
Technical Report No. 61

Page 1, Paragraph 3

Error: The Annual Summary of the "Hilo Local Climatological Data," published by the Environmental Data Service of the National Oceanic and Atmospheric Administration, contains a synopsis of the Hilo climate, as well as that of the published summary, together with additional data on the extremes of Hilo rainfall.

Correction: The Annual Summary of the "Hilo Local Climatological Data," published by the Environmental Data Service of the National Oceanic and Atmospheric Administration, contains a synopsis of the Hilo climate, as well as that of the Island of Hawaii. The following information is based largely on that published summary, together with additional data on the extremes of Hilo rainfall.

Page 5, Lines 24 to 27

Error: amounts measures at the Hilo airport. There appears to be no correlation between the frequency of frontal passages with the December-January monthly rainfall for Hilo during the 30-year period results in a curious inverse relationship (see Table 1).

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Page 16, Figure 6

Shaded portion refers only to rainfall received during 50% of the years of record. Arrow should point at the dot in the center of the shaded area.

Page 18, Figure 7

Shaded portion refers only to rainfall received during 50% of the years of record.
Page 21, Figure 9

Time intervals 3-4: upper block should be shaded to indicate rainfall intensity of 0.50 - 0.99 IN/HR.
Time intervals 13-14: the upper block is correctly shaded; the next block down, now unshaded, should be shaded to indicate rainfall intensity of 0.25 - 0.49 IN/HR.

Page 23, Figure 11

Time interval 2-3; the upper block is correctly shaded; the next block down should be shaded to indicate rainfall intensity of 0.25 - 0.49 IN/HR.
Time interval 12-13: the upper block is correctly shaded, the next block down should be shaded to indicate rainfall intensity of 0.25 - 0.49 IN/HR.

Page 34, 7th Reference

Error: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service. 1970. Local climatological data, annual summary with comparative data, Hilo, Hawaii. 4 p. (In addition, weather parameters including hourly rainfall, as measured at the Hilo airport station.)
Correction: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service. 1970. Local climatological data, annual summary with comparative data, Hilo, Hawaii. 4 p. (In addition, Local Climatological Data is published monthly, reporting a variety of weather parameters including hourly rainfall, as measured at the Hilo airport station.)

Technical Report No. 60

Page 7, Line 1

Error: a) Undeveloped land areas, e.g., Waialua Bay, Oahu
Correction: a) Undeveloped land areas, e.g., Kahana Bay, Oahu
A RAINFALL CLIMATOLOGY OF HILO, HAWAII

by

Charles M. Fullerton

Technical Report No. 61
UHMET 72-03

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Partial Project Completion Report
of
SPACE-TIME VARIATIONS IN HIGH INTENSITY RAINFALL ON
THE WINDWARD COAST OF THE ISLAND OF HAWAII, PHASE I
OWRR PROJECT NO. B-024-HI, GRANT AGREEMENT NO. 14-31-0001-3575
Principal Investigator: Charles M. Fullerton
PROJECT PERIOD: July 1, 1971 to December 31, 1972

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Department of Meteorology, University of Hawaii.
ABSTRACT

Annual, monthly, and hourly rainfall data for Hilo, Hawaii are plotted and analyzed as a preliminary phase of the study of space-time variations in high intensity rainfall in this locality. A brief summary of the Hilo climate is provided. Annual rainfall amounts are shown to be highly variable, while the annual rainfall frequency remains relatively constant at about 33 percent. Monthly rainfall and maximum 24-hour rainfall amounts are displayed in the form of a monthly rainfall expectancy graph.

Hourly rainfall amounts are divided into four intensity categories: 0.01 - 0.24, 0.24 - 0.49, 0.50 - 0.99 and ≥ 1.00 inches per clock hour. The percentage distribution of annual and monthly rainfall amounts and frequencies by rainfall intensity category are plotted and discussed. Hourly data are displayed in a series of monthly diurnal distributions by rainfall intensity category.
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INTRODUCTION

As a preliminary phase of the study of space and time variations in high intensity rainfall on the windward coast of the island of Hawaii, it seems advisable to examine the general characteristics of rainfall in Hilo. In particular, it is of interest to know the diurnal variation in rainfall; that is, the total quantity of rain recorded during each hour in the various months of the year. From these monthly diurnal values, it is possible to construct seasonal or annual diurnal curves to study yearly rainfall trends or to compare conditions during limited experimental periods with historical variations over longer intervals of time (see, for example, Takahashi and Fullerton, 1972). Furthermore, it appears appropriate to evaluate available rainfall records in the light of hourly variations in rainfall. This analysis can be viewed as a first approximation to the study of instantaneous rainfall rates in Hilo and its vicinity on the island of Hawaii.

The basic data used in this report are hourly rainfall amounts, in inches, measured at the National Weather Service first order station at the Hilo airport from 1953 through 1971. The information is available as a part of the one-page summary, "Local Climatological Data," published monthly by the National Weather Service. Reported rainfall amounts are those measured during the clock hour. There is no information in the cited publication on instantaneous rainfall rates.

CLIMATOLOGICAL SUMMARY

The Annual Summary of the "Hilo Local Climatological Data," published by the Environmental Data Service of the National Oceanic and Atmospheric Administration, contains a synopsis of the Hilo climate, as well as that of the published summary, together with additional data on the extremes of Hilo rainfall.

The state of Hawaii consists of eight major islands and 124 minor islands with a total land area of 6,425 square miles and a coastline of 750 miles. The island of Hawaii is by far the largest of the Hawaiian chain, with an area of 4,038 square miles, more than twice the area of all the other islands combined. It is diamond-shaped, about 93 miles long from north to south and 76 miles wide (Fig. 1).
Hawaii lies well within the belt of northeasterly trade winds generated by the semi-permanent Pacific high pressure cell to the north and east. The climate of the island is greatly influenced by its topography which is dominated by the volcanic masses of Mauna Loa and Mauna Kea. The highest point on the island, and in the north Pacific Ocean basin, is the 13,796-foot summit of Mauna Kea closely followed by Mauna Loa which rises to 13,680 feet. Other major topographic features are Hualalai (8,271 feet), the Kohala Mountains (5,480 feet) and Kilauea (4,090 feet). The island of Hawaii is made up of these five volcanic mountains, their slopes, and the broad saddles between them. Mauna Loa and Kilauea, which occupy the entire southern half of the island, are still active volcanoes and, hence, smooth-sloped in contrast to the deeply eroded valleys found along the slopes of Mauna Kea and the Kohala Mountains.

The principal features of the island's climate are the marked variations in rainfall with location and elevation, the persistent northeasterly trade winds in areas exposed to them, and the equable temperatures, both daily and seasonally, in localities near the coastline.

Over the island's windward slopes, precipitation occurs as a result of one or a combination of climatic effects. Rainfall, in general, may be related to (1) trade-wind showers, (2) frontal or cyclonic storms and (3) intense convective storms referred to, for convenience, as thunderstorms. High intensity rainfall is generally associated with the latter two cases.

Most precipitation on the windward coast, in terms of frequency of occurrence, takes the form of showers within the ascending moist trade winds. Mean annual rainfall increases from 100 inches or more along the coasts to over 300 inches at elevations of 2,000 to 3,000 feet, and then declines to about 15 inches at the summits of Mauna Kea and Mauna Loa. Leeward areas, the southern and western sections of the island, are, in general, topographically sheltered from the trades, hence from trade-wind showers, and are therefore drier. Even in lee areas, however, afternoon and evening cloudiness and showers result from the onshore and upslope movement of sea breezes caused by the daytime heating of the land.

Where mountain slopes are steeper, mean annual rainfall may range from 30 inches along the coast to 120 inches at elevations of 2,500 to 3,000 feet. The driest locality on the island, and in the state, is the
FIGURE 1. TOPOGRAPHIC MAP OF THE ISLAND OF HAWAII.
coastal strip just leeward of the southern portion of the Kohala Mountains and the saddle between the Kohala Mountains and Mauna Kea, which has an average annual rainfall of less than 10 inches.

These contrasts in rainfall are reflected in the soil and vegetation, which are characterized by frequent and abrupt transitions from lush tropical growth to near-desert conditions, such as occurs between the wet windward slopes of Kilauea volcano and the Ka'u desert just to the south.

Hilo is a small city (population of about 28,000) located near the midpoint of the windward (eastern) coast of the island. Within the city the average rainfall varies from about 130 inches near the shore to as much as 200 inches in the higher elevations. The wettest part of the island of Hawaii, with a mean annual rainfall exceeding 300 inches, is at an elevation of about 3,000 feet about 6 miles upslope from the city limits. It rains on an average of about 280 days a year in the Hilo area.

Rainfall is measured in Hilo at several stations. Most of the data used in the present report were obtained from records of the National Weather Service's airport station for 1953 to the present. During this period, the annual rainfall varied from a maximum of 173.23 inches (1969) to a minimum of 71.40 inches (1962), the maximum monthly rainfall was 50.82 inches (December, 1954) and the minimum monthly rainfall was 0.36 inches (January, 1953), and the maximum 24-hour rainfall was 15.70 inches (February, 1969).

Hawaii's equable temperatures are associated with its mid-ocean location and the small seasonal variation in incident solar radiation. At Hilo, the range in average temperature from February and March, the coldest months, to August, the warmest month, is only 5.2°F and the average daily range is approximately 15°F. The highest temperature of record at the Hilo airport is 94°F; the lowest 53°F. Greater variations occur in localities with less rain and cloud cover, but temperatures in the mid-90's and low 50's are uncommon anywhere near the coastline of the island.

The trades prevail throughout the year, although, because of large scale climatic reasons, they may be absent for days or even weeks at a time, particularly in the winter. The trade winds which are predominantly northeasterly and their interaction with the topography have a profound influence on the climate of the island. Places on the windward side of the island exposed to the trades may be affected by local mountain circulations. For
example, the prevailing wind at the Hilo airport is not the northeasterly trade, but the southwesterly wind that drifts downslope off Mauna Loa during the night and early morning hours. The island's entire western (Kona) coast is sheltered from the trades by the high mountains. Occasionally, however, unusually strong trade winds may sweep through the relatively low (2,600 foot) saddle between the Kohala Mountains and Mauna Kea and reach the areas to the lee.

Except for occasionally heavy rains, severe weather seldom occurs on the island as a whole. During the winter, cold fronts or cyclonic storms may bring high intensity rainfall to the island from the north or from the south, often producing blizzards on the upper slopes of Mauna Loa and Mauna Kea with snow extending downward at times to the 9,000-foot level or below and icing near the summit.

Worthley (1967) studied the number and frequency of frontal passages over the four principal islands of the Hawaiian chain from 1937 through 1966. His report on the study includes a variety of interesting relationships in graphical form such as the mean monthly number of frontal passages and the 30-year frequency of frontal passages per winter season. Since the number of frontal passages varies with latitude, Hilo is the least affected of any of the stations (Lihue, Honolulu, Kahului, Hilo) and has the shortest "winter season" (number of days between the first and the last frontal passage), which lasts on an average of 140 to 145 days. Worthley's data on frontal passages through the Hilo area were compared with monthly and annual rainfall amounts measures at the Hilo airport. There appears to be no correlation between the frequency of frontal passages with the December-January monthly rainfall for Hilo during the 30-year period results in a curious inverse relationship (see Table 1).

According to Table 1, if Hilo experiences two or more frontal passages during the December-January period, the monthly rainfall is less than would be expected if there were no frontal passages, assuming no rain mechanism other than the frontal passage. Data are not available to calculate the effect of frontal passages on daily rainfall amounts measured in Hilo. It is probable that frontal passages increase the rainfall at other island stations which are more exposed to the direct influence of winter storms.

Heavy rains also are produced as a result of intense convective activity,
which often occurs during the absence of the trade-wind inversion, which is normally present at an elevation of about 6,000 feet. Such storms usually are accompanied by electrical activity and are classified as thunderstorms, even if lightning and thunder are not obvious. While Hilo averages only 8 thunderstorms per year, periods of enhanced convective activity can occur particularly in the winter. For example, in the single month of January 1971, Hilo recorded 9 thunderstorms.

Lee (1967) studied the occurrence of thunderstorms in Hawaii and presented an analysis of monthly and diurnal thunderstorm and lightning distributions for the four principal islands of the state. He used data from the Hilo Airport station from February 1946 to August 1966 to plot the following variations for Hilo:

(1) Monthly distribution of thunderstorm days
(2) Diurnal distribution of thunderstorm occurrences
(3) Diurnal distribution of lightning occurrences

While Lee's data will not be repeated in this report, it is of interest to summarize his principal findings with respect to thunderstorms in Hilo.

Lee notes that there are nearly equal numbers of thunderstorm days during October, November, and December which increase rapidly to maximum activity during February and March. Thunderstorm days decrease substantially in April and May and reach a minimum during June through September. Hilo

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**TABLE 1. FRONTAL PASSAGES AND HILO RAINFALL (DECEMBER-JANUARY, 1937-66).**

<table>
<thead>
<tr>
<th>FRONTAL PASSAGES PER MONTH</th>
<th>NUMBER OF MONTHS</th>
<th>DEC.-JAN. MONTHLY RAINFALL (INCHES)</th>
<th>% OF MEAN RAINFALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9</td>
<td>15.62</td>
<td>128</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>16.02</td>
<td>131</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>9.69</td>
<td>79</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>11.10</td>
<td>91</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>6.13</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>5.46</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>MEAN 12.25</td>
<td></td>
</tr>
</tbody>
</table>
thunderstorms are clearly a "winter-time" phenomenon, as indicated by the fact that thunderstorm days during October through March are nearly four times as numerous as during April through September.

The diurnal distribution of Hilo thunderstorms is distinctly bimodal, with the primary maximum near 1500 local time, and a secondary maximum at 0300. Minimum activity occurs between 0700 and 1100 with little variation between 1800 and 0200.

**ANNUAL RAINFALL IN HILO**

As previously noted, the annual rainfall in Hilo is highly variable. Figure 2 shows the annual rainfall over the 40-year period from 1931 to 1970. The values plotted on the graph are from the Annual Summary of the "Local Climatological Data" for Hilo, Hawaii, 1970.

Rainfall measurements during this period were made at two different locations. From 1931 through April 1942 and from January 1945 through February 1946, rainfall data shown in Figure 2 were recorded at the Federal Building in downtown Hilo at an elevation of 40 feet above sea level. All other values were measured at the Hilo airport, approximately 2 miles east of the Federal Building site. While minor changes in the location of the rain gauge occurred during the 1940's and early 1950's, the instrument has been in a relatively fixed position since February 1954. The Hilo Airport station is located at 19°43'N, 155°04'W, at an elevation of 27 feet above sea level.

The mean annual rainfall during the period 1931-1970 was 136.18 inches (the currently used climatological mean annual rainfall is 136.62 inches). Except for the three-year period of 1936 to 1938, when the annual rainfall measurements exceeded 180 inches each year, records obtained from the Hilo Federal Building appear comparable to more recent ones from the airport station.

During 1953 to 1971, the average annual rainfall was 133.86 inches. Values ranged from a high of 173.23 inches (129 percent of the average) to a low of 71.40 inches (53 percent of the average). Twelve of the 19 years of record fell within 20 percent of the average rainfall amount.

The insert in Figure 2 indicates the annual rainfall frequency at the Hilo airport over the interval of 1953 to 1970. The frequency is defined
FIGURE 2. ANNUAL RAINFALL IN HILO FOR 1931 TO 1970. INSERT SHOWS RAINFALL FREQUENCY (RATIO OF RAIN PLUS TRACE HOURS TO TOTAL HOURS) FOR EACH YEAR FROM 1953 TO 1970.
by the ratio of the number or rain hours to the total number of hours in the year. A rain hour is any clock hour in which rain was recorded at the airport station and includes both measurable and trace rainfall amounts. As the graph indicates, rain fell at the Hilo airport during approximately one-third of all the hours in the 18-year period. On the average, 96 percent of all rain hours indicate light rains of less than 0.25 inches recorded in a clock hour. These light rains contributed approximately 62 percent of the total rainfall during the period. On the other hand, heavy rainfall, defined as more than one inch in a clock hour, accounted for slightly more than 5 percent of the total precipitation, yet occurred in less than 0.2 percent of the hours in the year.

The relative constancy of the annual rainfall frequency indicates the necessity of investigating rainfall rate as the dominant factor contributing to the total amount of rainfall in Hilo. If rainfall occurs at the Hilo airport during approximately one-third of all the hours, year after year, then the high variability in the annual rainfall can only be due to variations in rainfall intensity. Furthermore, the relative constancy of the annual frequency indicates that most rainfall in the Hilo area probably is produced by a simple and regular physical process, possibly related to the local wind circulation.

In his investigation of the association of synoptic and local wind circulations with diurnal rainfall over Malaya, Ramage (1964) found that the rainfall variation was substantially controlled by local wind changes within the prevailing flow. It appears that similar relationships may exist on the windward coast of the island of Hawaii.

To more fully investigate the variation in the annual rainfall in Hilo with rainfall rate, the hourly precipitation data have been divided into four intensity categories: 0.01 to 0.24 inches per clock hour, 0.25 to 0.49 inches per clock hour, 0.50 to 0.99 inches per clock hour, and rainfall of 1.00 or more inches per clock hour and tabulated (Table 2).

Figure 3 shows the percentage of the total annual rainfall in each of the four intensity categories for each year in the period 1953-1970 (note that 1971 is not plotted). Table 3 shows the average contribution of each intensity category to the annual rainfall and the range of values about the average. It is interesting to observe that heavy rains of one or more inches per clock hour, while occurring on an average of only five hours per
## TABLE 2. RAINFALL DATA BY INTENSITY CATEGORIES

<table>
<thead>
<tr>
<th>YEAR</th>
<th>1 IN./HR.</th>
<th>0.50-.99 IN./HR.</th>
<th>0.25-.49 IN./HR.</th>
<th>0.01-.24 IN./HR.</th>
<th>TRACE</th>
<th>TOTAL RAINFALL</th>
<th>RAINFALL FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AMOUNT (INCHES)</td>
<td>HRS.</td>
<td>AMOUNT (INCHES)</td>
<td>HRS.</td>
<td>AMOUNT (INCHES)</td>
<td>HRS.</td>
<td>AMOUNT (INCHES)</td>
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<tr>
<td>1953</td>
<td>4.8</td>
<td>3</td>
<td>9.65</td>
<td>13</td>
<td>10.24</td>
<td>32</td>
<td>65.27</td>
</tr>
<tr>
<td>1954</td>
<td>19.27</td>
<td>14</td>
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<td>33.94</td>
<td>100</td>
<td>85.94</td>
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<tr>
<td>1955</td>
<td>0</td>
<td>0</td>
<td>8.09</td>
<td>11</td>
<td>29.12</td>
<td>82</td>
<td>86.21</td>
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<td>9.16</td>
<td>6</td>
<td>28.18</td>
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<td>80</td>
<td>89.95</td>
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<td>10.99</td>
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<td>66</td>
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<td>1966</td>
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<td>25</td>
<td>37.77</td>
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<td>1970</td>
<td>4.70</td>
<td>4</td>
<td>26.68</td>
<td>39</td>
<td>32.39</td>
<td>94</td>
<td>90.21</td>
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<td>1971</td>
<td>4.25</td>
<td>3</td>
<td>23.41</td>
<td>36</td>
<td>34.96</td>
<td>124</td>
<td>77.99</td>
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</tbody>
</table>

| TOTAL | 136.49 | 99   | 336.14 | 503 | 525.89 | 1580 | 1544.87 | 30251 | 22020 | 2543.39 | 59453 | 621.20 |

| AVE. PER YEAR | 7.18 | 5.21   | 17.69 | 26.47 | 27.68  | 83.16 | 81.31  | 1592.16 | 1158.95 | 133.86 | 2865  | 32.69 |
TABLE 3. PERCENTAGE AMOUNTS AND FREQUENCIES BY RAINFALL RATE.

<table>
<thead>
<tr>
<th>RAINFALL RATE (INCHES/CLOCK HR.)</th>
<th>AMOUNT (PERCENT)</th>
<th>FREQUENCY (PERCENT)</th>
</tr>
</thead>
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<tr>
<td>TRACe AMOUNTS</td>
<td>--</td>
<td>41</td>
</tr>
<tr>
<td>0.01 - 0.24</td>
<td>62.3</td>
<td>55</td>
</tr>
<tr>
<td>0.24 - 0.49</td>
<td>19.9</td>
<td>2.8</td>
</tr>
<tr>
<td>0.50 - 0.99</td>
<td>12.5</td>
<td>1.0</td>
</tr>
<tr>
<td>≥ 1.00</td>
<td>5.3</td>
<td>0.2</td>
</tr>
<tr>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

year, contribute about 5 percent of the annual rainfall.

The insert diagram in Figure 3 shows the mean rainfall rate; that is, the annual rainfall divided by the total hours of measurable rain. Since light rains constitute the major contribution to the total rainfall in Hilo, it is not surprising that the rainfall rate curve is approximately a mirror image of the 0.01 to 0.24 inches per hour intensity curve. The average rainfall rate is 0.078 inches per hour and the rate varies, as would be expected, from 0.053 inches per hour in the year of minimum rainfall (1962) to 0.095 inches per hour in the year of maximum rainfall (1969).

While rainfall rate is probably a meaningless expression when applied to periods of one year, the variations in the rate indicate the relative importance of the different rainfall categories. For example, during 1962 and 1967, while the rainfall frequency was approximately the same (30 percent), the recorded rainfall in 1967 (154.00 inches) was more than twice that of 1962 (71.40 inches). In 1962, approximately 80 percent of the total rainfall was from light rains, while the corresponding value in 1967 was 54 percent.

Annual frequency relationships for the various rainfall intensity categories are shown in Figure 4. The number of hours of trace rainfall and measurable rainfall in each of the intensity categories is expressed as a percentage of the total rain hours in each year and plotted on a logarithmic scale. Averages and ranges of values are given in Table 3.

The curve labeled "rainfall frequency (all hours)" shown in Figure 4 is presented for comparison with the other curves, although it is derived
FIGURE 4. PERCENTAGE VARIATION IN ANNUAL RAINFALL FREQUENCY IN HILO IN FOUR INTENSITY CATEGORIES AND TRACE AMOUNTS. THE CURVE LABELLED "RAINFALL FREQUENCY (ALL HOURS)" IS THE SAME AS THAT SHOWN IN THE INSERT IN FIGURE 2.
in a different way. It is the same curve shown in the insert box in Figure 2, and it thus indicates the percentage of rain hours in the year.

MONTHLY RAINFALL IN HILO

Figure 5 is a plot of the Hilo monthly rainfall during the 40-year period 1931 through 1970. As previously mentioned, data were taken at the Hilo Federal Building from 1931 through April 1942 and from January 1945 through February 1946. All other rainfall data were measured at Hilo airport. Monthly amounts in excess of 40 inches were recorded during five months: March 1939; March 1942; December 1946; December 1954; and February 1969. There were also four months in the 40-year period when the monthly rainfall was less than one inch: January 1940; February 1941; January 1953; and December 1963. It is interesting to note that all of the monthly extremes occurred during the winter season in Hilo.

The 40 years of record for each calendar month were divided into three groups: the 10 years with the highest monthly rainfall (upper quartile), the 10 years with the lowest monthly rainfall (lower quartile), and the intermediate 20 years of record. This information is plotted in Figure 6, which may be considered a monthly rainfall expectancy graph for Hilo.

The maximum monthly rainfall, 50.82 inches, occurred in December 1954 and the minimum, 0.36 inches, occurred in January 1953. The months of highest rainfall, both in the maximum recorded amount and in the upper limit of the 50 percent section, are February, March, and December. If the February monthly rainfall is normalized to 31 days (for better comparison with the March and December data), it exceeds the amount measured in March. The two months which have the highest normalized rainfall are December and February. The decrease in monthly rainfall in January, occurring in mid-winter and directly between the two months of highest rainfall, is probably a result of the reduced rainfall frequency in January (see Figure 8, p. 19).

The months of lowest mean rainfall amount in Hilo are June, July, and September. Since Figure 6 was drawn, three new monthly lows have been established and have been added to the figure.

Figure 7, showing the maximum 24-hour rainfall in each month, is plotted
LEGEND:

- □ VALUES > 40"
- ▲ VALUES < 1"

FIGURE 5. MONTHLY RAINFALL FOR HILO (1931 TO 1970).
FIGURE 6. QUARTILE DISTRIBUTION OF RAINFALL IN HILO BY MONTH (1931-1970).
in the same fashion as Figure 6, except that the period of record considered is 1953-1970. The months of highest 24-hour rainfall are February and November, while the lowest 24-hour maximum rainfalls were recorded in January and December. Excluding the high rainfall months of February and November and the lower summer months of June, July, and September, all maximum 24-hour rainfall amounts fall in the range of 9.5 ± 0.8 inches.

The concentration of heavy rainfall in the winter months is shown clearly in Figure 8, where the total rainfall in the 18-year period, 1953 to 1970, is plotted by month and by intensity category. More than 75 percent of the total rainfall in June, July, and September is associated with light rains, i.e., those less than 0.25 inches per clock hour. On the other hand, about 50 percent of the monthly rainfall in February and November is associated with rainfall of more than 0.25 inches per hour.

Figure 8 also indicates the monthly frequency of rainfall in the Hilo area. While less than 25 percent of the January hours are rain hours, rain falls in more than 35 percent of the hours in April, May, and August.

**DIURNAL RAINFALL IN HILO**

More than 160,000 hours of rainfall data recorded by the National Weather Service at the Hilo airport have been used to construct diurnal rainfall graphs. Hourly rainfall amounts have been divided into the four intensity categories previously described and plotted by month. The January through June graphs (Figures 9 through 14) show total rainfall for each hour of the day over the 19-year period from 1953 through 1971. The graphs for July through December (Figs. 15 through 20) are for the 18-year period from 1953 to 1970.

On an annual basis, heavy rains may occur during any hour of the day, particularly in the winter months. During the entire period of record studied, there were no heavy rains recorded in June and only one such event in July. Furthermore, in the daytime hours between 0800 and 1400, there was only one hour of heavy rainfall recorded during the six-month period from May through October. Heavy rains occur most frequently in the hourly periods ending at 0800, 1500, 1800, and 2200 local time.

The data demonstrate convincingly that the annual diurnal rainfall curve for Hilo exhibits a minimum in the afternoon, between 1400 and 1500 hours. This effect, however, is masked during the winter months by the
FIGURE 7. QUARTILE DISTRIBUTION OF MAXIMUM 24-HOUR RAINFALL IN HILO BY MONTH (1953-1970).
FIGURE 8. PERCENTAGE VARIATION IN MONTHLY RAINFALL AMOUNTS IN HILO BY FOUR INTENSITY CATEGORIES (1953-1970).
relatively heavy rainfall associated with synoptic disturbances and convective activity. It is difficult to see any particular diurnal pattern in the January and February rainfall (Figs. 9 and 10). The tendency toward decreasing afternoon precipitation, particularly of the light rains, begins to appear in the diurnal graph for March (Fig. 11). The months of May through October (Figs. 13 through 18) illustrate clearly the normal summer-time diurnal variation in Hilo rainfall. This pattern also can be seen in the November graph (Fig. 19), although not as distinctly, and by December (Fig. 20) the predominantly winter-type rainfall again complicates the simple nighttime maximum-daytime minimum relationship.

The graph for August (Fig. 16) illustrates a diurnal pattern frequently observed in Hilo. In addition to the afternoon minimum, the rainfall often shows two maxima, one in the early evening between 2000 and 2300 and another in the early morning between 0300 and 0500.

The diurnal variation in rainfall frequency also has been calculated for each month. The frequency curves have not been reproduced in this report since they are quite similar to the diurnal variation in light rainfall amounts. The boundary between the shaded and unshaded portion of each diurnal curve (Figs. 9 through 20) may be taken as a close approximation to the frequency curve for that month. This result might be anticipated, since more than 93% of the hours of measurable rain are hours of light rainfall, that is, less than 0.25 inches per clock hour.

The monthly diurnal graphs may be combined to study seasonal variations or to derive an annual curve. Such a curve has been plotted for each year from 1953 to 1970. While the curves have not been reproduced in this report, it is of interest to note that they are quite similar to one another, year after year. The annual rainfall amounts vary widely, but the diurnal pattern persists. This fact suggests, as does the relative constancy of the annual rainfall frequency, that Hilo rainfall is produced by a simple and regular process. The details of the physical mechanism underlying rainfall in Hawaii are currently being investigated at the Cloud Physics Observatory.

OTHER SOURCES OF INFORMATION

Probably the best single source of data on rainfall in the State of Hawaii is Taliaferro's (1959) *Rainfall of the Hawaiian Islands*. Taliaferro
FIGURE 10. MONTHLY DIURNAL RAINFALL DISTRIBUTION FOR HILO SHOWING TOTAL RAINFALL PER CLOCK HOUR BY INTENSITY CATEGORY: FEBRUARY 1953-1971.
FIGURE 11. MONTHLY DIURNAL RAINFALL DISTRIBUTION FOR HILO SHOWING TOTAL RAINFALL PER CLOCK HOUR BY INTENSITY CATEGORY: MARCH 1953-1971.
FIGURE 15. MONTHLY DIURNAL RAINFALL DISTRIBUTION FOR HILO SHOWING TOTAL RAINFALL PER CLOCK HOUR BY INTENSITY CATEGORY: JULY 1953-1970.
FIGURE 17. MONTHLY DIURNAL RAINFALL DISTRIBUTION FOR HILO SHOWING TOTAL RAINFALL PER CLOCK HOUR BY INTENSITY CATEGORY: SEPTEMBER 1953-1970.
LEGEND:
RAINFALL DISTRIBUTION

- 1.0 OR MORE IN / HR
- 0.50 - 0.99 IN / HR
- 0.25 - 0.49 IN / HR
- 0.01 - 0.24 IN / HR

FIGURE 18. MONTHLY DIURNAL RAINFALL DISTRIBUTION FOR HILO SHOWING TOTAL RAINFALL PER CLOCK HOUR BY INTENSITY CATEGORY: OCTOBER 1953-1970.
FIGURE 20. MONTHLY DIURNAL RAINFALL DISTRIBUTION FOR HILO SHOWING TOTAL RAINFALL PER CLOCK HOUR BY INTENSITY CATEGORY: DECEMBER 1953-1970.
presents annual and monthly median isohyetal maps for the islands of Hawaii, Maui, Molokai and Lanai, Oahu, and Kauai, based on data for the 25-year period, 1933 to 1957. In addition, he provides tables of median and extreme monthly rainfall amounts and median, upper and lower quartile, and extreme annual rainfall amounts for approximately 1400 active and discontinued rain gauges. The compilation includes an index of rain gauges, along with locator maps, and a useful bibliography of 88 publications related to Hawaiian rainfall.

The Department of Land and Natural Resources of the State of Hawaii has published *An Inventory of Basic Water Resources Data: Island of Hawaii* (1970). The report contains monthly and annual rainfall amounts for more than 100 stations and an isohyetal map of the island showing mean annual rainfall during 1931 to 1960, based on records from 97 gauges. Additional selected data on temperatures, evaporation, wind, humidity, stream flow, ground-water resources, and water quality are also provided.

A valuable source of literature on rainfall and other weather phenomena in Hawaii has been compiled by Ekern and Worthley (1968). In most cases the author's abstract or a brief description of the paper is given.

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