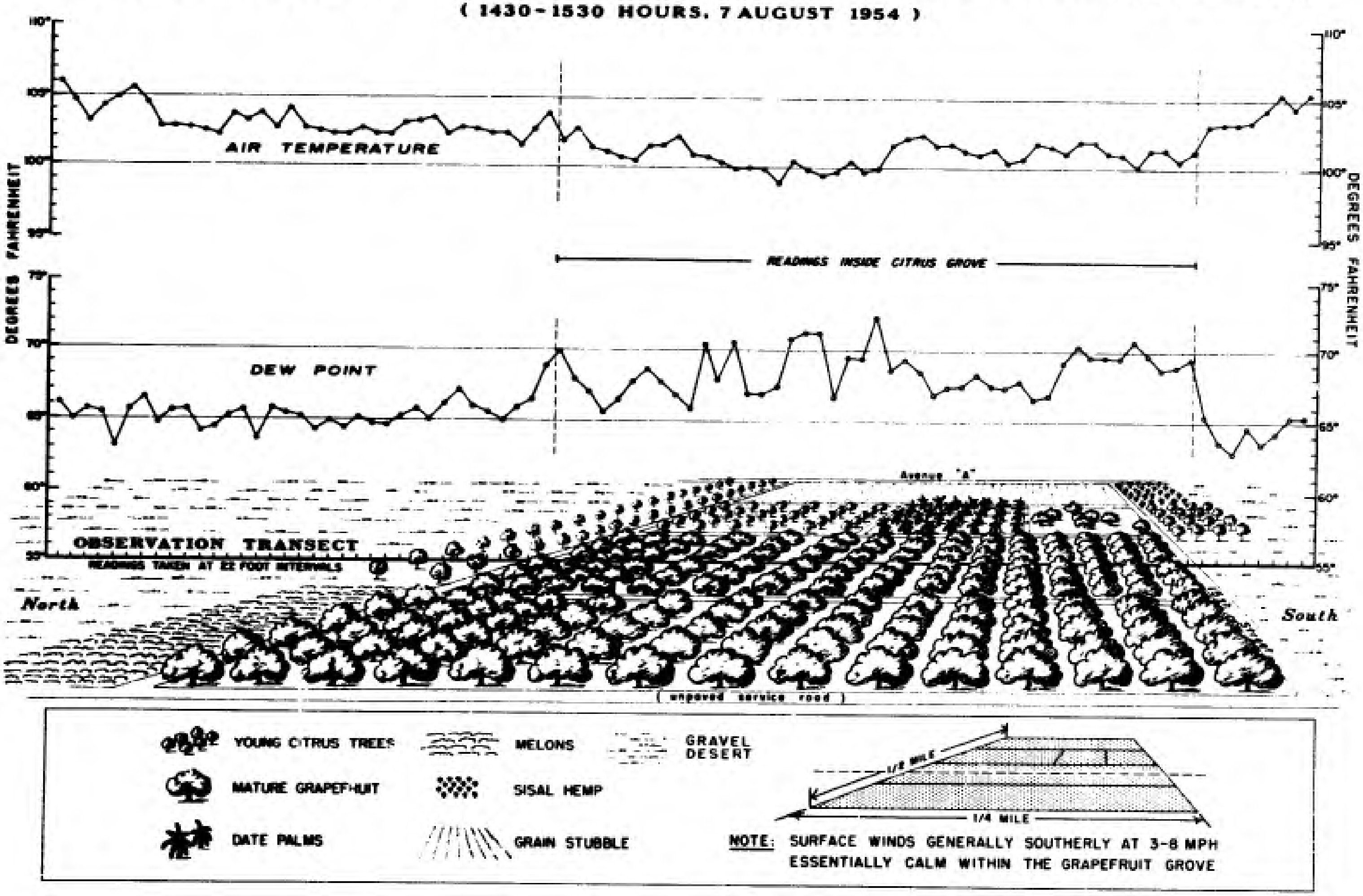


Figure 11

AIR TEMPERATURE & DEW POINT SURVEY

CITRUS GROVE, UNIVERSITY OF ARIZONA CITRUS FARM

(1430-1530 HOURS, 7 AUGUST 1954)



C-150 EPD OM R&D

Figure 12

5 AUG 1955 ADH

the ground level and at 1-foot intervals thereafter to the 7-foot level. Wind speeds were estimated at 2 to 3 mph. Beneath the top level of the cotton, dew points remained high: about 87°F, while dry-bulb readings varied only between 91° and 92°F. Above the top of the cotton (the 3-foot level) to 7 feet, dew points dropped steadily to 68°F and dry-bulb values increased to about 97°F.

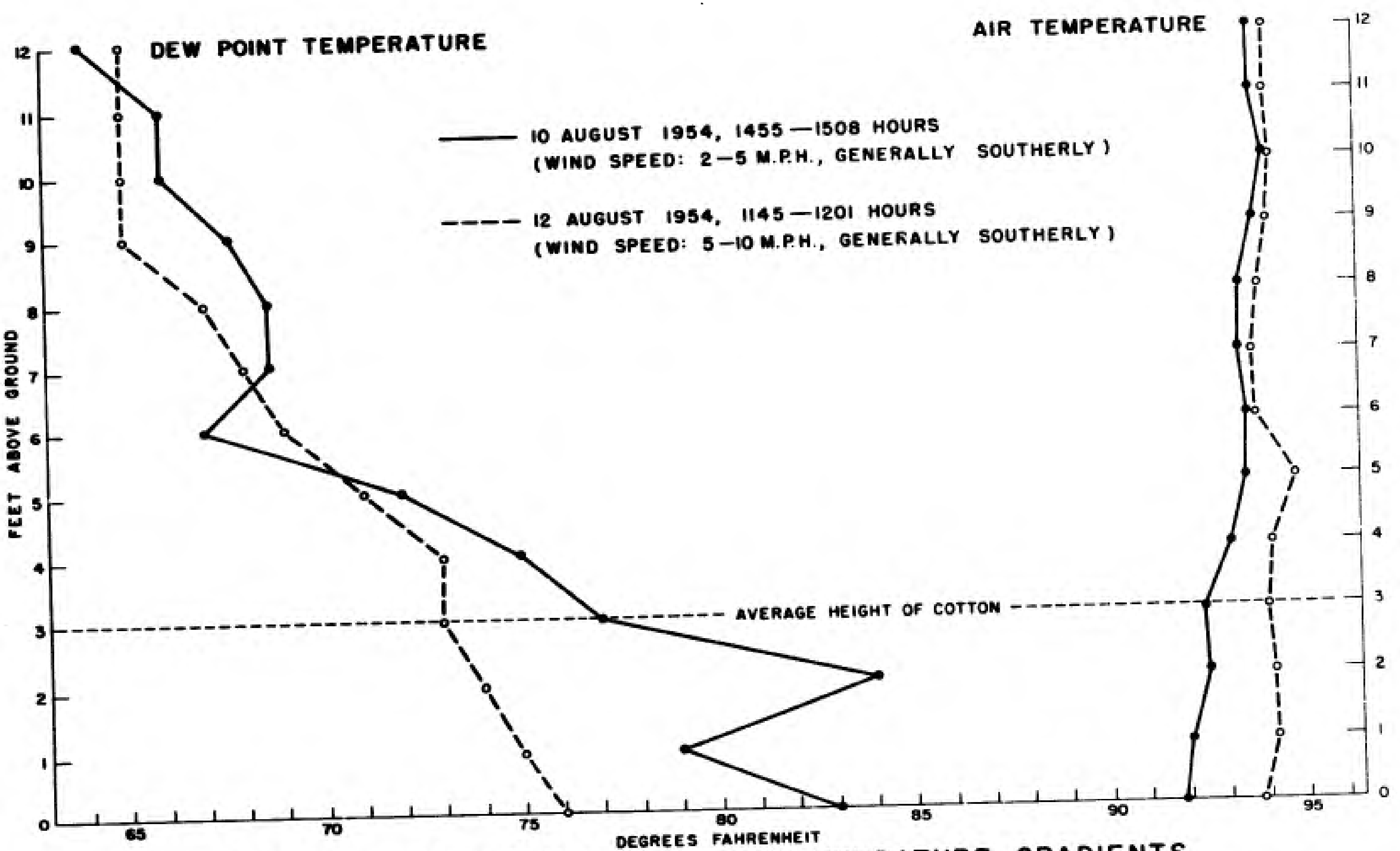
On the 10th of August a similar survey was made in a cotton field on the University of Arizona Experimental Farm. Measurements were made at each one-foot interval to 12 feet above the surface. Wind speeds were low, varying from calm to 4 mph during the 16-minute period of observation from 1145 to 1201. Dew points were again relatively high beneath the top of the cotton (79° to 84°F), and above the cotton, values dropped to 69°F at 7 feet and 64°F at 12 feet.

The third and last survey was made on the 12th of August, again in the cotton field on the experimental farm. Wind speeds were generally higher on this day, varying from 4 to 12 mph during the 13-minute period of observation from 1455 to 1508. The wind apparently acted to some degree as a ventilating agent within the cotton itself, for dew point values were somewhat lower, though there was still a marked vertical gradient. Beneath the top of the cotton, dew points ranged between 74° and 76°F. Above the cotton, values dropped to 65°F at the 9-foot level, remaining constant thereafter to the 12-foot level.

The results of the surveys for 10 and 12 August 1954 are shown graphically in Figure 13.

d. Dew Point Variance within the Agricultural District

The cross-section of humidity samplings taken at half-mile intervals along a 20-mile north-south axis between 1100 and 1230 hours on the 8th of August provides some information about humidity variation within the irrigated district itself. Winds were light, varying from 2 to 10 mph, and were generally from a southerly direction. It should be noted that winds generally paralleled the road, and therefore humidity increases generated within the fields were not in all cases being sampled in their most characteristic values. Furthermore, the observations represent samplings taken in various agricultural situations involving a variety of crop types in different stages of growth. Dew point values, as indicated by the data, were generally higher at points in the north of the transect than they were in the south, varying from 58.8°F at a site in the southern desert to 73.9°F at a point adjacent to a mature cotton field in the north. In general, the higher values were associated with observations taken next to mature field crops at times when wind eddies brought air directly from the fields. However, the higher dew points in the north could be attributed, at



VERTICAL DEW POINT AND AIR TEMPERATURE GRADIENTS
UNIVERSITY OF ARIZONA EXPERIMENTAL FARM (COTTON FIELD), YUMA, ARIZONA

C-152 EPD OMRBD

Figure 13

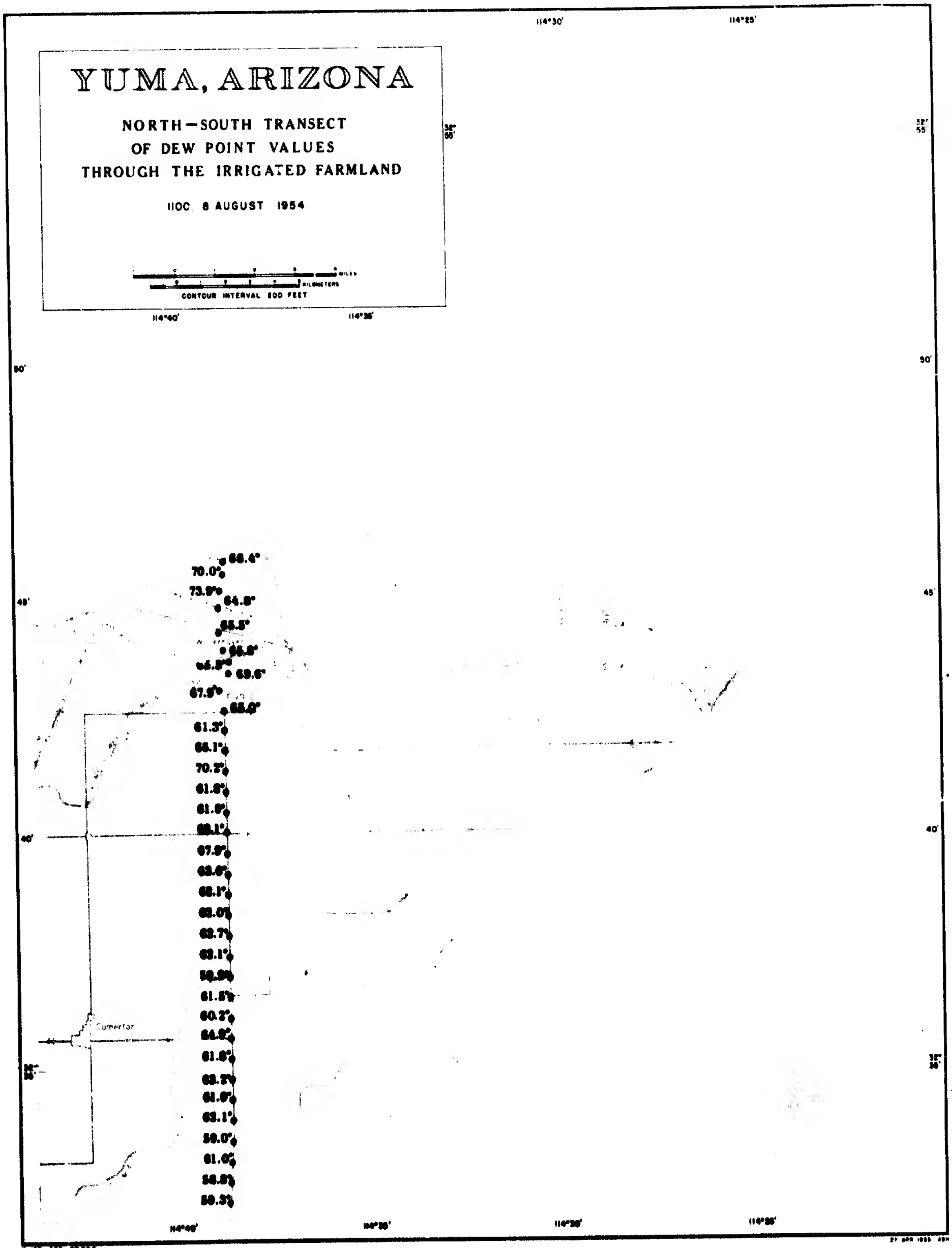

YUMA, ARIZONA
NORTH—SOUTH TRANSECT
OF DEW POINT VALUES
THROUGH THE IRRIGATED FARMLAND
11OC 8 AUGUST 1954
CONTOUR INTERVAL 500 FEET

Figure 14

least in part, to the normal increase in dew point as air temperature approaches its daily maximum. Factors seemingly affecting dew point values are: proximity to the field, wind speeds and directions, stage of crop growth, irrigation periods, and type of crop. Dew point values observed during the making of the cross-section have been plotted on the map shown in Figure 14.

On the afternoon of August 8th, a few observations were taken in representative agricultural situations. In those cases involving field crops the observation was taken to the lee (north side) of the field at a point approximately 10 feet from the edge of the field. Winds were generally from a southerly direction at speeds from 2 to 10 mph. Values for certain situations are given in Table III below:

TABLE III: DEW POINTS IN VARIOUS SITUATIONS WITHIN IRRIGATED AREA, AFTERNOON OF 8 AUGUST 1954

	Mature cotton	Brush	Alfalfa	Canal bridge, center	Irrigated bare ground, standing water	Stubble	Palm grove	Hemp
Dew point (°F)	73.9	62.2	64.7	64.7	67.8	64.6	66.2	67.9
Wind speed (mph)	3	8	6	6	10	5	2	5
Wind direction	SSW	SW	SW	SW	S	S	S	S

Still another guide to dew point fluctuation within the irrigated district is afforded by the observations of wet- and dry-bulb temperatures provided by the International Boundary and Water Commission. These data were taken intermittently on certain days during the period 2 to 12 August 1954 by river control observers at their regular service points along or near the Colorado River. Dew point values for those observations taken on 11 August between the hours of 0900 and 1500 are shown on the map in Figure 15. It should be pointed out, however, that little is known of the vegetational characteristics of the observation sites, and therefore the data should be used with some discretion.

e. Regional Distribution of Dew Point

Dew point temperatures for Yuma (taken at the Municipal Airport) bear a striking similarity to those for other stations in southern Arizona and southern New Mexico. As shown in Figure 16 there is a marked difference in dew point values for the 8th of August at 1430 between southern and northern stations. Yuma, Needles, Phoenix, Tucson, Douglas, Columbus,

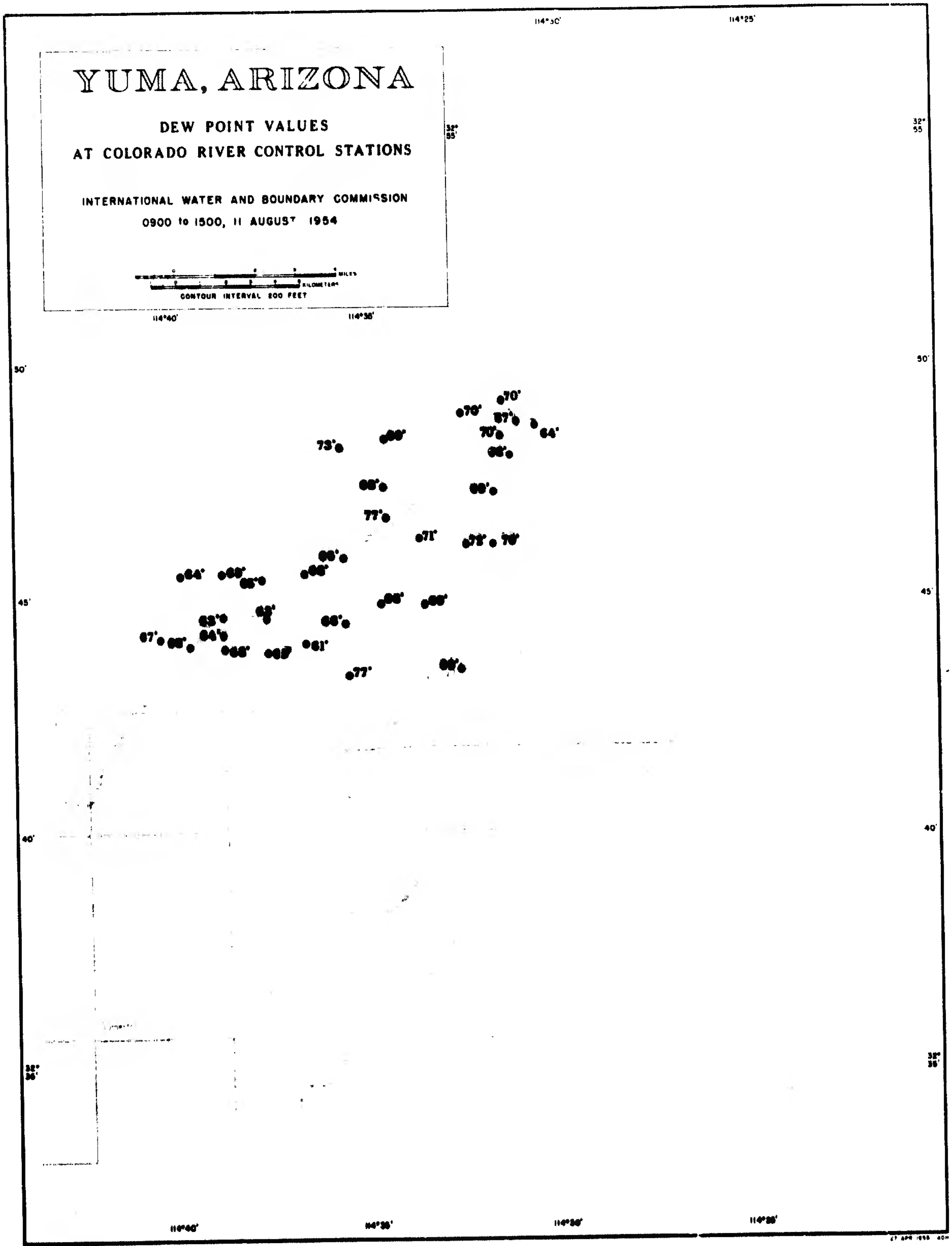

YUMA, ARIZONA
DEW POINT VALUES
AT COLORADO RIVER CONTROL STATIONS
INTERNATIONAL WATER AND BOUNDARY COMMISSION
0900 to 1500, 11 AUGUST 1954
CONTOUR INTERVAL 200 FEET

Figure 15

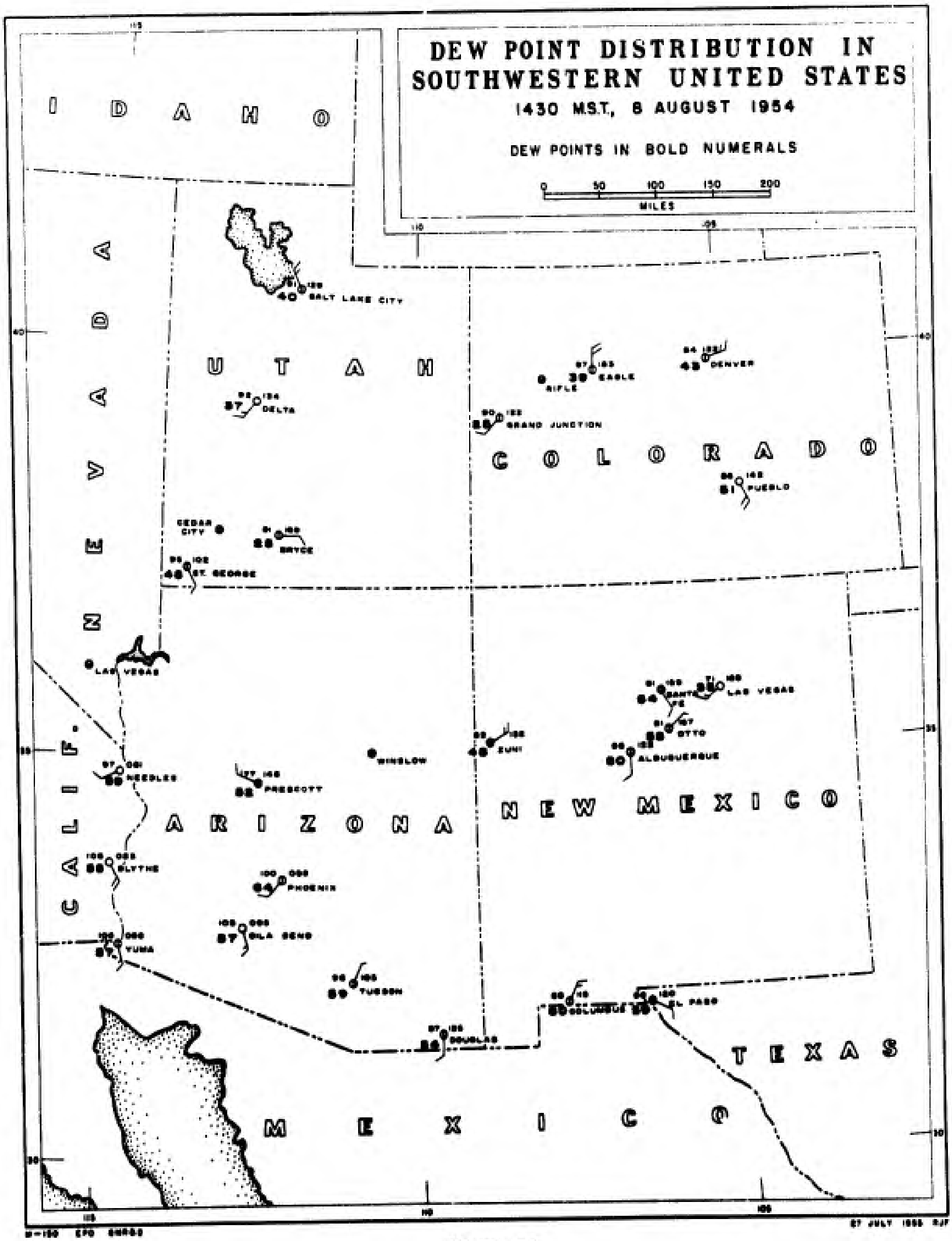

DEW POINT DISTRIBUTION IN SOUTHWESTERN UNITED STATES
1430 M.S.T., 8 AUGUST 1954
DEW POINTS IN BOLD NUMERALS
0 50 100 150 200
MILES
IDAHO
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
CALIF.
TEXAS
MEXICO
SALT LAKE CITY
DELTA
RIFLE
EAGLE
DENVER
GRAND JUNCTION
PUEBLO
CEDAR CITY
BRYCE
ST. GEORGE
LAS VEGAS
SANTA FE
OTTO
ALBUQUERQUE
WINSLOW
ZUNI
NEEDLES
PRESCOTT
BLYTHE
PHOENIX
GILA BEND
YUMA
TUCSON
DOUGLAS
COLUMBUS
EL PASO

Figure 16

and El Paso all report dew points in the high 50's or low 60's, as compared to values some 10 to 25 degrees lower for stations in Nevada, Utah, and northern Arizona. The higher dew points for the southern stations extending from western Texas to southwestern Arizona indicate the presence of a moister air mass in the southern districts, probably air from the Gulf of Mexico. The presence of Gulf air in southwestern Arizona is further substantiated when air flow about the summer pressure trough is considered. Assuming that a normal circulation pattern exists about the trough, the southern stations would be more directly in the path of northwesterly moving air from the Gulf than stations farther north. Pacific air becomes important at an undetermined distance west of Yuma in summer, and probably to the north of the pressure trough also.

4. Summary

In July and August 1954, a microclimatological field study designed to determine the moisture characteristics of heated air before and after passage over irrigated farmland was conducted at Yuma, Arizona. The conclusions reached relate only to daytime conditions and especially to the period from 1200 to 1500 hours.

The results of the study indicate that under the conditions of the experiment: (1) transpiration and evaporation processes cause measurable increases of dew point in the order of 6 to 8 degrees (F) and decreases of temperature in the order of 4 to 6 degrees (F) at an approximate height of 3 feet when wind speeds are less than 10 mph within the immediate area of cultivation; (2) the leeward transport of irrigation influences upon air mass characteristics at crop height levels is limited to distances of 100 feet, and largely to the first 40 feet, from the moisture source when wind speeds are less than 10 mph; (3) within the irrigated land, the areal pattern of crop distribution and crop development is a strong index to humidity distribution; and (4) the influence of irrigation upon humidities in the various testing sites of Yuma Test Station is negligible.

5. Acknowledgments

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Engineer, International Water and Boundary Commission, Yuma, in providing climatic data at points along the Colorado River is greatly appreciated. Large amounts of climatic data for Yuma were made available through the courtesy of Mr. Sherd F. Baldwin, Chief, U. S. Weather Bureau Station at Yuma Airport. Appreciation is expressed to Mr. Al Face, County Agent, Yuma County, for his kindness in providing information and material on water requirements for irrigation crops and farming techniques in the Yuma area. Acknowledgment is made of the part played by Dr. Peveril Meigs, Chief, Regional Research Section, Environmental Research Branch, who conceived the original idea for the project, made a preliminary site survey in the field, and made many valuable suggestions during the course of the investigation; by Dr. David H. Miller, Chief, Environmental Analysis Section, and Mr. Iven Bennett, Geographer, Environmental Analysis Section, for their review of the text; and by Messrs. Andrew D. Hastings, Jr., Roland J. Frodigh, and Jameson D. MacFarland, Cartographic Section, Environmental Research Branch, who designed and prepared the graphic illustrations contained in the study.

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The results of the study indicate that evaporation and transpiration cause an average increase of 6 to 8 degrees (F), in the dew point of the air directly over an irrigated area, but that the lateral extent of this effect is limited to distances of 100 feet or less from the fields. The influence of irrigation agriculture upon humidities in the various testing sites within Yuma Test Station therefore is negligible.

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The results of the study indicate that evaporation and transpiration cause an average increase of 6 to 8 degrees (F), in the dew point of the air directly over an irrigated area, but that the lateral extent of this effect is limited to distances of 100 feet or less from the fields. The influence of irrigation agriculture upon humidities in the various testing sites within Yuma Test Station therefore is negligible.

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