KITT PEAK NATIONAL OBSERVATORY

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IN ASTRONOMY, INC.

under contract with the
NATIONAL SCIENCE FOUNDATION

Contribution No. 45

FINAL REPORT ON THE SITE SELECTION SURVEY FOR THE NATIONAL ASTRONOMICAL OBSERVATORY

By
A. B. MEINEL

March 1958
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FINAL REPORT
ON THE
SITE SELECTION SURVEY
FOR THE
NATIONAL ASTRONOMICAL OBSERVATORY

March 1, 1958

A. B. Meinel

The research reported in this document was performed under grants from the National Science Foundation to the University of Michigan during the three years of 1955, 1956 and 1957, and under a contract with the Association of Universities for Research in Astronomy, Inc. in 1958.

This new edition was prepared by Helmut A. Abt and Eleanor S. Biggs; new drawings were made by DeWayne Graham and Hugh Ferguson.

Contributions from the Kitt Peak National Observatory, No. 45.

October 1963

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This report was prepared from the combined efforts of the following persons:

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A special acknowledgement is made to the collaboration with Dr. Helmut Abt who ably assisted in most of the early site exploration phases of this project.

Drawings for the instrumentation and structures for the automatic site testing program were made by the following persons:

H. J. Thompson

Kenneth H. Kirk

The engineering aspects of the 16-inch telescope were supervised by W. W. Baustian.

Figure 1

Photograph of southern Arizona taken from the Viking 12 rocket flight over White Sands, N. M.

I. SCOPE

The area examined for possible sites for the National Astronomical Observatory includes six western states centered upon Arizona. All possible regions were examined in Southern California, Arizona, New Mexico, and parts of Nevada, Utah and Texas.

The general region of the Southwestern United States was selected because of the high percentage of clear skies that are found in this area.

Preliminary reconnaissance of possible sites was made by examination of rocket photographs, principally those taken on the Viking flights. This examination was followed by an aerial reconnaissance of the entire region. Extensive photographs were obtained. The aerial reconnaissance narrowed practical sites to 150 sites.

A ground examination of the sites succeeded in elimination of all but a dozen sites. Sites were rejected for a variety of reasons relating to the practicability of testing and erecting an observatory facility.

Early assessment of meteorological factors, rainfall, cloudiness, dust and the artificial factors of smog, smoke, and city lights enabled five sites to be selected for initial testing. The sites were Chevalon Butte, south of Winslow, in latitude 35; Summit Mountain, south of Williams, in latitude 35; Hualapai Mountain, south of Kingman, in latitude 35; Kitt Peak, southwest of Tucson, in latitude 32; all four in Arizona; and Junipero Serra Peak, near Monterey, in California in latitude 36.

The first year of site testing led to the elimination of Chevalon Butte and Summit. In their places Mormon Mountain, south of Flagstaff in latitude 35 was selected, but actual testing was limited to Slate Mountain, north of Flagstaff.

Numerous sites were offered by various individuals and Chambers of Commerce, but in each case the mountain in question had already been examined and rejected.

A map showing the elevated areas in Arizona is shown in Fig. 2.

MAP OF ARIZONA SHOWING ELEVATIONS ABOVE 6000 FT.

FIG. 2

II. DESCRIPTION OF SITES

A. Kitt Peak, Pima County, Arizona $31^{\circ}57'$, 111.6°W.

Located in the Quinlan Mountains at the North end of the Baboquivari Range. No mining claims valid in area. In the Papago Indian Reservation, Schuck-Toak District. Elevation 6875 ft., covered with oak, Mexican Pinyon pine and a Sonoran chaparrel. Permission granted to test this site by the Papago Tribal Council. Land not available for purchase. Support town: Tucson 200,000 pop., University of Arizona.

B. Hualapai, Mojave County, Arizona $35^{\circ}7'$, 113.9°W.

Located in the northern end of the Hualapai Range at 7400-foot elevation. Comprises an area including Frieze Peak, Getz Peak and Dean Peak. Covered with stands of Ponderosa pine and manzanita brush. Part of the George Getz Ranch, sections of which are deeded, US, and Arizona School sections. Procurement possible through gift. Mining rights to Santa Fe, but assignable to observatory. Support town: Kingman, 5500 pop.

C. Mormon Mountain, Coconino County, Arizona, $34^{\circ}55'$, 111.4°W.

Located along the west rim of the Arizona Plateau rising to 8400-ft. elevation above a plateau elevation of 7500 ft. Located in the Coconino National Forest, government land, but encumbered with mining claims, patented land strips, timber and cattle leases. Procurement not examined, but probably involved with many interests. Covered with tall Ponderosa pine and includes several fine aspen stands. Located in heavy snow area so testing was done at Slate Mountain, which was easier of access during winter. Support town: Flagstaff 15,000 pop., Lowell and Naval Observatories, Arizona State College.

D. Junipero Serra Peak, San Mateo County, California, 36°8', 121.4°W.

Located in the Los Padres National Forest in the Santa Lucia Range at an elevation of 5600 ft. Covered with dense manzanita growth and Ponderosa pine, Douglas fir, and sugar pine on north exposures. Government land, but encumbered with minor usages. Adjacent to north boundary of the Hunter-Liggett Military Reservation. Support town: King City, 5000 pop. This site abandoned by AURA decision in November 1957.

E. Summit Mountain, Coconino County, Arizona, 35°8', 112.2°W.

Located in the Kaibab National Forest along the western edge of the Arizona Plateau, rising to 7400 ft. above a plateau level of 7000 ft. Covered with Ponderosa pine and some scrub oak. Government land, but encumbered with a transcontinental microwave relay installation of some magnitude. Located in a region of heavy winter snowfall and low temperatures. Support town: Williams, 3500 pop. This site abandoned by AURA decision in November 1957.

F. Chevalon Butte, Coconino County, Arizona, 34°40', 110.8°W.

Located at the northern extremity of the Sitgreaves National Forest, 40 miles north of the Mogollon Rim country. Elevation 6875 ft., covered with Juniper and range grasses. Land owned by the Chevalon Butte Cattle Company (M. J. O'Haco) with five acres deeded to the federal government for a lookout as this is the only elevation for 70 miles in any direction. Probably available by purchase. Located in a dusty region and turbulent air. Support town: Winslow, 7500 pop. This site abandoned by AURA decision in November 1957.

Figure 3

Photograph of Kitt Peak from near the Tucson-Ajo highway. The Papago village of Pan Tak is at the foot of the mountain.

III. ROAD ACCESS

Roads were constructed to Hualapai, Kitt and improved at Slate. Primitive roads were available at Chevalon, Summit, and Mormon. Good roads exist to the proximity of all sites except Chevalon.

A. Kitt. State highway 85 from Tucson to Gila Bend via Ajo and Sells passes 6 miles airline north of Kitt Peak. A tractor trail was built from Alambre Valley to the summit by Pima County in 1956. A truck trail was placed up the mountain from Pan Tak village by the project in 1957. A route approximately 12 miles long is necessary for a public access road at an estimated cost of $100,000 per mile based upon the terrain.

B. Hualapai. US 66 transcontinental highway passes 12 miles airline north of the site. A paved county highway from Kingman to the Hualapai County Park passes the foot of the site mountain. A jeep trail 1.3 miles long reaches the site summit from the County Park. A route 3 miles long is necessary to develop the site at a cost of $150,000 per mile plus improvements to the existing county road of $350,000.

C. Mormon Mountain. A paved highway passes the site 6 miles to the east connecting Flagstaff to Phoenix via Payson. A new allignment of a state highway is under construction 6 miles to the west that will provide rapid access between Flagstaff and Phoenix via Black Canyon highway. A jeep trail through the forest reaches the extensive summit. A route 6 miles long would connect the site to either highway; and at a cost of $75,000 per mile over nearly level terrain.

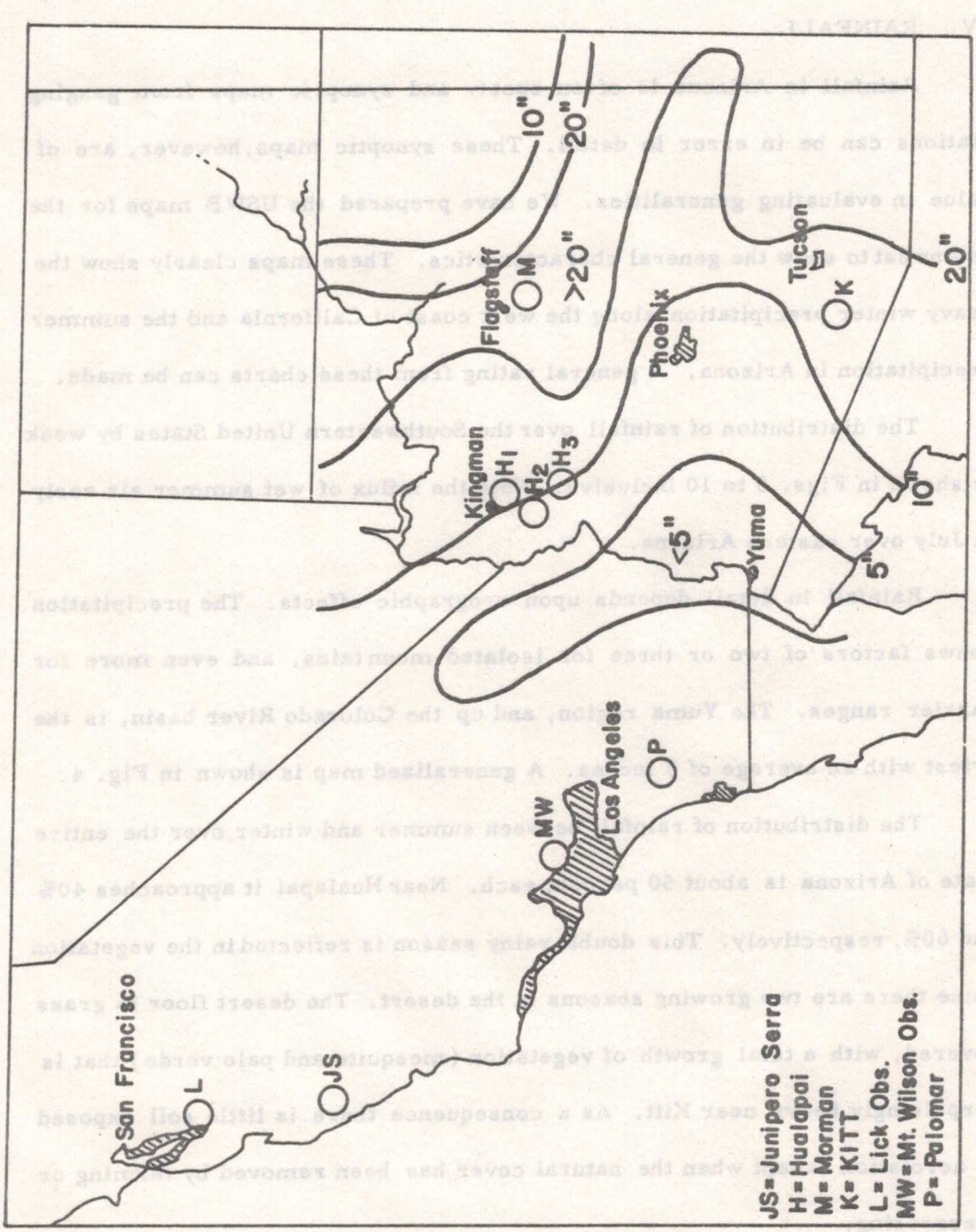
IV. RAINFALL

Rainfall in Arizona is often spotty and synoptic maps from gauging stations can be in error in detail. These synoptic maps, however, are of value in evaluating generalities. We have prepared the USWB maps for the Southwest to show the general characteristics. These maps clearly show the heavy winter precipitation along the west coast of California and the summer precipitation in Arizona. A general rating from these charts can be made.

The distribution of rainfall over the Southwestern United States by week is shown in Figs. 5 to 10 inclusive. Note the influx of wet summer air early in July over eastern Arizona.

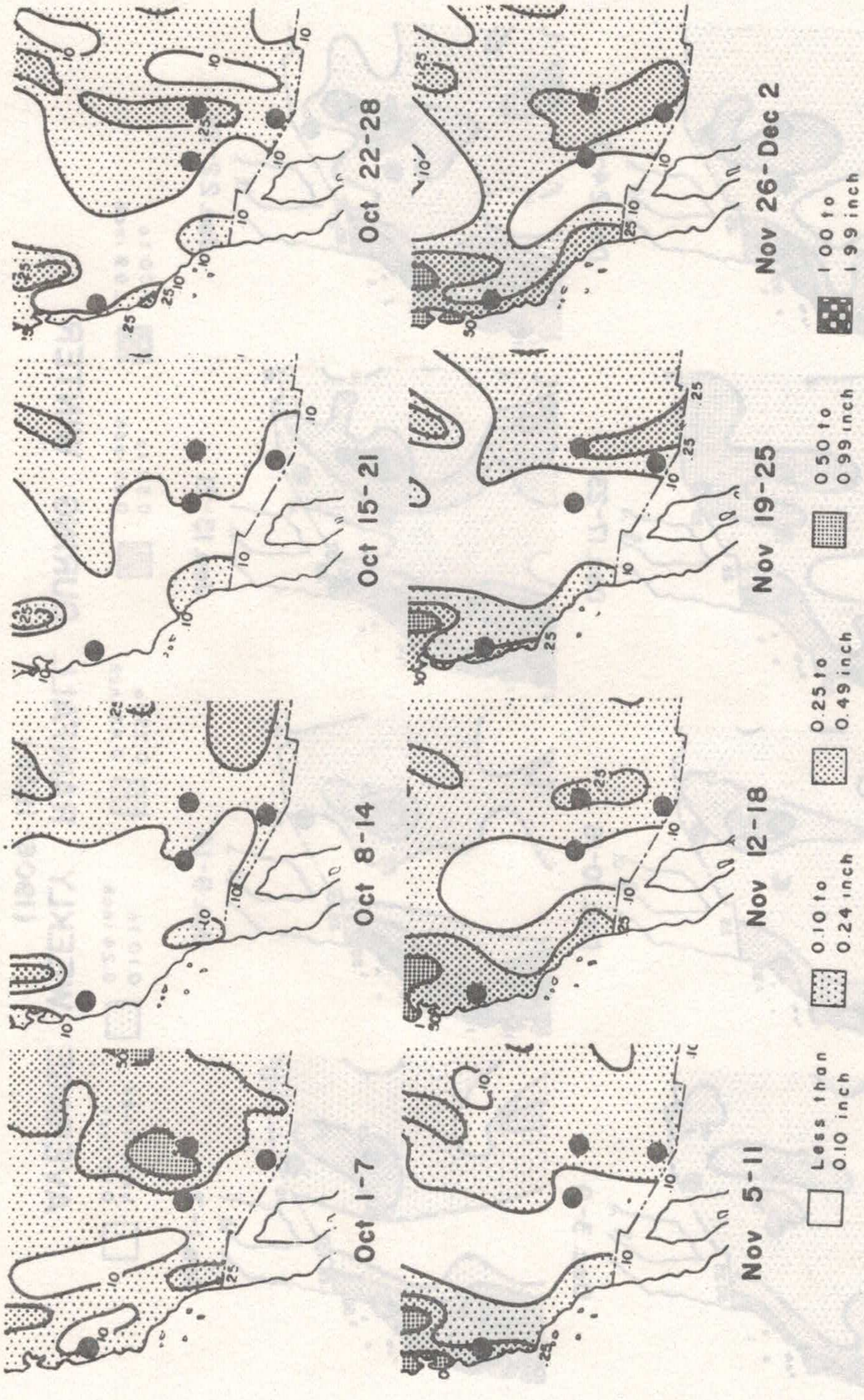
Rainfall in detail depends upon orographic effects. The precipitation shows factors of two or three for isolated mountains, and even more for barrier ranges. The Yuma region, and up the Colorado River basin, is the driest with an average of 3 inches. A generalized map is shown in Fig. 4.

The distribution of rainfall between summer and winter over the entire state of Arizona is about 50 percent each. Near Hualapai it approaches 40% and 60%, respectively. This double rainy season is reflected in the vegetation since there are two growing seasons in the desert. The desert floor is grass covered, with a total growth of vegetation (mesquite and palo verde) that is surprisingly heavy near Kitt. As a consequence there is little soil exposed to aerolation except when the natural cover has been removed by farming or overgrazing.



ANNUAL AVERAGE RAINFALL, SOUTHWEST

FIG. 4



AVERAGE WEEKLY RAINFALL DURING WINTER
(1906-1935)

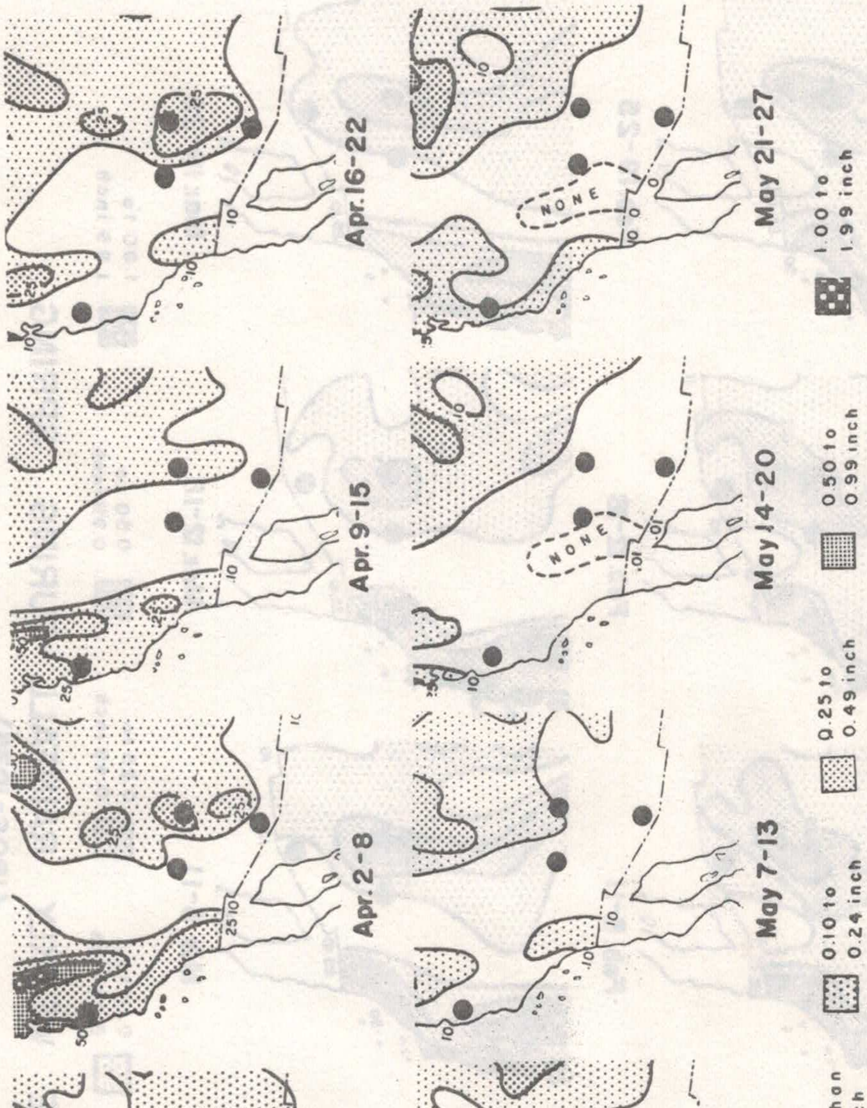
FIG. 5

AVERAGE WEEKLY RAINFALL DURING WINTER
(1906-1935)

FIG. 6

AVERAGE WEEKLY RAINFALL DURING SPRING
(1906-1935)

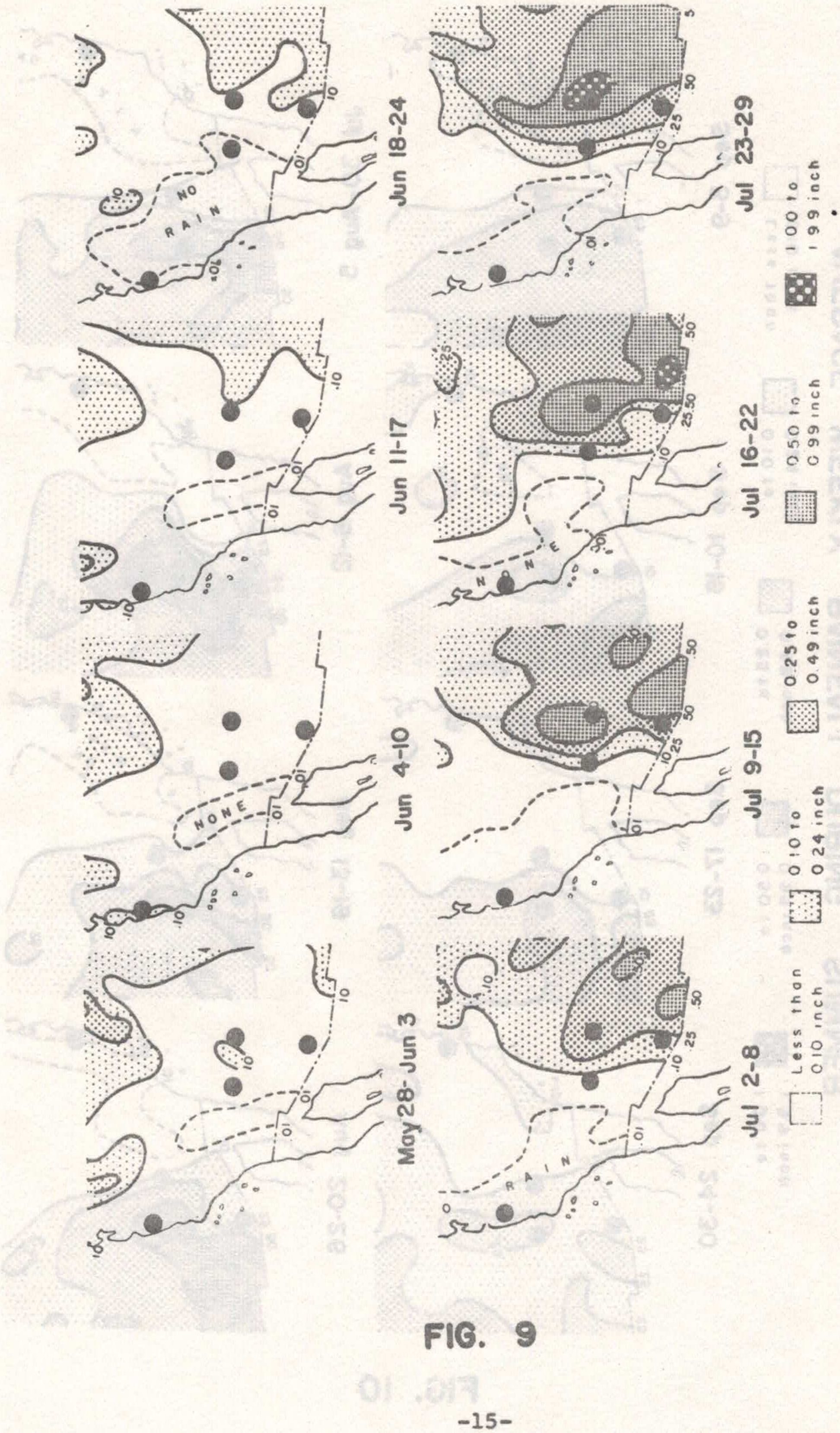
FIG. 7



AVERAGE WEEKLY RAINFALL DURING SPRING

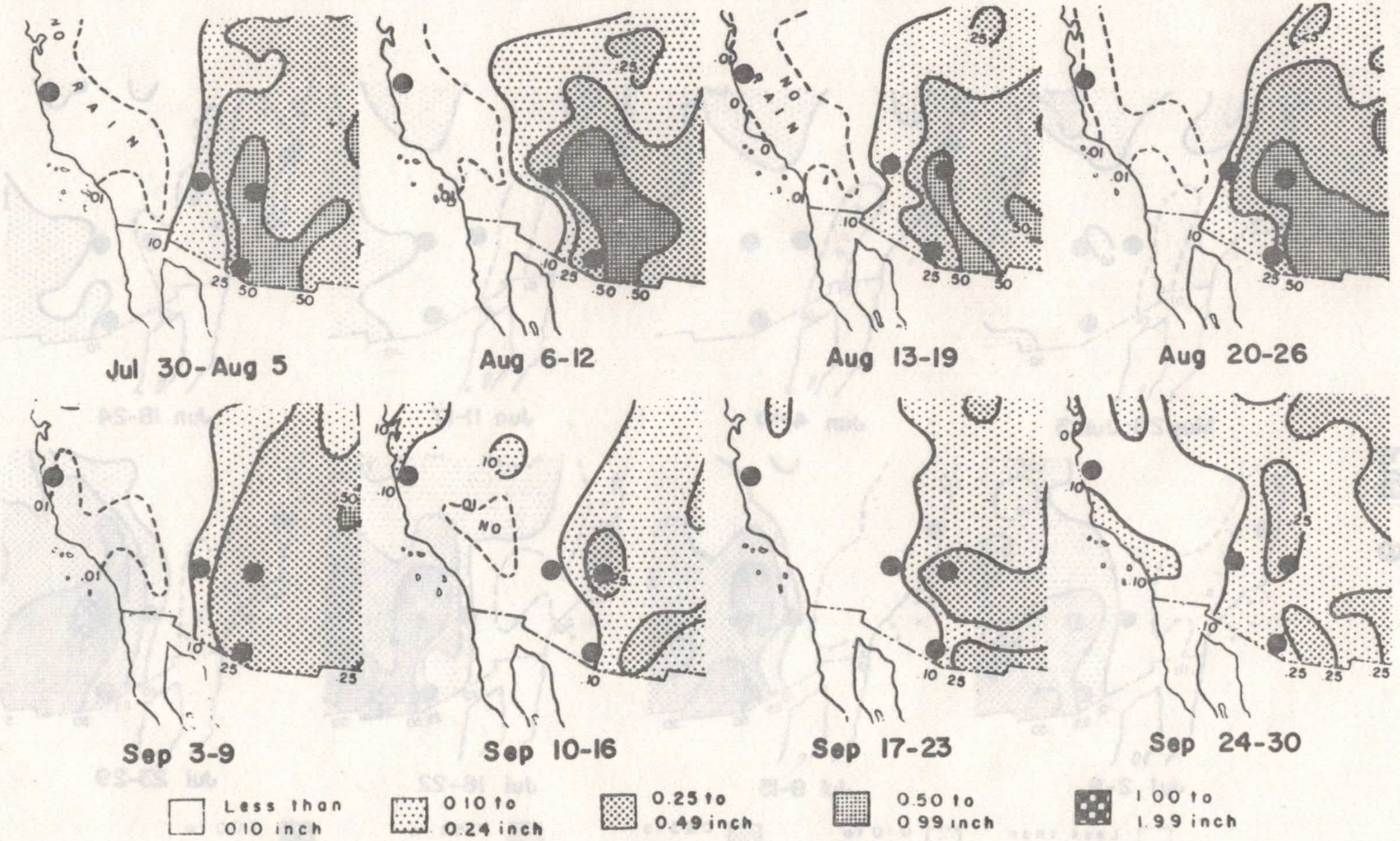
(1906-1935)

FIG. 8



AVERAGE WEEKLY RAINFALL DURING SUMMER
(1906-1935)

FIG. 9


Jul 30-Aug 5
Aug 6-12
Aug 13-19
Aug 20-26
Sep 3-9
Sep 10-16
Sep 17-23
Sep 24-30

AVERAGE WEEKLY RAINFALL DURING SUMMER
(1906-1935)

FIG. 10

V. DENDROCLIMATOLOGY

The validity of an evaluation of the observatory from recently acquired data is open to some serious questions. The long-range climate of Arizona and the entire Southwestern United States has not been typical in the last three decades, during which time the area has received subnormal rainfall paralleled only by the drought of the 13th century. The signs of this fact are amply shown by the vanished lakes common to the Arizona plateau, notably in the Williams-Flagstaff-Heber arc. The present year since midsummer has been one of "unprecedented cloudiness and rainfall". The question that troubles me is whether or not this year may be <u>more typical</u> of the climate than that of recent years within the ready recollection of local inhabitants. An effort to find the answer has led to two principle sources — weather bureau records for recent times and dendroclimatic studies for a long view of the weather.

The weather bureau records for the Southwest are gathered principally in inhabited areas. The individual quantities have been gathered in varying completeness since the turn of the century. The reconstruction of the information bearing upon astronomical criteria is not always easy. Cloud records are the least extensive and the least reliable. Rainfall fluctuates widely depending upon the number of downpours that happened over the gauging station, so that the correlation factor between two stations a mile apart is often surprisingly low. This is solely a reflection of the thunder shower nature of the summer rainfall, which incidentally accounts for 50-60 percent of the annual total.

The availability of abundant records obtained by the Laboratory of Tree-Ring Research at the University of Arizona, directed by Edmund Schulman, has offered new information to our problem. Measurement of the annual growth ring size of carefully chosen drought-sensitive species shows variations that appear to be excellent indicators of the climatic conditions. Ring growth, however is not a simple function of rainfall. Growth is more logically a consequence of the general sub-soil moisture. This moisture reflects not only the rate of precipitation, since a heavy summer shower and its immediate runoff contributes little to sub-soil moisture compared to a day-long winter drizzle, but also on the evaporation rate. The evaporation rate is a function of several variables, but the percentage of cloudiness is a major term. As a consequence, the sub-soil moisture as indicated by the tree ring growth is perhaps a better indicator of average astronomical conditions than are local weather records.

The study of dendrochronologies offers us the possibility of examining the climate of a given area not over only centuries but millenia. While the most numerous and completely fixed chronologies are for the last 800 years there are enough records of still living trees to carry our knowledge back to 2000 BC for the California desert region. The discovery by A. E. Douglas of the 46-year drought of the 13th century, which explained the destruction of the civilization of the early Arizona Indian tribes was a triumph for this new science. This severe drought, however, is now equalled in severity by the current 36-year drought starting in 1920 and which is now possibly ending. A graph of the records averaged for all species and distributed over the Gila River drainage area is shown in Figure 11. An examination of this figure causes one some doubt concerning the applicability of any survey made during the last few years as an indication of what to expect in the next few decades.

The drought chronologies for any specific area may show significant trends. In order to answer the detailed rating of a particular site region it would be highly desirable to have some of the trees in the region sampled. The trees that are most appropriate are generally not those that one expects. Relatively small but stunted trees may have lifetimes centuries longer than their "healthier" neighbors. Even lowly sagebrush is drought sensitive, and a base three inches thick may represent 500 years of growth. It is intended that we shall take samples and prepare such records for our principle areas.

To illustrate the fact that such local records may be important I would like to quote some passages from "Dendroclimatic Changes in Semiarid America" by E. Schulman: "In Southern Arizona the rainfall chronology parallels, on the whole, that in the main catchment areas of the Colorado River in Colorado (Rockies) and Utah (Wasatch). Yet some years and intervals are decidedly different. For example, the wetness of 1932-33 in Southern Arizona (see Figure 11) is not found farther north in such degree, even in the nearby Verde River Basin (south of Flagstaff) a northern tributary of the Gila; also, the 1920's average near normal (i.e., wetter) in the Verde, whereas in Southern Arizona this decade averaged well below normal."

At present it is not possible to evaluate the absolute rainfall of an area from growth rings of the same species of tree since the sensitive trees grow near the natural selection limit zones of varying altitude. The general level of rainfall, however, can be reasonably estimated from the tree species population distributions.

Dendroclimatic studies indicate that there has been no detectable secular climatic change in the Southwestern United States during the past 4000 years. The pattern of drought and heavy rainfall, moreover, shows no periodic tendency, and the frequency spectrums of duration of drought or heavy rainfall shows no terms longer than one century. The main problem of evaluation of the long-ranged performance of our test sites is therefore to establish where we stand during the test years with respect to the long-term average.

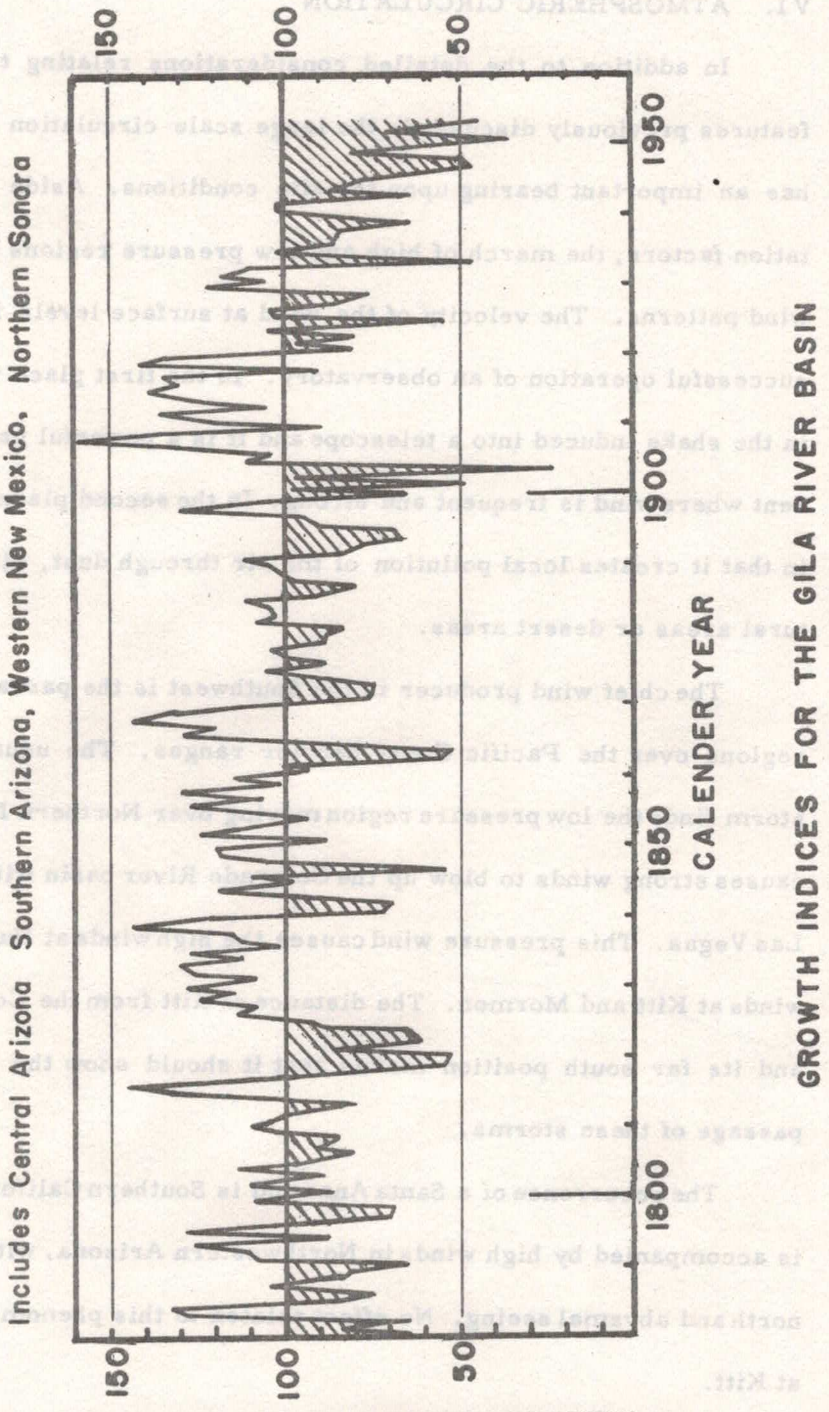

GROWTH INDICES FOR THE GILA RIVER BASIN
Includes Central Arizona, Southern Arizona, Western New Mexico, Northern Sonora
CALENDER YEAR
1800
1850
1900
1950
150
100
50
PERCENTAGE OF NORMAL GROWTH

FIG. 11

VI. ATMOSPHERIC CIRCULATION

In addition to the detailed considerations relating the meteorological features previously discussed, the large scale circulation of the atmosphere has an important bearing upon the site conditions. Aside from the precipitation factors, the march of high and low pressure regions is accompanied by wind patterns. The velocity of the wind at surface levels is important to the successful operation of an observatory. In the first place wind is a handicap in the shake induced into a telescope and it is a powerful psychological deterrent where wind is frequent and strong. In the second place wind is a handicap in that it creates local pollution of the air through dust, either from agricultural areas or desert areas.

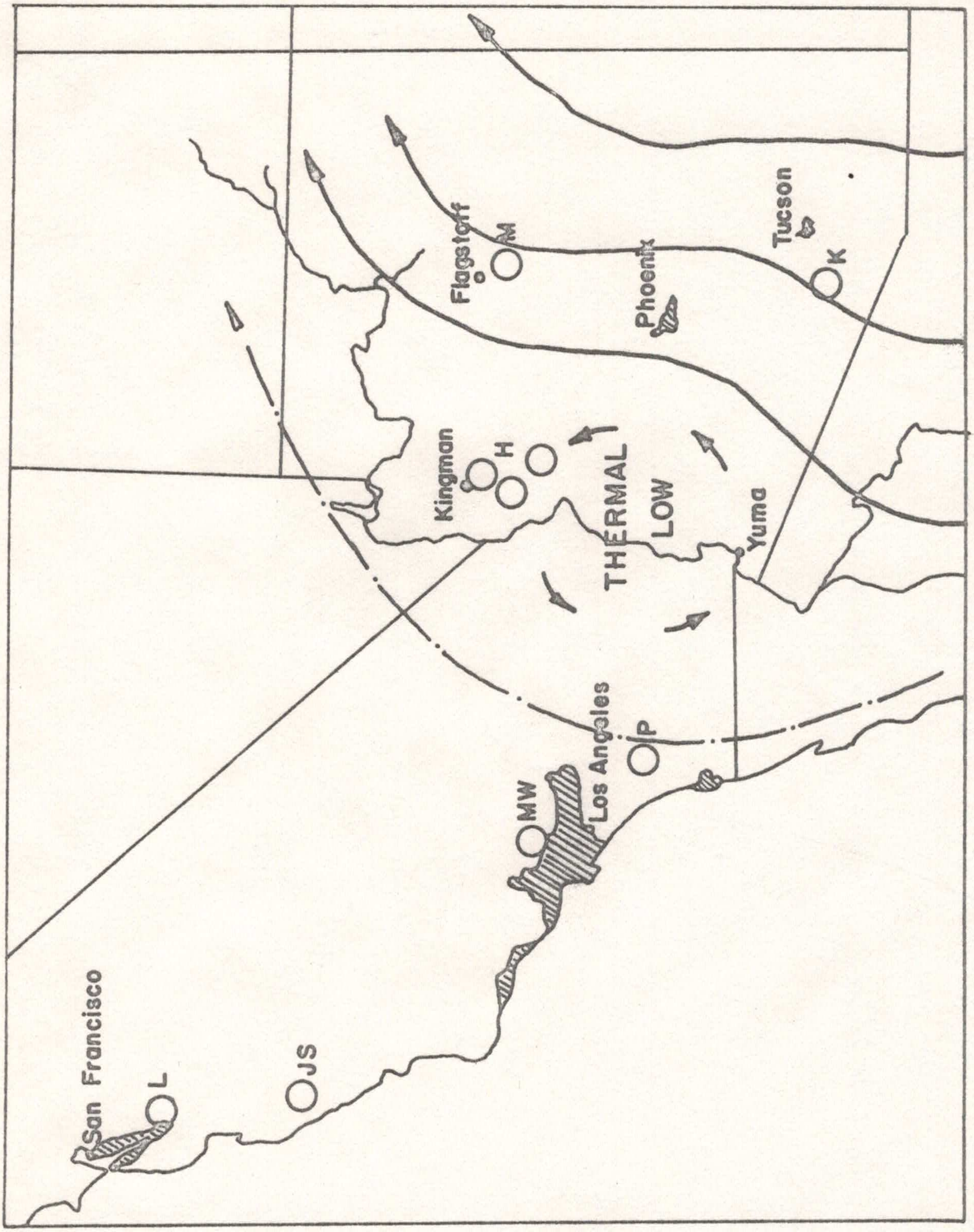
The chief wind producer in the Southwest is the passage of low pressure regions over the Pacific Coast barrier ranges. The usual path of a Winter storm finds the low pressure region moving over Northern Nevada. This event causes strong winds to blow up the Colorado River basin with a maximum near Las Vegas. This pressure wind causes the high winds at Hualapai, with lesser winds at Kitt and Mormon. The distance of Kitt from the Colorado River basin and its far south position means that it should show the least effect of the passage of these storms.

The occurrence of a Santa Ana wind is Southern California (off the desert) is accompanied by high winds in Northwestern Arizona, with a wind out of the north and abysmal seeing. No effect related to this phenomenon has been noted at Kitt.

In summer the atmospheric circulation pattern in Arizona is completely controlled by the Bermuda low. The Bermuda low causes an influx of Gulf of Mexico air to be forced westward over Northern Mexico. This low is aided by a generally stagnant westerly flow in summer. In winter the westerly flow is intense and the wet gulf air is pulled northward over the region east of the Mississippi delta.

The intense heating of the desert region around Yuma also plays a major role in the summer air glow. The creation of a quiescent "thermal low" bends the gulf flow eastward over the Arizona plateau as is shown in Fig. 12. The diversion of the flow is strong in June and early July, causing most of the precipitation to spread northward along the rim country. The weather bureau maps shown in Figs. 5-10 show the effect of this flow in the precipitation over the Flagstaff region.

As the moist flow deepens the summer thunderstorms spread westward enveloping the Kitt region.. In late summer the thermal low weakens and rains can occur as far west as the Southern California coastal belt. Hualapai is the clearest of all the Arizona sites in summer.



TYPICAL MOIST AIR TRAJECTORIES IN SUMMER

FIG. 12

Figure 13

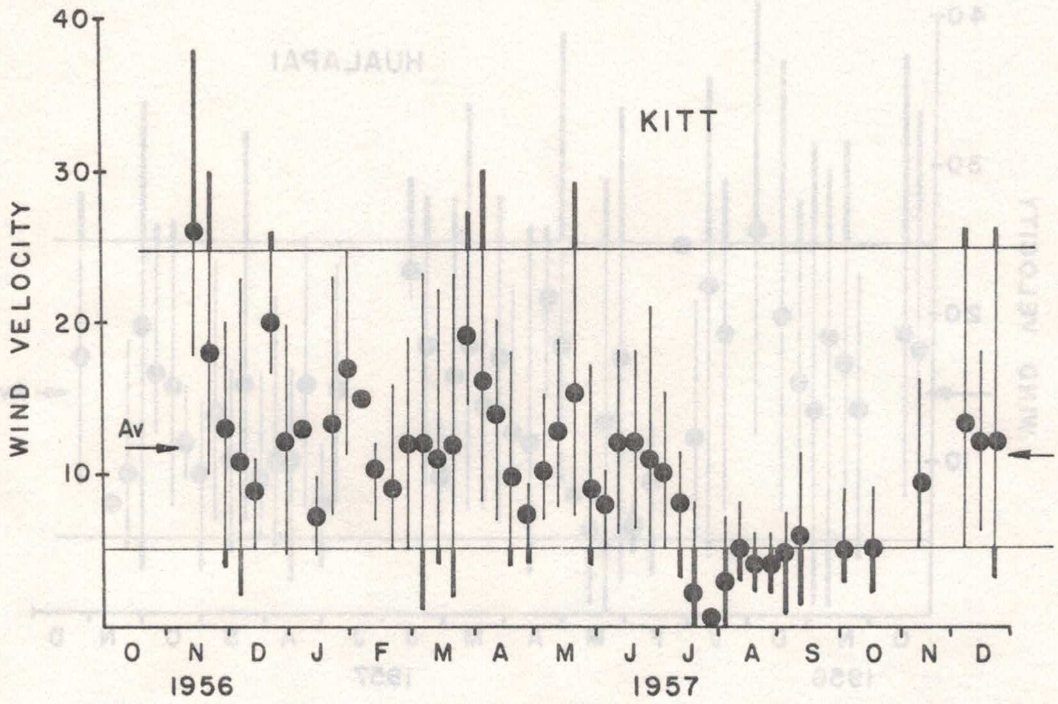
Photograph of the Hualapai Mountains from Kingman. The site range encompasses the elevated region at the center of the picture. The test site was developed on the peak at the right edge of the central region.

VII. WIND VELOCITIES

The 60-foot test towers were used to record wind velocity and temperatures as well as measure seeing. A record of the weekly average of the wind velocity is shown in Figs. 14-17. The length of the vertical line shows the range of the daily average during each week. The heavy portions of the line mark arbitrary limits of either too high a velocity for comfort (25 mph) or low enough to not require a dome for protection of a telescope (5 mph).

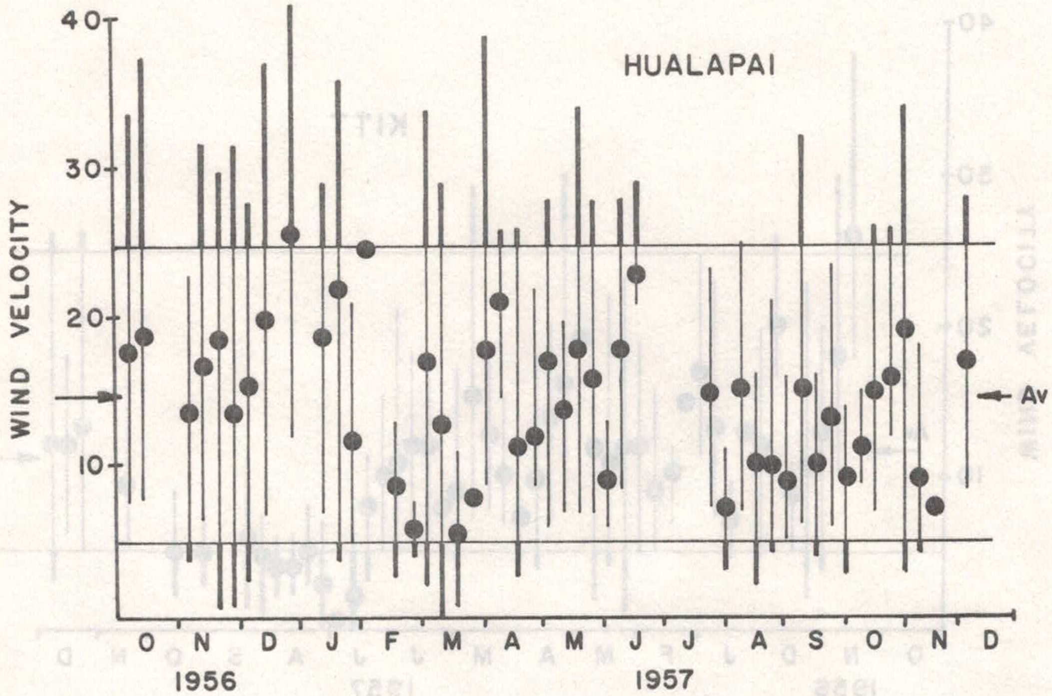
The records show Kitt to be the site with the lowest winds. Incidentally, a study of free air soundings made at Tucson show that a mountain like Kitt causes a wind acceleration amounting to 1.5 times the velocity of the free air because of aerodynamic effects.

The diagrams shown in Figs. 18-21 show the relative frequency distribution among velocity groups according to 3-minute averages read each hour. Fig. 22 shows the relative number of hours with winds under 10 mph as compared to Lick Observatory.



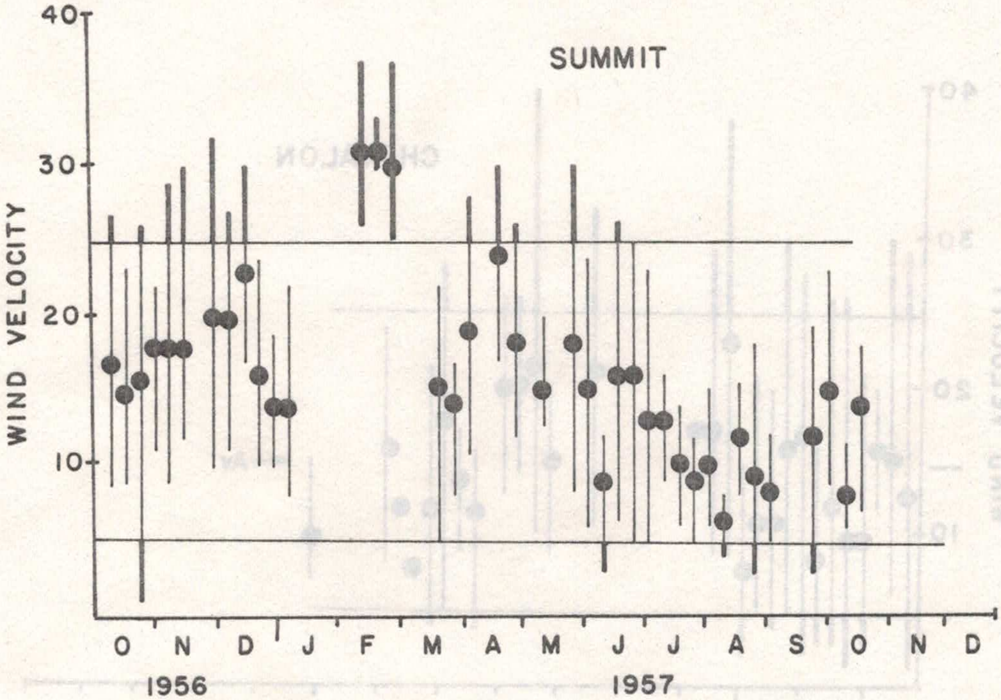
WEEKLY AVERAGE WIND VELOCITY AND DAILY-AVERAGE RANGE

FIG. 14



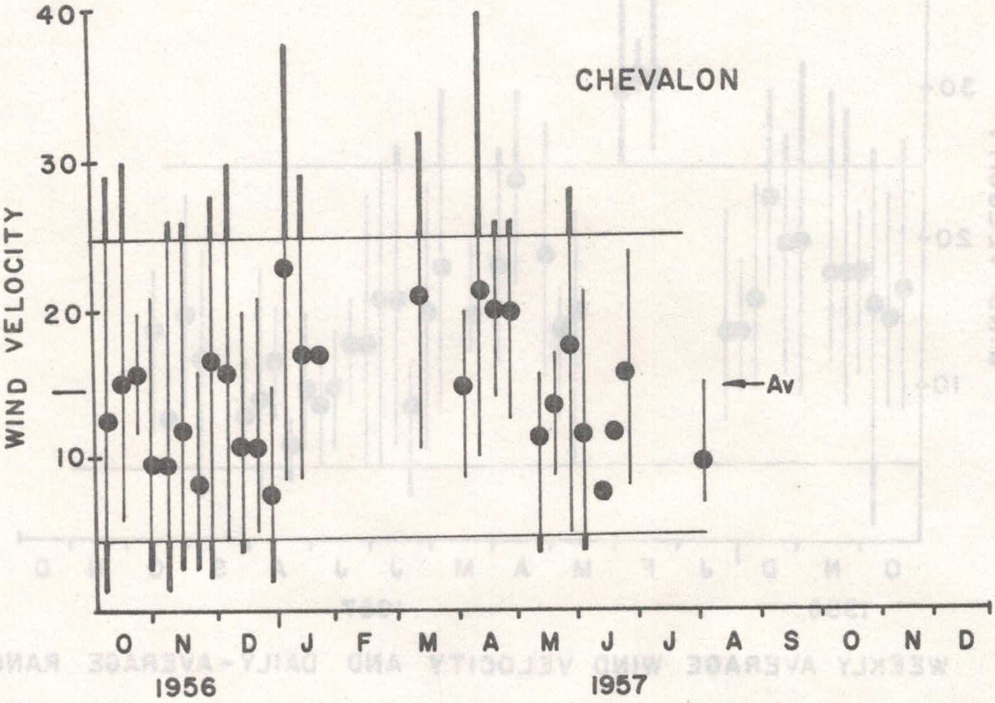
WEEKLY AVERAGE WIND VELOCITY AND DAILY-AVERAGE RANGE

FIG. 15



WEEKLY AVERAGE WIND VELOCITY AND DAILY-AVERAGE RANGE

FIG. 16



WEEKLY AVERAGE WIND VELOCITY AND DAILY - AVERAGE RANGE

FIG. 17

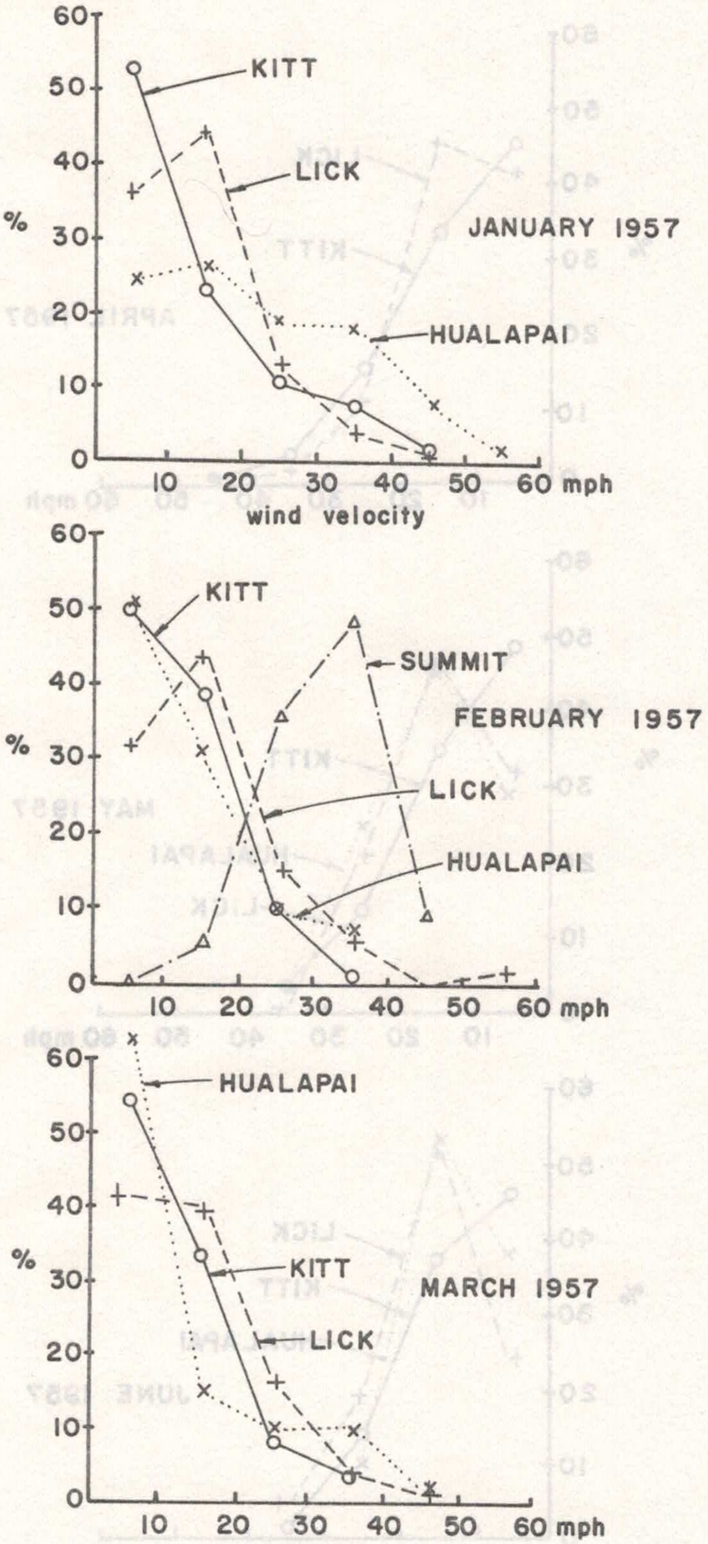

JANUARY 1957
KITT
LICK
HUALAPAI
%
60
50
40
30
20
10
0
10
20
30
40
50
60 mph
wind velocity
FEBRUARY 1957
KITT
SUMMIT
LICK
HUALAPAI
%
60
50
40
30
20
10
0
10
20
30
40
50
60 mph
MARCH 1957
HUALAPAI
KITT
LICK
%
60
50
40
30
20
10
0
10
20
30
40
50
60 mph

FIG. 18

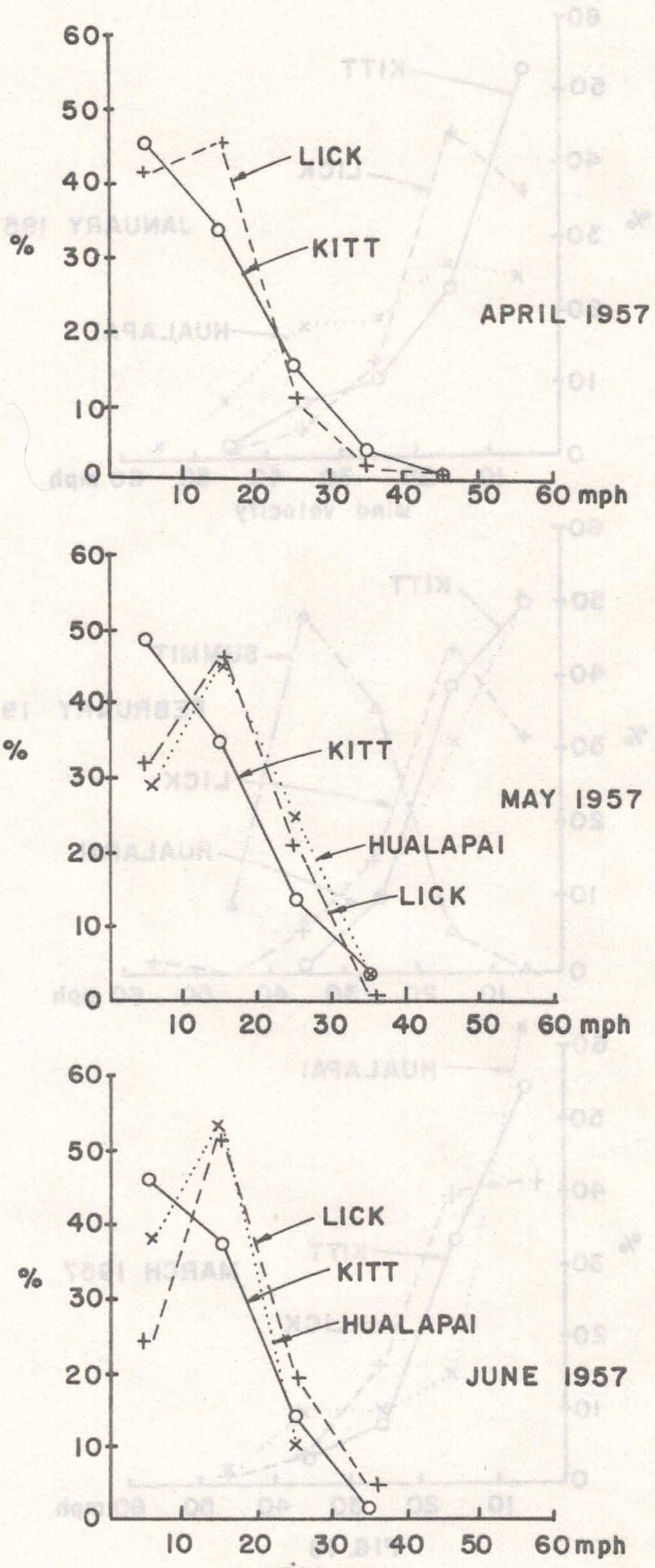

60
50
40
%
30
20
10
0
10
20
30
40
50
60 mph
LICK
KITT
APRIL 1957
60
50
40
%
30
20
10
0
10
20
30
40
50
60 mph
KITT
MAY 1957
HUALAPAI
LICK
60
50
40
%
30
20
10
0
10
20
30
40
50
60 mph
LICK
KITT
HUALAPAI
JUNE 1957

FIG. 19

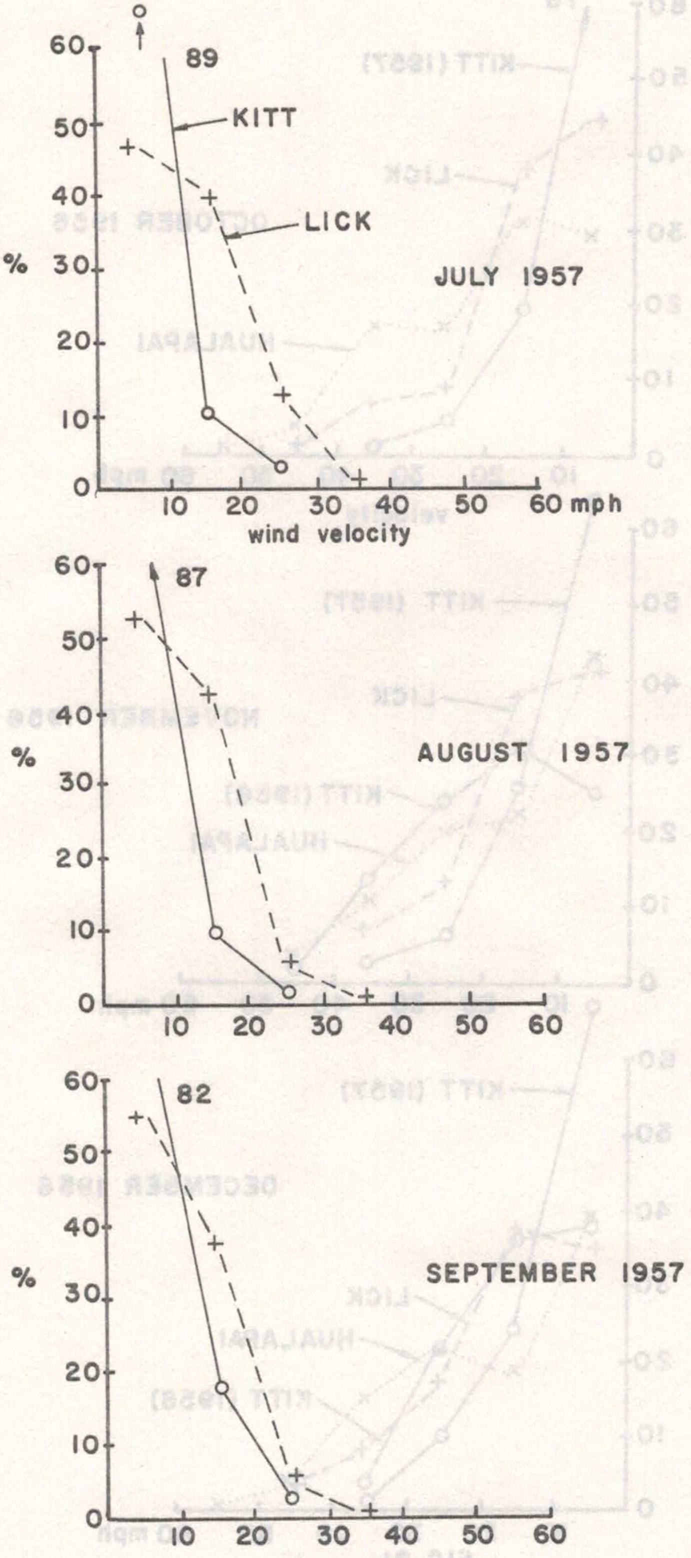

89
KITT
LICK
%
60
50
40
30
20
10
0
JULY 1957
10
20
30
40
50
60 mph
wind velocity
87
%
AUGUST 1957
82
%
SEPTEMBER 1957

FIG. 20

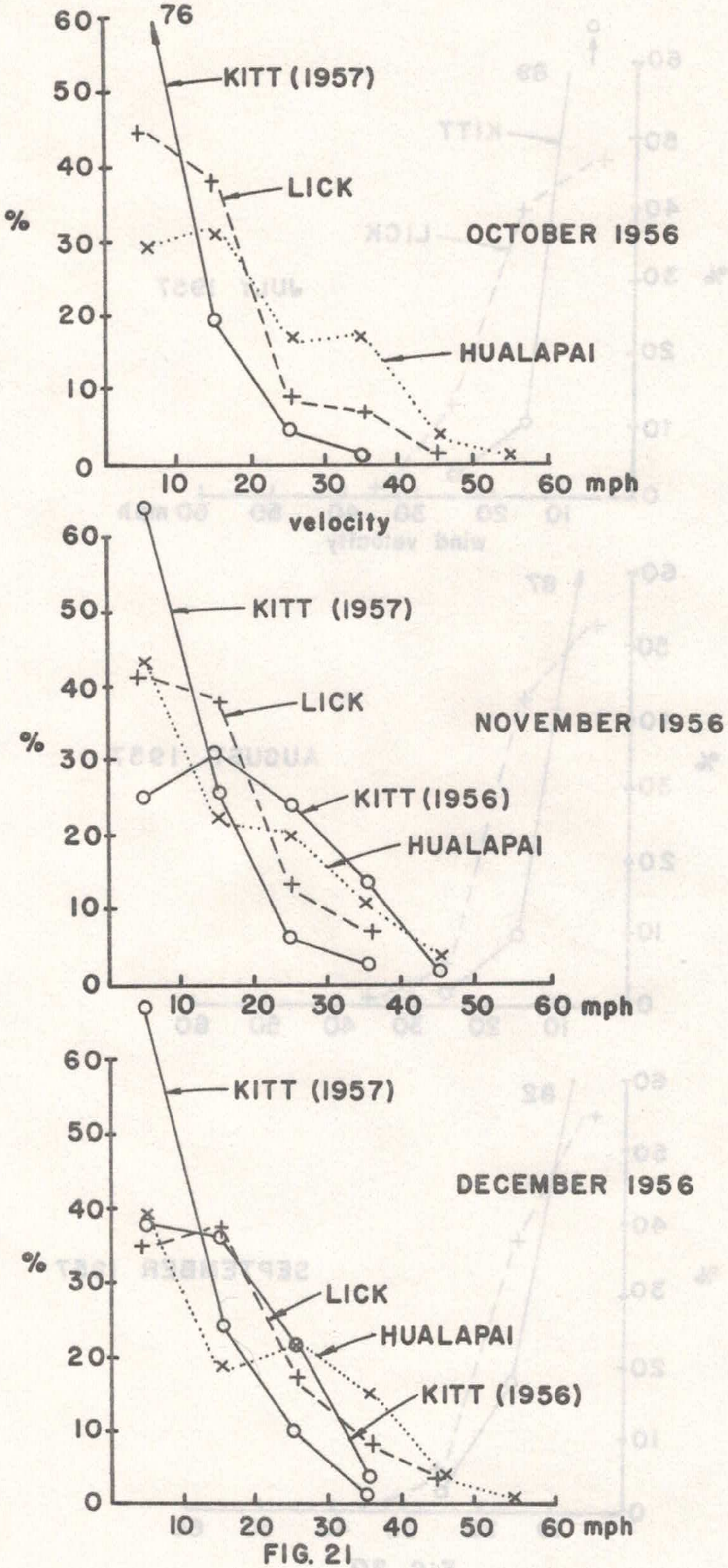
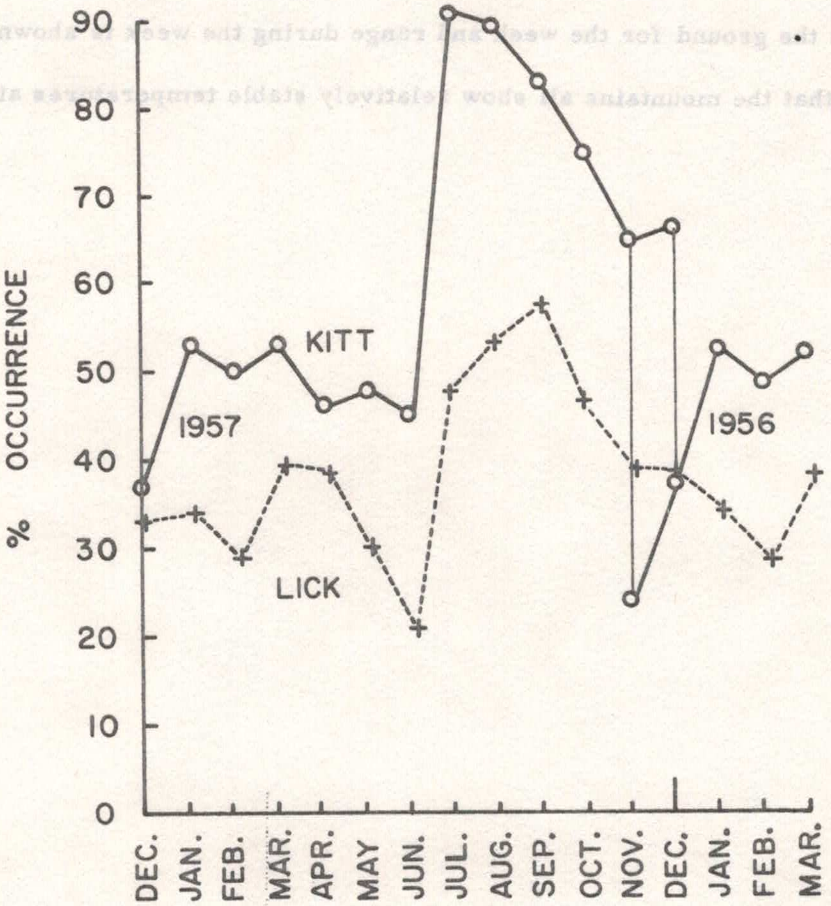

60
50
40
30
20
10
0
%
76
KITT (1957)
LICK
OCTOBER 1956
HUALAPAI
10
20
30
40
50
60 mph
velocity
60
50
40
30
20
10
0
%
KITT (1957)
LICK
NOVEMBER 1956
KITT (1956)
HUALAPAI
10
20
30
40
50
60 mph
60
50
40
30
20
10
0
%
KITT (1957)
DECEMBER 1956
LICK
HUALAPAI
KITT (1956)
10
20
30
40
50
60 mph

FIG. 21

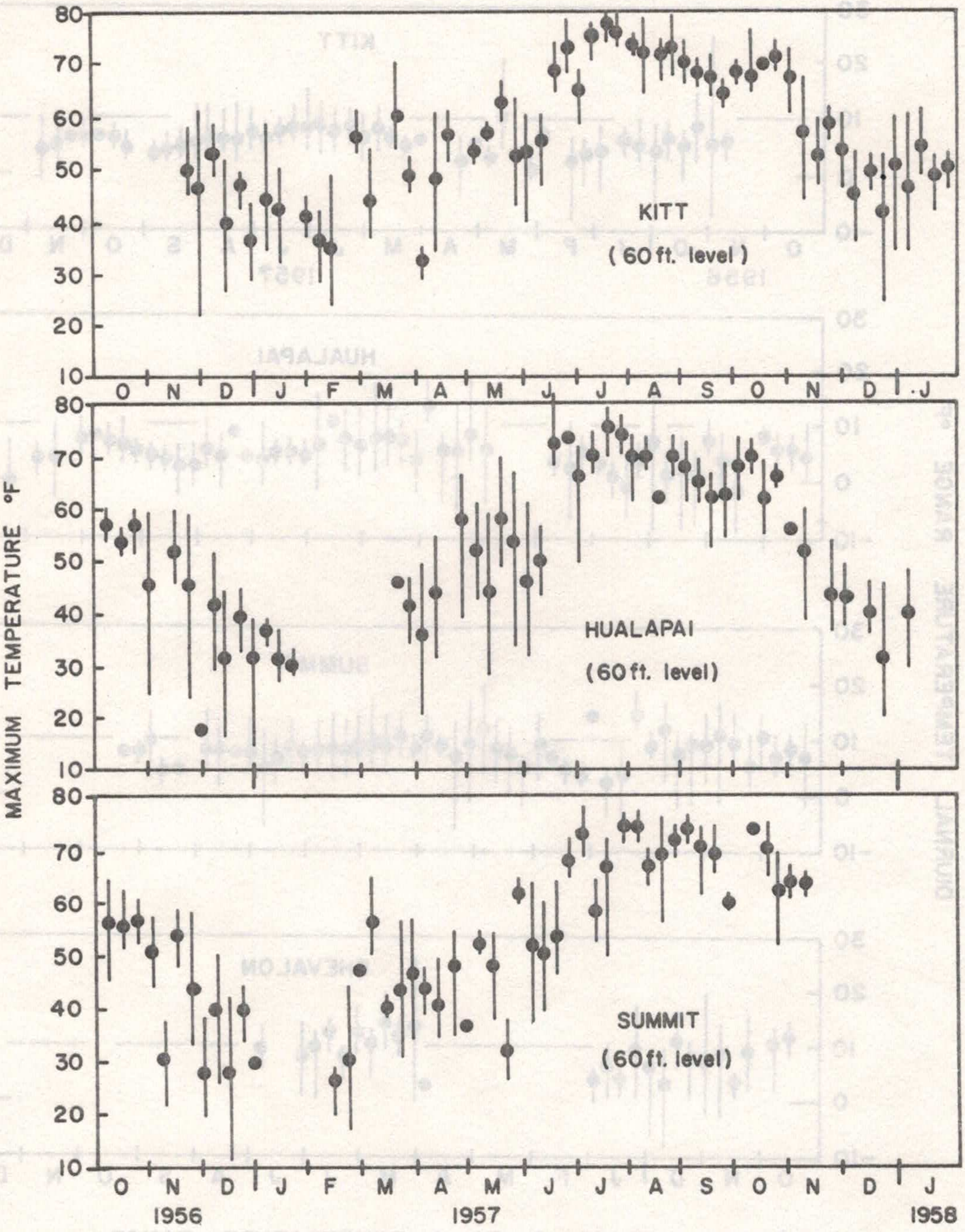


PERCENTAGE OF WINDS WITHIN 0-10mph GROUP

FIG. 22

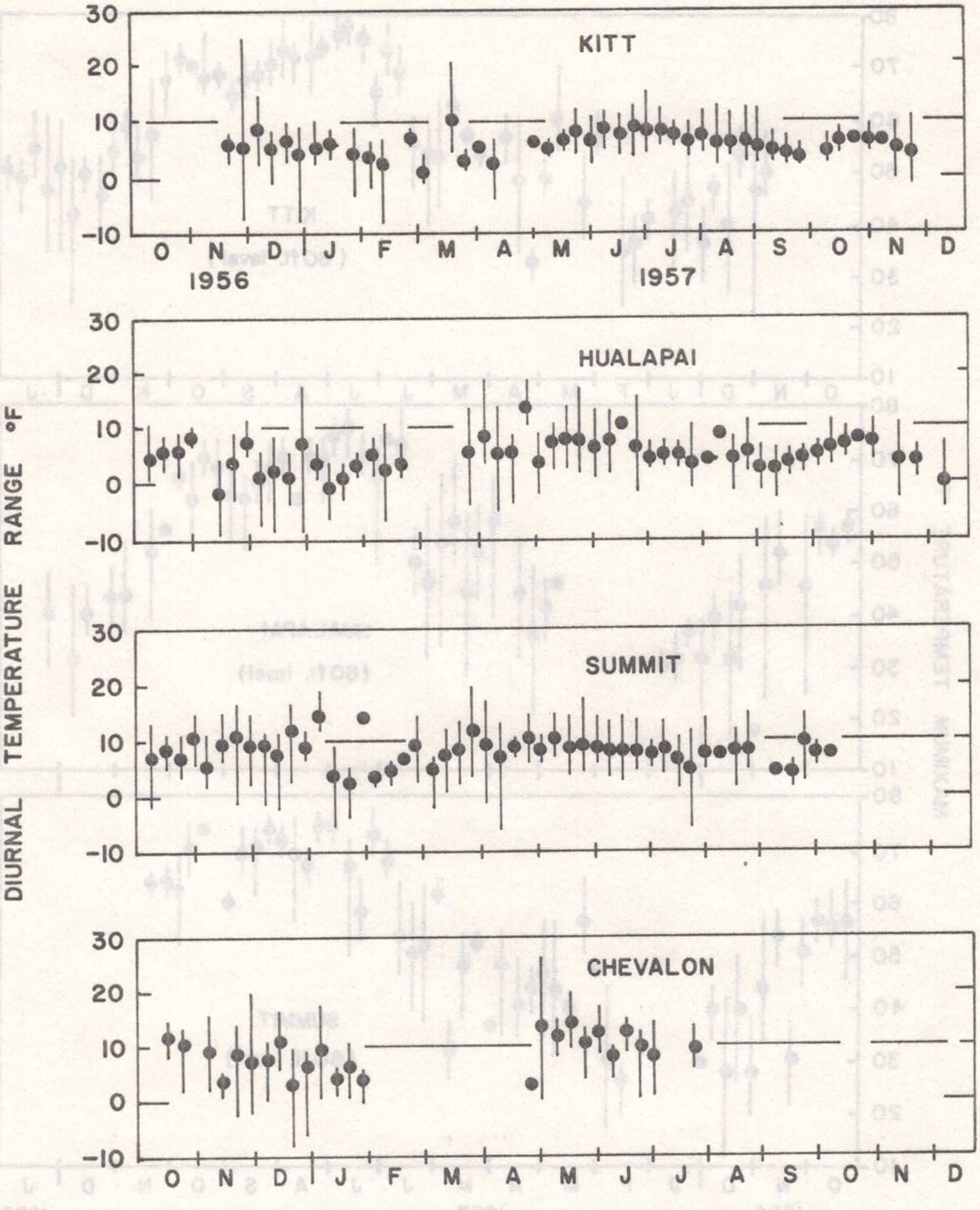
VIII. THERMAL PROFILES

The records of the weekly average temperature and daily average range during the week are shown in Fig. 23. The diurnal range average at 60 feet above the ground for the week and range during the week is shown in Fig. 24. Note that the mountains all show relatively stable temperatures at 60 feet.



WEEKLY AVERAGE TEMPERATURE & DAILY-AVERAGE RANGE

FIG. 23



WEEKLY AVERAGE & DAILY TEMPERATURE RANGE

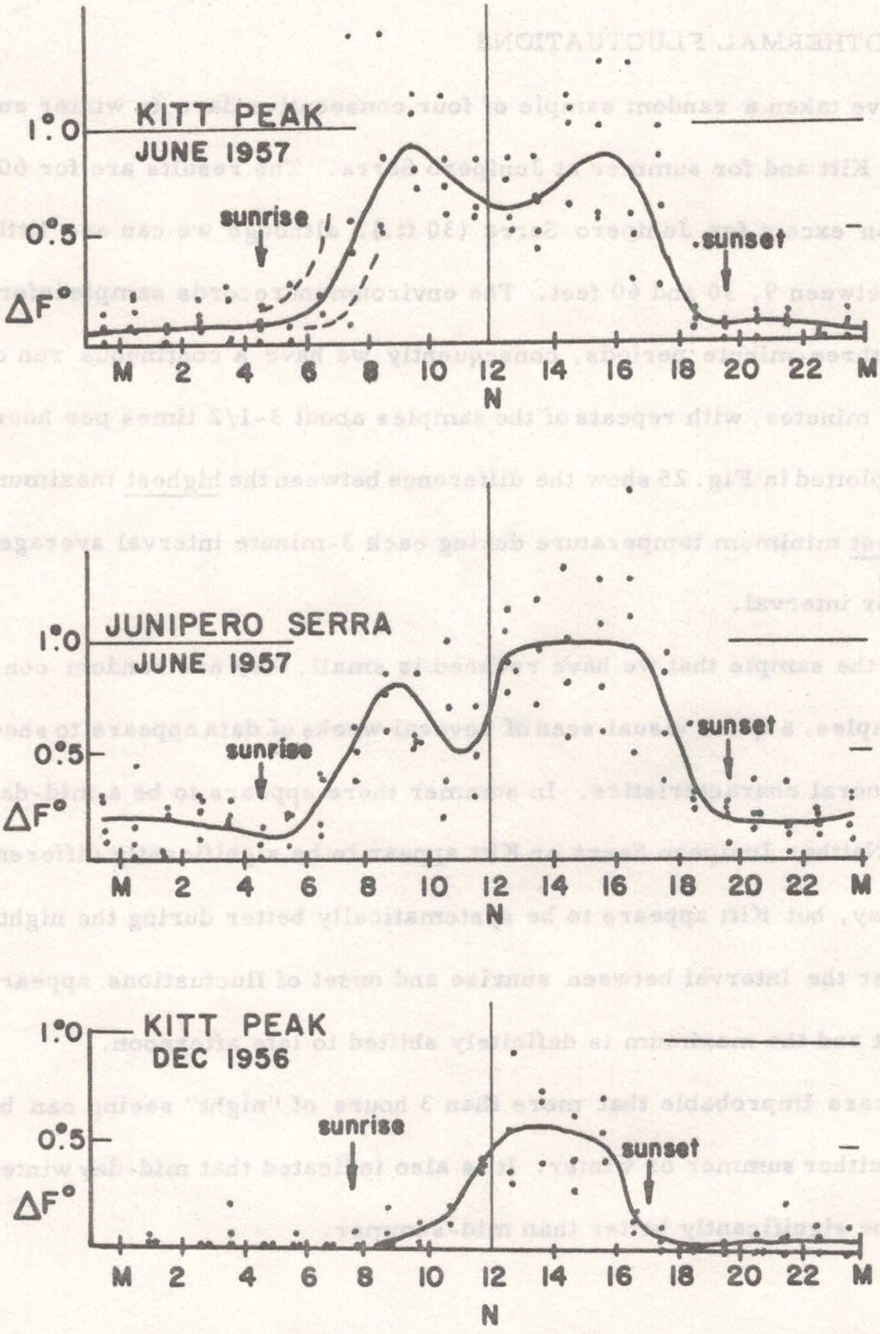
FIG. 24

IX. MICROTHERMAL FLUCTUATIONS

We have taken a random sample of four consecutive days in winter and summer for Kitt and for summer at Junipero Serra. The results are for 60-foot elevation except for Junipero Serra (30 ft.), although we can see little difference between 9, 30 and 60 feet. The environment records sample information for three-minute periods, consequently we have a continuous run of values for 3 minutes, with repeats of the samples about 3-1/2 times per hour. The figures plotted in Fig. 25 show the difference between the highest maximum and the lowest minimum temperature during each 3-minute interval averaged for each hour interval.

While the sample that we have reduced is small, they are random consecutive samples, a quick visual scan of several weeks of data appears to show the same general characteristics. In summer there appears to be a mid-day minimum. Neither Junipero Serra or Kitt appear to be significantly different during the day, but Kitt appears to be systematically better during the night. During winter the interval between sunrise and onset of fluctuations appears to be longest and the maximum is definitely shifted to late afternoon.

It appears improbable that more than 3 hours of "night" seeing can be expected in either summer or winter. It is also indicated that mid-day winter seeing will be significantly better than mid-summer.



DIURNAL MICROTHERMAL FLUCTUATIONS

$T_{max} - T_{min}$ (°F) for 3^m intervals

60 ft. above ground

FIG. 25

X. MICROTHERMAL SEEING

The fluctuations of temperature in the air at a level of 60 ft. means a density fluctuation. The microthermals must therefore contribute to the optical disturbance observed by a telescope. The local seeing conditions should therefore be indicated by the microthermal fluctuations.

We have examined the microthermal fluctuations observed at 60 feet above the ground for KITT and for SUMMIT and CHEVALON to see if the results have any bearing upon the relative seeing performance of these sites. The records of temperature have a duration of 3 minutes each time the temperature is sampled. We have measured the total range of the temperature during that interval of time. Since the result is given in terms of tenths of a scale division we have devised an arbitrary function to yield a "seeing" value ranging between 0 as a limit and 5 as a limit. When the fluctuation Δ is zero, the "seeing" scale reads 5. When Δ is 0.1 div. (0.14°F) then the "seeing" is 2.5. During the night the range of Δ is between 0 and 0.4 div.

The reduction of the microthermal records is tedious. The daily results shown in Fig. 27 do not represent all of the records, but only enough samples to indicate the results. Each temperature sample during the night is used to arrive at a value of $\bar{\Delta}$ that is the mean for the night. The relative frequency of each seeing factor is shown in Fig. 28. The results that KITT is the better site of these three. More significantly, Fig. 28 indicates that the poorness of the seeing at the northern sites could be due to local effects.

If we examine nature for a source of thermal differences in the ground layers of air we do not have far to look for the probable explanation of the poorer optical homogeniety of the northern sites. Both CHEVALON and

SUMMIT are low sites with respect to their surroundings, being 800 and 400 feet higher, respectively. KITT, on the other hand, is 4000 feet higher than its surroundings. We now feel that relative elevation above surroundings may be one of the important factors bearing upon the excellence of a site.

The ground temperature drops rapidly throughout the night. In level areas at high elevations the thermal drop may be 10 to 15 degrees during the night. This cold air drains into low pockets and forms local inversions. A strong inversion layer is the characteristic calm condition most of the year in the low areas of the Arizona Plateau. Staff at Lowell Observatory note that the temperature difference between Mars hill and Flagstaff can be 10-20 degrees. The low temperature at Flagstaff can be 10 to 15 degrees below zero with plus temperatures on the hill.

The inversion layer phenomenon is not present when there is wind. This fact does not mean that the ground does not chill at night, since the rate of energy loss by radiation is only dependent upon the opacity of the radiating surface and the infrared transparency of the air. The lack of inversion then must signify its disruption by mixing with the free air. In the presence of mixing of the radiation-chilled air and the free air we would expect both microthermal fluctuations and poor seeing. The presence of these fluctuations would be expected to some extent even on a high peak from cold air locally formed, but the great reservoirs of cold air present near the northern sites would be lacking. Fig. 28 shows the SUMMIT and CHEVALON have a significantly higher fluctuation average and correspondingly poorer microthermal seeing than does KITT.

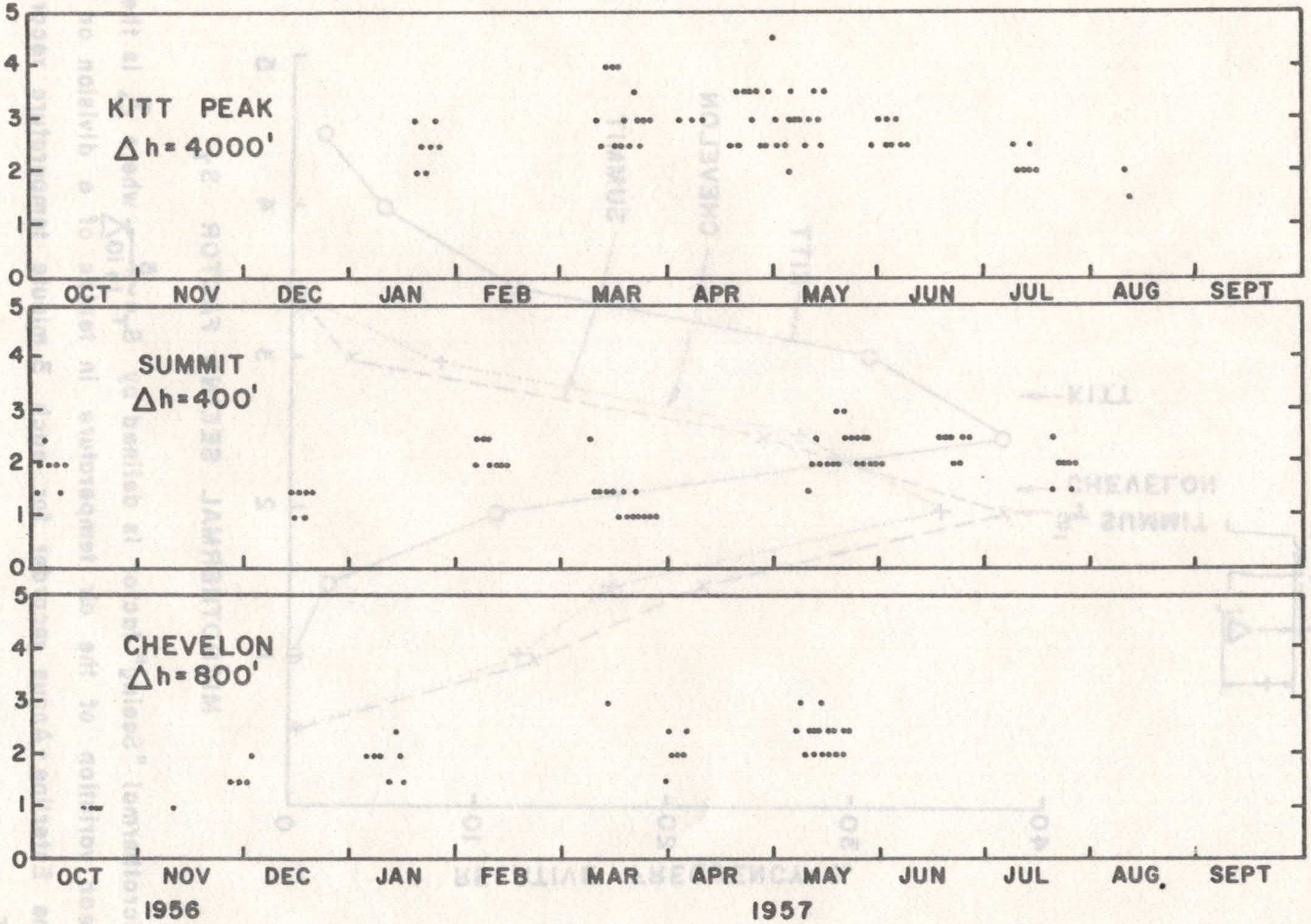
In actual telescope observations CHEVALON is poorer than SUMMIT. Since these sites are located in the same general air mass it is unlikely that the higher seeing is the difference. The difference must therefore be in the depth of the mixed layer since the amplitude of microthermal fluctuation should rank the sites in the reverse order. Again the answer can be found in the local configuration. The air stream crossing CHEVALON traverses many miles of downslope forest from the Mogollon Rim country. This downslope accelerates the wind, adiabotically warms the air, and could mix the air in large depth. The local reservoir of cold air at SUMMIT is smaller and the total depth of mixed air correspondingly less.

The annual distribution of microthermal fluctuations for KITT shows an interesting but logical feature. The "seeing" appears to be poorest in July and August. It is during these months that heavy afternoon showers occurred, so that the surface of the mountain was damp. The higher opacity of damp foliage and ground would encourage radiation cooling and a lower seeing index based upon microthermals.

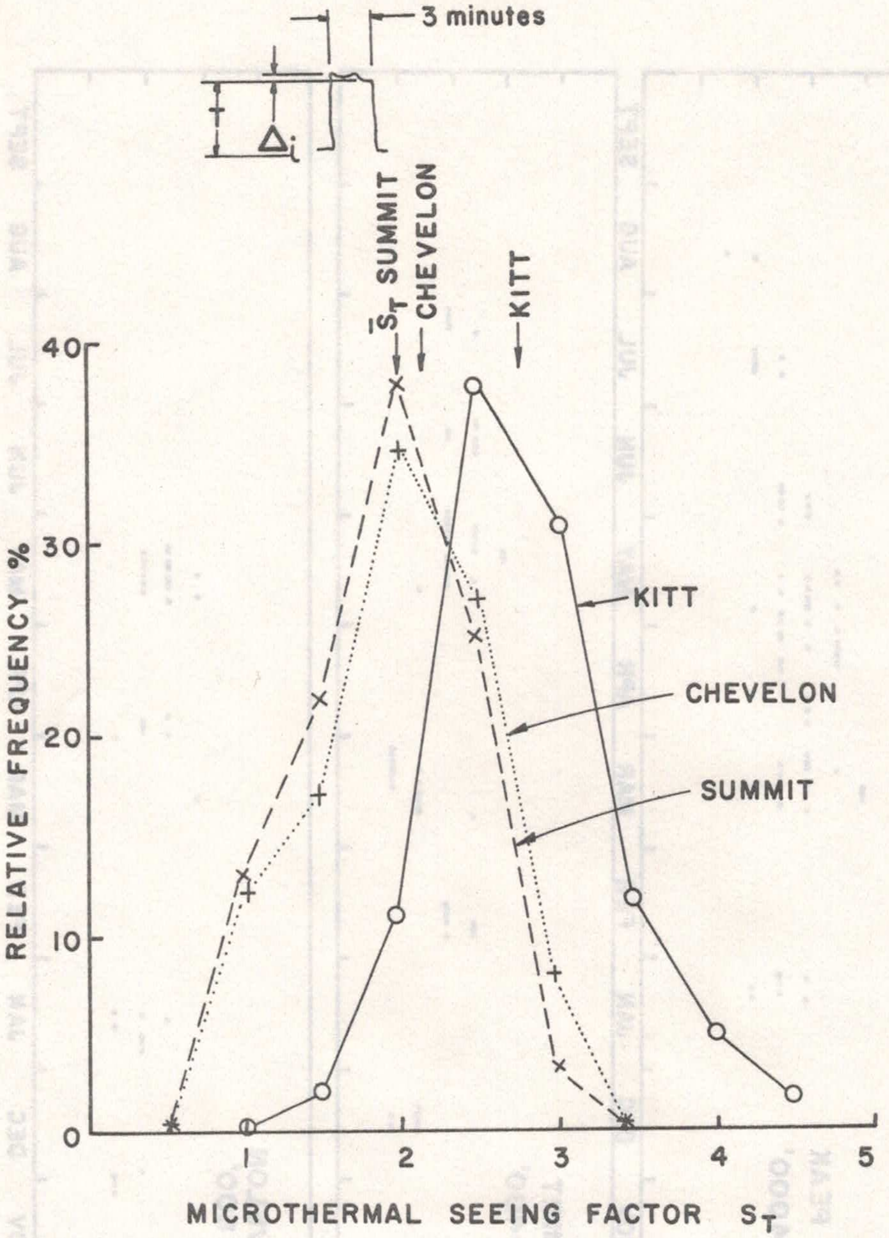
Figure 26

Photograph of Chevalon Butte from the North. Test tower is detectable near the right end of the summit area.

FIG. 27



ANNUAL DISTRIBUTION OF THE MICROTHERMAL "SEEING" FACTOR S_T.



Microthermal "Seeing" factor is defined by $S_T = \frac{5}{1+10\bar{\Delta}}$ where $\bar{\Delta}$ is the mean variation of the air temperature in tenths of a division on the Esterline-Angus recorder for each 3 minute temperature record. $\bar{\Delta}$ is the nightly average of the range of fluctuation Δ_i. One division is equal to 1.4°F.

FIG. 28

XI. OBSERVATORY RECORDS

Mt. Wilson records of the number of full and part nights provide a comparison for the evaluation of test sites. The experience of our group has been that the winter observing conditions in Arizona have been overrated. A comparison over long periods of time with Arizona observatories is not possible since there is no full-time observatory in operation. In lieu of this record we have taken Weather Bureau records where applicable.

Fig. 29 shows the number of totally clear 24-hour periods for four Arizona stations. The number during the winter of 1957 was very low. For comparison we have plotted the 9-year average for Tucson which does not show a marked effect during winter.

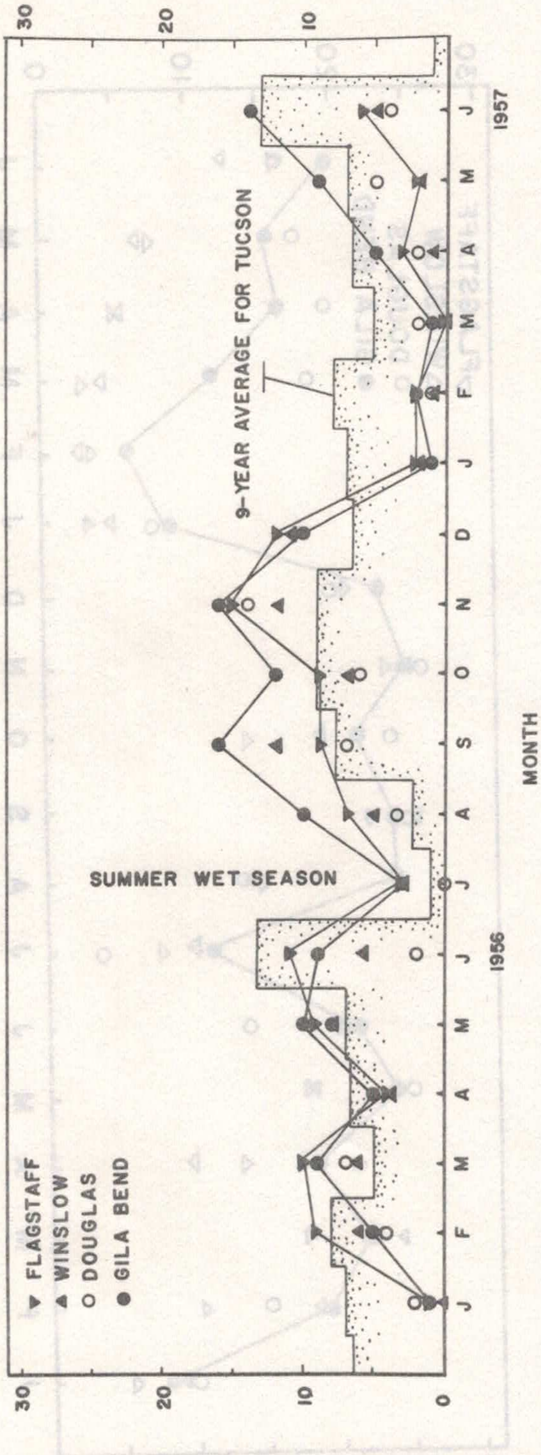
Fig. 30 shows the number of totally clear nights for 1956-57, as late as records are on hand. The two southern stations, Gila Bend and Douglas show a better winter record.

Fig. 31 shows a comparison of the Gila Bend record for 1956-57 with the 9-year average for Tucson. According to this comparison the winter of 1956-57 was abnormally cloudy.

Fig. 32 compares the Tucson 9-year average with the Mt. Wilson 10-year averages. In terms of full nights, the Tucson record is some better in winter. If we include part nights, then the Mt. Wilson record is substantially identical to the Tucson record. Since the Tucson record includes up to 0.2 cloudiness, the Tucson record may be closer to the Mt. Wilson full plus part night record rather than the full record.

We feel that there is some question whether an Arizona site will offer any more clear nights in winter than would a Pacific Coast site. In summer, an Arizona site is definitely inferior to a Pacific Coast site due to the summer rainy season.

With regard to general cloudiness considerations Fig. 33 shows the U.S. Department of Agriculture annual number of clear days in the Southwest.



NUMBER OF TOTALLY CLEAR 24 HR PERIODS

(< 0.1 CLOUDY)

FIG. 29

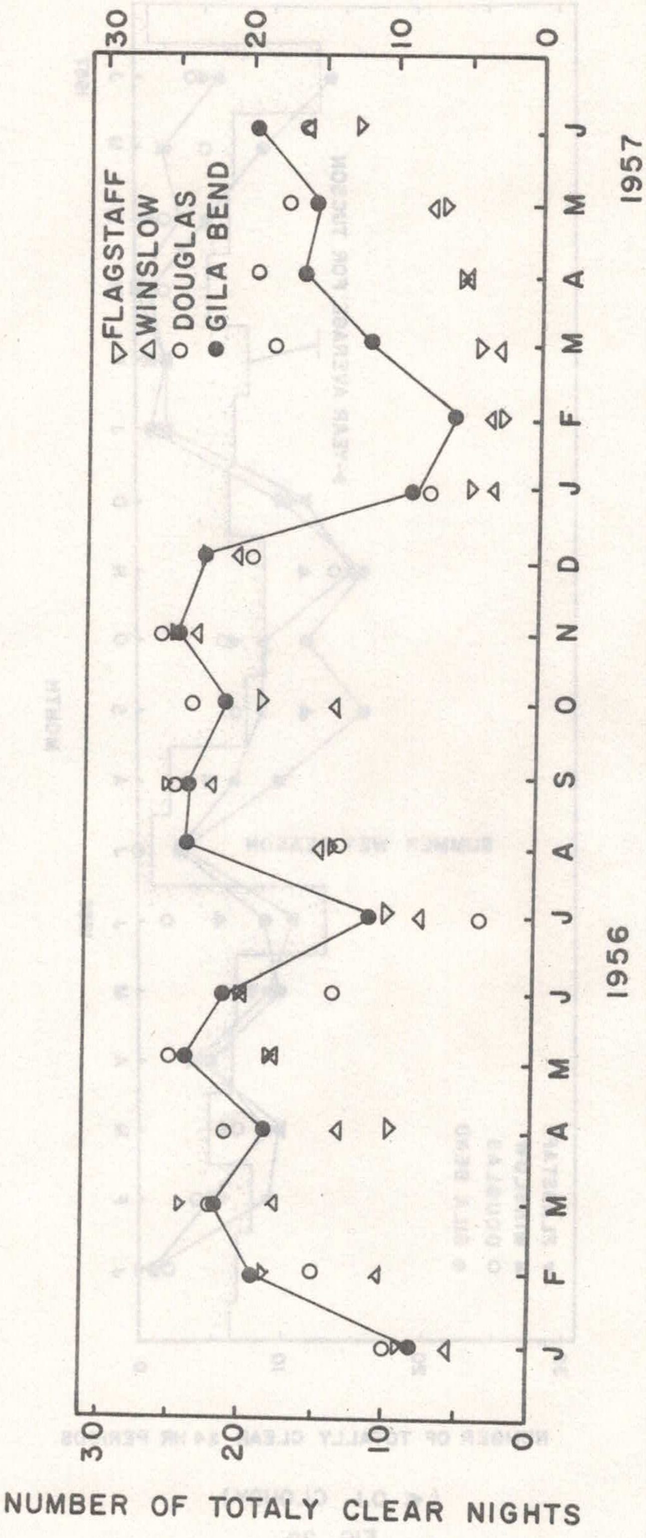
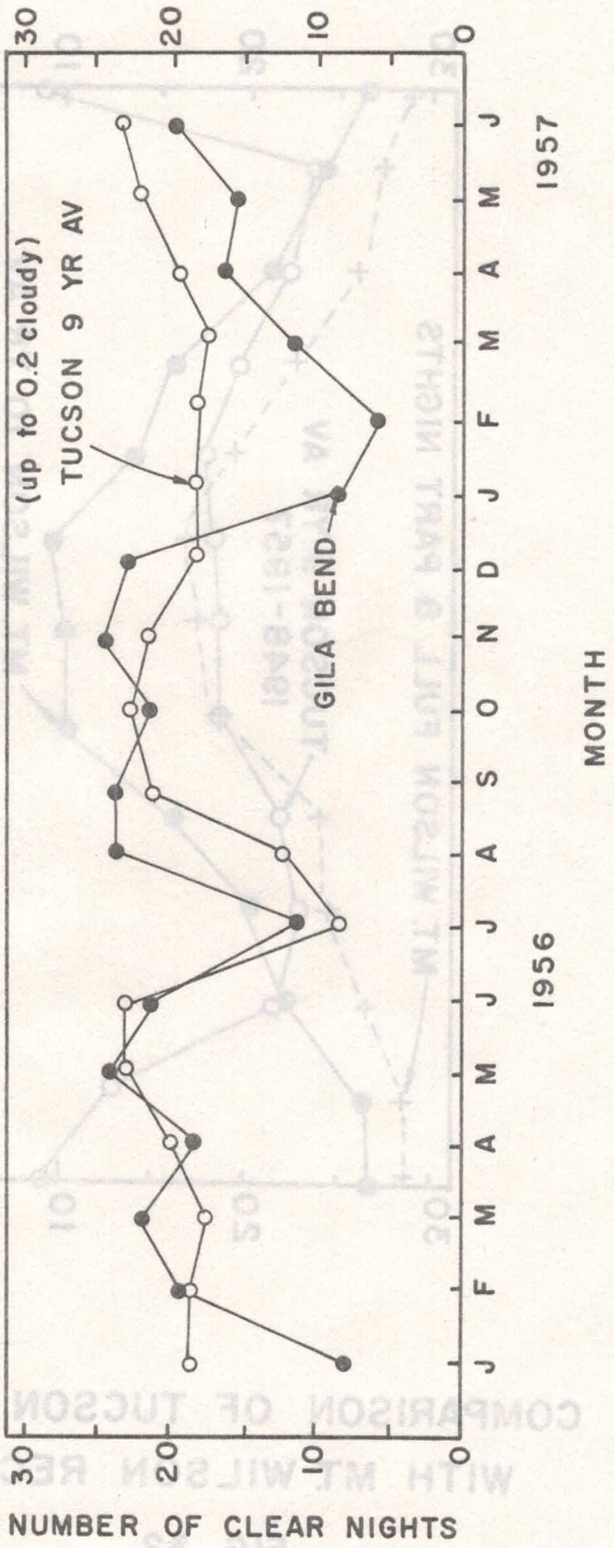
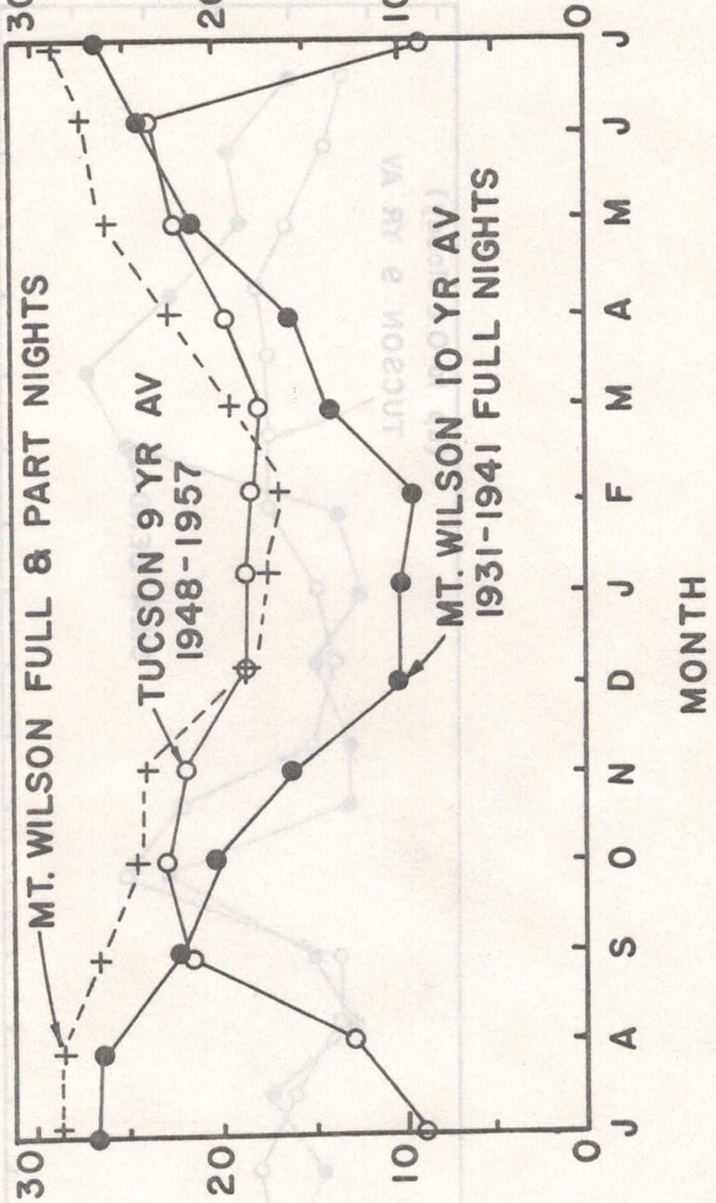

▽ FLAGSTAFF
△ WINSLOW
○ DOUGLAS
● GILA BEND
30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
1956
1957
MONTH
NUMBER OF TOTALY CLEAR NIGHTS

FIG. 30



30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
1956
1957
MONTH
TUCSON 9 YR AV
(up to 0.2 cloudy)
GILA BEND
NUMBER OF CLEAR NIGHTS

FIG. 31



COMPARISON OF TUCSON NIGHTS WITH MT. WILSON RECORDS

FIG. 32

OBSERVING RECORD MOUNT WILSON

AVERAGE

July 1, 1931 - June 30, 1941

60-Inch	Whole Nights	Part Nights	None
January	11.4	8.8	10.8
February	9.6	7.1	11.6
March	13.7	8.2	9.1
April	15.9	7.4	6.7
May	21.2	6.3	3.5
June	23.1	4.5	2.4
July	26.7	2.9	1.4
August	26.2	3.6	1.2
September	22.0	4.8	3.2
October	20.0	5.8	5.2
November	16.1	8.5	5.4
December	11.5	8.8	10.7
TOTAL	217.	77.	71.

AVERAGE

July 1, 1912 - June 30, 1941

60-Inch	204	85	75

AVERAGE

July 1, 1946 - June 30, 1956

	Whole and Part Nights	None
60-Inch	276	90
100-Inch	292	73

Lick Observatory
36-inch Observing Hours

	1950	1951	1952	1953	1954	1955	1956	1957	means
Jan.	29	121	7	117	100	108	46	52	75
Feb.	117	72	46	203	194	128	131	58	127
Mar.	32	73	76	164	110	176	165	28	114
Apr.	135	102	126	128	149	(66*)	106	95	124
May	177	150	206	131	168	(108*)	112	84	157
June	159	174	136	159	116	(114*)	170	190	152
July	227	174	210	232	212	182	183	227	203
Aug.	244	150	234	213	196	235	226	223	214
Sept.	199	184	225	234	246	231	230	228	221
Oct.	175	184	241	211	246	170	144	148	196
Nov.	162	95	216	114	182	(96*)	236		168
Dec.	146	62	69	152	112	75	211		118
	1802	1541	1792	2058	2031	(---*)	1960		

*Some mechanical failure cut observing hours. Not used in averages.

AVERAGE YEARLY HOURS: 1864

Reasons for not observing:
- clouds
- wind
- high humidity (over 90 percent)
- poor seeing (for double stars)

Lick Observatory

Nights on which Observing was Done for 1 hour or more (36-inch)

	1950	1951	1952	1953	1954	1955	1956	1957	means
Jan.	4	14	3	16	13	16	7	13	10
Feb.	18	11	10	22	19	20	17	8	17
Mar.	6	16	12	21	13	22	22	8	16
Apr.	20	15	16	16	20	(9)*	17	15	17
May	27	23	27	21	27	(20)*	20	13	24
June	24	28	21	25	19	(21)*	25	28	24
July	30	28	29	30	29	29	26	31	29
Aug.	30	24	30	26	28	29	31	30	28
Sept.	24	23	29	28	29	29	28	27	27
Oct.	19	24	27	24	28	24	20	20	24
Nov.	19	14	23	12	20	(16)*	28		19
Dec.	17	8	9	20	15	9	24		15
	238	228	236	261	260	(---)*	265		

*Some mechanical failure cut observing hours, not used in averages.

AVERAGE NUMBER OF NIGHTS ON WHICH THE 36-inch WAS USED 1 HOUR OR MORE: 248

Lick Observatory

Nights on which the 36-inch was used all night

	1950	1951	1952	1953	1954	1955	1956	1957	means
Jan.	0	2	0	2	5	2	0	0	1.6
Feb.	3	2	0	14	13	5	5	4	6.0
Mar.	1	2	2	8	7	9	8	0	5.3
Apr.	4	4	10	10	10	(4)*	4	4	7.0
May	10	10	18	6	14	(6)*	6	7	10.7
June	11	13	9	11	9	(8)*	20	19	12.2
July	22	12	21	27	25	19	20	23	20.9
Aug.	22	7	21	21	17	23	19	21	18.6
Sept.	14	12	16	18	21	15	17	17	16.1
Oct.	14	11	17	15	16	9	7	7	12.7
Nov.	10	3	12	7	13	(2)*	10		9.2
Dec.	6	3	4	6	5	3	8		5.0
	117	81	130	145	155	(---)*	124		

*Some mechanical failure cut observing hours. Not used in averages.

AVERAGE NUMBER OF NIGHTS ON WHICH THE 36-inch WAS USED ALL NIGHT: 125

XII. VAPOR TRAILS AND CIRRUS

Vapor trails, or more properly contrails, constitute one of the chief nuisances in the entire Southwestern U.S. In geographical distribution contrail formation does not show as marked a variation as casual observations would indicate. The chief reason for the frequency of this type of event in the SW is that the high frequency of otherwise clear skies increases the probability of observation of contrails.

The upper air conditions during passages of high-pressure regions show progressive a transition from stable to unstable conditions. During the initial stable phases high altitude aircraft produce only temporary vapor trails. As the degree of saturation increases the vapor trails become stable contrails. Often the contrail acts as a catalyst to cover large areas of the sky with Cirro-stratus.

Although contrails precede the natural influx of cirrus formations, there are often several days of otherwise photometric skies that could have been used in the absence of contrails.

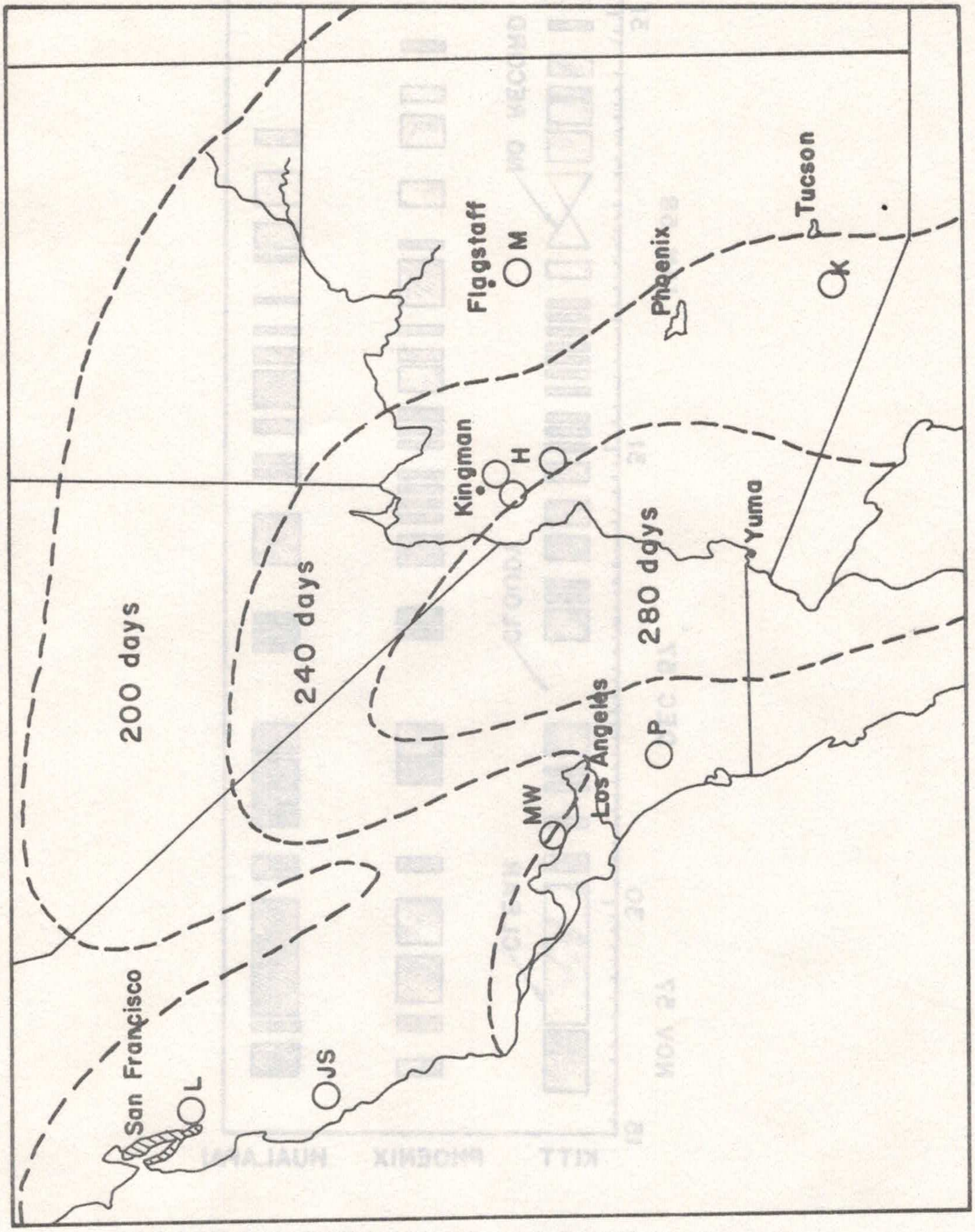
The problem of contrails is one that will only increase in severity with time. The solution to this problem apparently lies in avoiding it as much as geographical limitations will allow. In other words, a site on the peripheral extremeties of the U.S. would tend to have a lower frequency of contrail events.

If we consider our sites in relation to the above factors there is a clear division of the relative merits. All of the Northern Arizona sites lie along the heavily travelled transcontinental radio beacon routes. At present the amount of jet traffic is limited to military flights; however, the impending inauguration of civilian jet flights would indicate a potential hazard to these sites.

Kitt Peak stands relatively clear of local interference from jets since it is south of all jet traffic because of its proximity to the Mexican border.

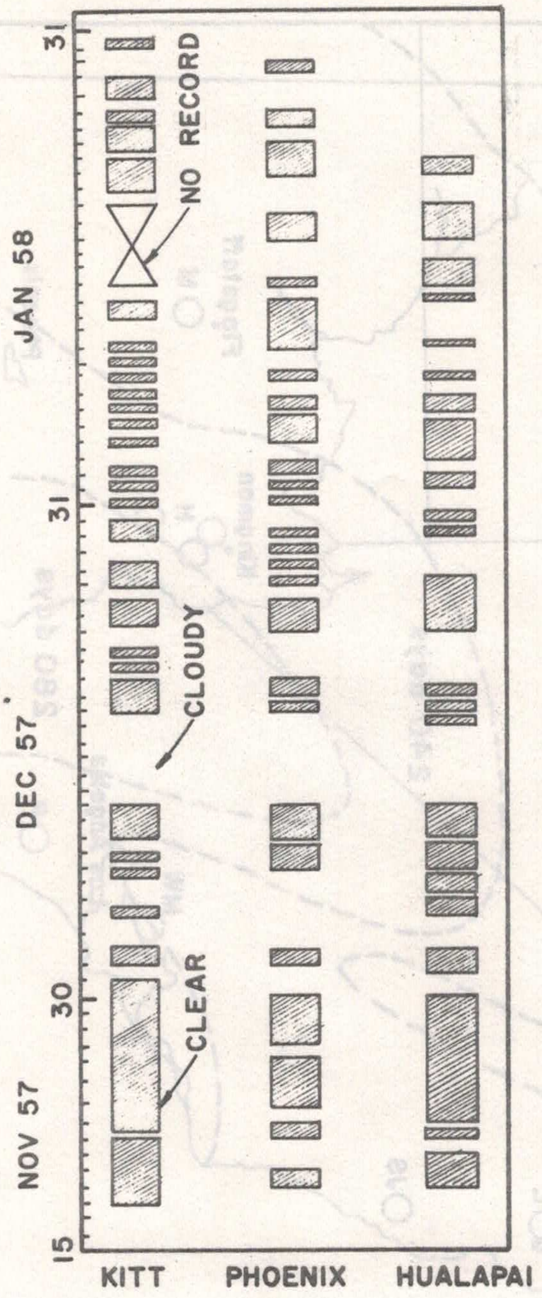
Freedom from contrail formation in the vicinity does not necessarily mean freedom from the cirrostratus resulting from contrails elsewhere. Cirrus cloud types are rather stable. The lifetimes are such that contrails formed over the heavily travelled skies over Southern California could affect Arizona sites. Location of contrails at any point along the upper air trajectory should be considered. When we examine the probability of a given trajectory (Sec. XIII) we find that Kitt can also be subject to contrail cirrostratus from Southern California, but not as frequently as the Northern Arizona sites would be.

Fig. 34 shows the distribution of cirrus and vapor-trail free days for the Kitt and Hualapai sites this winter. There is apparently no great difference in the acceptability of these two sites based upon this criterion.



ANNUAL NUMBER OF CLEAR DAYS
(U.S. DEPT. OF AGRICULTURE)

FIG. 33



DAYTIME AUTOMATIC PHOTOMETRIC RECORDS.

FIG. 34

XIII. JET STREAM

There is a popular misconception that Arizona is south of the winter jet stream. This myth has also been expounded for Pic du Midi. In reality the mean position of the winter jet stream is across the tip of lower California. Secondary flow amplifications do occur across the U.S. during the winter, but the principle jet is almost entirely in Mexico.

In summer, the mean position of the jet stream is the Canadian border. As a consequence, the jet stream crosses the U.S. frequently during the fall and spring.

The jet stream has cirrus associated with it. The belt of "fair weather" cirrus lies in a band 50 to 500 miles wide and principally on the southern side of the jet stream. Clear weather generally lies on the north side of the jet stream.

XIV. AIR TRAJECTORIES

The path traversed by an element of air that passes over a site is of considerable interest. Both pollutants and clouds can cause observing difficulties at an observatory. The location of a large area of air pollution to the west of Arizona makes this question of particular importance. The effect of contrails formed over populated areas on the west coast also depends upon the air trajectories.

The exact determination of an air trajectory requires upper air data at close time intervals. While radiosonde data are available for a number of southwestern stations several times each day, access and utilization problems prohibit an exact analysis. We have at our immediate disposal the daily charts showing the winds at the 500 millibar pressure level (about 15,000 ft.). These charts readily show the flow lines of the wind field. In the following charts we have plotted the points where these flow lines cross the borders of the continent for the configurations passing over Kitt Peak.

The charts as actually shown are not true air trajectories. If the flow velocity were rapid compared to the rate that the air flow pattern changes, then these diagrams would be close to air trajectories. In reality the operation of pressure fields causes the flow pattern to change considerably before an element can travel over a long flow line to reach Kitt Peak. The net effect is to compress the pattern of points, but the centers of gravity remain as shown.

The winter flow pattern shown in Fig. 35 shows points distributed from Alaska to lower California. A concentration point is near San Diego with a lesser concentration near San Francisco. In other words, clouds or any disturbance injected into the 500 mb level anywhere on the west coast can affect Kitt.

An examination of the air trajectories with respect to clear or cloudy skies at Kitt shows a definite trend. On the first day of clear weather the flow is from the north. Each succeeding day of clear finds the entry point at a lower latitude. This lowering of the entry point also signals a rise in the relative humidity of the air aloft and the incipient formation of contrails and cirrus. When the entry point reaches a point below the mean position the sky is usually overcast in some degree. The velocity of the air aloft also shows a steady decrease in intensity. The onset of cloudiness usually accompanies rather stagnant air aloft. We incidentally note better than average seeing when stars can be seen under such conditions. With the passage of a frontal system the velocity of the air aloft abruptly increases and the entry point re-appears at northern latitudes.

The example of the progression of air trajectories with time during winter is shown in Fig. 38. In each case eight clear days followed each cloudy period, although cirrus and contrails caused deterioration of the sky conditions two or three days prior to the onset of cloudiness on the ninth day.

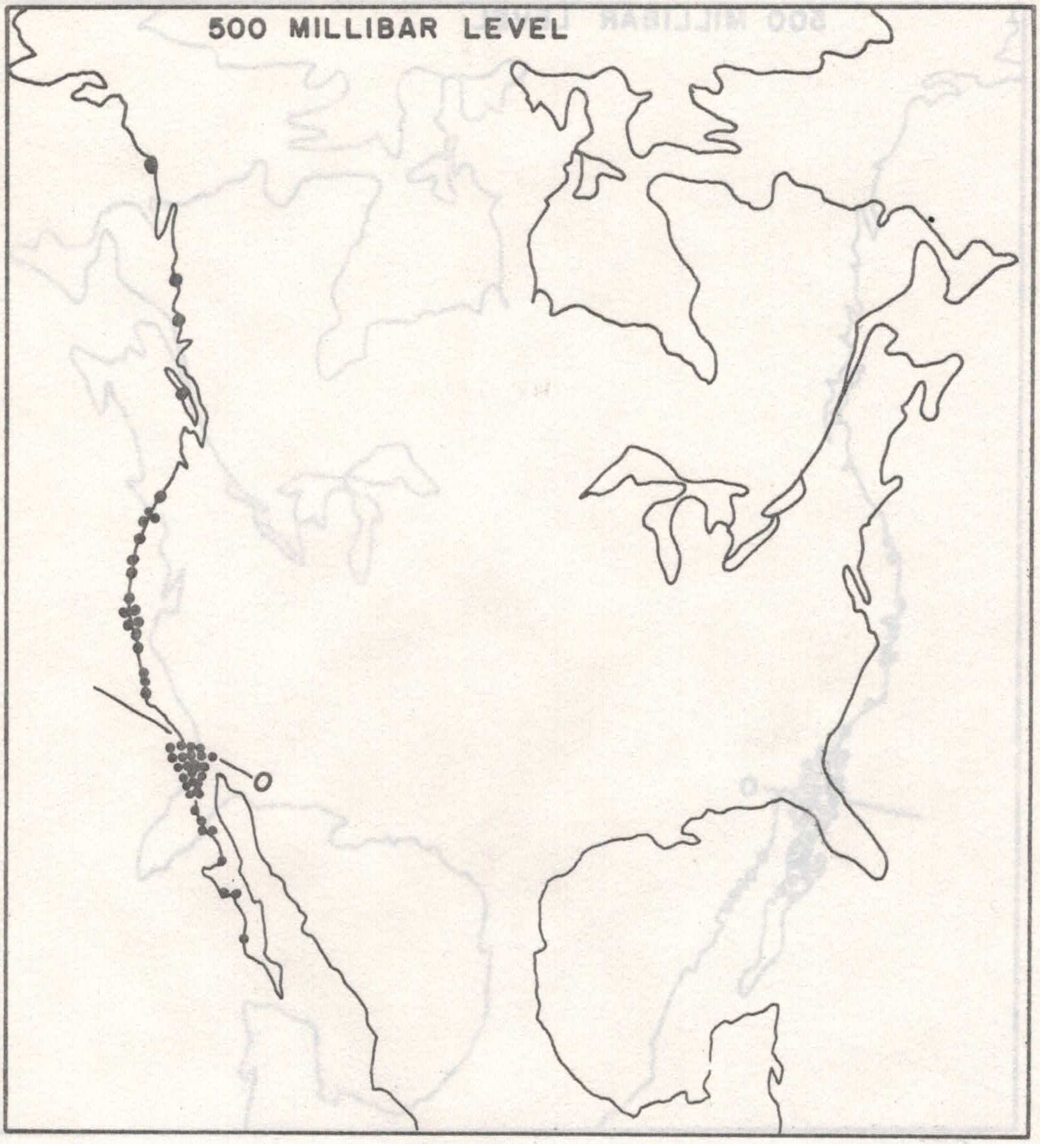
The map of air trajectories for late spring shows a concentration of entry points near San Diego and only a few farther north. This period is characterized by low air velocities aloft, about 10 to 20 knot winds compared to 20 to 150 knots in the winter period. The amount of freedom from clouds is highest during this period and cirrus is infrequent. The seeing appears to be generally fine during these months.

The map of air trajectories for late summer shows a spread of entry points far to the south. Some entry points even occur on the Gulf of Mexico perimeter. These months are the wet season in Arizona when moist air travels at low levels from the Gulf of Mexico over Northern Mexico. There are few influxes of air from the North Pacific. Clear skies now result from the influx of air from the region of San Diego whereas in winter an influx of air from this region usually signals cloudy weather.

While the dispersion of air trajectories is large it would appear that Kitt will be less bothered by contrails originating over the Pacific Coast north of San Diego than would a site on latitude 35.

Low level air trajectories are those chiefly concerned with the distribution of pollutants. In this regard Hualapai is most vulnerable. The pall of Los Angeles smog is frequently clearly visible centered at the west point of the horizon. We have suspected this explanation for noticeable palls northwest of Kitt, but the number of instances is small. The occurrence of forest fires in Southern California has given the opportunity to verify these observations. In each case the smoke has drifted in the belt between Phoenix and Las Vegas.

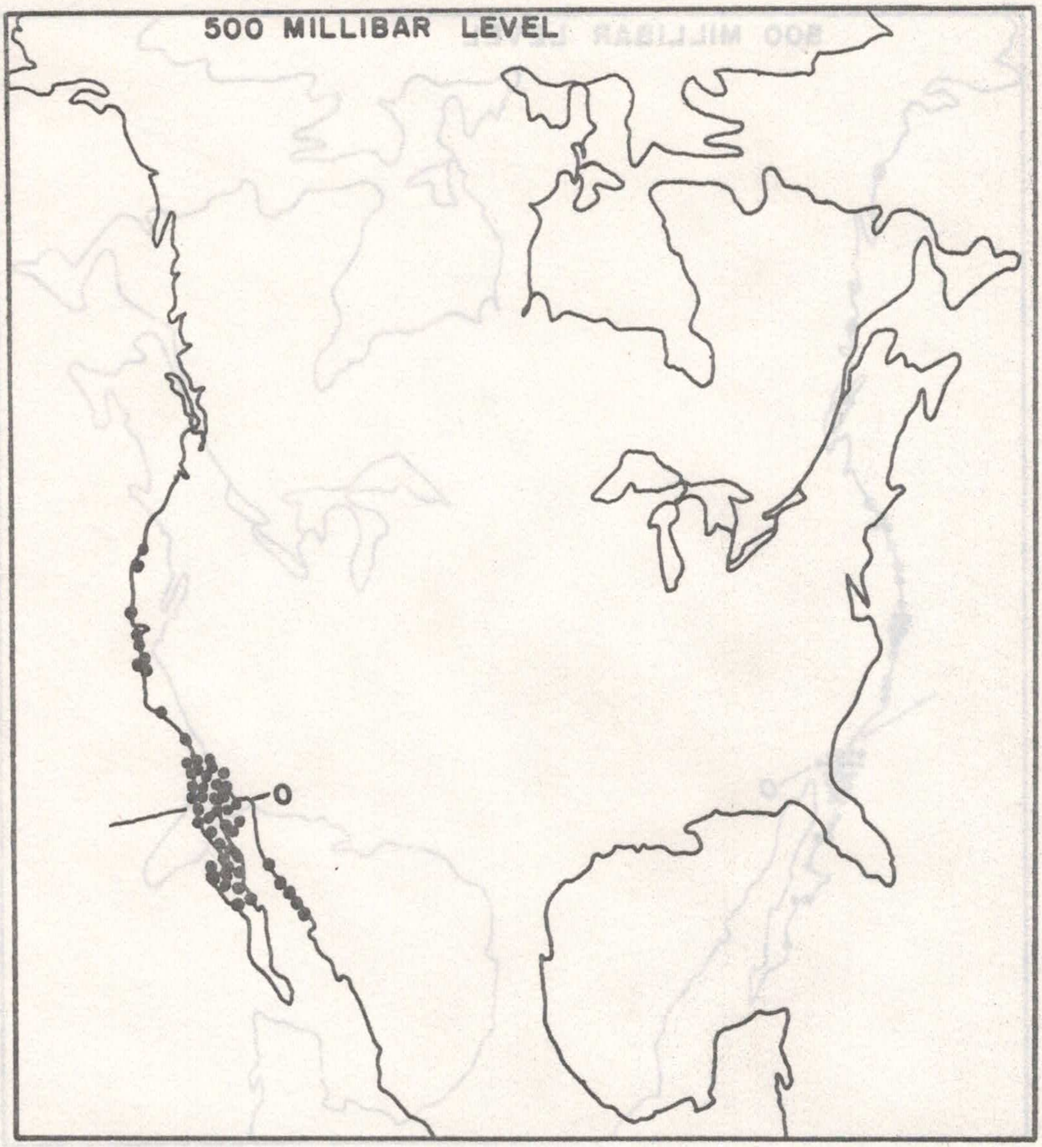
Dust can be created at all the sites. The chief regions are the Colorado basin for Hualapai, Chino Valley agricultural regions for Mormon, and the agricultural regions south of the Mexican border and rarely Yuma for Kitt. A distribution of pollutants is shown in Fig. 39.



UPPER AIR TRAJECTORIES FOR KITT PEAK
JAN.-FEB. 1958

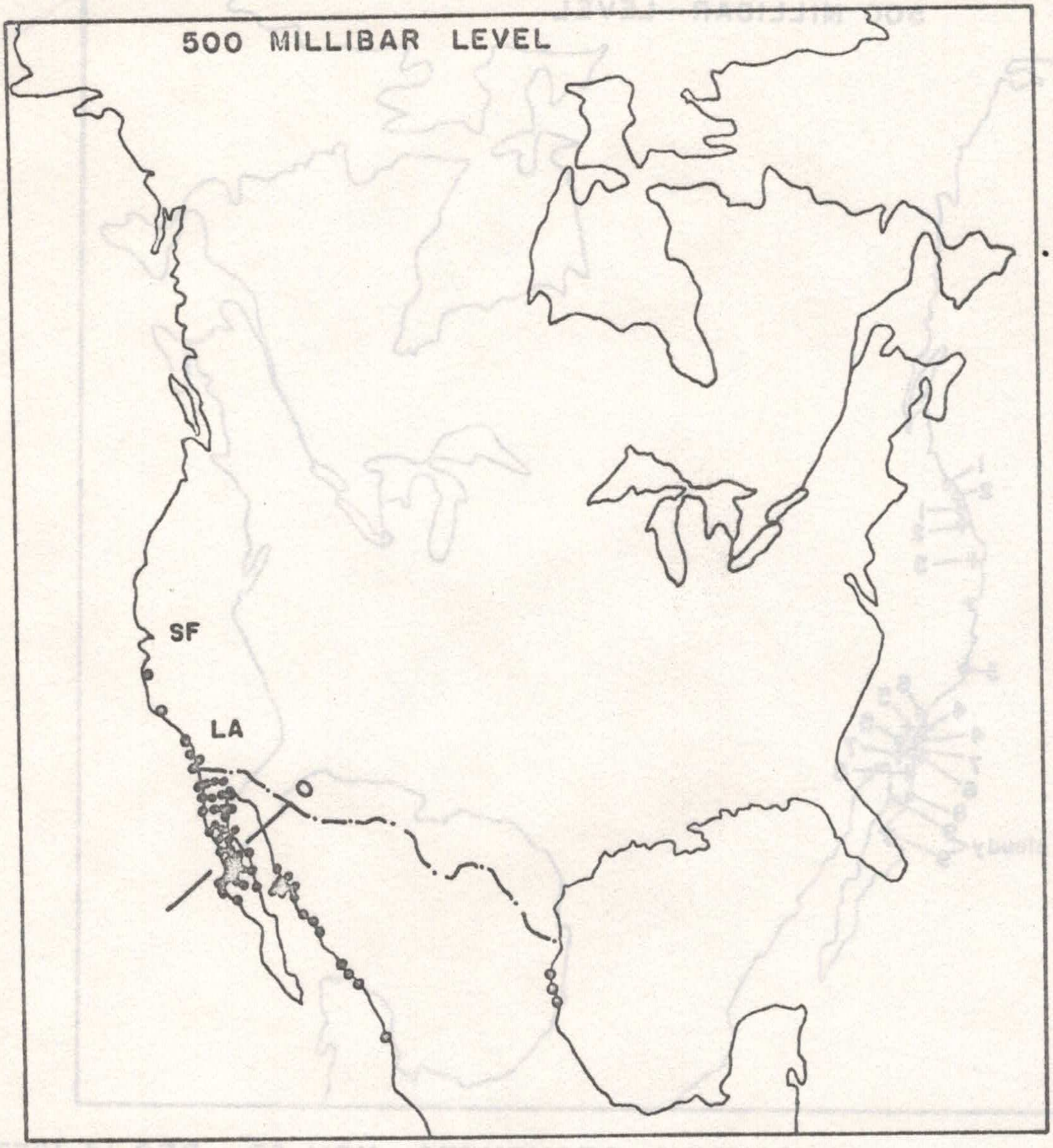
Each point marks the origin of an air flow line as it crosses the continental limits and which passes over KITT PEAK.

FIG. 35



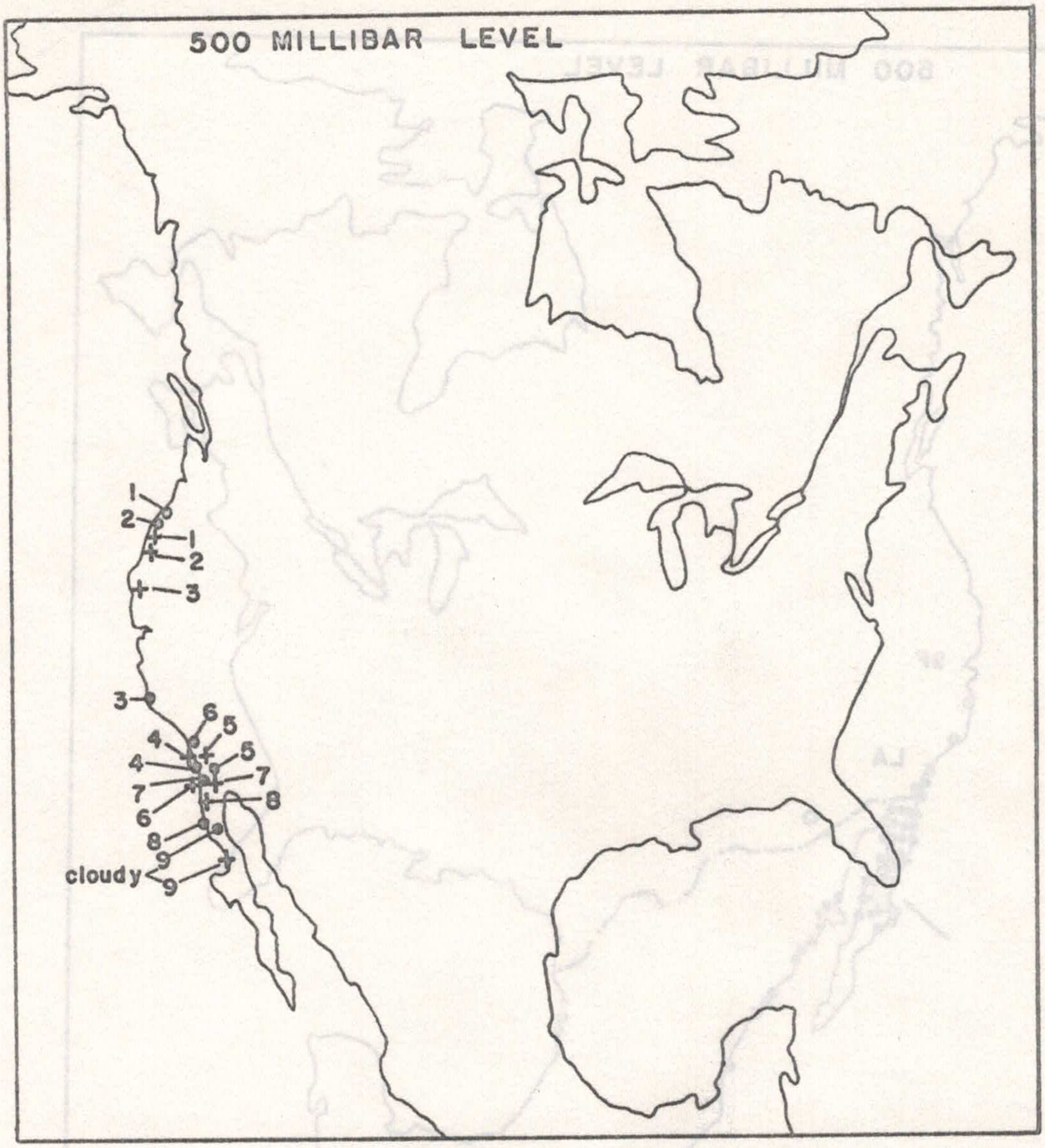
UPPER AIR TRAJECTORIES FOR KITT PEAK
MAY – JUNE 1957

FIG. 36



UPPER AIR TRAJECTORIES FOR KITT PEAK
JULY- AUGUST 1957

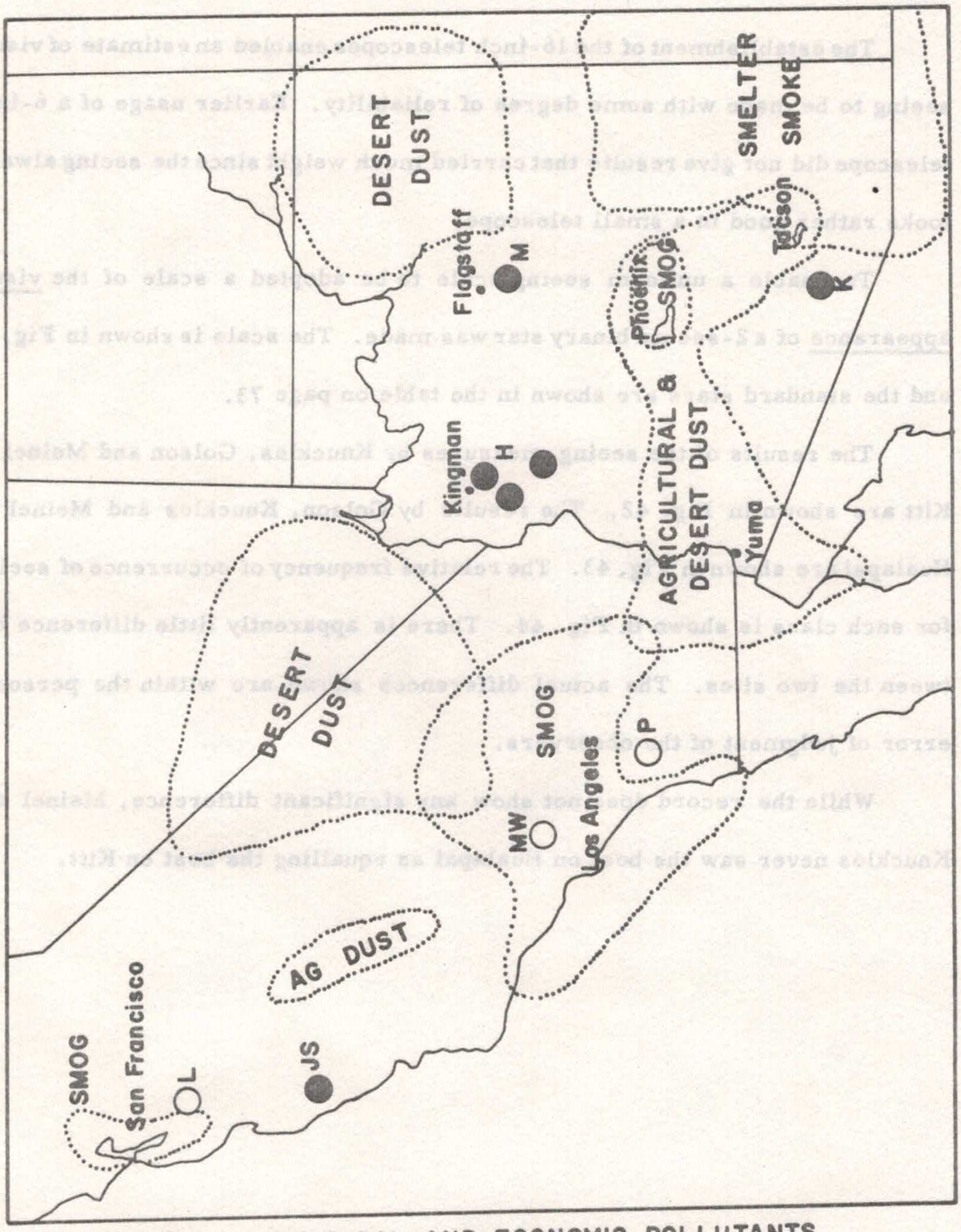
FIG. 37



UPPER AIR TRAJECTORY SEQUENCES NOV. 27 - DEC. 14, 1957

Marked from 1 for first clear day up to 9 for the onset of cloudiness.

FIG. 38



DISTRIBUTON OF NATURAL AND ECONOMIC POLLUTANTS.

FIG. 39

XV. VISUAL SEEING RECORDS

The establishment of the 16-inch telescopes enabled an estimate of visual seeing to be made with some degree of reliability. Earlier usage of a 6-inch telescope did not give results that carried much weight since the seeing always looks rather good in a small telescope.

To enable a uniform seeing scale to be adopted a scale of the visual appearance of a 2-second binary star was made. The scale is shown in Fig. 41 and the standard stars are shown in the table on page 73.

The results of the seeing measures by Knuckles, Golson and Meinel on Kitt are shown in Fig. 42. The results by Golson, Knuckles and Meinel on Hualapai are shown in Fig. 43. The relative frequency of occurrence of seeing for each class is shown in Fig. 44. There is apparently little difference between the two sites. The actual differences shown are within the personal error of judgment of the observers.

While the record does not show any significant difference, Meinel and Knuckles never saw the best on Hualapai as equalling the best on Kitt.

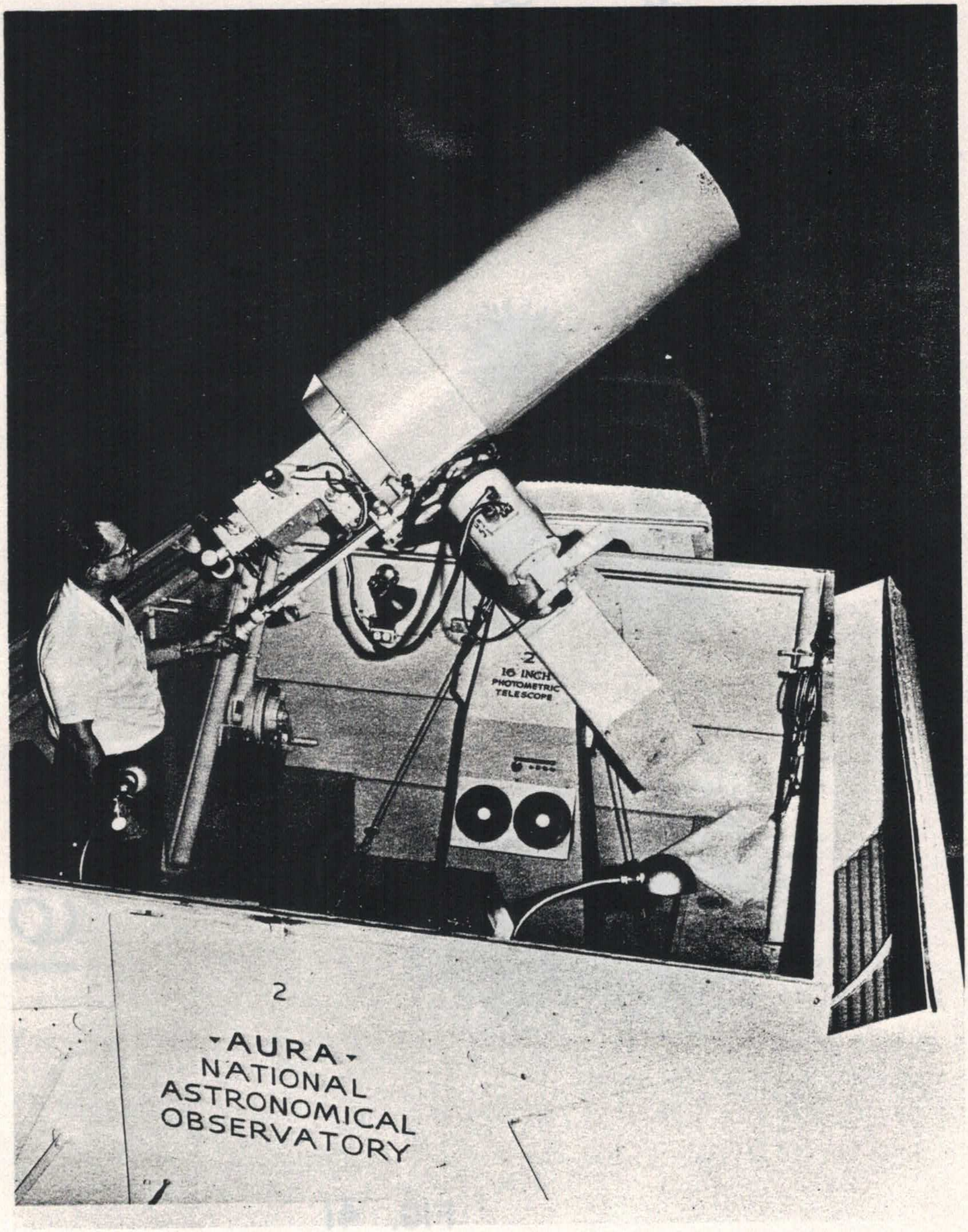


Figure 40

Photograph of the NAO 16-inch photometric telescope shown with W. W. Baustian at the control arm. Two of these telescopes were constructed.

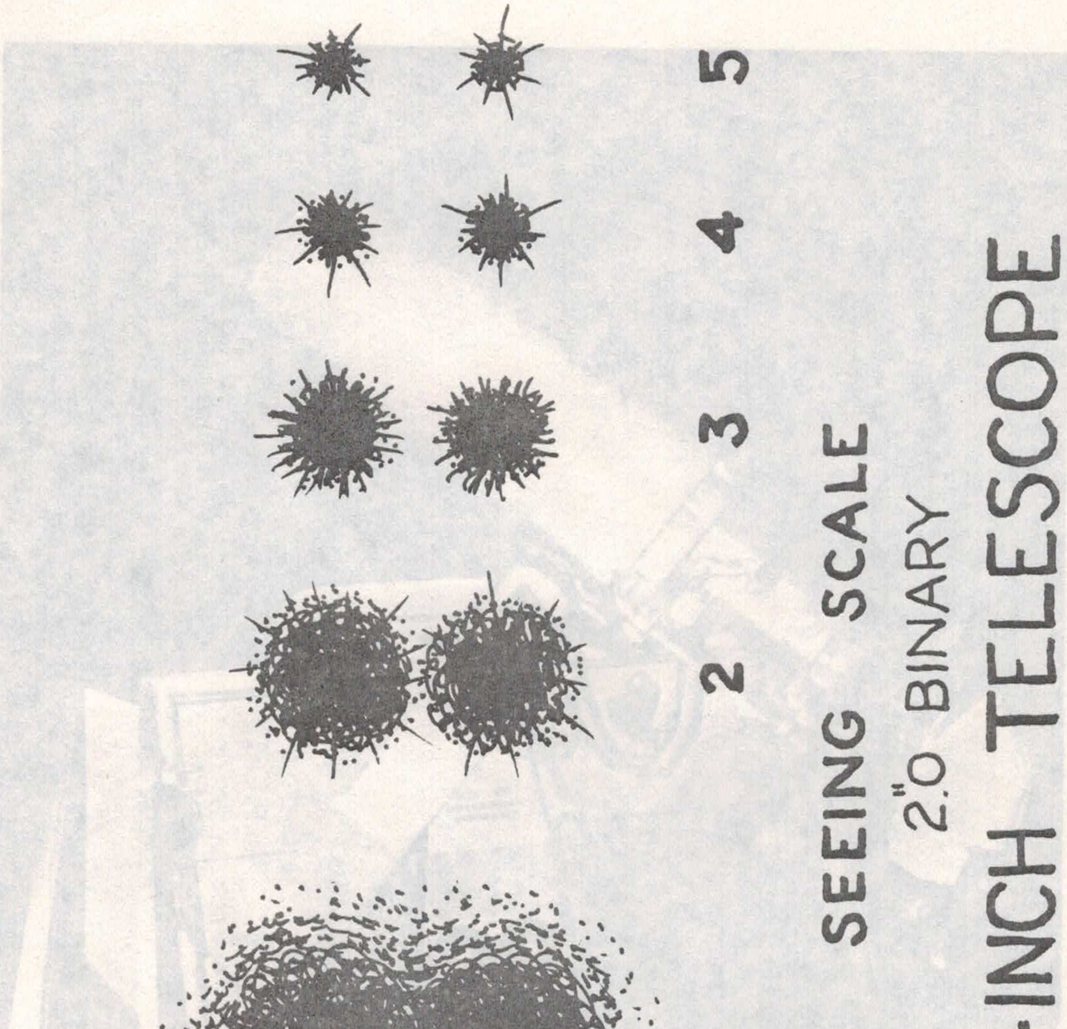


FIG. 41

OBSERVING LIST OF DOUBLE STARS

SELECTED FROM *Norton's Star Atlas*

(Separation less than 2", magnitude difference less than 1.5 mag.)

(1950)	Name	Magnitudes	Separation* (1955)	Position (1950)
052803	33 Ori	6.0 - 7.3	1".8	$5^h\ 29^m$ $+\ 3^\circ\ 15'$
111531	Xi UMa	4.4 - 4.9	1".8	$11^h\ 16^m$ $+31^\circ\ 50'$
144613	Mu Lib	5.4 - 6.3	1".7	$14^h\ 47^m$ $-13^\circ\ 57'$
152337	Mu^2 Boo	6.7 - 7.3	2".0	$15^h\ 23^m$ $+37^\circ\ 32'$
180008	Tau Oph	5.0 - 5.7	2".0	$18^h\ 00^m$ $-\ 8^\circ\ 11'$
205750	Struve 2741 (Cyg)	6.0 - 7.3	1".9	$20^h\ 57^m$ $+50^\circ\ 16'$
	E^2 Lyrae	4.9 - 5.2	2".3	$18^h\ 43^m$ $+39^\circ\ 34'$
235733	Struve 3050 (And)	6.0 - 6.0	1".5	$23^h\ 56^m$ $+33^\circ\ 27'$

*Values corrected by H. M. Jeffers mostly from the current Lick observations

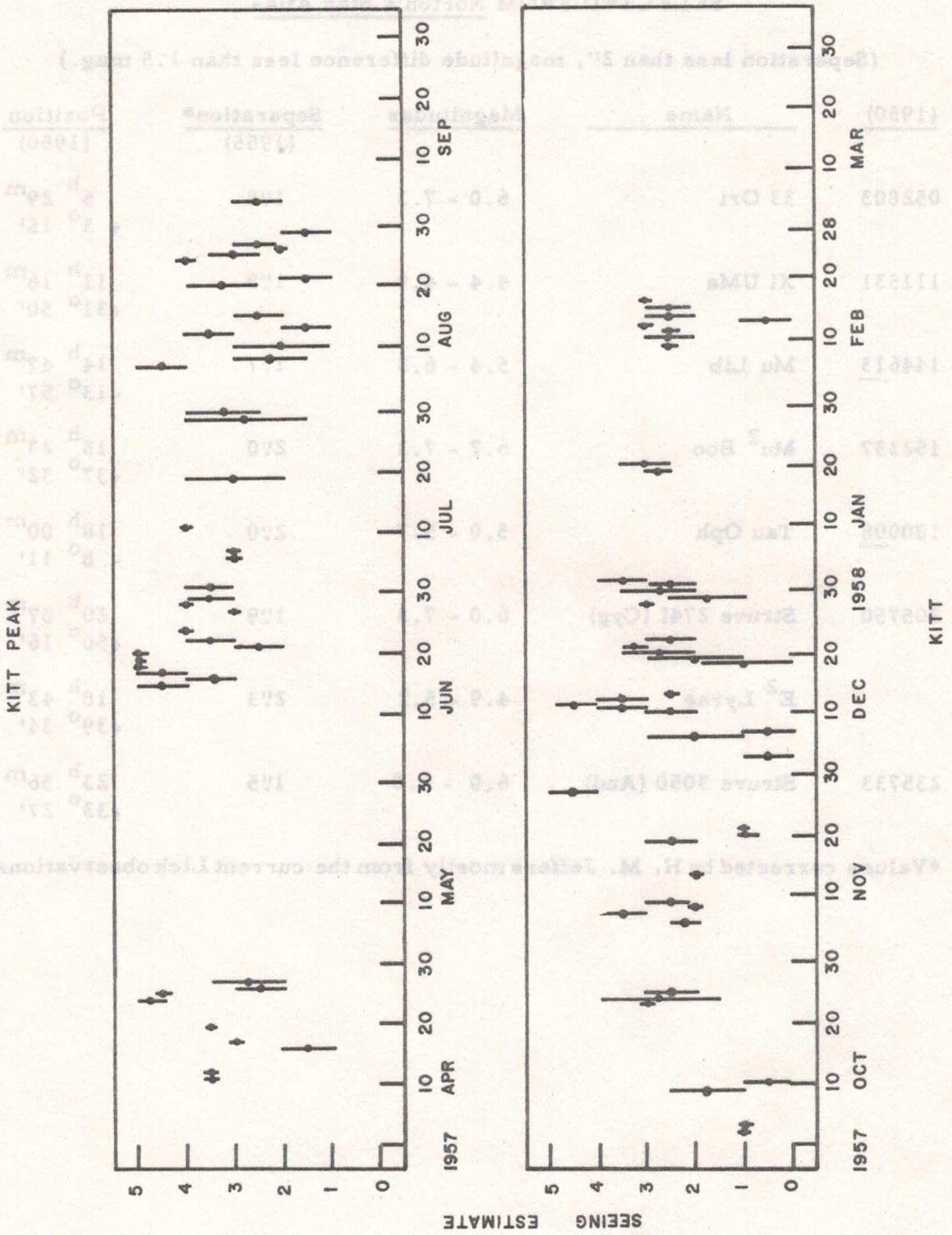

KITT PEAK
KITT
SEEING ESTIMATE
0
1
2
3
4
5
1957
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1958
JAN
FEB
MAR
10
20
28
30

FIG. 42

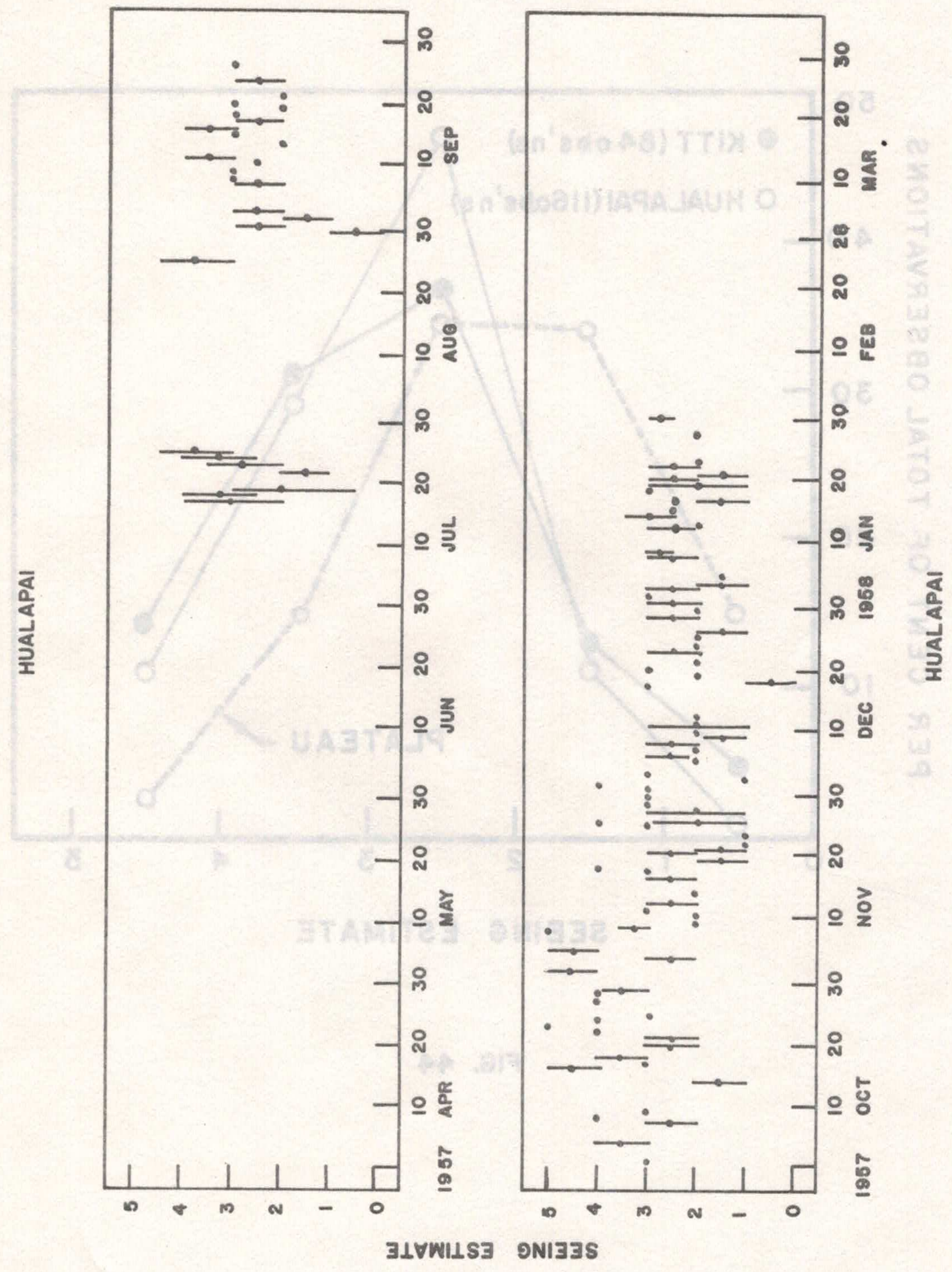

HUALAPAI
SEEING ESTIMATE
0
1
2
3
4
5
1957
APR
MAY
JUN
JUL
AUG
SEP
10
20
30
HUALAPAI
1957
OCT
NOV
DEC
1958
JAN
FEB
MAR
10
20
30
28

FIG. 43

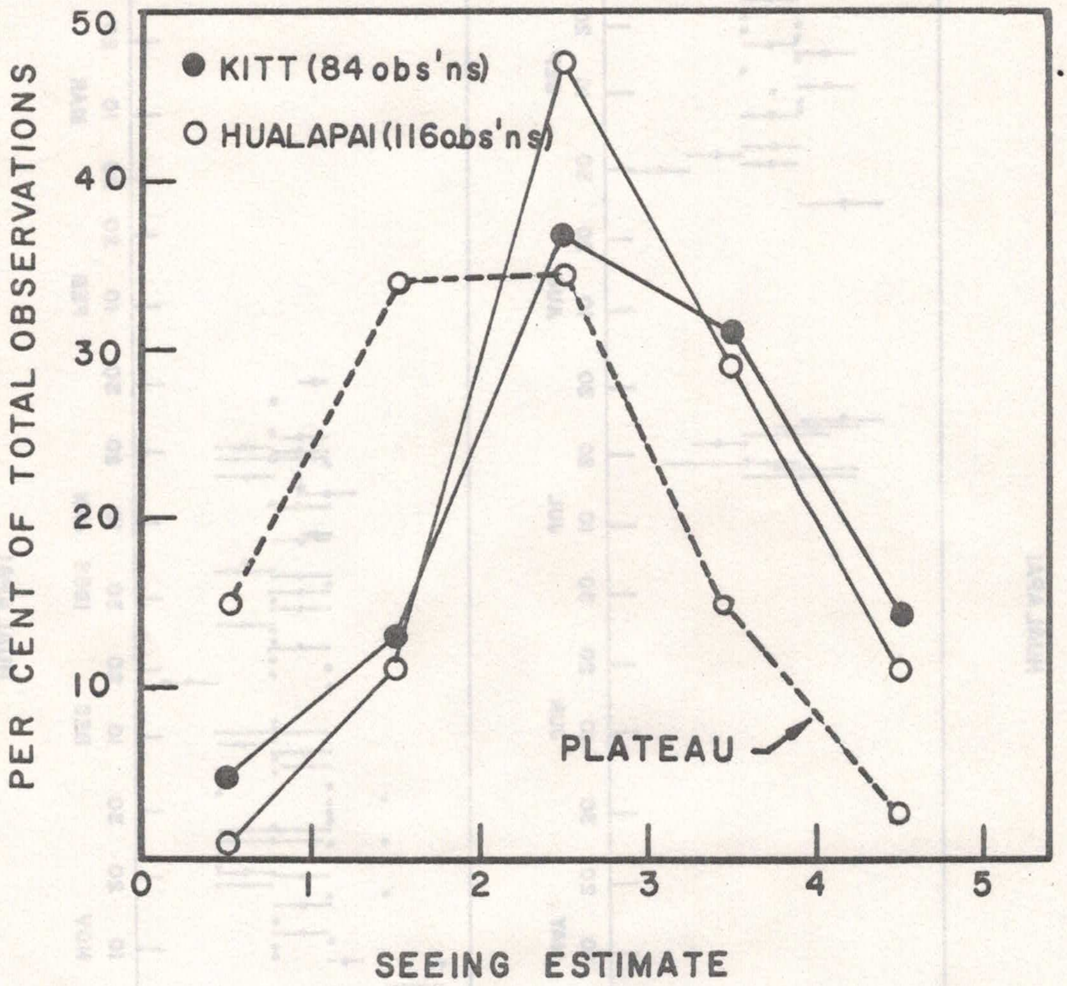

50
40
30
20
10
PER CENT OF TOTAL OBSERVATIONS
● KITT (84 obs'ns)
○ HUALAPAI (116 obs'ns)
PLATEAU
0
1
2
3
4
5
SEEING ESTIMATE

FIG. 44

XVI. AUTOMATIC SEEING RECORDS

The synoptic seeing records obtained to date on the Kitt Peak Polaris telescope in the 10-foot tower have been reduced. From February to August a total of 75 nights yielded good records. A similar period of 75 nights from August to February also yielded good records. The remaining nights were either cloudy, the tower shake was too severe, the tracking inaccurate or the equipment was not operating owing to any of several reasons. Of the 150 nights a reasonable number yielded records only during part of the night because of a mis-alignment of the instrumental pole or prism pickup. In general four or five observations per night out of twenty-five were measured for this report.

In this limited analysis a single parameter has been selected for measurement. Selection of the occultation depth for the 1.04 bar was made. The reason is that visual inspection of this trace showed the largest variation in depth and that the depths are close to the mid-intensity point.

The tracings inherently contain a large amount of information relating to the seeing disc from the nature of the instrument and the mode or recording. If an entire trace sequence is used it is not necessary to assume any arbitrary shape to the intensity distribution across the image. The amount of labor involved in the process is so great that we have been unable to employ it to date. As a consequence, in this preliminary report wherein only one occultation depth is used, it is necessary to assume a distribution curve of one parameter. For simplicity we have assumed that the intensity distribution across the image can be represented by a Gaussian distribution.

The image formed by this telescope is composed of three parts. The geometrical aperture shape causes a particular diffraction pattern to arise.

The geometrical abberrations of the telescope, consisting of natural astigmatism (see Technical Report No. 7), mal-alignment aberrations like coma, and defocussing further affect the "perfect condition image". Finally we have the additional effect of seeing that causes this diffraction image to jump about and blurr out at times. The visual appearance of the image and the type of intensity distribution that it yields are shown in Fig. 46. While the pattern is not Gaussian in detail I feel that a Gaussian approximation is certainly not grossly in error.

The image size of the total image adopted for this report is σ, the dispersion parameter for a Gaussian distribution. This definition of the image size when applied to the astigmatic-line image defines the width within which 68 percent of the energy is contained.

The Polaris telescope amplifier circuit integrates the light showing around the occultation wire over a time of one second. In one second of time the diurnal motion of Polaris moves it 1/4". The time interval of the integration is therefore great enough that the chart record includes the effect of jumping of the image. If the integration time were short then the telescope would only measure blurr of the image. Under conditions of good seeing the chief observable effect detectable in a 6-inch telescope is tremor of the image. Only for poor seeing is the disc noticeably fuzzy. The actual sample of the atmosphere that the Polaris telescope integrates is therefore a line element 6 inches wide and of length determined by the wind velocity. For an average wind of 10 mph, the integration is effectively over an aperture 6" x 200". The seeing disc profile recorded by the Polaris telescope should therefore be equivalent to that which would be obtained with a much larger telescope.

Visual correlation bearing upon the above reasoning was made in Scottsdale using the 6-inch Fecker equatorial telescope. It was found that the visual seeing under both resolution and the Danjon criteria was always far better than the Polaris telescope showed. A Polaris disc of 3" corresponded to a visual resolution of binary stars 1" apart. I therefore have confidence that the Polaris telescope record really measures the disc as it would be seen with a large telescope.

The reduction of the Polaris record using the 1" reticle is made by measuring the effective σ_o for the actual image. In the following analysis we have assumed a value of 0".8 for the natural dispersion value for the undisturbed image. If the real value is 0".7 or 0".9 the result is only a shift of the zero point. The contribution of the seeing to the image is therefore $\sigma^2 = \sigma_o^2 - 0.64$, which assumes both to be representable by a Gaussian distribution. While this assumption will not be exact, an error should not significantly alter these results.

On the basis of Gaussian distributions we have determined a calibration curve for $\sigma(A/B)$. If the optical system did not have scattered light we would obtain the upper curve shown in Fig. 47. The contribution to the scattered light is difficult to estimate. According to our assumptions as to the light distribution, the excess in the wings of the image can be considered "scattered light". In addition to this component of the scattered light we have a second due to actual small angle scatter $>3''$ because of the aluminum reflecting surfaces and dust on the transmission surface. We estimate that the sum of these scatter terms is probably larger than 10 percent. A value of 10 percent is therefore selected to arrive at the $\sigma(A/B)$ function shown in Fig. 47. If the true value is greater, as is possible, then the actual seeing is better than indicated by Fig. 47.

The results for the seeing on KITT obtained on the 150 nights are shown in Figs. 48 and 49. The distribution of image sizes shown in Figs. 50 to 52 indicates that this site is characterized by generally good seeing with infrequent occurrences of poor seeing, but that poorer seeing has prevailed since summer of 1957. The black histogram in Fig. 53 shows the image sizes measured with the same telescope near Phoenix, 800' above the floor of the Salt River valley. This comparison shows beyond doubt that the difference between these two sites is appreciable. No successful measures were obtained at other tower sites due to a succession of difficulties with the stability of the structure.

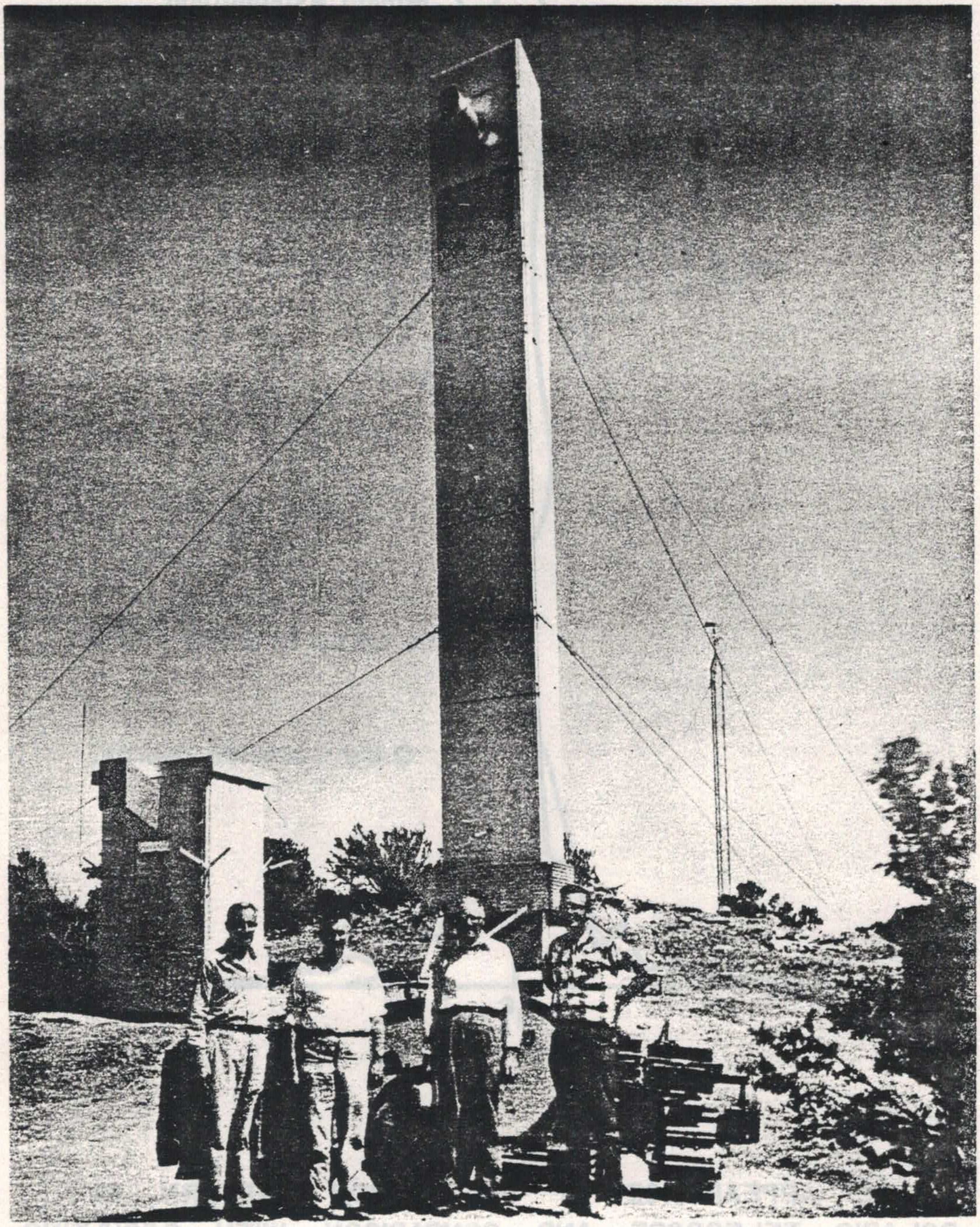
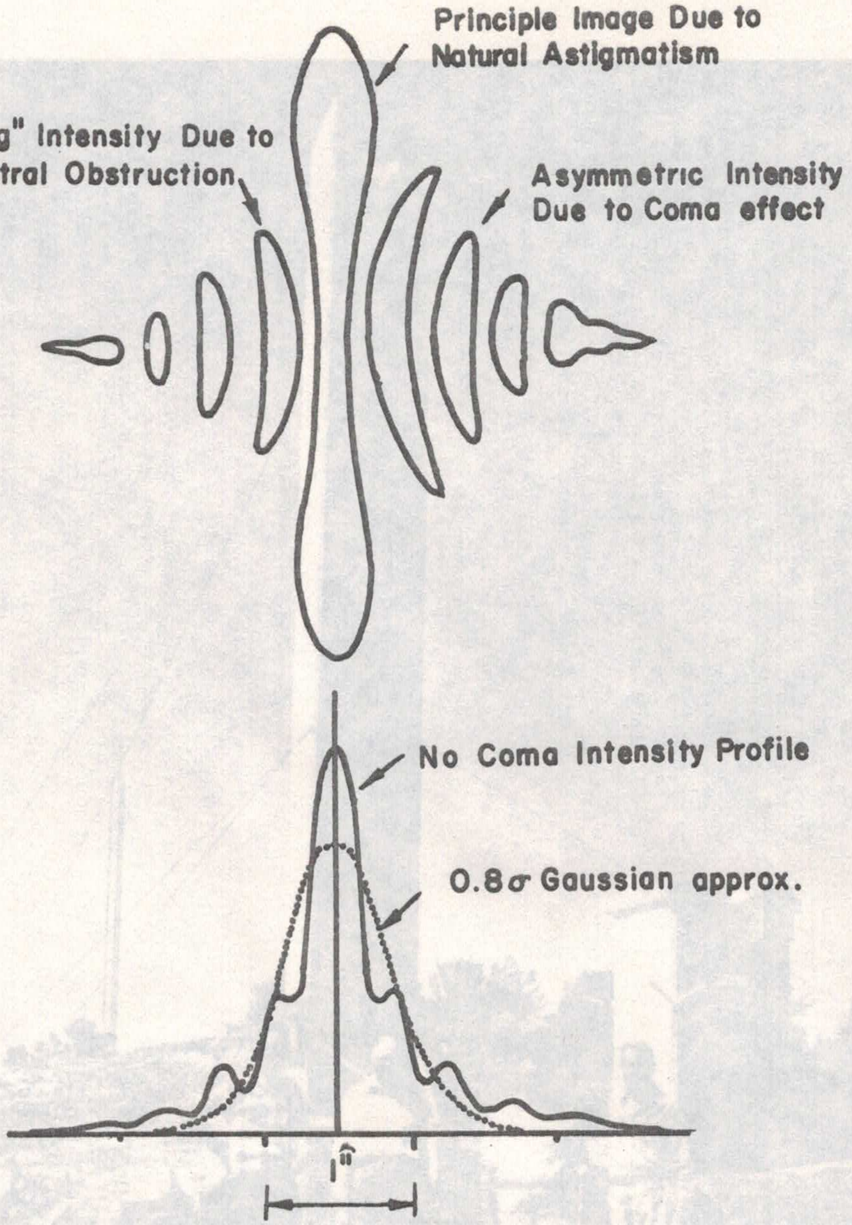


Figure 45

Photograph of Polaris seeing telescope towers on Kitt Peak. The tractor and trailer used for early access to the summit is shown. The persons are, from the left: Drs. Edwin F. Carpenter, Steward Observatory: Frank K. Edmondson, NSF Program Director for Astronomy during 1956-7; John C. Duncan, Steward Observatory; A. B. Meinel, Executive Secretary, NAO Advisory Panel.



VISUAL APPEARANCE OF DIFFRACTION PATTERN IN POLARIS TELESCOPE AND COMPARISON WITH OCCULTING RETICLE WIDTH.

FIG. 46

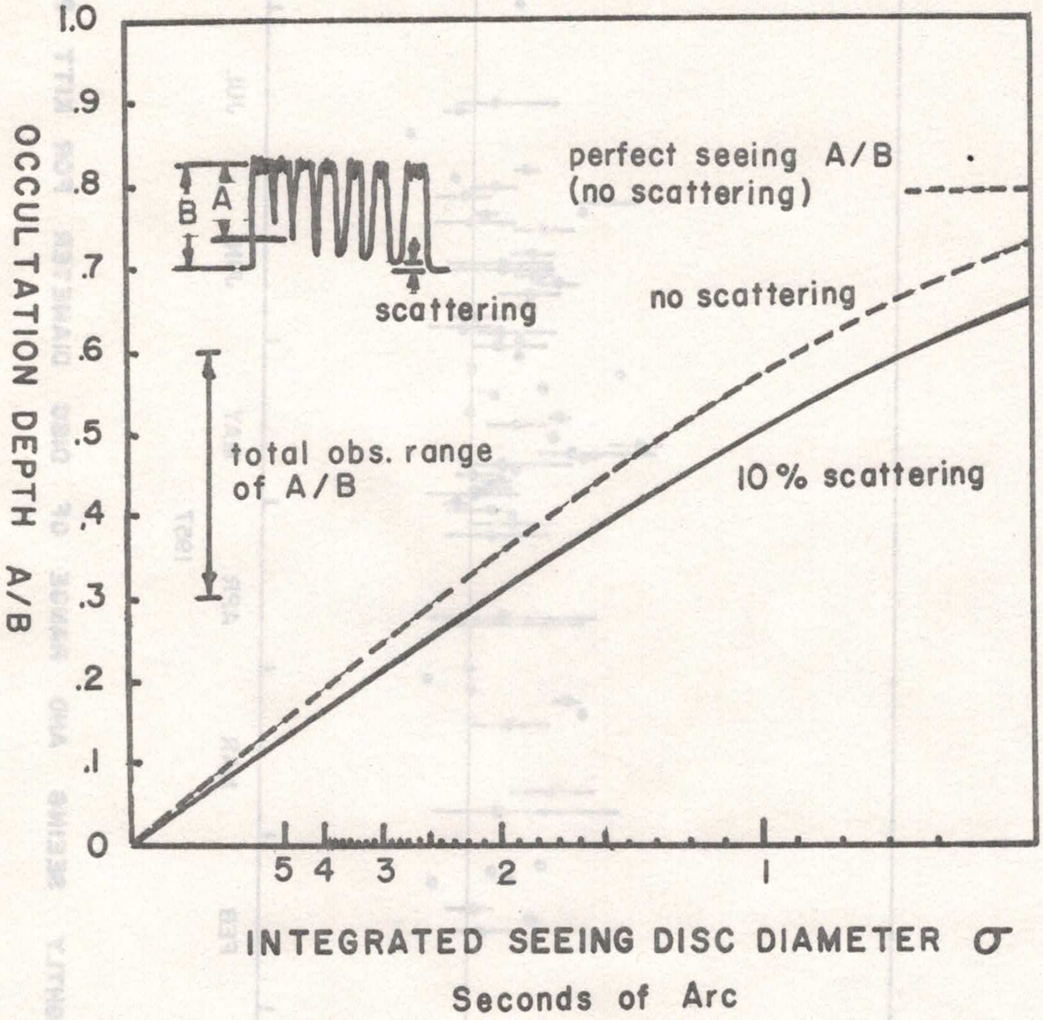
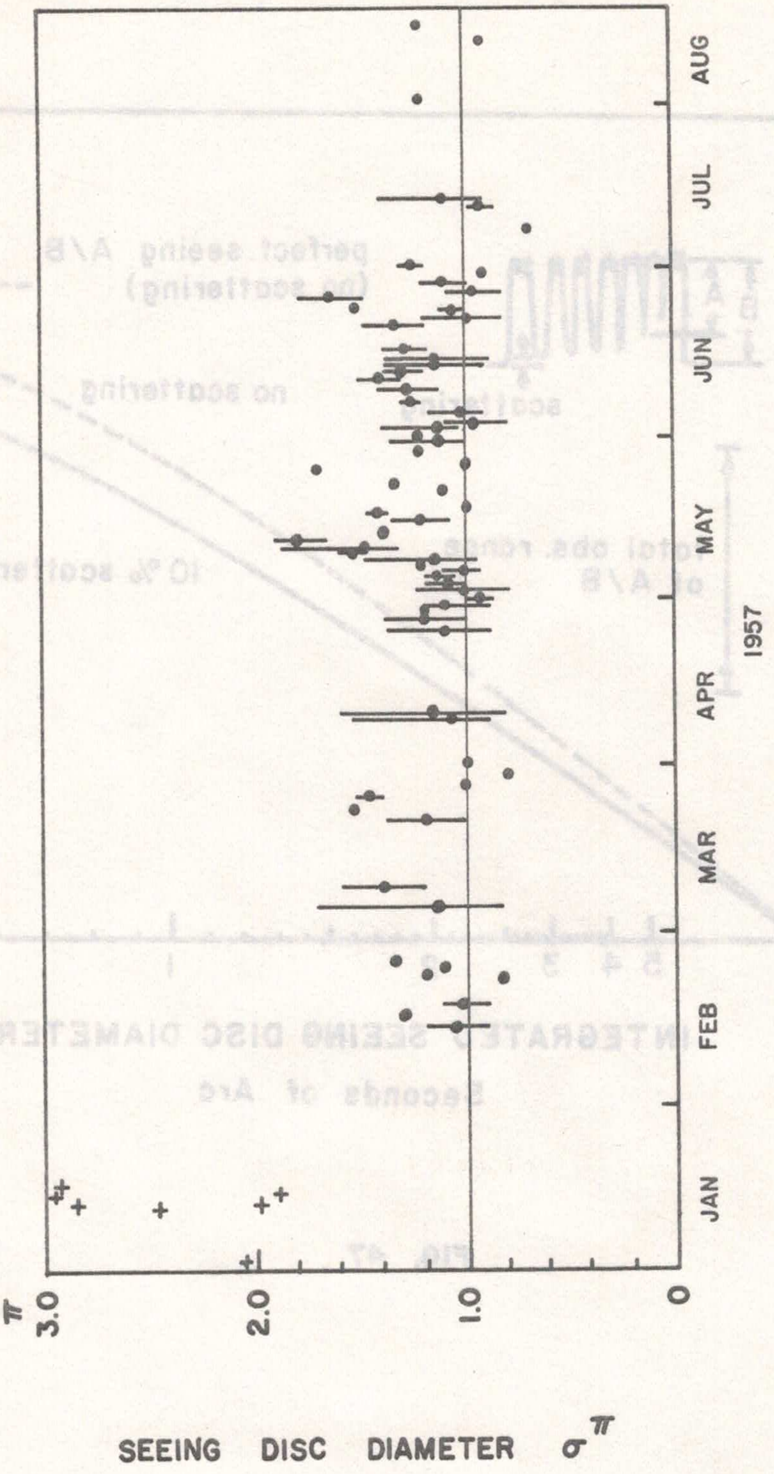
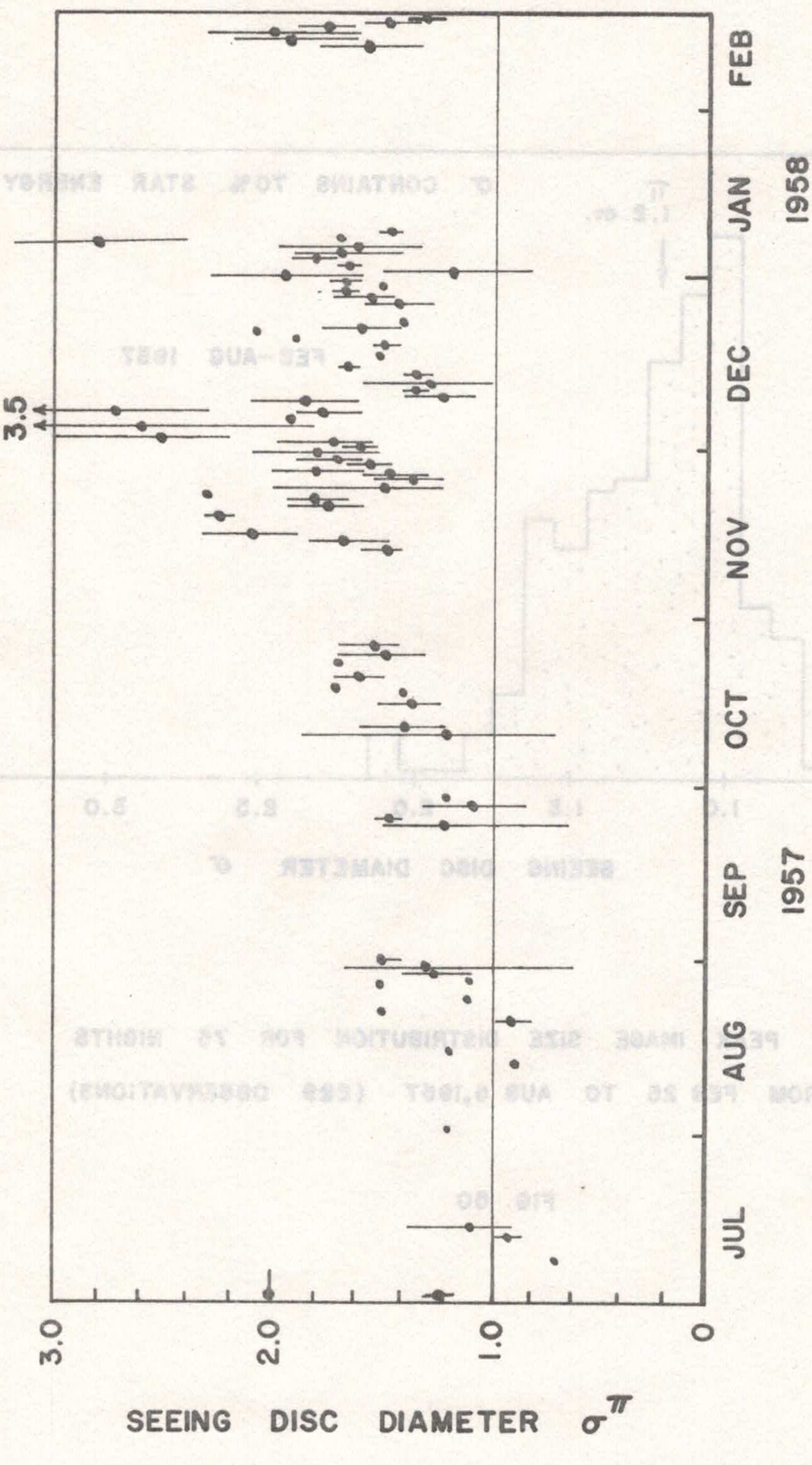

OCCULTATION DEPTH A/B
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
B
A
scattering
perfect seeing A/B
(no scattering)
no scattering
10% scattering
total obs. range
of A/B
5
4
3
2
1
INTEGRATED SEEING DISC DIAMETER σ
Seconds of Arc

FIG. 47



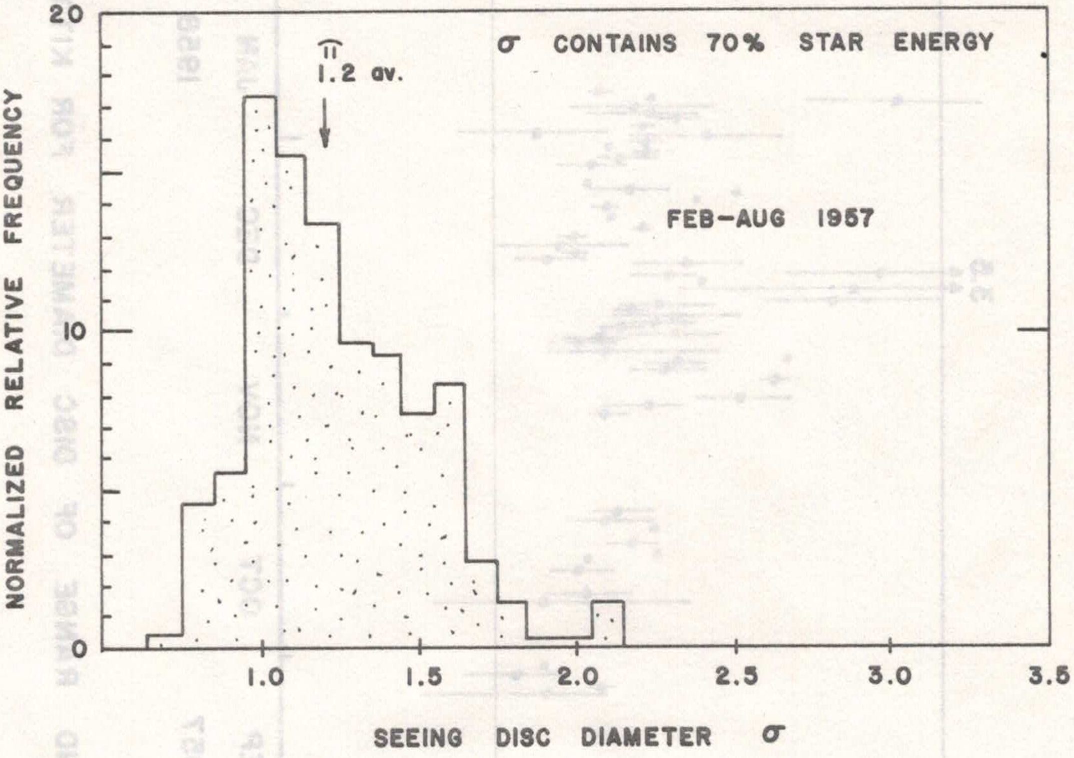
AVERAGE NIGHTLY SEEING AND RANGE OF DISC DIAMETER FOR KITT PEAK

FIG. 48



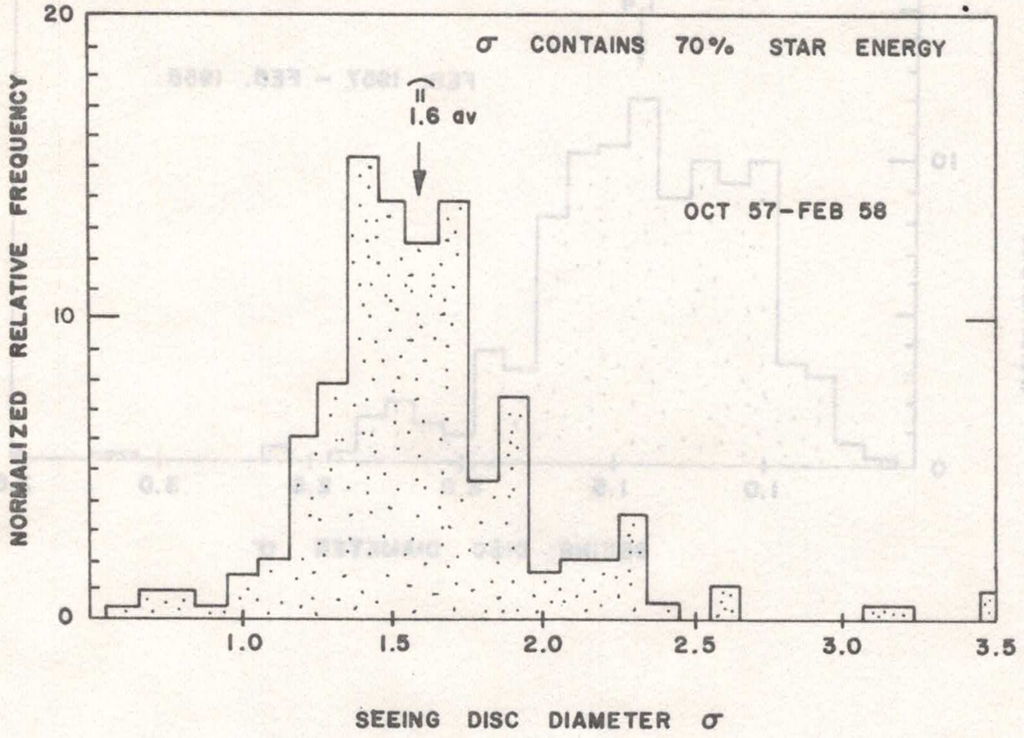
AVERAGE NIGHTLY SEEING AND RANGE OF DISC DIAMETER FOR KITT PEAK

FIG. 49



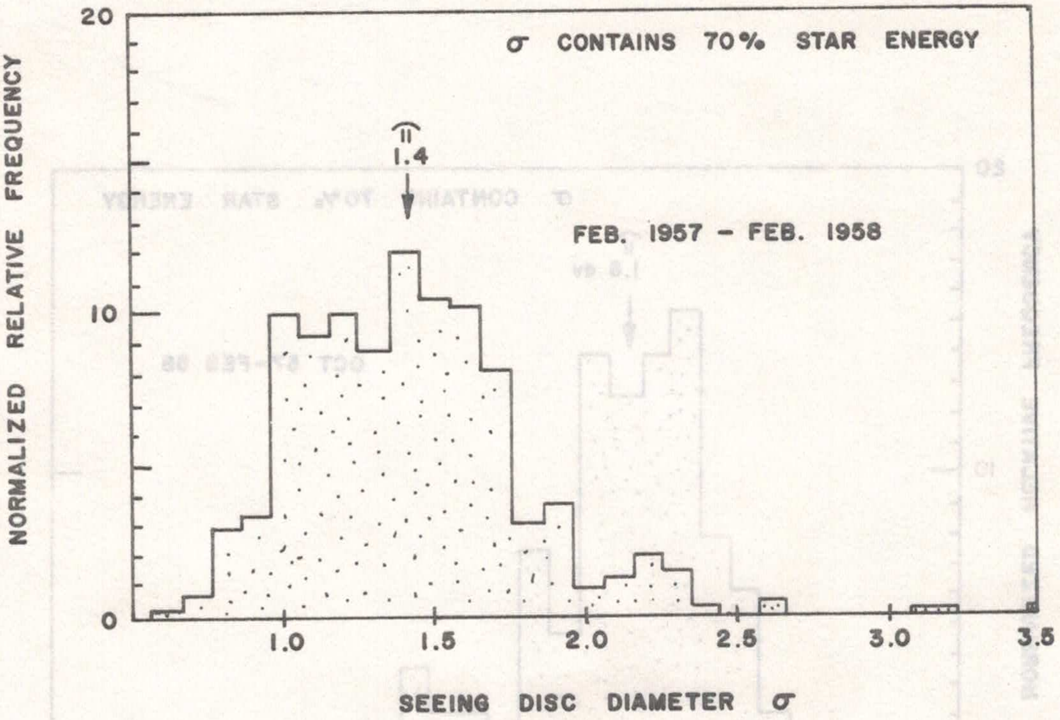
KITT PEAK IMAGE SIZE DISTRIBUTION FOR 75 NIGHTS
FROM FEB 25 TO AUG 5,1957 (229 OBSERVATIONS)

FIG 50



KITT PEAK IMAGE SIZE DISTRIBUTION FOR 75 NIGHTS
FROM OCTOBER 1957 TO FEBRUARY 1958 (202 OBSERVATIONS)

FIG. 51



KITT PEAK IMAGE SIZE DISTRIBUTION FOR 150 NIGHTS
FROM FEBRUARY 1957 - FEBRUARY 1958 (431 OBSERVATIONS)

FIG. 52

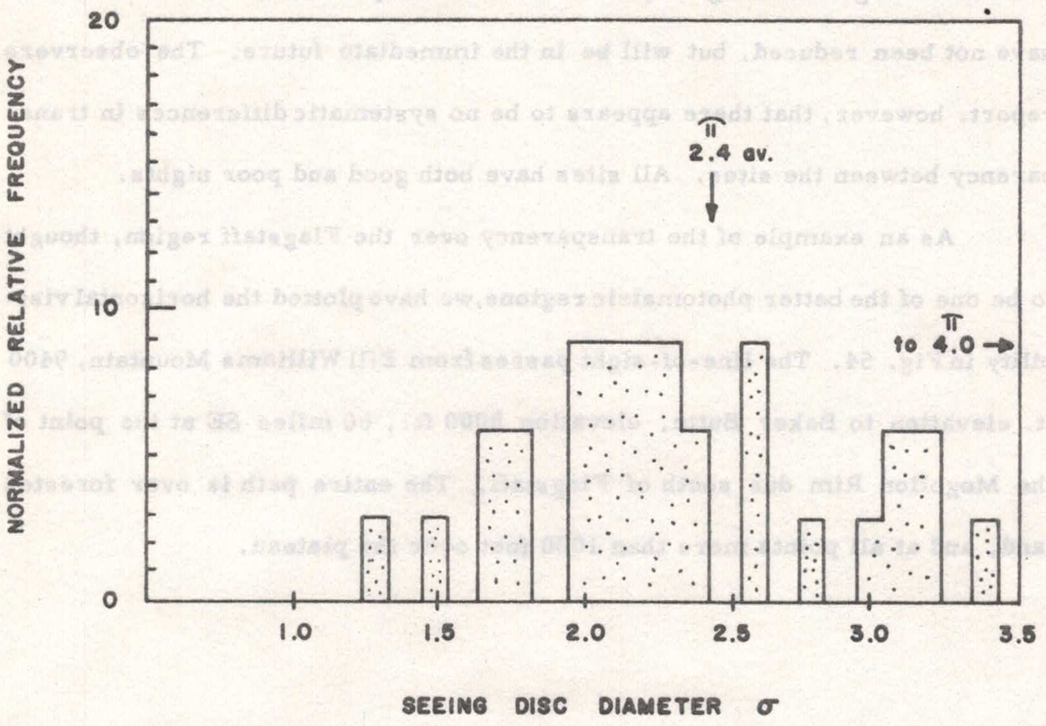


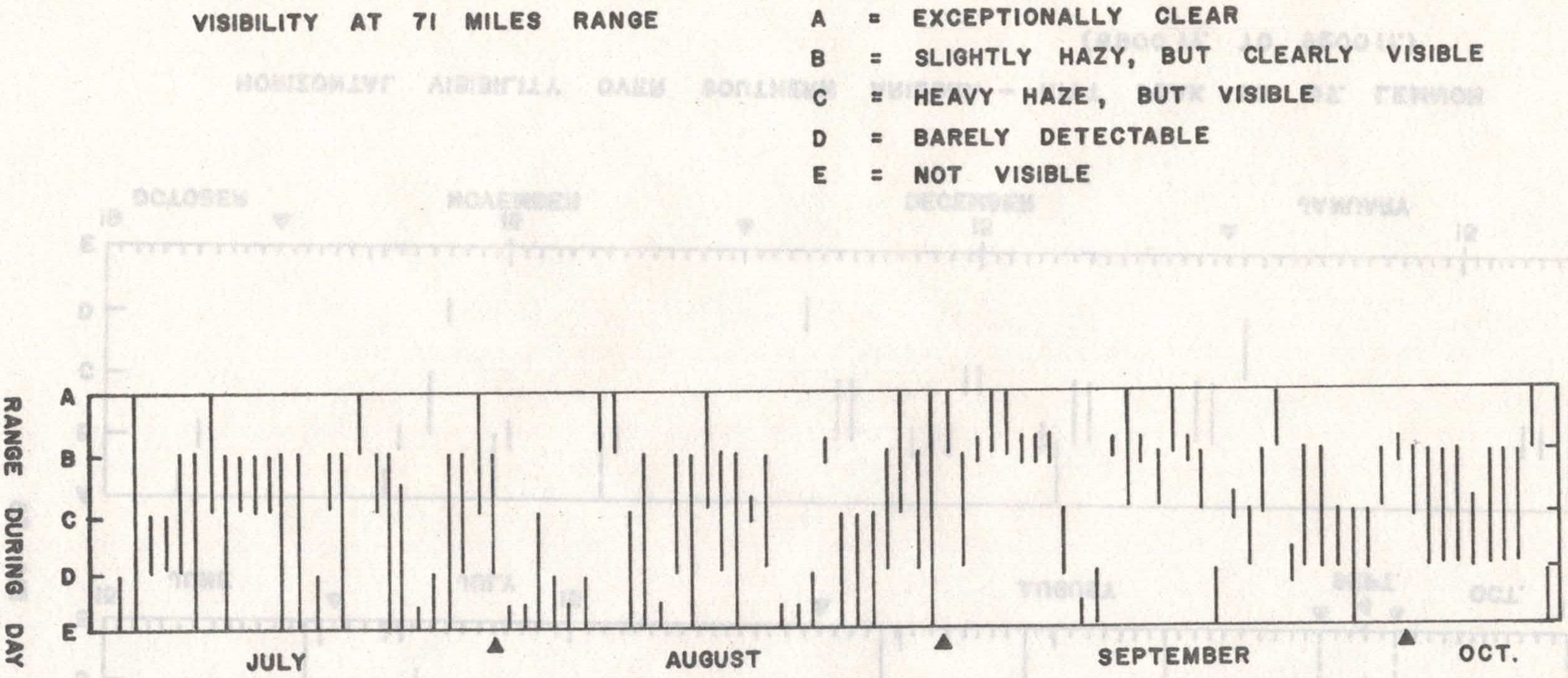
IMAGE SIZE DISTRIBUTION FOR DESERT SITE (NEAR PHOENIX)

FIG. 53

XVII. TRANSPARENCY

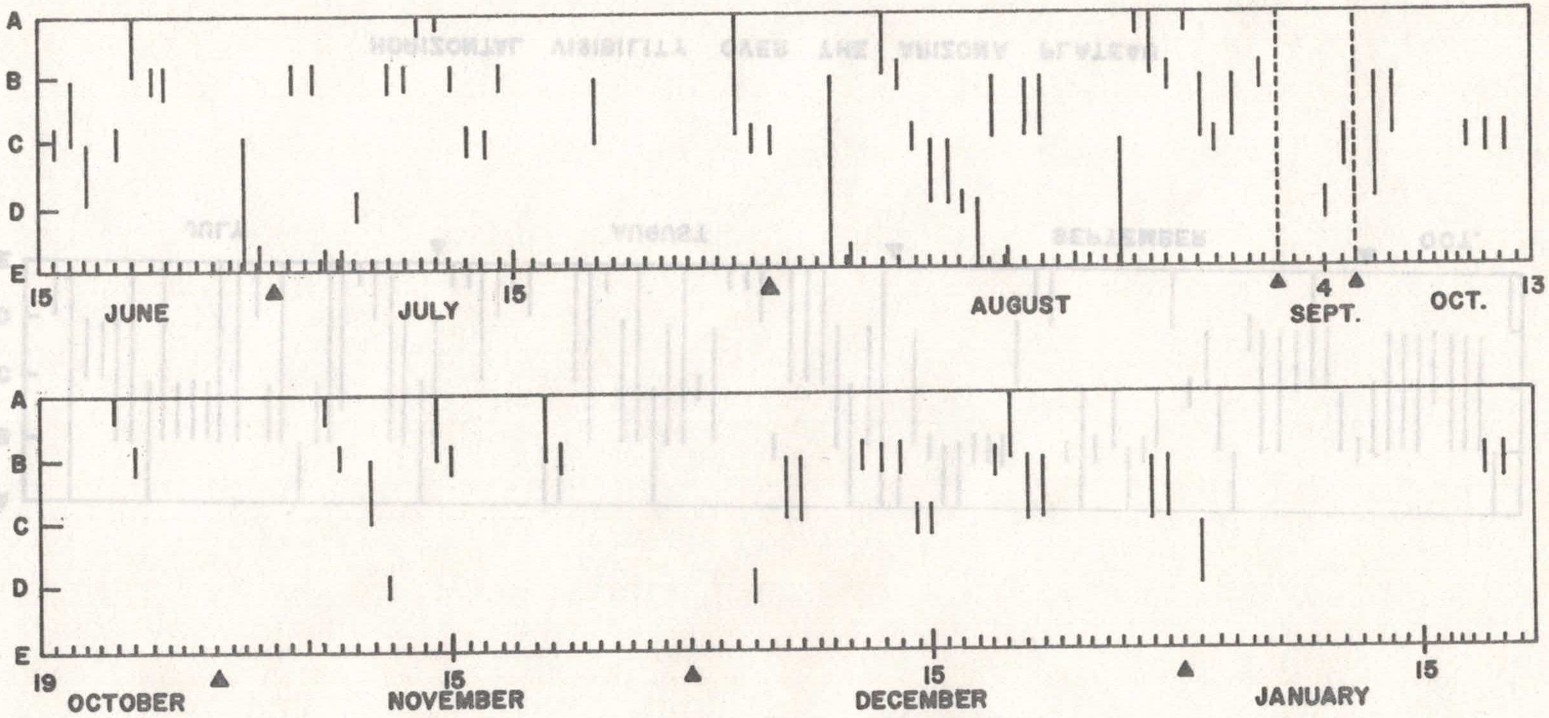
Transparency information about the sites was obtained by making photometric observations with the 16-inch telescopes and by estimating visibility of horizontal targets at ranges up to 90 miles. The photometric records to date have not been reduced, but will be in the immediate future. The observers report, however, that there appears to be no systematic differences in transparency between the sites. All sites have both good and poor nights.

As an example of the transparency over the Flagstaff region, thought to be one of the better photometric regions, we have plotted the horizontal visibility in Fig. 54. The line-of-sight passes from Bill Williams Mountain, 9400 ft. elevation to Baker Butte, elevation 8000 ft., 60 miles SE at the point of the Mogollon Rim due south of Flagstaff. The entire path is over forested land, and at all points more than 1000 feet over the plateau.



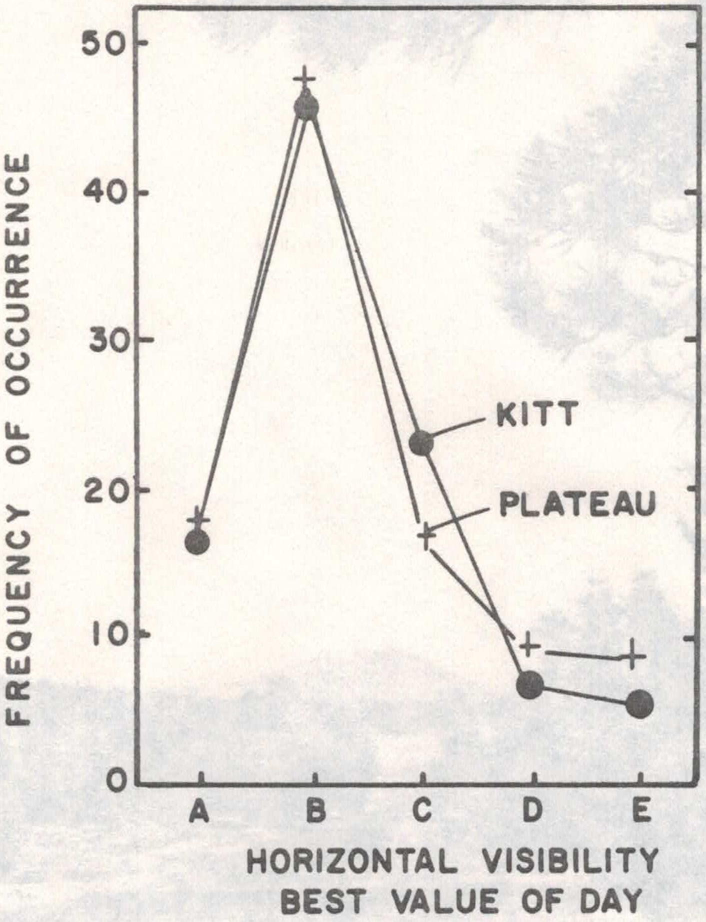
HORIZONTAL VISIBILITY OVER THE ARIZONA PLATEAU

FIG. 54



HORIZONTAL VISIBILITY OVER SOUTHERN ARIZONA - KITT PEAK TO MT. LEMMON
(6900 ft. TO 9200 ft.)

FIG. 55



RELATIVE FREQUENCY OF HORIZONTAL VISIBILITY

FIG. 56

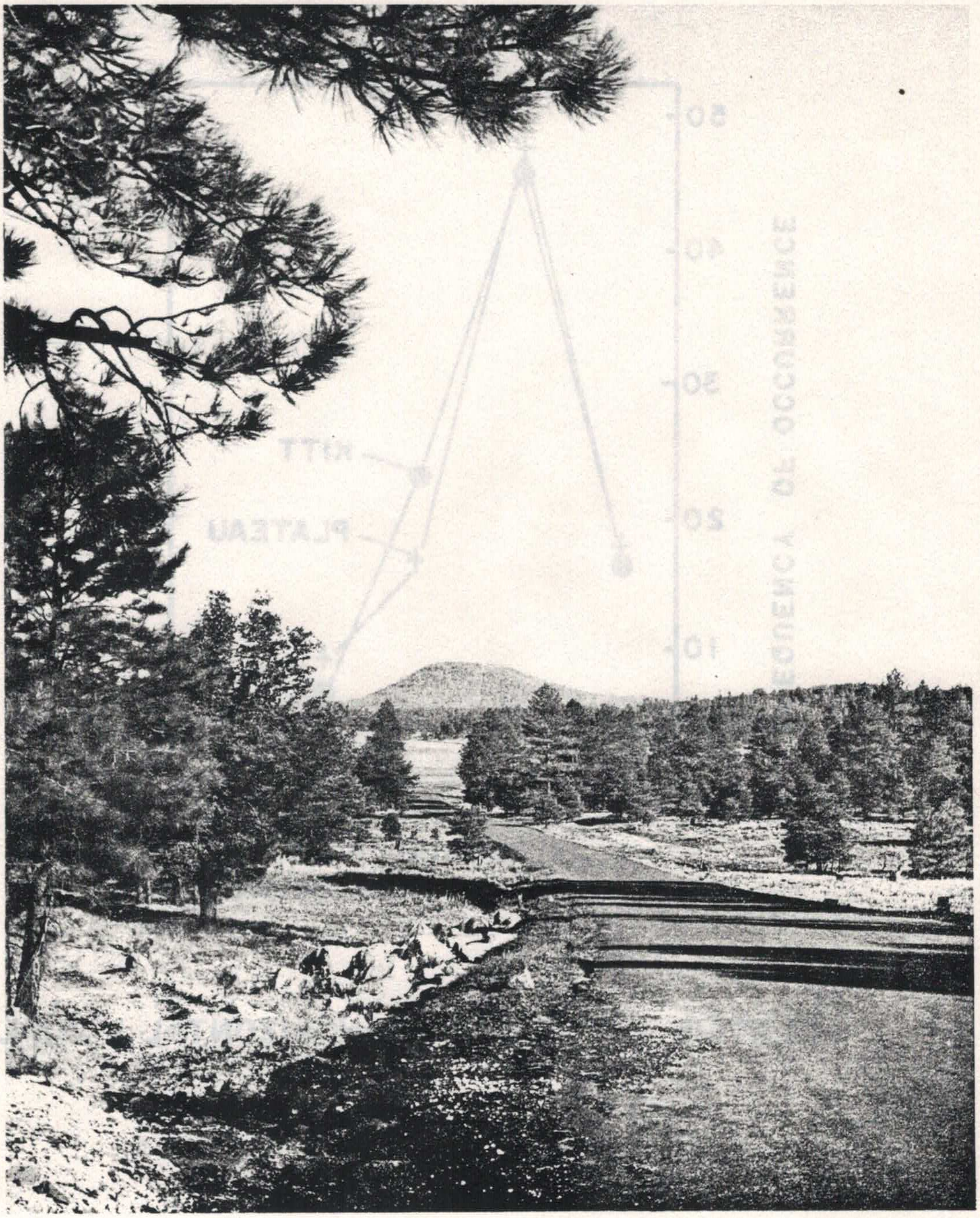


Figure 57

Photograph of Summit Mountain from the road to Williams. The transcontinental microwave tower is near the center of the summit.

XVIII. ADDENDA

Discussions at the meeting of the Scientific Committee in Pasadena on March 1-2, 1958 to review the site survey for a recommendation for a site selection covered several topics not explicitly covered in the preceding text. These additions have been added to the current report.

A. Sky Darkness

In the absence of sky illumination from artificial light sources the brightness of the night sky depends upon the albedo of the earth and the illuminence arising from the airglow and scattered starlight. The airglow is composed of line emission and molecular band or continuum emissions. At times the line and band emissions in particular are greatly enhanced by the occurrence of auroral activity, by factors up to 10^3. The normal airglow is relatively constant in total integrated flux although the intensity of certain of the forbidden atomic lines varies by a factor of 5 or 10. The green line $\lambda 5577$ shows such variation and is noticed by the human eye since it is at the peak of the eye sensitivity. Recent IGY (Roach) studies of both the line emission and the integrated emission show in the absence of auroral activity that there is no latitude effect over the region of the site test. The probability of auroral enhancement of the night sky is higher for the northern portion, but the general effect should not be of importance.

The component of skylight not related to the emission of airglow does show variations that could be significant. This component is in part due to diffusion or scattering of both airglow and stellar radiation by the troposphere. Consequently a more strongly scattering atmosphere would appear brighter. We have no definitive evidence that the scattering properties are different between the sites (XVII).

The effect of ground albedo can be large. A snow covered ground will show an albedo above .50 while normal ground cover is between .15 and .30. The high albedo effect of snow has been used in northern latitudes to obtain airglow spectra with shorter exposure time. The effect is also responsible for the "ice blink" effect in the sky that was of practical importance for polar explorers.

The albedo of the regions included in the sites varies over a wide range. Unfortunately the darkest ground can be the brightest. Both Junipero Serra and Mormon are dark by virtue of the ocean and by their forest cover. The ocean, however, has a nightly fog cover during the best observing season for Junipero Serra and Mormon has a snow cover. The ground albedo for Kitt and Hualapai is slightly higher than the principle forest areas as is apparent from the Viking 12 photograph. The difference is a few percent, and not significant when the relative transparencies of the atmosphere is not known to this accuracy.

Photoelectric measures of the sky at Hualapai, Flagstaff, and Kitt were made by Mr. Knuckles. The scatter from night-to-night is larger than any possible difference between the sites. We feel that a long series of measurements would be necessary to establish the probably small mean differences and the effort would hardly yield a definitive factor.

B. City Effects

By city effects we refer principally to the sky glow from the city. The greater the distance to the city the less its effect will be. Obviously a smaller city can be closer with equal effect for a more remote metropolis. In the cases under study the distances range from 12 miles for Kingman - Hualapai; 30 miles for Flagstaff - Mormon; and 45 miles for Tucson - Kitt. At present the sky is unaffected at all sites. With a site as close as 12 miles, the site is precariously situated with respect to growth potential. We have been concerned with the large growth potential of Kingman and we feel apprehensive about the future because the city is in direct view.

The present sky glow from Tucson is appreciable on the NE horizon. Most of the city is hidden from view by the Tucson mountains. The glow does not extend very high in the sky, but its effect can be traced spectroscopically over a 15 degree angle over the city. The present growth potential of Tucson is not as high percentage-wise as Kingman because of water limitations; nevertheless the situation could become of annoyance if Tucson should expand to the westward. The probability of growth in this direction is small due to the natural barrier imposed by the Tucson mountains. Current growth is to the eastward of Tucson. Natural terrain features and rail and road systems will tend to keep the development chiefly east of the Tucson mountains for many years. The availability of low cost reclaimed water in the indefinite future could change the entire face of Arizona, but the development of a space observatory may have rendered this eventuality of minor consequence to the future of astronomy by that time.

C. Practicality

The practicality of a site covers a host of details, some of which are matters of convenience and other matters of importance. The developability of the site region is of great importance. The arrangement of the area and its total developable area is reflected in the costs of construction. As a good example, both Kitt and Hualapai have close to the same total instrumental capacity. At Kitt the sites are all connected by level terrain and the entire site system is contained within 70 acres within a T-shaped area 3000' by 3000'. At Hualapai the ruggedness of the terrain scatters the sites as relatively peaked rises along a circular arc two miles long.

If the area distribution, however, were the only factor the preceding arguments would weigh heavily against Hualapai. When the road and utilities access problems are considered we find that Hualapai has a strong advantage over Kitt in that one fifth the road system is required to open the site to development. As far as the development of water the problem is resolved in favor of Hualapai through the availability of springs. Springs exist at Mormon but their legal status is not clear. Water at Kitt will depend largely upon the collection of rain water. (see Appendix A)

In view of the function of the observatory to have visiting astronomers, the transportation facilities for each site should be considered. Both Hualapai and Mormon have similar problems. Direct transcontinental rail service is available via Santa Fe. Transcontinental service is available via AA or TWA to Phoenix and by TWA and UAL to Las Vegas. Feeder service is available via Bonanza to Kingman and Frontier to Flagstaff. The Kitt site has direct transcontinental train service via SP. Airline service is via TWA and AA to all major eastern cities.

The observatory has several other functions that inter-relate to the base town. The availability of small manufacturing facilities would simplify the research activities. Tucson not only has a good selection of supporting facilities, but also has a University with a Department of Astronomy. This factor is of considerable weight. The Mormon site has two existing observatories at Flagstaff and the location of a third observatory would be of mutual benefit to all three. The Hualapai site has rather limited support facilities, but the measure of enthusiasm and cooperation received from the citizens of Kingman makes up in large degree the lack of these facilities.

Among the practical problems the snowfall is one of importance. The operation of an observatory under conditions of heavy snowfall is possible if suitable maintenance vehicles are provided. All of the Arizona sites can be subject to snowfall as large as 75 inches at one time, including the Kitt site. As a rule Kitt has infrequent snowfall, with Hualapai close behind. The Mormon site has a disadvantage of being in a very heavy snowfall region, but the flatness of the terrain would make the snow problem easier to take in stride than the occasional snows at a more precipitous site.

D. Latitude

While the latitude of an observatory is primarily reflected in the climate, the latitude in itself is important from an astronomical viewpoint. Many of the regions of particular importance, including the nucleus of the galaxy, lie at appreciable southern declinations. The difference of slightly more than three degrees of latitude between Kitt and Hualapai is therefore of more importance than a casual glance would indicate.

E. Land Procurement

The problem of land procurement is vastly different in complexity and difficulty. The land at the Hualapai site is entirely on the ranch of the George Getz Corporation. This land has been offered at no cost to AURA by Mr. George Getz subject to final legal arrangements.

The Mormon site is in public domain and its procurement would cross problems of patented land claims, mining claims, water and timber rights and grazing rights. The procurement of clear title to the land would therefore be complicated.

The problem at Kitt revolves about the fact that the site is on the Papago Indian Reservation. It is already established that title cannot be procured for this land. The only arrangement that appears to be practicable is to secure an indefinite lease of the site. The use of the Kitt site therefore is faced with the passage of enabling legislation of some degree of complexity.

F. Desert Sites

The number of questions directed to us concerning why no sites in the Yuma region were selected for test are enough to warrant a special discussion. Evidence favorable to a Yuma site has been presented by Irwin and by McCrosky and Smith. The apparent number of days reported in these two sources is open to question and a discussion has been set forth elsewhere. The argument for a greater number of days of photometric weather is fallacious since cirrus clouds, which are the principle bane of the photometrist, are statewide phenomena. There is probably little difference in the pure cirrus cover for the region reaching from Palomar to Kitt. Yuma does have a distinct advantage as far as other cloud types are concerned.

The Yuma region is located at the northern tip of an extensive area of sand dunes as is shown well on the Viking photograph (Fig. 1). The frequency of winds up the Colorado River basin cause sandstorms in this area. The prevalence of agricultural land in the area further contributes to the dust problem.

The location of a suitable site in the extremely arid belt around Yuma and extending up into eastern California would entail finding an elevated region high enough to be above the dust layers. It has been felt necessary to be above 6000 ft. to be above the normal winter confective zone. There are no mountains within this basin that attain such heights. The peripheral ring of mountains that reach these heights are the Santa Rosa Mts. in southern California west of the Salton Sea, the Hualapai Mts. near Needles and Kingman, Harquahala, near Salome in Arizona and Kitt Peak, near Tucson. Within this ring are the Eagle Mts. near Desert Center, California and the Kofa Mts. in Arizona.

The Kofa Mts. and Eagle Mts. are less than 5000 ft. in elevation and are sunburned piles of rock with minimal desert vegetation. They are extremely forbidding from a practical aspect and eliminated from the testing program. Harquahala was considered; however, the experiences gained with this mountain when it was the site of the Smithsonian Astrophysical Observatory Solar station, coupled with the difficulties of access for testing combined to rule out further effort on this mountain.

There are numerous desert hills in the vicinity of 2000-3000 ft. elevation in the Yuma region, but they are not high enough to surmount the local dust problems.

XIX. AURA SCIENTIFIC COMMITTEE EVALUATION

The Scientific Committee of AURA, under the chairmanship of C. D. Shane reviewed the information in the preceding document at a meeting held in Pasadena, California on March 1 and 2, 1958. The committee examined each factor and voted concurrence in the following evaluation of factors. The principle discussion was limited to the Hualapai and Kitt sites.

1.	Number of clear nights	Hualapai
2.	Astronomical seeing	Kitt
3.	Wind velocity (low)	Kitt
4.	Thermal profiles (even)	Kitt
5.	Microthermal fluctuations	Kitt
6.	Air trajectories	Kitt
7.	Vapor trails	Kitt
8.	Rainfall	Equal
9.	Transparency	Equal
10.	Sky darkness	Equal
11.	Developable area	Kitt
12.	Road access	Hualapai
13.	Utilities	Hualapai
14.	Support facilities	Kitt
15.	Academic facilities	Kitt
16.	Land procurement	Hualapai
17.	Water supply	Equal
18.	Latitude	Kitt
19.	City lights	Kitt
20.	Dendroclimatology	Equal

Hualapai	4
Equal	5
Kitt	11

The Scientific Committee of AURA regretted that it was necessary to reach a final decision with a limited baseline of observations. It was felt however, that a survey to be significantly more definitive should continue for at least five years. Inasmuch as this is not practicable under the urgency of getting the observatory built, the Committee reached a unanimous decision to recommend Kitt as the site for the National Astronomical Observatory, to the National Science Foundation, subject to its availability and the passage of pertinent enabling acts by the Congress of the United States.

APPENDIX A

REPORT

on

WATER SUPPLY AT KITT PEAK

W. W. Baustian

To The Scientific Committee

AURA, Inc.

Dr. C. D. Shane, Chairman

February 1958

KITT PEAK

Water Supply and Development

The original thoughts on the problem of developing a suitable supply of water for Kitt Peak were along two lines of approach.

First, to build one or more dams in the drainage area on the easterly slope of the mountain. These would necessarily have to be located some 1000 or 1500 feet below the summit to secure enough drainage area above the catch basins. Investigation in the field indicated that there were no favorable dam sites or economical reservoir areas available. Observation of this drainage area during storm periods also made it apparent that there was considerable underground storage capacity so that relatively little surface runoff was obtained until after several inches of rainfall. It was also observed that the surface runoff contained a relatively large percentage of fine silt, which had a very slow settling rate.

The conclusions reached were:

1. That the construction of suitable dams and reservoir areas would be unduly costly.
2. That the percent of surface runoff was lower than would normally be expected in a mountain region of granitic origin, with a relatively large amount of moisture being used in the saturation of the soil cover.
3. That water that would be collected in the reservoirs would have a considerable content of finely divided silt. This would necessitate a rather large filtering installation.
4. That the water would have to be raised at least 1000 feet and more - probably 1500 or 2000 feet, to deliver it to the top of the mountain.

Second, to locate and develop springs of sufficient volume to satisfy our requirements. This means an average flow of at least one gallon per minute for minimum requirements of the stellar installation only, assuming an average population of 10 persons. To date no springs have been found within 1000 or 1500 feet of the top, in the more readily accessible areas on the mountain. Some evidence is seen from a distance that there is some seepage or drainage over a few sections of the cliffs on the north side of Kitt Peak. To date these have not been reached to check their flows or their duration. In general they are noticeable from below only after a rainfall.

From general observations these "springs" are at least 1000 feet below the summit and would be quite difficult to reach with a pipe line.

The above conditions lead to reconsidering our approach to the water supply problem. The conclusion was that it would be best to take the rain falling on the top of the mountain and keep it there. Also to keep it as clean as possible in the process of collecting it. Calculations show that a paved collection area of 3 acres would be sufficient to supply 540,000 gallons per year from a total rainfall of 8 inches. From records taken from approximately 1930 to 1940, at Baboquivari canyon to southwest of Kitt Peak and at a lower elevation, the minimum rainfall was 8 inches per year and the average was 18 inches. It is reasonable that as much can be expected at Kitt Peak. The attached charts show the distribution of rainfall for Tucson for the period from 1900 to 1956. Since Kitt Peak is in the same weather pattern as Tucson it is felt that the distribution pattern at Tucson can be also taken as representative for both areas.

The plan of using paved collection areas was discussed with Mr. Leopold A. Heindl of the U.S.G.S. Water Resources Branch in Tucson. He indicated that his recommended solution to our problem would have been the same as ours. He did say that the estimated water usage per person of 150 gallons per day was higher than is normally used in estimating the water supply needed by desert mining communities. The 150 gallon estimate was based on the demand at Lick Observatory. The other point to bear in mind is that with the addition of the Solar installation the catchment area may be expanded to suit the additional needs. It may also be advisable to add one more 550,000-gallon storage tank.

Table I, which follows, is a summary of the costs for the various development systems. This is followed by a detailed study of the different proposals.

For temporary storage on the mountain during the first phases of the construction it is planned to use a 10,000 gallon galvanized iron tank. If possible we will try to develop a local source of water with reasonable hauling distance from the top.

TABLE I

Kitt Peak - Water Supply Summary

I. REQUIREMENTS:

Based on Average Population of 10 @ 150 gal./day/person.
Max. Yearly Requirement = 540,000 gal.

II. SUPPLY:

A. Rainfall - 1930-1940 average = 18"/yr.
8" rainfall/yr. required to supply max. yearly requirement w/3-acre paved collection area.

B. Supply from spring:
1 to 1-1/2 gal./min. average flow required.

III. COSTS:

Budget Allowance = $132,000 (FY 59)

Source	Surface Storage 1,100,000 gal.	Surface Storage 600,000 gal.	Press. Tank 30,000 gal.	Elevated Storage - 100 ft. 100,000 gal.	Elevated Storage - 100 ft. *40,000 gal.	Capitol Cost
A. Spring	X			X		$ 97,870.00
B. Spring		X			X	80,870.00
C. Spring	X		X			66,870.00
D. 3-acre Collect. Area	X			X		118,243.00
E. 3-acre Collect. Area		X			X	101,243.00
F. 3-acre Collect, Area	X		X			87,243.00

* Plus 300 gal. per minute fire pump.

2-28-58
W.W.B.

KITT PEAK

Water Supply and Development

I. Rainfall

A. Amount: 18 inches per year - 1930-1940

B. Distribution: Approximately half or more in the late summer season and half or less in the spring season.

II. Requirements (Estimated population - 10)

A. Requirements per day: 1,000 gallons minimum
1,500 gallons maximum
(No lawns and minimum landscaping)

B. Maximum yearly requirement: 540,000 gallons

III. Development

A. Rainfall Catchment Area: Paved area = 3 acres (2" gunite with wire mesh 6-6-10-10). Yield per inch rainfall = 71,600 gallons. Catchment storage = 150,000 gallons.

B. Pump Units

1) For transfer from catchment area to storage tanks - Maximum size required: 300 gallons per minute capacity - @ 150 ft. head - 15 hp - 3600 rpm motor

2) For transfer from storage tanks to tower tank:
1 - 300 gallons per minute capacity @ 150 ft. head - 15 hp - 3600 rpm motor

1 - 25 gal. per minute @ 150 ft. head, est. 1-1/2 hp

C. Storage Tanks

1) Maximum: 2 - 550,000 gal. surface tanks.
1 - 100,000 gal. elevated tank, 100 ft. high.

2) Medium: 2 - 300,000 gal. surface tanks.
1 - 40,000 gal. elevated tank, 100 ft. high.

(Plus gasoline driven five pump, 300 gal. per minute @ 300 ft. - connected in line.)

3) Minimum: 2 - 550,000 gal. surface tanks.
1 - 30,000 gal. pressure tank

D. Filters

1) Duplicate Systems
Capacity each 300 gal. per min

E. Fence around Catchment Area

Type: 4-ft. sheep and cattle fencing plus 3 strands barbed wire. Steel posts (drive type) @8'-3"(1/2 rod) centers.
Total fence height: 6 ft.
Maximum length: 1,500 ft.

Estimated Costs

Item				
III-A.	Catchment Area (3 acres)			
	2" gunite with mesh @ $35.00/cu.yd. $8.00/cu.yd. haulage.			
	$\frac{3 \times 43{,}560 \text{ sq.ft.}}{162 \text{ sq.ft./cu.yd.}}$ = 807 cu.yd. @ $43.00 =			$ 34,700.
III-B.	Pump Unit			
	1)- 300 gal./minute @ 150' head, 15 hp motor			900.
	2)- 300 gal./minute @ 150' head, 15 hp motor			900.
	25 gal./minute @ 150' head, 1.5 hp motor			200.
III-C.	Storage Tanks			
	Maximum - Two 550,000 tanks - surface		$36,000	
	One 100,000 tank - tower		40,000	
				76,000.
	Medium - Two 300,000 tanks - surface		$32,000	
	One 40,000 tank - tower		25,000	
	One Fire pump unit		2,000	
			59,000	
	Minimum - Two 550,000 tank	$36,000		
	One 30,000 tank	9,000		
		45,000		
III-D.	Filters	5,000	5,000	5,000
	Sub-totals	86,700 (Min.)	100,700 (Med.)	117,700 (Max.)

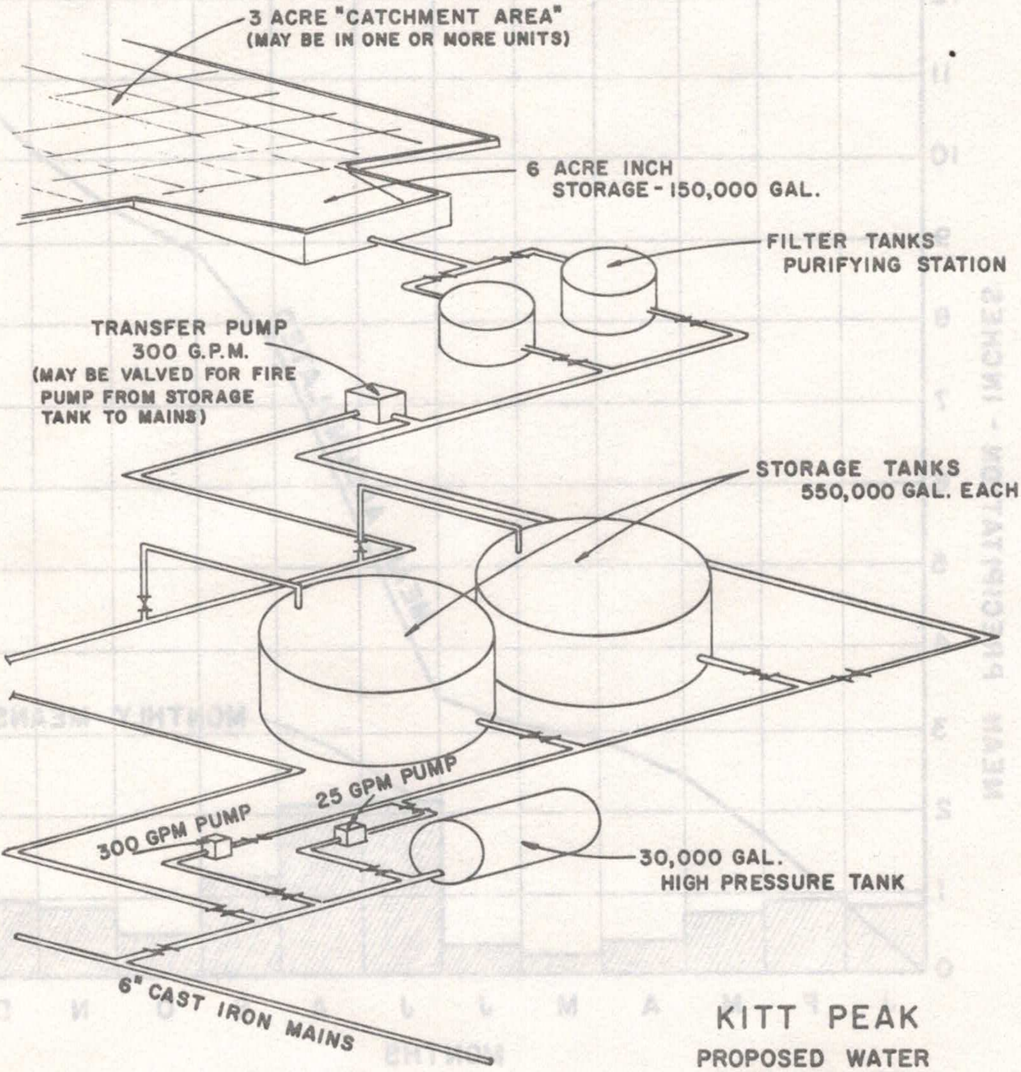
		Min.	Med.	Max.
		$86,700	$100,700	$117,700
III-E. Fencing - 1500 ft. or 90 rods				
49" Sheep & Cattle fencing, 90 rd.@.95	$ 85.50			
3 Strands barbed wire 270 rds. @.12	34.50			
180 Fence posts @1.35 each	243.00			
Labor - 90 man hrs. @$2.00	180.00	543.	543.	543.
		$87,243	$101,243	$118,243

Water Supply From Springs
(If available)

IV.	Spring Development	$ 500.
	Storage Tank at spring 10,000 gal. - galvanized iron	1,200.
V.	Pump	
	12 gal./minute - 1000 ft. head, 5 hp	1,200.
VI.	Pipe Line - Est. length 3000'	
	2" dia. extra strong - $ .62/ft. Labor - trenching, etc. 2.00/ft. 2.62	7,860.
VII.	Power Line - Est. length 1500'	
	3 No. 8 Conductors in 2" dia. conduit Place in same trench with pipe line Wire: $.04/ft., 2" dia. conduit: - $.62/ft. =	1,110.
		11,870.
	Road - 2 miles @ $5,000/mile =	10,000.

		Min.	Med.	Max.
VIII.	Storage Tanks Item III-C	45,000	59,000	76,000.
		$66,870	$80,870	$97,870

Estimated power consumption for pumping 540,000 gallons per year @ $.02/kwh $850,000

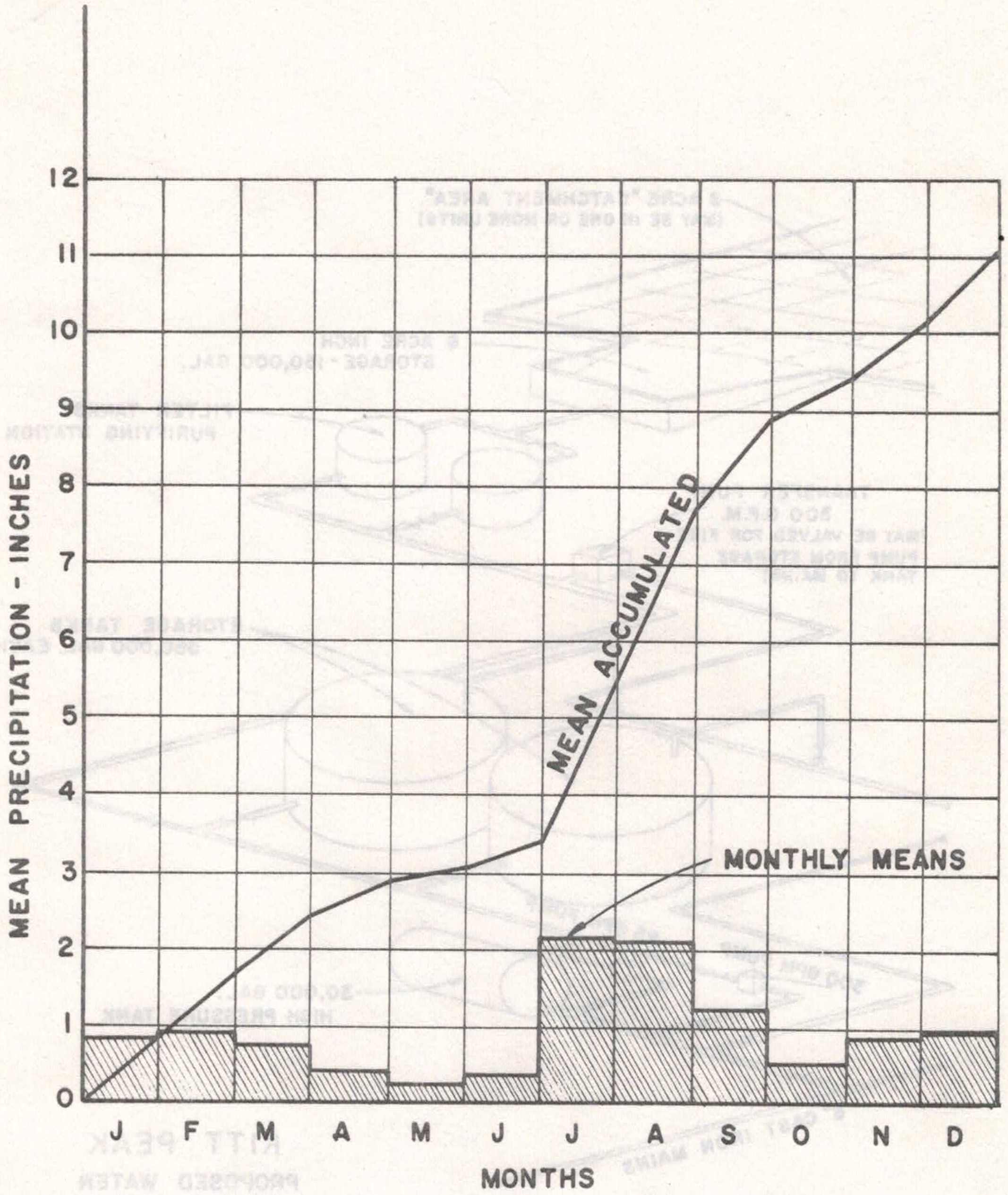


KITT PEAK

PROPOSED WATER
SUPPLY SYSTEM

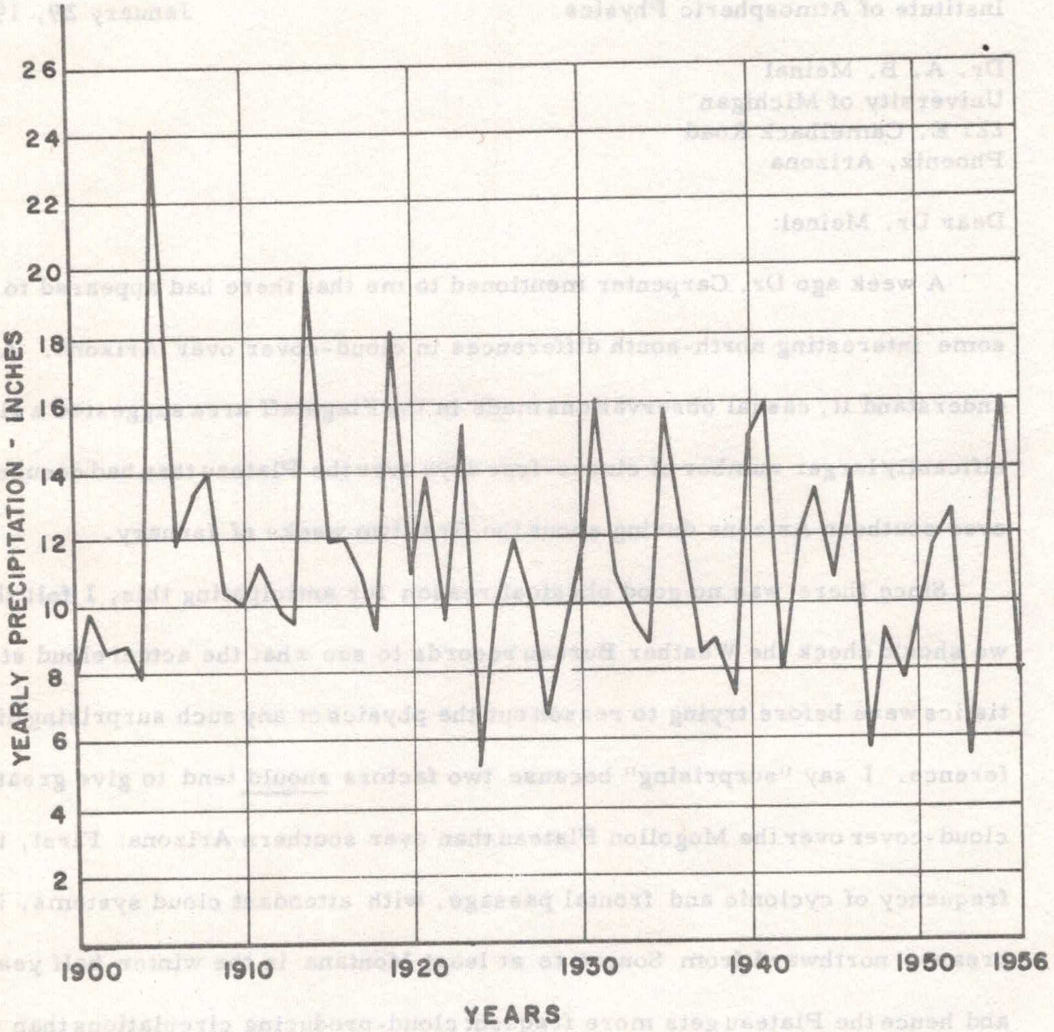
FIG. 58

2-28-58



PRECIPITATION—TUCSON
MEAN FOR 1900-1956
YEARLY AMOUNTS: MAX. 24.17"
MIN. 5.16"
MEAN 11.12"

FIG. 59



PRECIPITATION - TUCSON
YEARLY TOTALS

FIG. 60

Appendix B

UNIVERSITY OF ARIZONA

Tucson 25, Arizona

Institute of Atmospheric Physics

January 29, 1958

Dr. A. B. Meinel
University of Michigan
221 E. Camelback Road
Phoenix, Arizona

Dear Dr. Meinel:

A week ago Dr. Carpenter mentioned to me that there had appeared to be some interesting north-south differences in cloud-cover over Arizona. As I understand it, casual observations made in the Flagstaff area suggested a significantly larger number of cirrus-free days over the Plateau than had occurred over southern Arizona during about the first two weeks of January.

Since there was no good physical reason for anticipating this, I felt that we should check the Weather Bureau records to see what the actual cloud statistics were before trying to reason out the physics of any such surprising difference. I say "surprising" because two factors <u>should</u> tend to give greater cloud-cover over the Mogollon Plateau than over southern Arizona: First, the frequency of cyclonic and frontal passage, with attendant cloud systems, increases northward from Sonora to at least Montana in the winter half year, and hence the Plateau gets more frequent cloud-producing circulations than we do down here, on the average. Second, the Mogollon escarpment should tend, by and large, to produce uplift that increases cloud-cover there over and above that in southern and southwestern Arizona under otherwise uniform flow conditions, especially with a southernly component of motion at middle tropospheric altitudes. With northerly components, it is an uncertain question as to whether downslope adiabatic heating of air coming off the Plateau would make a significant difference in suppressing cloudiness here over that on the Plateau. I doubt this, as an off-hand guess, because it would require almost a north wind to realize this effect, and northwesterly winds are more common than truly north winds aloft, and then southern Arizona (Tucson area) is not really in the adiabatic lee of the Rim.

At any event, in the particular instance of recent weeks, it seemed desirable to find out what was actually taking place. John Russo, an Army forecaster now stationed at Huachuca, started working with us on a part-time basis the day after Dr. Carpenter mentioned this problem, so I asked him to work on this study. He did so, and finished it off very quickly, doing some of it with the teletype data available to him at Huachuca. All of the Weather Bureau's hourly observations and observations from five different Stations were used. Flagstaff reports only as a morning station, but nearby Winslow seemed to afford a good enough indication of Plateau conditions. As a cross-check, John compared Flagstaff, Winslow and Tucson for those hours where overlap exists.

We have summarized the results as a Technical Memorandum, and I enclose three copies for your information. If you could use one or two more copies, let us know, because we have about that many spares.

As you will quickly see, on reading this report, there is no evidence at all that the past month brought significantly better observing to the Plateau area. In fact, the evidence is weakly in the opposite direction. Thus, Table 4 on p. 4 shows that, considering all cloud types, the Tucson Weather Bureau station reported about 50% of all 685 observations with some cloud-cover, while about 63% of all 686 available Winslow Weather Bureau observations showed some cloud-cover. Considering just cirrus, and considering it in any amount, one finds from Table 1 that Tucson reported 40% of all observations with some form of cirrus, while Winslow reported about 43%. Only in the case of cirrus covering less than one-half of the sky (Table 3) does the Plateau exhibit lower frequencies, and this is almost certainly simply due to the fact that at many times when Tucson was reporting only scattered cirrus, the Plateau was reporting broken cirrus or even lower clouds obscuring the cirrus. There are a number of other points of major interest, but I believe the report brings them out well enough to dispense with other comments here.

Do you recall my asking you, on the phone some time back, for a copy of the Kitt Peak data for a particular period? We put up a thermograph on the ranger tower at 8500 ft. on Mt. Bigelow in the Catalinas as a means of cross-checking the peculiarly low diurnal ranges you told us about on Kitt. We are about to get at the summary of the Bigelow data and would like very much to incorporate, as a comparison, the Kitt data for the same short period. The days are the following 6-13-57 to 8-18-57. We would like to obtain, if possible, hourly values of temperature and humidity, and daily or more frequent precipitation amounts. When this material is assembled, we shall, of course, send you a report (probably another Tech. Memo.). If you can help us out by having those data copied, we would appreciate it very much. The meteorological questions your earlier remarks raise are, as I believe you gathered, very interesting to us as well as to you.

Sincerely,

J. E. McDonald
Senior Physicist

JEM:dt
Encl.