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A STUDY OF HAWAIIAN AND LINE ISLANDS RAINFALL

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN METEOROLOGY

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By

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We certify that we have read this thesis and that in our opinion it is satisfactory in scope and quality as a thesis for the degree of Master of Science in Meteorology.

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1.0 INTRODUCTION

This report can be considered as yet another installment in what will probably be a never-ending study of precipitation in the vicinity of the Hawaiian and Line Islands. It began as an attempt to update an excellent study conducted by Solot (1950). Although Solot was primarily concerned with the problem of extended precipitation forecasts for the Hawaiian Islands, this study will focus on trends in precipitation which have become apparent with the significant extension of the data and on the relationships between Hawaiian precipitation and meteorologically significant events in other regions of the tropics.

2.0 THE HAWAIIAN ISLANDS

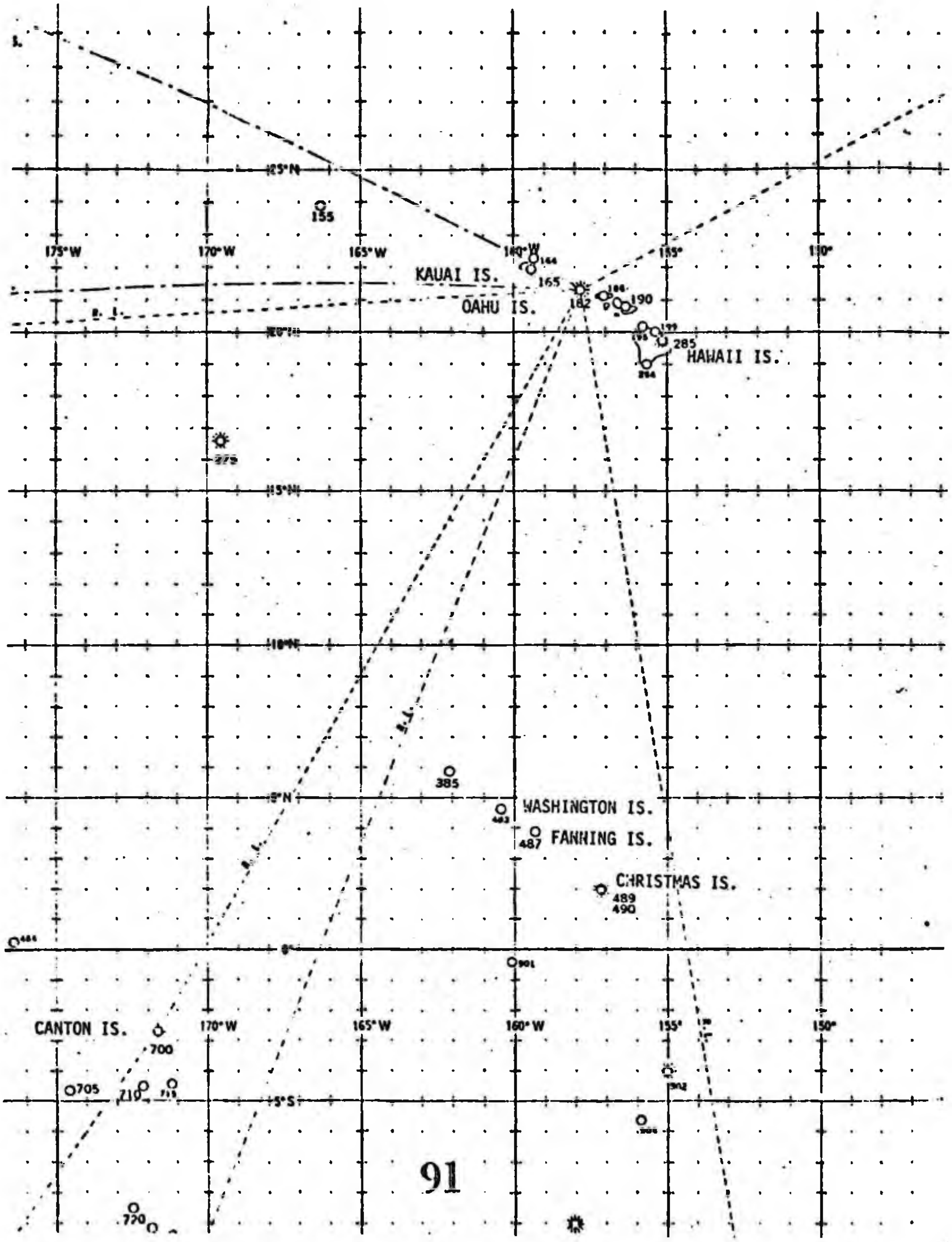
2.1 Selection of Stations

The monthly precipitation records of twenty-seven stations within the Hawaiian Islands, representative of the various climatic regimes, will be used in this study.

On the matter of the selection of the stations we quote from Solot's study:

> "Preliminary examination of the data showed that considerable variation exists among the rainfall regimes on the various islands. Synoptic experience indicates that the windward or northeast slopes of each island differ somewhat in rainfall regime from the leeward or southwest slopes. High correlation between rainfall amount and station elevation suggests height above sea level as possibly an important factor in the rainfall variability.
>
> "Thus it was decided to investigate the necessity of grouping stations by three physical

Figure 1. Location of islands used in study.


25°N
175°W
170°W
165°W
160°W
155°
150°
155
KAUAI IS.
OAHU IS.
165
182
190
285
HAWAII IS.
20°N
15°N
10°N
5°N
385
WASHINGTON IS.
FANNING IS.
487
CHRISTMAS IS.
489
490
0°
CANTON IS.
700
705
710
5°S
720

characteristics: geographic location, aspect with respect to the northeast trades, and height above sea level. It was further decided to use three distinct classes for each variable. For geographic location three islands were chosen: for southeast, the island of Hawaii; for central location, the island of Oahu; and for northwest, the island of Kauai. For aspect, the classes chosen include the windward or northeast slopes, the leeward or southwest slopes of each island, and an intermediate classification designated neutral, which includes central saddle areas as well as coastal stations located neither to windward nor leeward. For height, the classes chosen are: low level stations between sea level and 100 feet, middle level stations between 500 and 750 feet, and high level stations between 1000 and 1500 feet.

"... The 27 stations finally used were carefully chosen with regard to representativeness, absence of location changes, and length of record. An effort was made to spread the stations over the islands in such a manner as to avoid clustering."

Since a number of stations used in the original study are no longer operating it was necessary to select replacements for them. Whenever possible the same selection criteria were used as in the original study.

It was particularly difficult to find such stations on the island of Kauai. The choice lay between stations with long records which however had undergone significant location changes and fixed stations with shorter periods or record. Since there is such a great geographic variability of rainfall in the islands, any significant change of location would greatly detract from the representativeness of a station. Therefore, I decided to use fixed stations with shorter periods of record, whenever possible choosing stations whose reduced records might serve to complement one another. In all, seven replacement stations were selected. The other twenty stations remain as in the original study, with updated records.

The stations used in this study and their periods of record are listed in Table 1. Within each island grouping the stations are arranged by aspect: the first three are windward; the second three are neutral; and the last three are leeward. Within each aspect grouping the stations are arranged in order of elevation: high, middle, low. The replacement stations not used in the original study are identified with an asterisk. Therefore Station 5, East Lawai, one of the stations used in the original study by Solot, is a middle, neutral station on the island of Kauai. The locations of the stations are shown in Figures 2-4.

2.2 The Rainfall Index

In one of their studies of Hawaiian rainfall Stidd and Leopold (1951) pointed out that it is difficult to find a simple parameter which can adequately describe precipitation in the islands. On the method of selection of a representative index we again quote from Solot (1950):

> "The question of what kind of measure of rainfall to use in the computation of the indices then arises. An unweighted average of the depth of precipitation would tend to overemphasize those stations that have high normal values of rainfall. Since variations of normal precipitation among these stations is very large, it is necessary to choose some measure of rainfall that will provide a common scale. After considerable experimentation, it was found that the most satisfactory measure of rainfall for this purpose is percentile rank or accumulated percentage frequency. This quantity may be defined as the ratio of the rank of a given value in an ordered array, expressed as a percentage, to the total number of cases.

TABLE 1. LIST OF HAWAIIAN ISLANDS STATIONS

Station	Elevation	Length of Record
Kauai		
1. *Iliilula Intake--1050	1070 ft.	1935 - 1975
2. Kumaloa Ditch--996	835	1907 - 1948
3. Kealia--1112	15	1899 - 1975
4. Wahiawa Mountain--990	2250	1901 - 1973
5. East Lawai--934	450	1902 - 1975
6. Puuhi--940	80	1907 - 1963
7. *Puehu Ridge--1040	1660	1939 - 1975
8. Brydeswood Station--985	700	1910 - 1975
9. Waiawa--943	38	1894 - 1975
Oahu		
10. Nuuanu Reservoir #4--783	1100	1905 - 1975
11. Makapuu Point--724	550	1907 - 1973
12. Kahuku--912	25	1891 - 1973
13. Wahiawa--872	1000	1914 - 1965
14. *Waimea--892	420	1916 - 1975
15. Waialua Mill--847	32	1901 - 1975
16. Waianae Mauka--803	1575	1905 - 1973
17. Aiea Field 75--761	500	1907 - 1970
18. Ewa Plantation--741	42	1891 - 1975

Station	Elevation	Length of Record
Hawaii		
19. Hakalau Mauka--135	1200 ft.	1905 - 1963
20. *Paauhau--217	400	1890 - 1975
21. Papaikou Makai--144A	100	1899 - 1975
22. *Kiolakaa--6	1925	1929 - 1975
23. Naalehu--14	673	1890 - 1975
24. Kapolo--93	110	1891 - 1959
25. *Kaawaloa--29	1340	1901 - 1975
26. Napoopoo--28	650	1901 - 1975
27. *Holualoa Beach--68	10	1921 - 1975

Figure 2. Location of stations; island of Kauai.

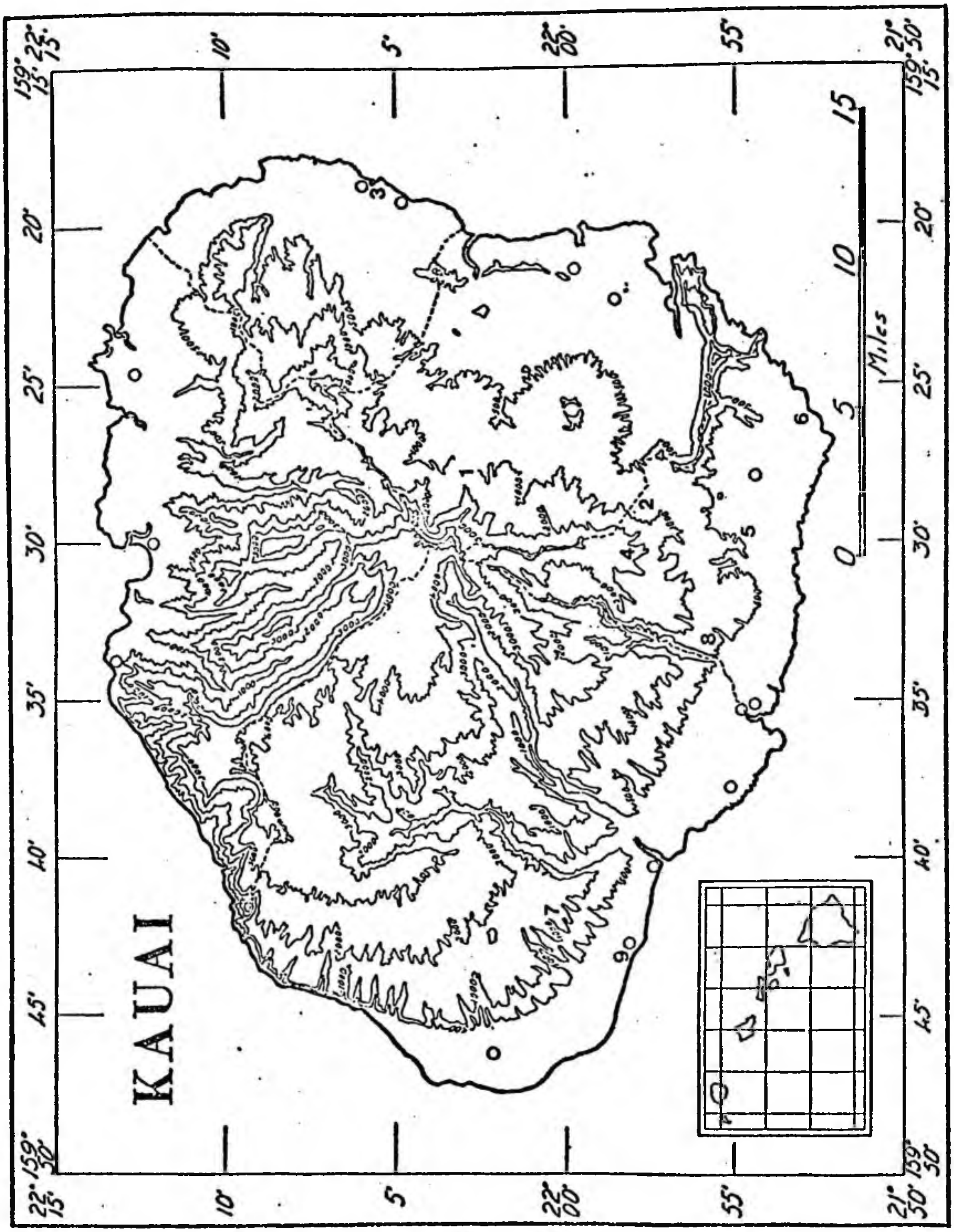

KAUAI
Miles
0
5
10
15

Figure 3. Location of stations: island of Oahu.

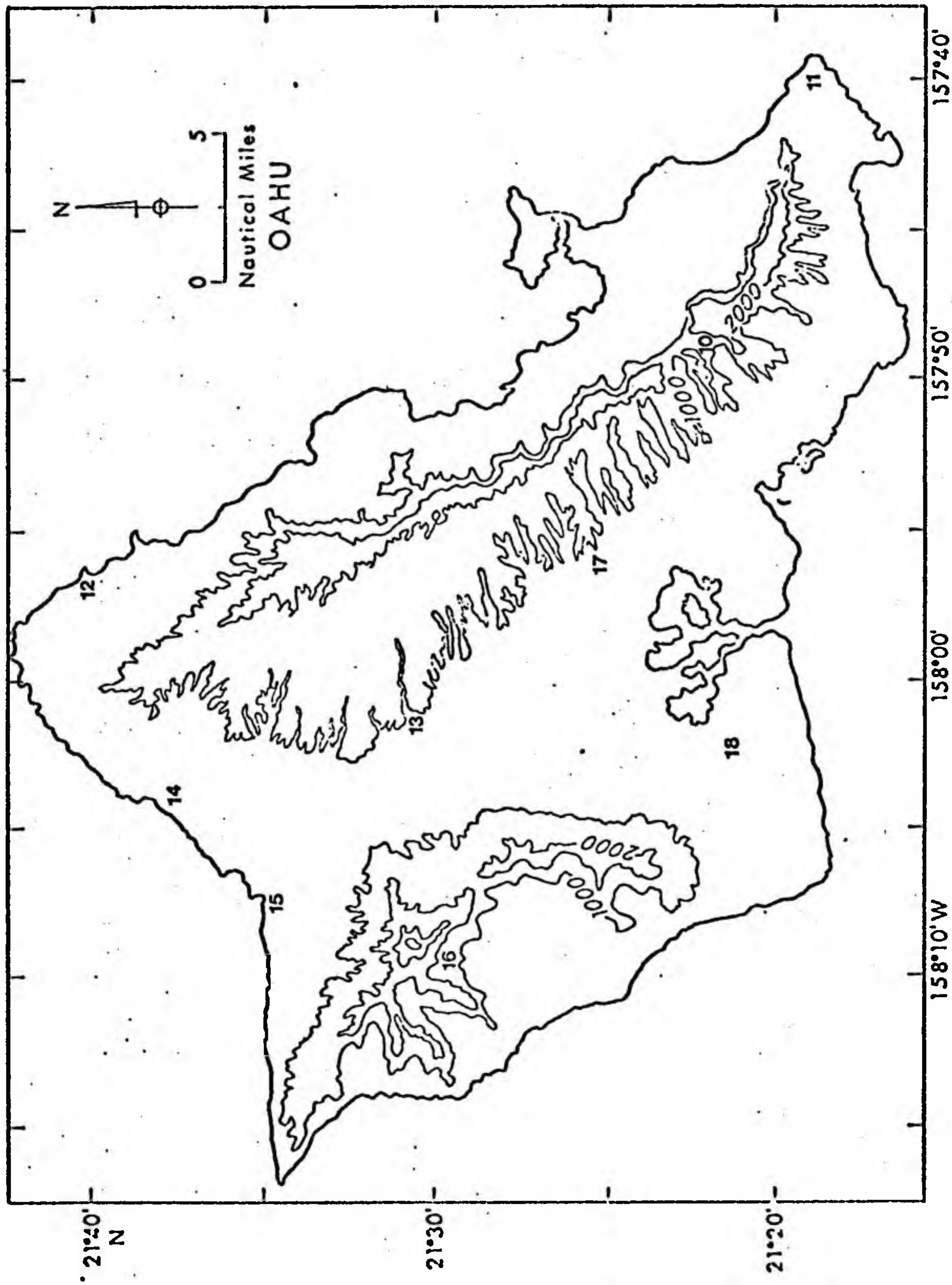
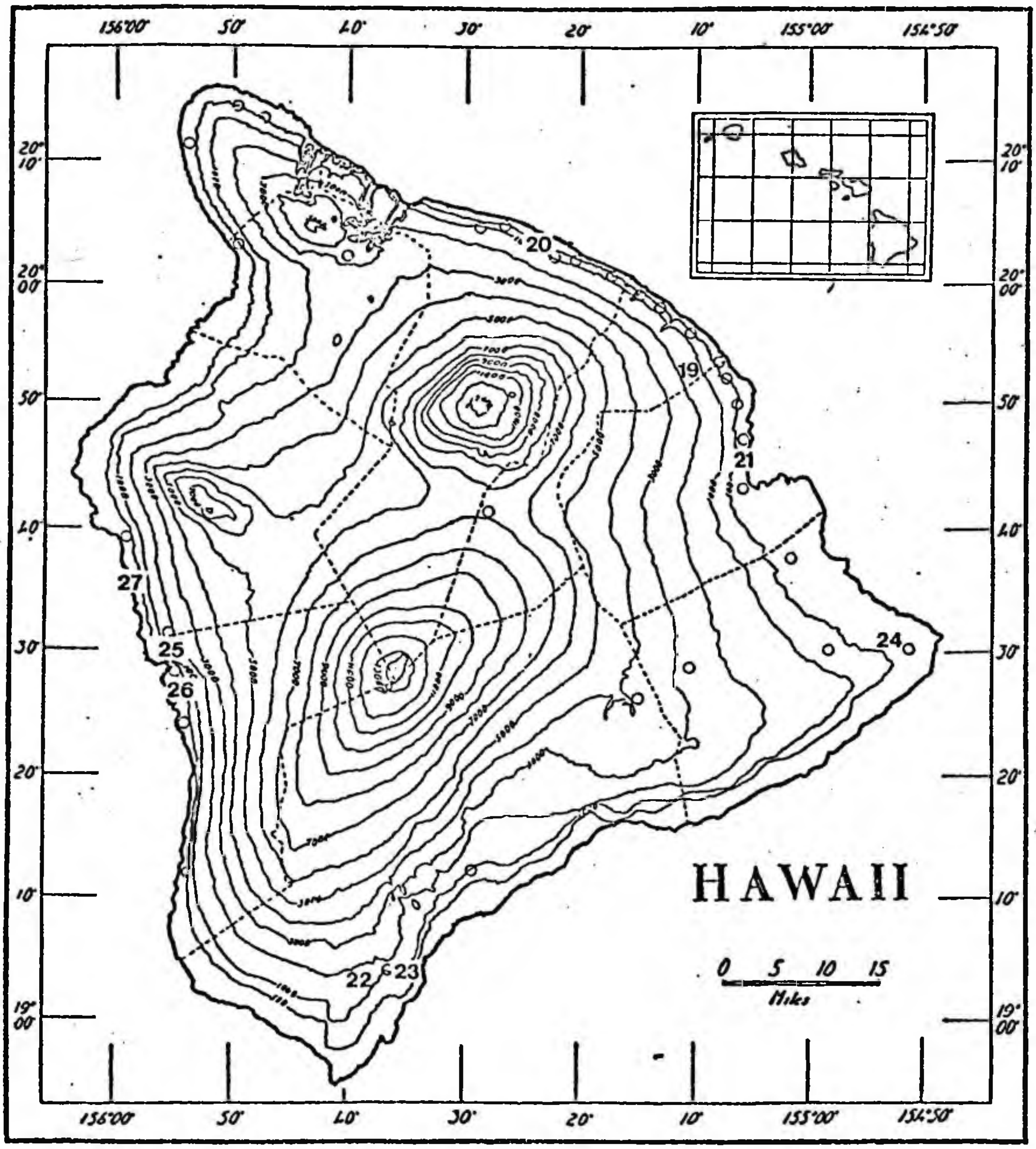

OAHU
Nautical Miles
0
5
N
21°40'
N
21°30'
21°20'
157°40'
157°50'
158°00'
158°10'W
11
12
13
14
15
16
17
18
1000
2000
1000
2000

Figure 4. Location of stations: island of Hawaii.


HAWAII
0 5 10 15
Miles
156°00'
50'
40'
30'
20'
10'
155°00'
154°50'
20° 10'
20° 00'
50'
40'
30'
20'
10'
19° 00'
19
20
21
22
23
24
25
26
27

"... Presumably also, if the distribution of values were smooth enough this number would represent the probability of occurrence of that amount of precipitation in that month at that station.

"... The use of percentile rank as a measure of precipitation magnitude has several advantages:
(1) It provides a common scale for all stations.
(2) The scale automatically adjusts itself to the density of the data, becoming finest in the region where the data are most plentiful.
(3) It provides a ready means of studying directly the frequency distribution function.
(4) It expresses magnitude in the same terms as the forecast."

This method of assigning indices to a sample group of data is demonstrated in Table 2.

The mean index value for all stations for each month from January 1890 to December 1975 was then calculated and the results are presented in Table 3.

2.3 Necessity for Station Classes

Before we depart from Solot's study, one other comparison will be made. Solot correlated the rainfall indices for the two extreme classes of each parameter (aspect, elevation and location) and presented these comparisons in graphical "scatter diagrams" (Figure 5). These computations were repeated using the extended data and the results are produced for comparison (Figures 6-8). One can see that the amount of scatter is about the same, indicating no significant effect due to either the substitute stations or the extension of the data. From this one can conclude that the distribution of rainfall within each parameter has not changed significantly since the time of the original study.

TABLE 2. SAMPLE RAINFALL INDEX CALCULATION

Sample Data	Ordered Data	Assigned Index Value
22.64	22.64	100
5.35	11.45	90
8.19	8.19	80
11.45	6.88	70
2.37	5.96	60
6.88	5.70	50
5.70	5.35	40
2.74	2.74	30
0.54	2.37	20
5.96	0.54	10

TABLE 3.
CALENDAR OF HAWAIIAN RAINFALL INDEX
ALL STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1890	84	80	84	58	66	77	93	71	53	89	47	51	1890
1891	60	45	25	22	26	19	39	48	66	54	20	37	1891
1892	74	43	20	39	51	55	37	44	23	47	21	50	1892
1893	43	77	54	63	33	20	39	14	20	14	70	25	1893
1894	55	88	46	36	10	25	38	25	27	29	76	36	1894
1895	41	48	24	47	45	48	60	58	81	59	60	65	1895
1896	44	43	51	53	54	41	30	73	33	25	50	40	1896
1897	24	22	27	16	35	52	27	50	55	54	58	30	1897
1898	53	63	88	24	29	56	52	26	37	19	27	30	1898
1899	16	39	62	56	75	58	43	34	22	71	7	23	1899
1900	10	48	19	42	45	33	49	61	35	70	72	17	1900
1901	38	84	63	55	69	47	55	27	39	48	59	73	1901
1902	16	32	90	37	46	61	55	47	65	65	64	73	1902
1903	40	38	24	62	41	37	58	45	60	37	44	15	1903
1904	49	88	54	65	38	50	50	80	64	46	33	38	1904
1905	17	11	19	27	50	49	52	72	74	44	68	35	1905
1906	42	8	19	34	52	35	40	73	43	36	69	76	1906
1907	75	74	64	32	54	77	65	83	69	40	37	31	1907
1908	19	63	71	40	37	39	22	47	60	32	16	29	1908
1909	42	53	73	45	47	51	57	25	39	36	9	80	1909
1910	58	26	32	43	50	76	49	58	67	40	59	47	1910
1911	70	76	55	38	59	61	53	42	81	33	32	39	1911
1912	14	43	38	44	35	37	37	40	23	52	33	48	1912
1913	39	36	30	49	74	85	28	52	42	56	77	21	1913
1914	48	21	54	52	82	71	56	64	90	28	54	65	1914
1915	12	35	16	70	27	76	60	33	60	65	83	82	1915
1916	83	36	60	47	77	58	61	53	50	59	61	79	1916
1917	68	45	79	63	70	61	46	42	51	47	47	49	1917
1918	69	80	78	89	40	46	67	72	38	45	76	54	1918
1919	26	18	30	37	34	41	46	31	49	50	26	42	1919
1920	63	18	68	39	57	54	52	51	61	55	44	70	1920
1921	90	28	22	39	33	32	48	38	40	51	31	71	1921
1922	64	51	46	40	48	29	27	35	75	53	50	10	1922
1923	87	68	75	73	37	29	40	36	44	45	16	78	1923
1924	12	38	27	81	39	29	59	32	29	61	29	46	1924
1925	35	23	64	51	39	46	47	41	52	42	40	33	1925
1926	22	18	16	15	18	74	40	56	41	39	16	38	1926
1927	56	33	73	74	69	54	61	51	68	33	61	93	1927
1928	27	27	24	56	43	36	67	41	40	38	63	34	1928
1929	40	60	28	41	46	30	56	60	38	44	76	66	1929
1930	67	36	54	42	30	66	40	51	81	60	67	15	1930
1931	14	26	30	39	55	25	46	74	74	57	42	26	1931
1932	51	90	37	55	60	47	48	46	42	27	61	46	1932
1933	59	70	68	39	42	54	40	28	41	11	25	40	1933
1934	43	35	18	47	60	85	53	36	83	59	48	37	1934
1935	55	70	47	29	28	50	53	40	73	61	54	24	1935
1936	48	49	51	41	53	44	71	78	71	85	35	60	1936
1937	75	77	63	51	79	39	78	69	51	57	43	58	1937
1938	54	78	65	58	69	71	57	71	25	46	43	32	1938
1939	42	71	76	80	54	65	53	30	45	77	52	17	1939
1940	38	27	45	41	71	36	52	77	49	62	57	17	1940
1941	22	18	27	18	52	57	31	60	67	81	21	20	1941
1942	17	42	58	61	41	68	45	51	52	53	45	77	1942
1943	71	38	47	27	66	66	35	55	40	26	16	38	1943
1944	11	76	72	28	50	67	48	31	24	33	26	47	1944
1945	8	33	44	82	28	43	44	62	36	46	40	58	1945
1946	66	68	39	53	15	50	56	28	27	40	49	75	1946
1947	25	13	46	31	63	54	47	73	56	35	56	50	1947
1948	65	49	58	56	59	54	53	62	57	36	70	61	1948
1949	88	68	39	18	33	54	44	32	18	24	37	58	1949
1950	75	62	43	81	62	28	42	62	35	28	51	49	1950
1951	51	73	90	43	27	35	38	66	57	87	55	67	1951
1952	66	37	61	37	44	53	44	20	38	64	54	18	1952
1953	21	57	55	26	41	40	25	23	21	24	27	46	1953
1954	32	54	58	49	50	66	79	62	45	47	67	71	1954
1955	49	80	59	43	51	38	45	59	57	37	68	64	1955
1956	74	84	37	47	58	62	38	60	40	75	68	52	1956
1957	80	52	14	59	32	32	54	69	19	34	61	69	1957
1958	20	40	60	19	46	52	80	37	49	79	33	39	1958
1959	60	55	14	45	45	17	43	80	39	22	53	35	1959
1960	36	45	61	38	71	48	32	44	64	60	35	49	1960
1961	37	45	32	56	62	62	50	45	42	76	62	54	1961
1962	58	44	70	59	65	46	35	37	41	43	18	29	1962
1963	68	33	79	91	75	67	65	39	66	35	18	26	1963
1964	54	36	74	58	50	47	64	44	53	51	72	77	1964
1965	58	44	26	75	86	48	66	53	58	70	88	55	1965
1966	34	70	19	18	31	39	58	53	46	67	82	38	1966
1967	40	58	75	56	64	47	68	74	47	42	70	81	1967
1968	68	54	59	78	33	38	51	22	53	67	51	89	1968
1969	72	61	37	43	50	38	64	47	53	27	51	39	1969
1970	53	19	7	56	54	46	61	48	49	48	71	46	1970
1971	81	44	61	77	27	48	31	27	60	30	49	58	1971
1972	64	71	48	74	40	47	39	46	50	67	33	35	1972
1973	20	19	34	28	46	37	29	20	40	48	67	58	1973
1974	70	40	63	72	56	63	62	18	60	62	63	36	1974
1975	73	76	50	37	33	22	33	18	17	32	60	46	1975

Figure 5. Scatter diagrams showing rainfall correlation between stations with contrasting characteristics, according to Solot (1950).

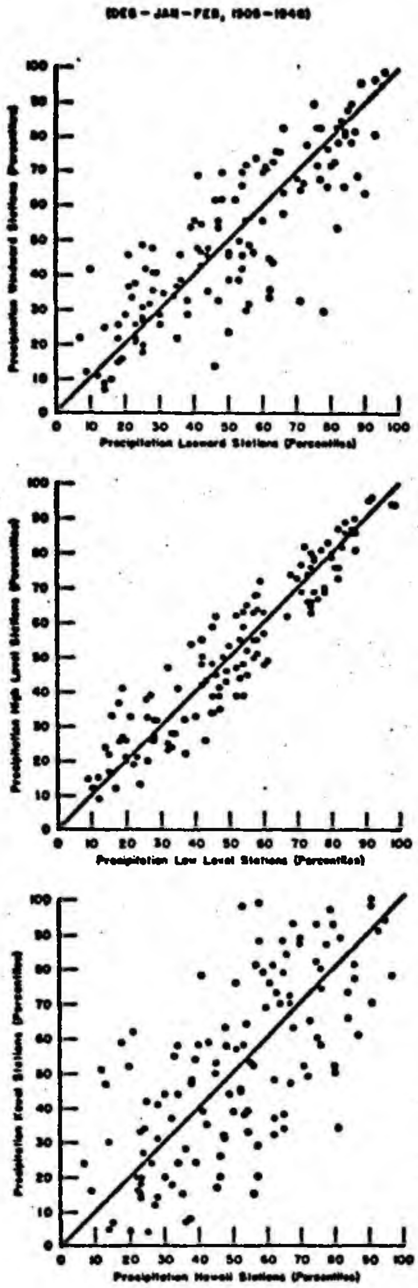


Figure 6. Rainfall correlation between stations with contrasting characteristics: windward vs. leeward.

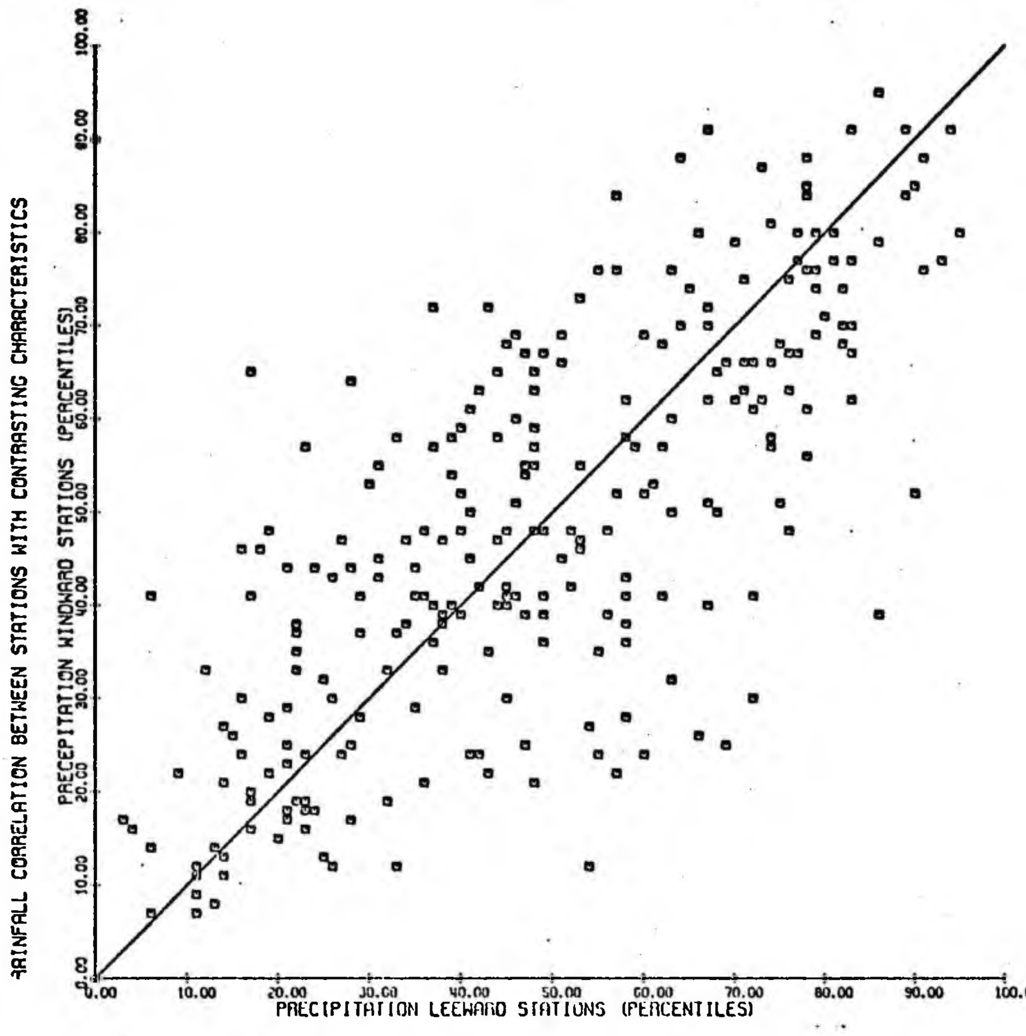
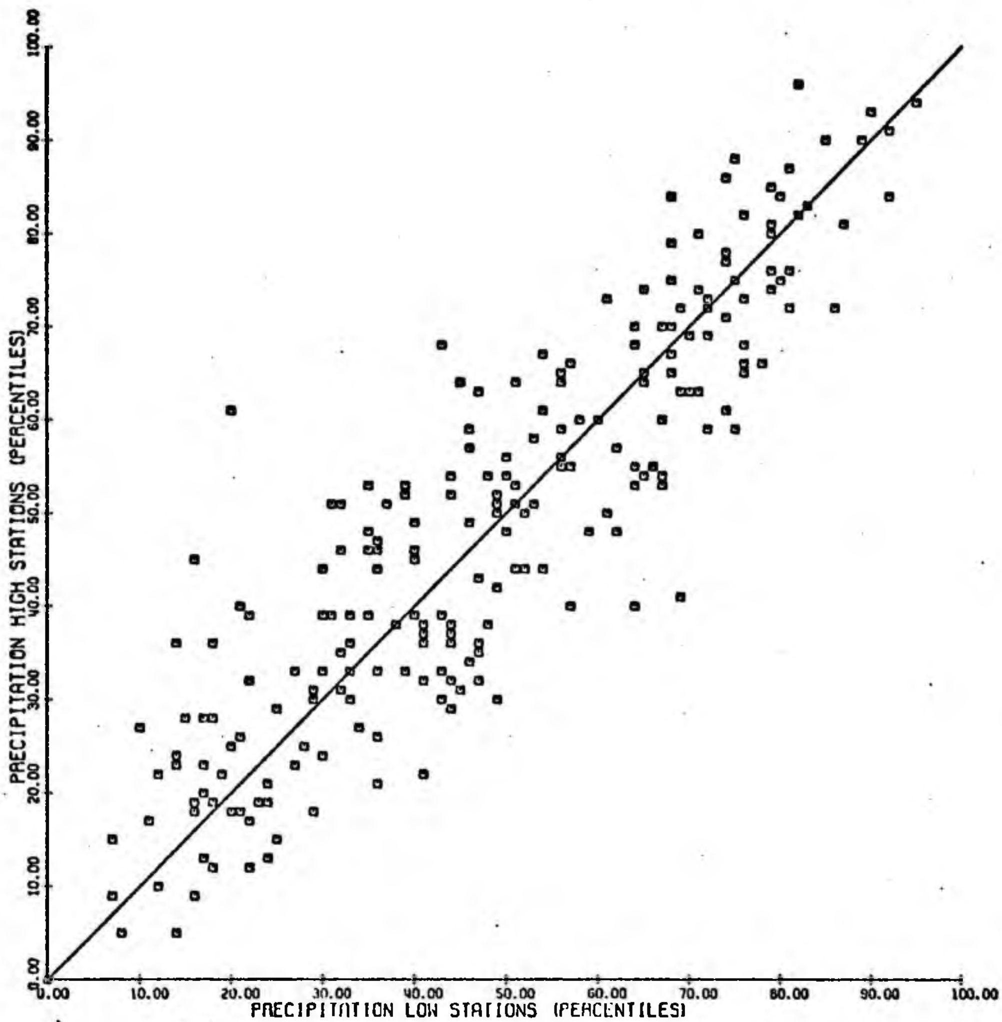
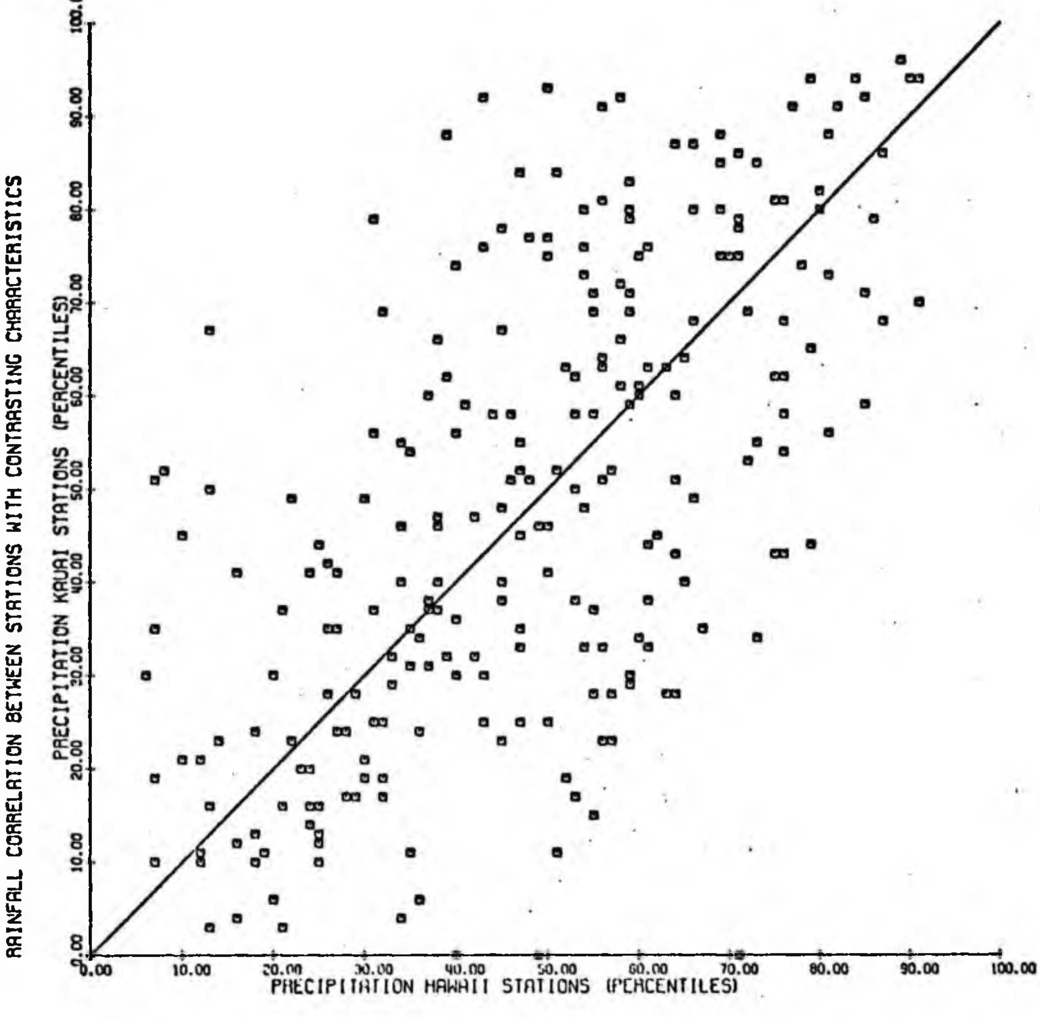

RAINFALL CORRELATION BETWEEN STATIONS WITH CONTRASTING CHARACTERISTICS
PRECEPITATION WINDWARD STATIONS (PERCENTILES)
PRECIPITATION LEEWARD STATIONS (PERCENTILES)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

Figure 7. Rainfall correlation between stations with contrasting characteristics: high vs. low.



RAINFALL CORRELATION BETWEEN STATIONS WITH CONTRASTING CHARACTERISTICS

Figure 8. Rainfall correlation between stations with contrasting characteristics: Kauai vs. Hawaii.



RAINFALL CORRELATION BETWEEN STATIONS WITH CONTRASTING CHARACTERISTICS
PRECIPITATION KAUAI STATIONS (PERCENTILES)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
PRECIPITATION HAWAII STATIONS (PERCENTILES)

The correlation coefficients between the groups with extreme characteristics were computed for each month of the year and are presented in Table 4. As with Solot, the grouping by location produces the greatest scatter; the scatter by aspect, although smaller, is significant; and the scatter by elevation is the least. Solot discarded the elevation aspect from his study since the scatter was so small. During the summer, however, the correlation between the high and low stations is less than that between Hawaii and Kauai stations during the winter. For this reason there is a need to keep the elevation classification in addition to those of aspect and location. This annual variation in the rainfall correlation between contrasting groups is to be expected since numerous studies, among them Solot (1948), Stidd and Leopold (1951), Landsberg (1951), and Mordy (1955) have all shown that general rainfall, associated with cyclonic storms and frontal passages, shows a winter maximum and a summer minimum.

2.4 Annual Rainfall Variations

Typical annual rainfall patterns for the various aspect groupings on each island are shown in Figures 9-17. The middle height stations are shown for all cases. The necessity for the neutral designation is most apparent in the curves for the island of Hawaii. The windward station exhibits the characteristic triple maxima-minima pattern typical of wet stations in the islands. The neutral station has a single winter maximum, characteristic of stations receiving the bulk of their rain from winter storms and frontal passages. The leeward station has a single summer maximum primarily due to rainfall from the

TABLE 4. CORRELATION BETWEEN STATIONS WITH CONTRASTING CHARACTERISTICS

Month	High-Low	Windward-Leeward	Hawaii-Kauai
January	R=0.918 (0.5%)	R=0.701 (0.5%)	R=0.622 (0.5%)
February	0.903 (0.5%)	0.752 (0.5%)	0.655 (0.5%)
March	0.871 (0.5%)	0.707 (0.5%)	0.583 (0.5%)
April	0.843 (0.5%)	0.682 (0.5%)	0.478 (0.5%)
May	0.766 (0.5%)	0.480 (0.5%)	0.137 (20%)
June	0.690 (0.5%)	0.473 (0.5%)	0.353 (1%)
July	0.575 (0.5%)	0.205 (10%)	0.165 (20%)
August	0.827 (0.5%)	0.596 (0.5%)	0.435 (0.5%)
September	0.829 (0.5%)	0.527 (0.5%)	0.343 (1%)
October	0.771 (0.5%)	0.598 (0.5%)	0.478 (0.5%)
November	0.810 (0.5%)	0.760 (0.5%)	0.438 (0.5%)
December	0.887 (0.5%)	0.724 (0.5%)	0.658 (0.5%)

Note: Numbers in parentheses indicate level of significance (student's t-test).

Figure 9. Annual variation in rainfall: windward station, Kauai.

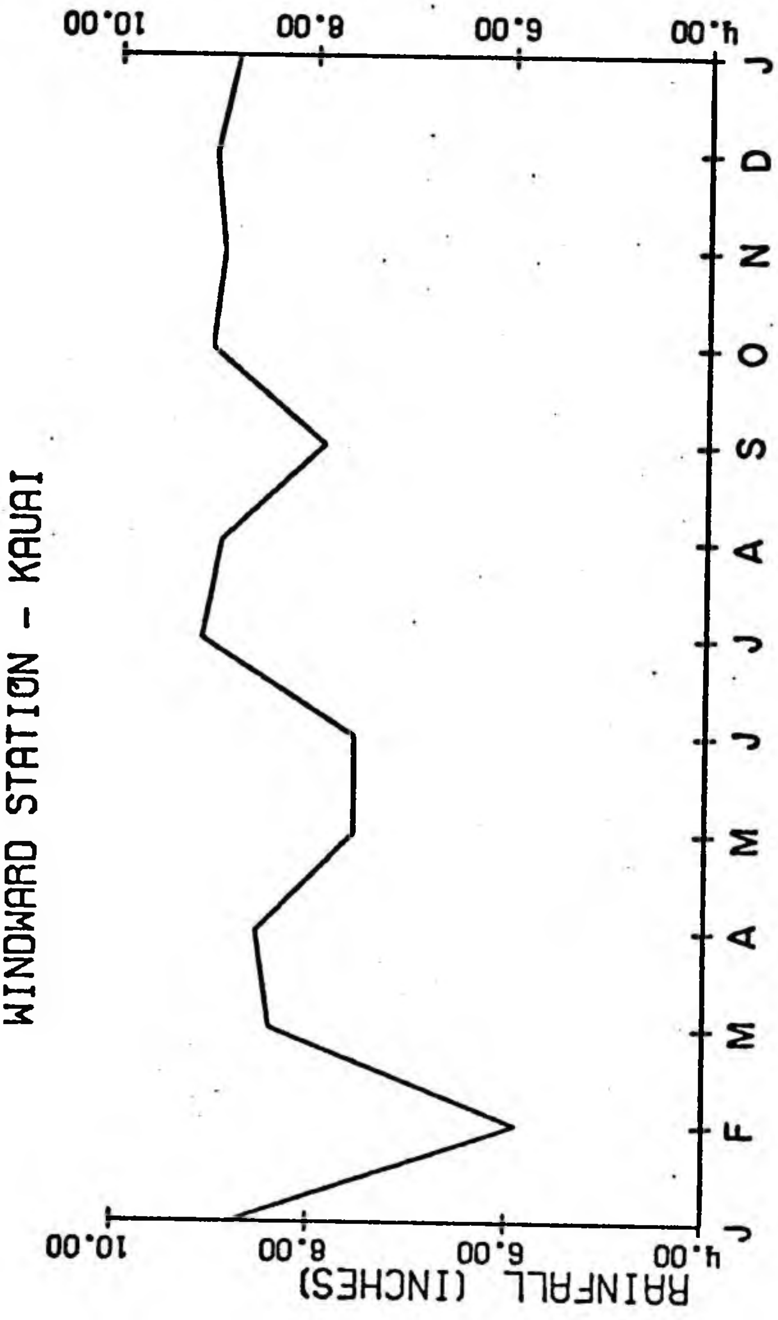

WINDWARD STATION - KAUAI
RAINFALL (INCHES)
4.00
6.00
8.00
10.00
J F M A M J J A S O N D J

Figure 10. Annual variation in rainfall: neutral station, Kauai.

NEUTRAL STATION - KAUAI

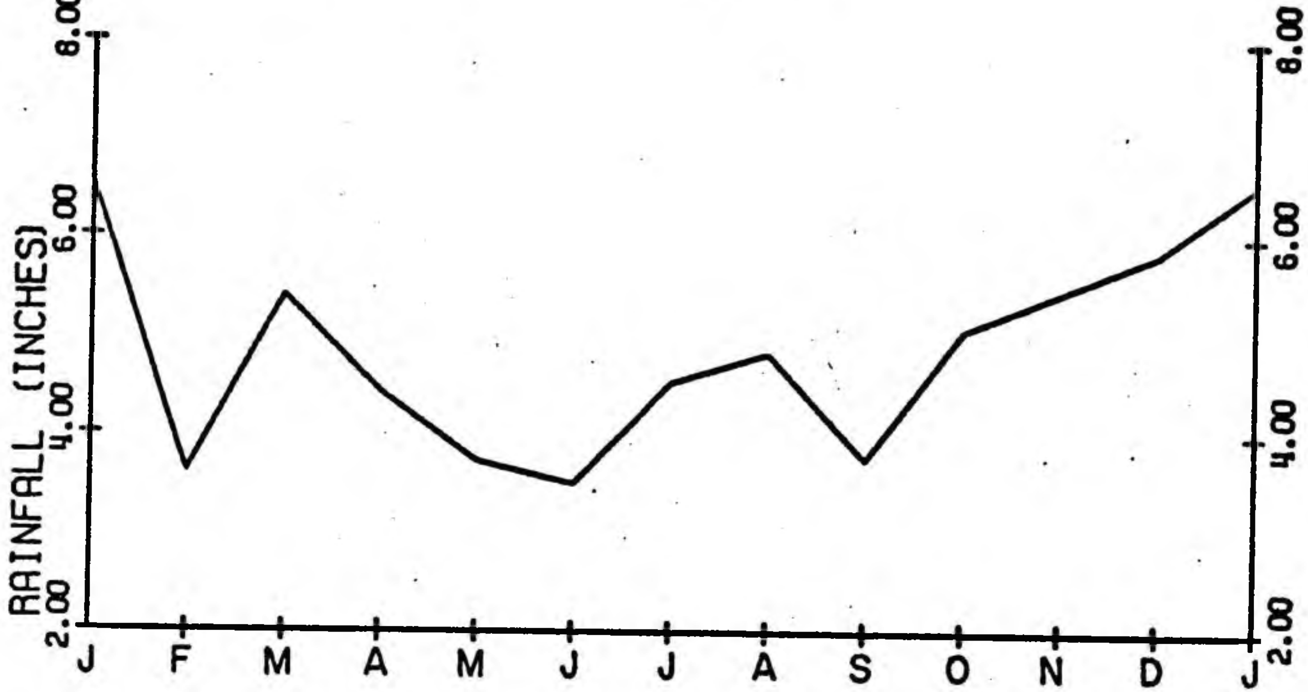


Figure 11. Annual variation in rainfall: leeward station, Kauai.

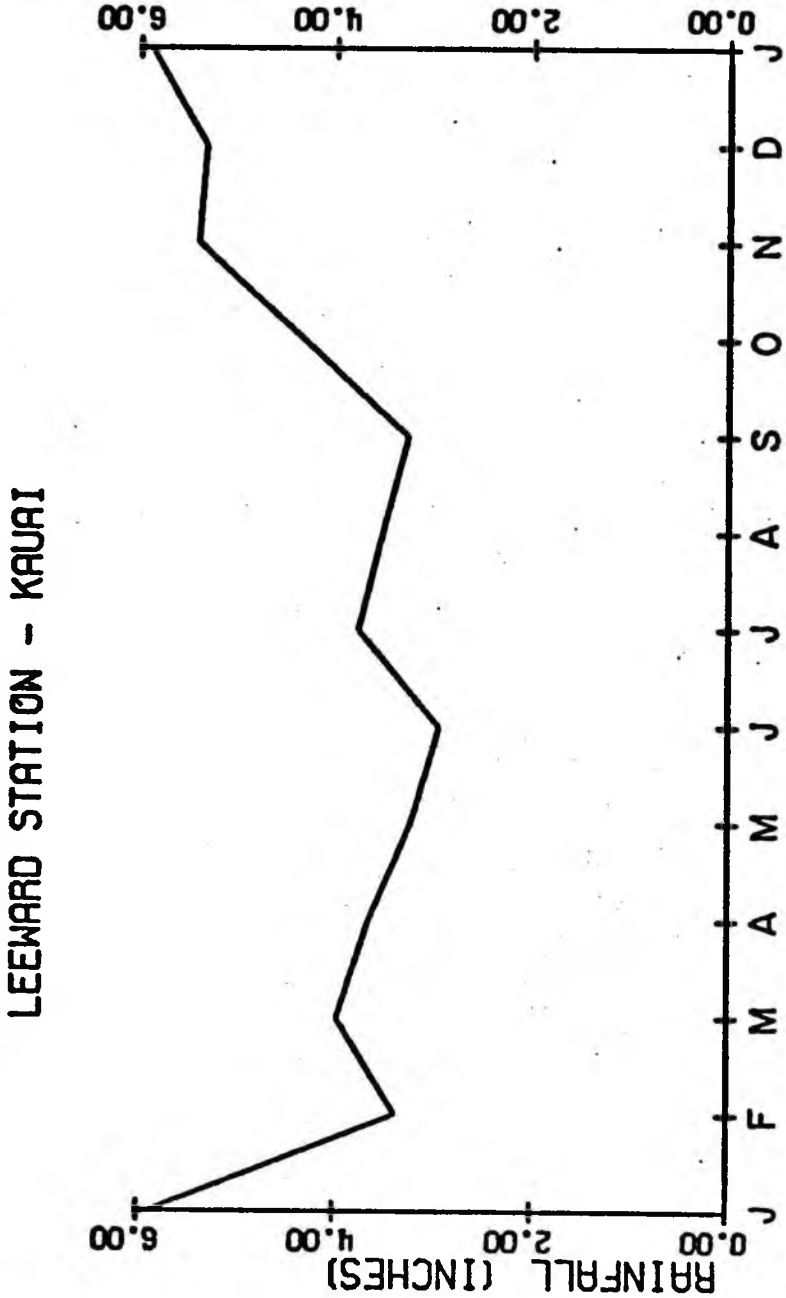

LEEWARD STATION - KAUAI
RAINFALL (INCHES)
0.00
2.00
4.00
6.00
J F M A M J J A S O N D J

Figure 12. Annual variation in rainfall: windward station, Oahu.

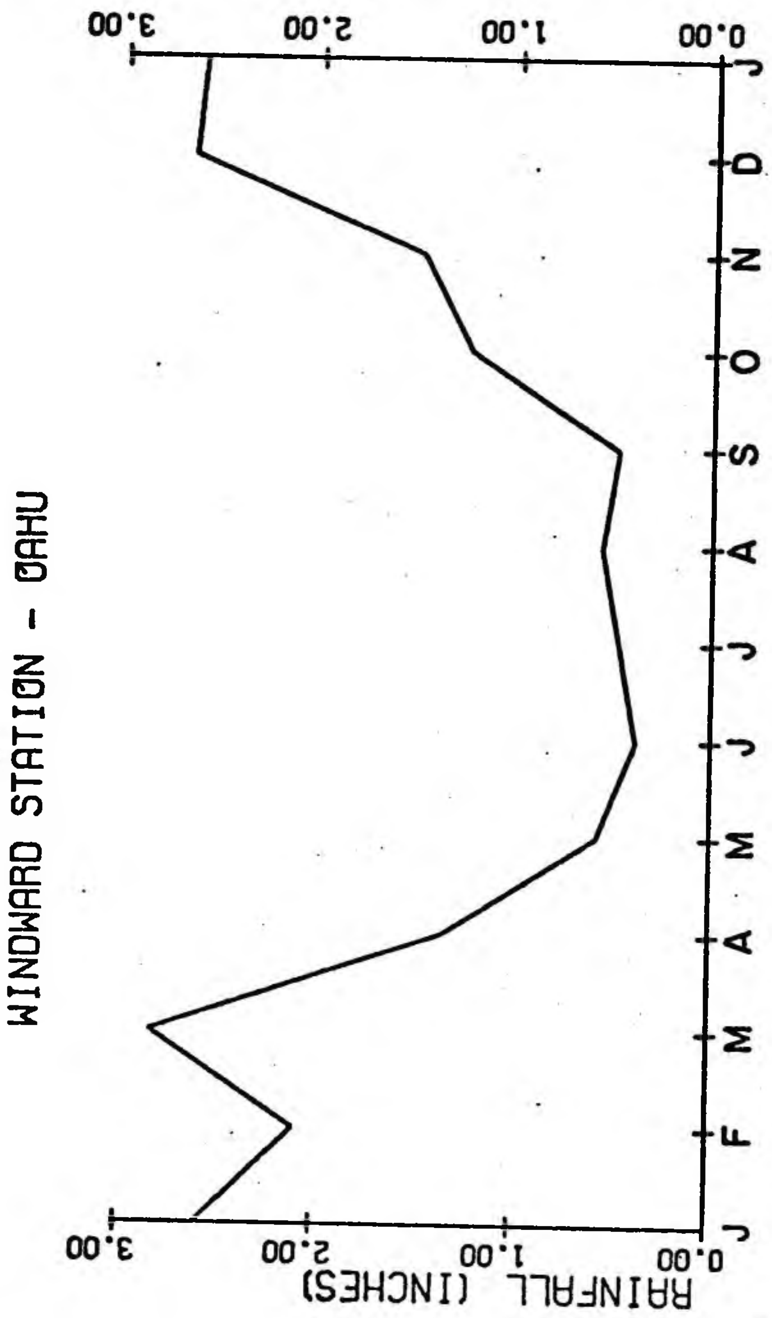

WINDWARD STATION - OAHU
RAINFALL (INCHES)
0.00
1.00
2.00
3.00
J
F
M
A
M
J
J
A
S
O
N
D
J

Figure 13. Annual variation in rainfall: neutral station, Oahu.

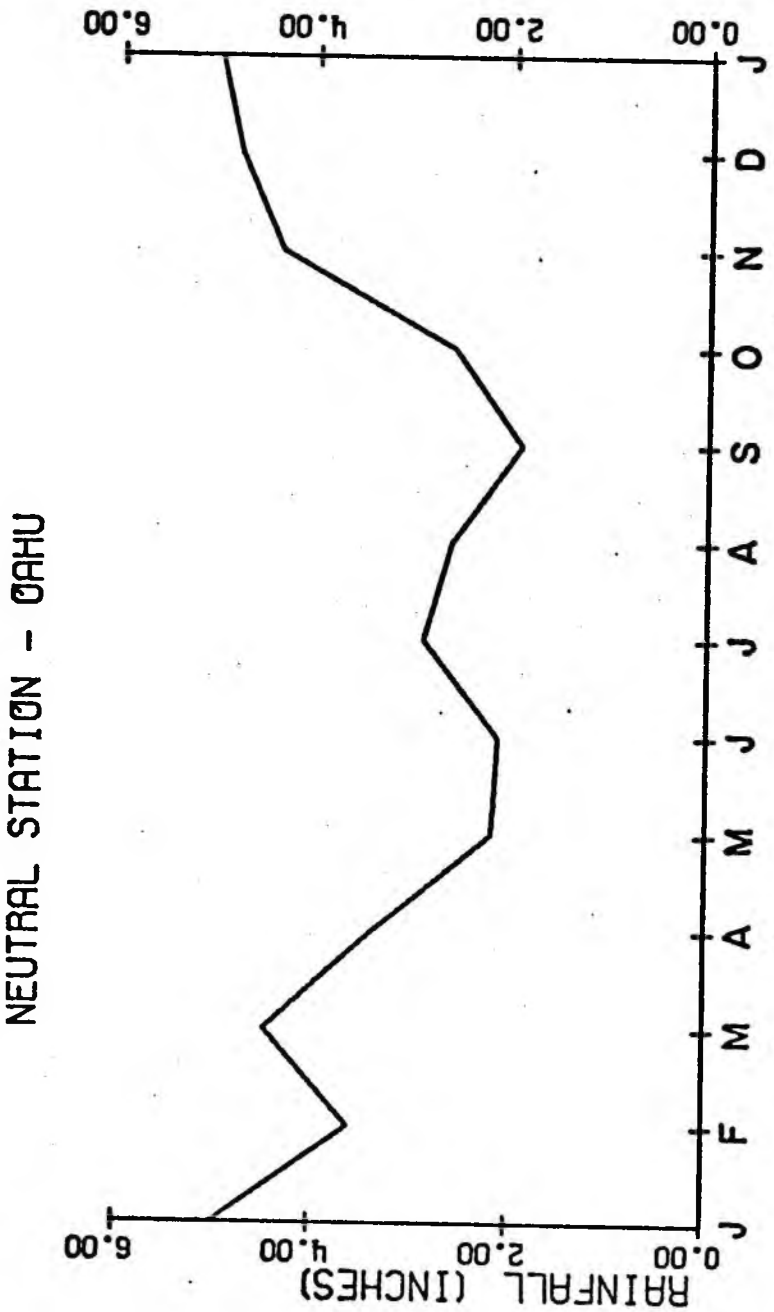

NEUTRAL STATION - OAHU
RAINFALL (INCHES)
0.00
2.00
4.00
6.00
J
F
M
A
M
J
J
A
S
O
N
D
J

Figure 14. Annual variation in rainfall: leeward station, Oahu.

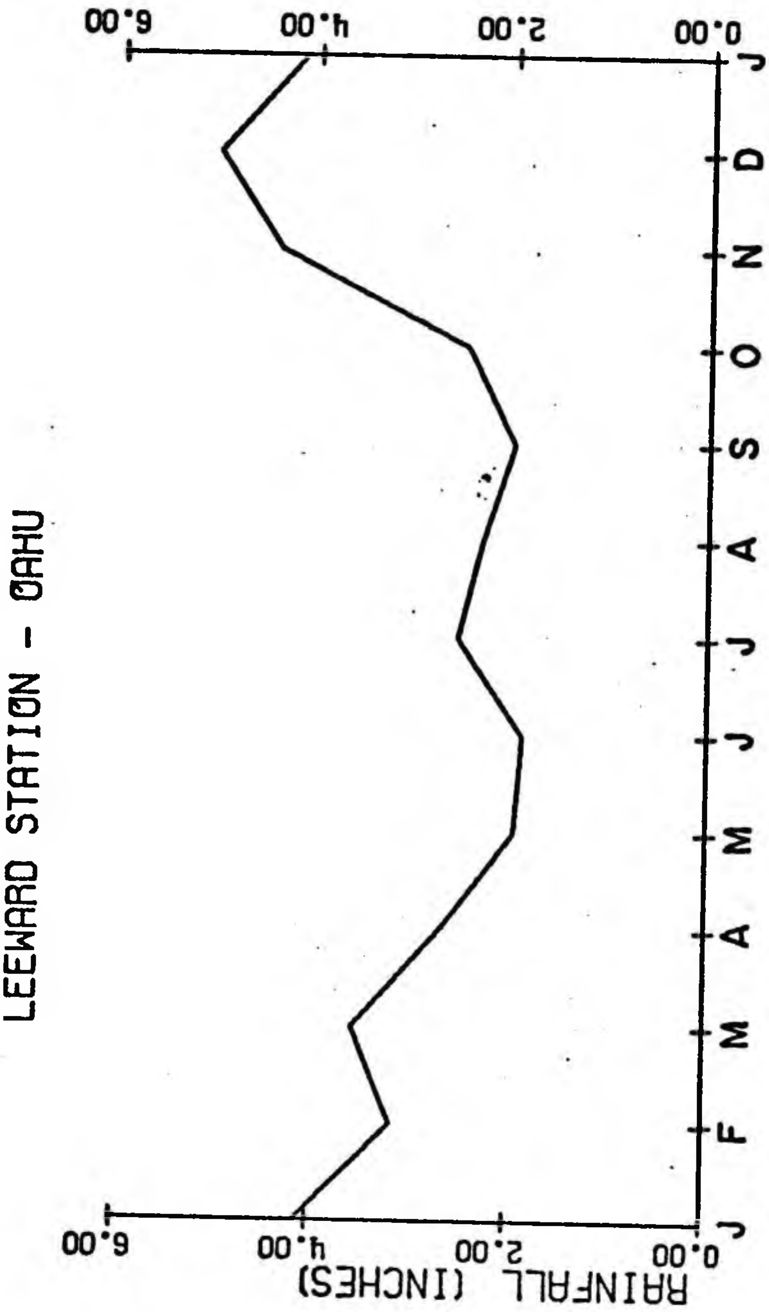

LEEWARD STATION - ØAHU
RAINFALL (INCHES)
0.00
2.00
4.00
6.00
J
F
M
A
M
J
J
A
S
O
N
D
J

Figure 15. Annual variation in rainfall: windward station, Hawaii.

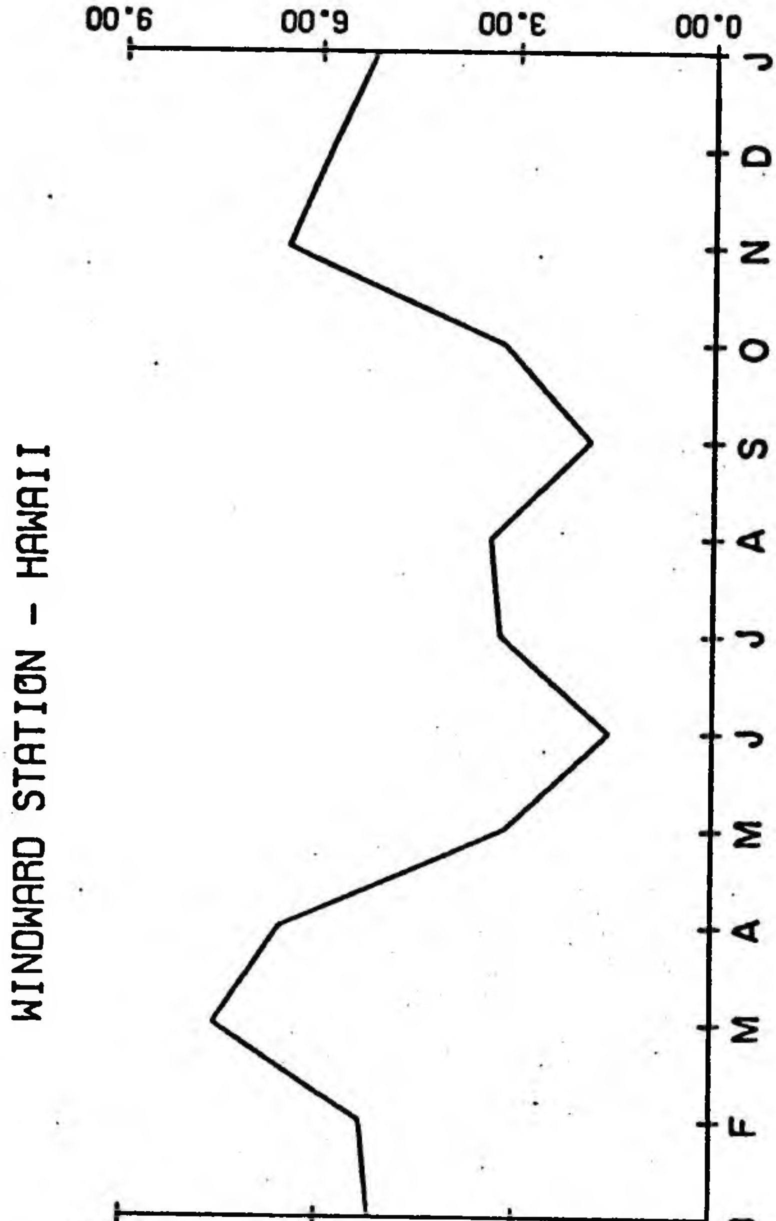

WINDWARD STATION - HAWAII
RAINFALL (INCHES)
0.00
3.00
6.00
9.00
J
F
M
A
M
J
J
A
S
O
N
D
J

Figure 16. Annual variation in rainfall: neutral station, Hawaii.

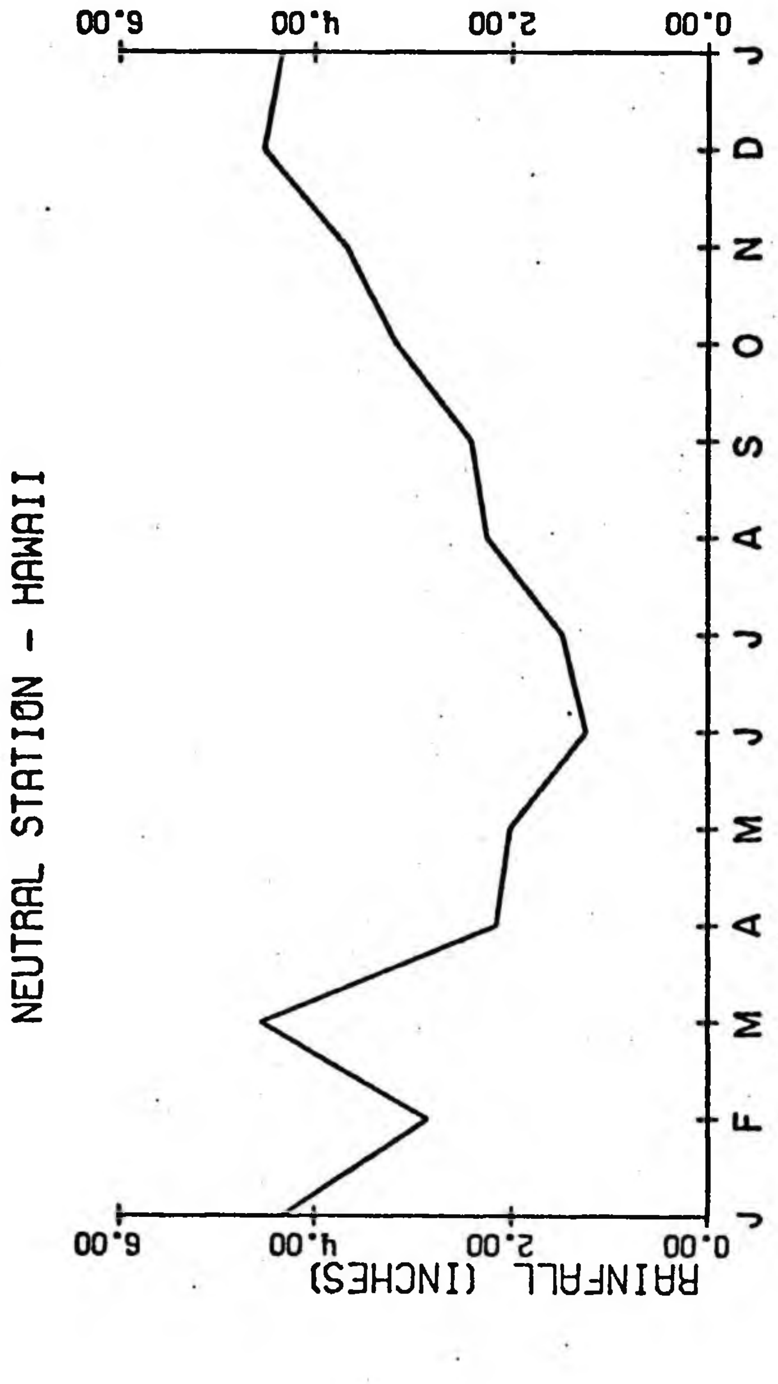
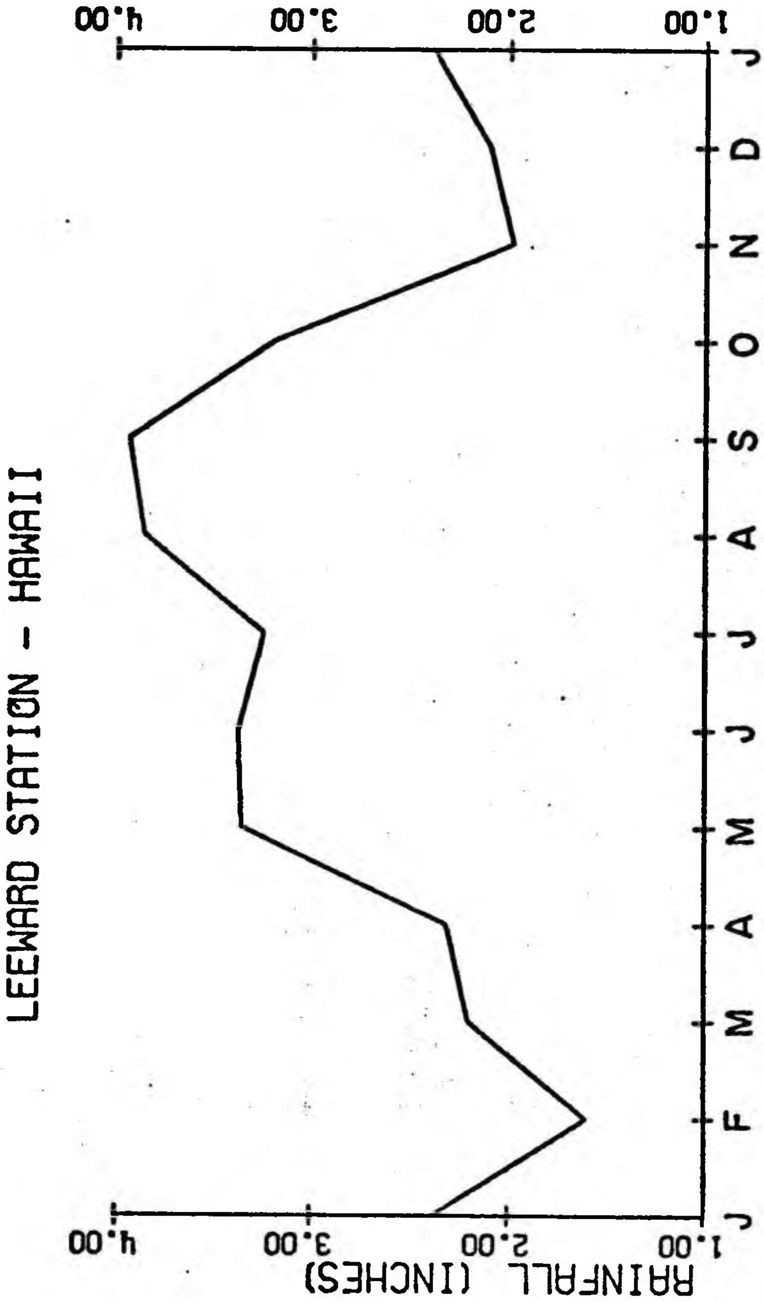

NEUTRAL STATION - HAWAII
RAINFALL (INCHES)
0.00
2.00
4.00
6.00
J
F
M
A
M
J
J
A
S
O
N
D
J

Figure 17. Annual variation in rainfall: leeward station, Hawaii.


LEEWARD STATION - HAWAII
RAINFALL (INCHES)
1.00
2.00
3.00
4.00
J
F
M
A
M
J
J
A
S
O
N
D
J

convergence of the trade winds and the resulting trade-induced sea breeze.

The explanation for these three different patterns was offered by Mordy (1955), who compared them with the annual variation of rainfall intensities. He showed that intense rains (greater than 0.4 in./day) comprise the greater portion of rainfall in winter but not in summer. Rainfalls of medium intensity (0.2-0.4 in./day) are rather evenly distributed throughout the year (Figure 18). Still smaller rains (less than 0.1 in./day) have a summer maximum. The triple maxima and minima is evident in the transition zone between the small and medium intensity rainfalls (0.1-0.2 in./day), as shown in Figure 19. Thus we have two opposite cycles present. The particular annual variation pattern of a station depends on the intensity of the rainfall which it usually receives--either high intensity winter rain, low intensity summer rain, or some combination of the two.

2.5 Persistence

"Today's weather tomorrow", persistence, plays a role in weather forecasting, and the question of persistence of Hawaiian rainfall from month to month has been investigated by Landsberg (1951), who stated: "Persistence of precipitation amounts, large or small, from month to month is not very pronounced on Oahu."

However, I decided to examine the annual variation of the persistence of rainfall in order to determine if there were at least certain times of the year when persistence played a dominant role.

For this purpose the mean monthly indices of all stations were

Figure 18. Annual variation in rainfall intensities--I. (According to Mordy, 1955.)

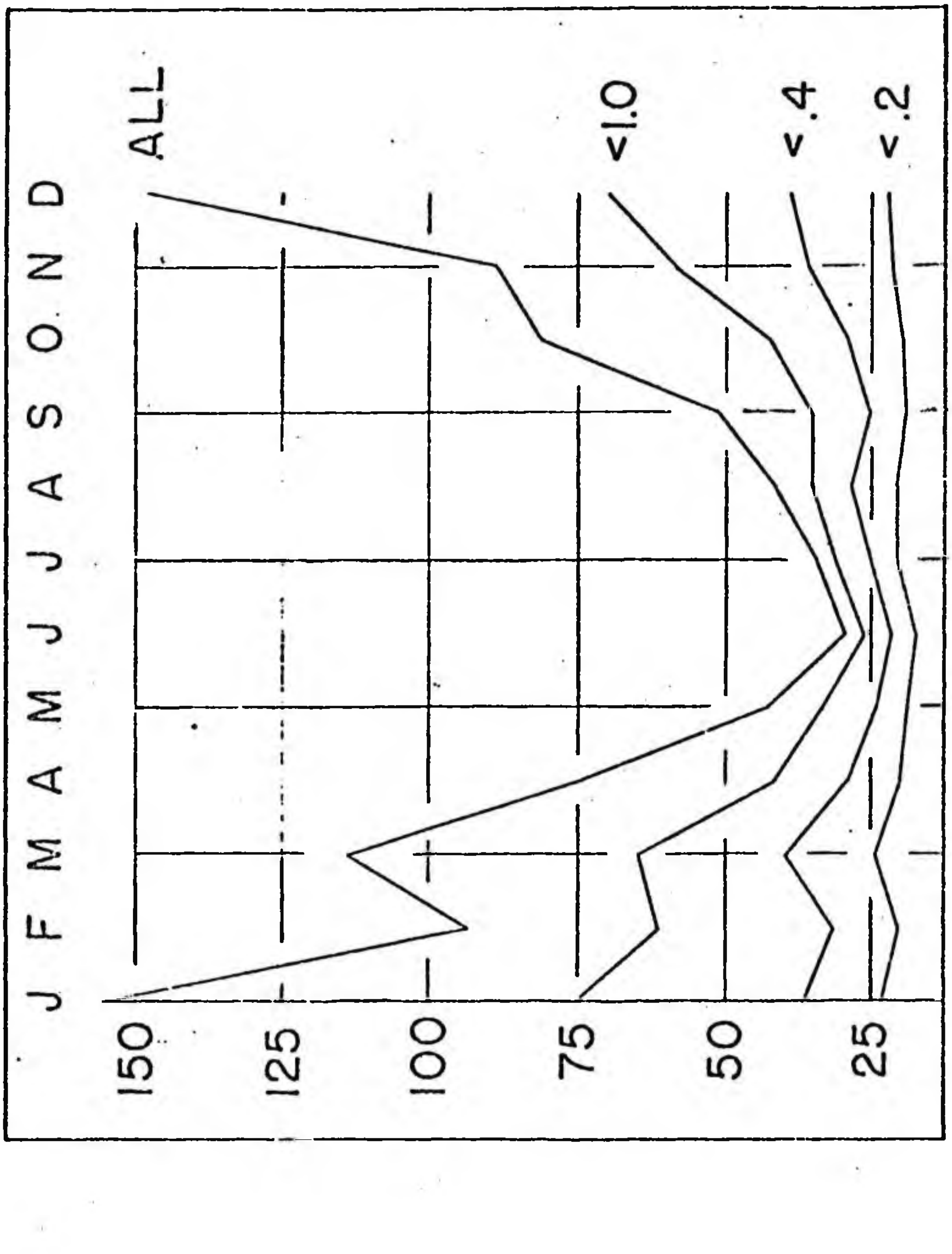
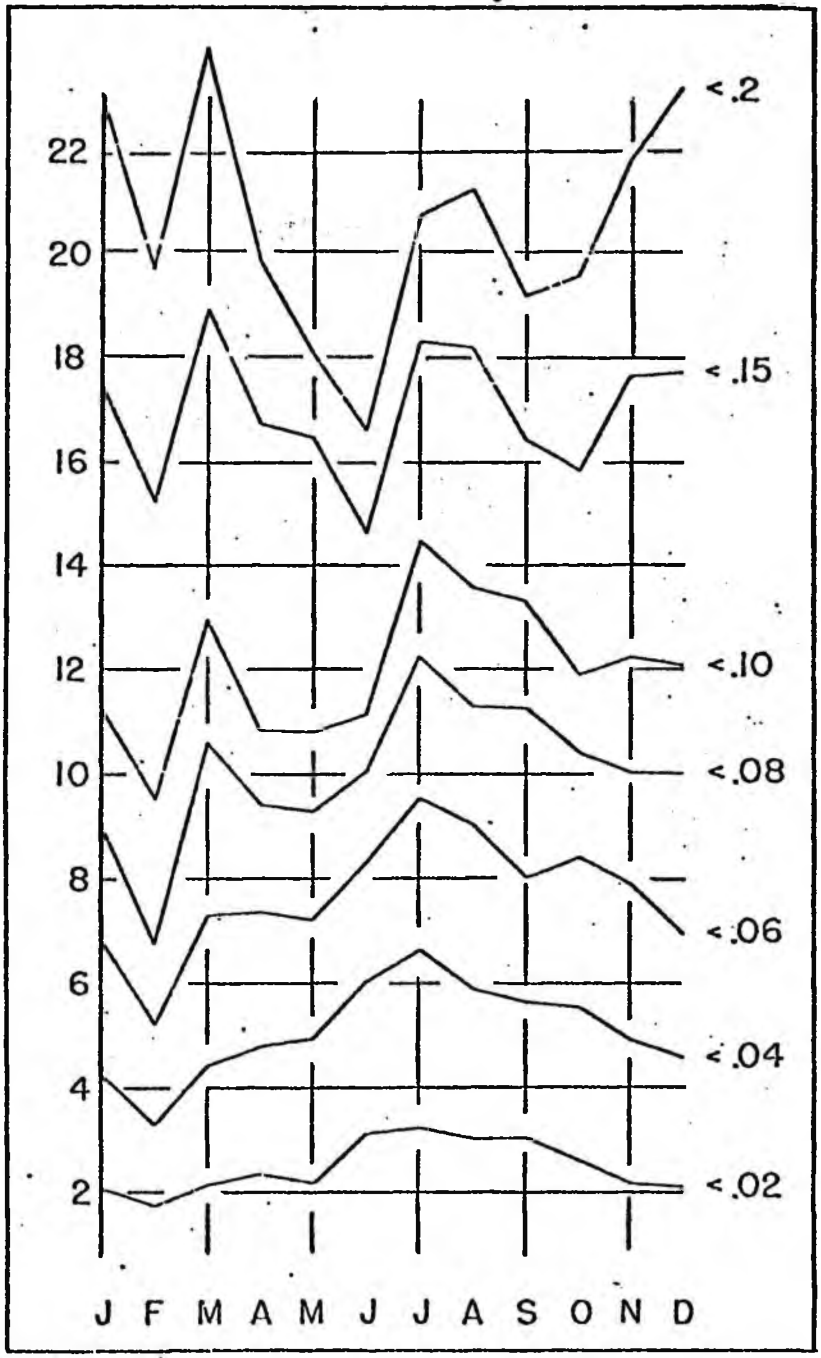

J F M A M J J A S O N D
150
125
100
75
50
25
ALL
<1.0
< .4
< .2

Figure 19. Annual variation in rainfall intensities--II. (According to Mordy, 1955.)


22
20
18
16
14
12
10
8
6
4
2
< .2
< .15
< .10
< .08
< .06
< .04
< .02
J F M A M J J A S O N D

grouped into quintiles: 0-19, 20-39, 40-59, 60-79, and 80-100. For each month of the year it was then determined how often the following month had an index value that was in the same quintile (persistence) or had an index value that was in a higher or lower quintile (no persistence). The mean absolute month to month change in the index value and the standard deviation of the change for each pair of months were also computed. The results are presented in Tables 5-16. For example, Table 5 shows that there were three years in which a January index value in the first quintile (0-19%) was followed by a February index in the third quintile (40-59%).

Examination of these tables shows that, by this criterion, persistence does play a role for part of the time during the summer. This is to be expected since the trade winds dominate summer weather in the islands and the number of exceptionally wet or dry months is much smaller than in winter. Since there are more "normal" months in summer, the chances that one "normal" month will be followed by another are quite good. One should remember that this index is the average of all the stations operating during each month.

In the winter though, since the rainfall amounts are more dependent on the number and intensity of frontal passages and cyclonic storms, there is a greater variation in the amount of rainfall received in any particular month--there are fewer "normal" months--so the chances of month-to-month persistence are quite small.

The data was also stratified by island with some interesting results. Of the three islands, Kauai showed the least month-to-month persistence throughout the year; on Oahu persistence was slightly more

TABLE 5. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
JANUARY - FEBRUARY

JANUARY	FEBRUARY 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	1	6	3	2	0
20-39%	5	5	5	1	1
40-59%	2	6	7	8	4
60-79%	1	4	8	8	2
80-100%	0	2	2	2	1

MEAN ABSOLUTE CHANGE 19.93

STANDARD DEVIATION 14.27

TABLE 6. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
FEBRUARY - MARCH

FEBRUARY	MARCH				
	0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	4	3	1	1	0
20-39%	2	8	5	7	1
40-59%	3	6	8	8	0
60-79%	1	4	6	8	2
80-100%	0	2	3	2	1

MEAN ABSOLUTE CHANGE 19.58

STANDARD DEVIATION 13.59

TABLE 7. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
MARCH - APRIL

MARCH			APRIL		
	0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	2	2	5	1	0
20-39%	3	6	11	2	1
40-59%	0	7	9	5	2
60-79%	1	6	11	5	3
80-100%	0	2	2	0	0

MEAN ABSOLUTE CHANGE 19.20

STANDARD DEVIATION 14.59

TABLE 8. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
APRIL - MAY

APRIL			MAY		
	0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	1	3	2	0	0
20-39%	1	6	13	3	0
40-59%	1	6	17	13	1
60-79%	0	7	3	2	1
80-100%	0	2	2	2	0

MEAN ABSOLUTE CHANGE 17.12

STANDARD DEVIATION 13.30

TABLE 9. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
MAY - JUNE

MAY	JUNE 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	0	1	1	1	0
20-39%	1	11	10	2	0
40-59%	1	10	16	10	0
60-79%	0	3	9	6	2
80-100%	0	0	1	1	0

MEAN ABSOLUTE CHANGE 14.15

STANDARD DEVIATION 11.32

TABLE 10. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
JUNE - JULY

JUNE	JULY 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	0	1	1	0	0
20-39%	0	8	14	3	0
40-59%	0	9	18	9	1
60-79%	0	2	12	5	1
80-100%	0	1	1	0	0

MEAN ABSOLUTE CHANGE 14.87

STANDARD DEVIATION 10.22

TABLE 11. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
JULY - AUGUST

JULY	AUGUST 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	0	0	0	0	0
20-39%	2	6	9	4	0
40-59%	0	16	15	13	2
60-79%	1	2	8	5	1
80-100%	0	0	0	1	1

MEAN ABSOLUTE CHANGE 15.85

STANDARD DEVIATION 9.88

TABLE 12. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
AUGUST - SEPTEMBER

AUGUST	SEPTEMBER 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	1	1	0	1	0
20-39%	1	10	8	4	1
40-59%	0	2	18	9	3
60-79%	1	7	10	4	1
80-100%	0	1	1	2	0

MEAN ABSOLUTE CHANGE 16.69

STANDARD DEVIATION 12.63

TABLE 13. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
SEPTEMBER - OCTOBER

SEPTEMBER	OCTOBER 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	1	2	0	0	0
20-39%	2	7	8	4	0
40-59%	1	9	16	9	2
60-79%	0	5	8	5	2
80-100%	0	2	2	1	0

MEAN ABSOLUTE CHANGE 16.49

STANDARD DEVIATION 12.65

TABLE 14. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
OCTOBER - NOVEMBER

OCTOBER	NOVEMBER				
	0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	1	2	0	1	0
20-39%	5	4	8	8	0
40-59%	2	7	14	11	0
60-79%	1	4	5	6	3
80-100%	0	2	2	0	0

MEAN ABSOLUTE CHANGE 19.67

STANDARD DEVIATION 14.06

TABLE 15. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
NOVEMBER - DECEMBER

NCVEMBER	DECEMBER 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	1	6	0	1	1
20-39%	0	8	9	2	0
40-59%	5	8	9	6	1
60-79%	2	6	6	10	2
80-100%	0	1	1	0	1

MEAN ABSOLUTE CHANGE 19.60

STANDARD DEVIATION 15.12

TABLE 16. MONTH TO MONTH VARIATION IN HAWAIIAN RAINFALL INDEX

ALL STATIONS
DECEMBER - JANUARY

DECEMBER	JANUARY 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	1	4	1	0	1
20-39%	7	3	15	4	0
40-59%	1	7	6	9	2
60-79%	3	2	4	8	2
80-100%	0	1	1	2	0

MEAN ABSOLUTE CHANGE 19.22

STANDARD DEVIATION 15.86

significant and occurred much more often in summer and less often in January than on Kauai; while on Hawaii persistence occurred in 33% of the years in every month to month pair except December-January (27%) and occurred in May-June in half of the years (50%).

Apparently latitude is an important factor in determining the degree of interaction with mid-latitude systems in the island chain, and the resultant variability in rainfall amounts. Worthley (1967) has shown that both the mean number and the standard deviation of winter frontal passages in the Hawaiian Islands increases with latitude. Similar interactions with mid-latitude systems, although not as obvious, may be operating in the summer months as well.

2.6 Trends in Precipitation

Cycles (days, months, seasons, years, etc.) play an important role in our lives and we are aware of cycles both in other organisms and in weather-related phenomena. For example, The Old Farmer's Almanac (Thomas, 1976) (which can be considered either a boon or bane to weather forecasting, depending on one's viewpoint) describes, among others, an eight year cycle in rainfall in Philadelphia, a twelve year cycle in sunspots and rainfall in London, and a 17-1/3 year cycle in maximum floods along the Nile.

Others have looked for cycles in Hawaiian rainfall. Cox (1924) found periods of 1, 3, 7, 11.1, and 33 years along with a correlation between the rainfall and the number of sunspots. He argued that forecasts made using these cycles could be of importance to the agricultural industries in the islands.

Out of curiosity then, I grouped the mean monthly indices by season, defining the period from May to September as summer and the period from November to March as winter. April and October were considered to be transition months between the two seasons. Such a separation is quite natural in the tropics and appears throughout the literature. Our particular selection was based on the normal precipitation amounts at Honolulu International Airport (Blumenstock and Price, 1967). By that criterion, winter months are those in which more than two inches of rain normally fall and summer months are those in which less than one inch of rainfall is normal.

After calculating mean summer and winter indices for each year, I examined them in order to determine if there was any correlation, either positive or negative, between the amounts of summer and winter rainfall in the islands. In other words, are wet or dry summers usually followed or preceded by wet or dry winters? In both instances no significant correlation was found. From this we can conclude that there is no relationship between summer and winter rainfall amounts.

Some interesting secular changes have occurred in both summer and winter rainfalls. These results are presented in Figures 20-21.

There appears to be both a short term and a long term cycle in summer rainfall in Hawaii. The short term cycle is "quasibiennial", since inspection of the curve shows what appears to be a two year cycle, with the summers of even-numbered years currently wetter than those of the odd-numbered years. However, in the 1960's the summers of odd-numbered years were the wetter. This oscillation appears to be much weaker or even lacking in the winter rainfalls. Also

Figure 20. Secular variation in Hawaiian mean winter rainfall index.

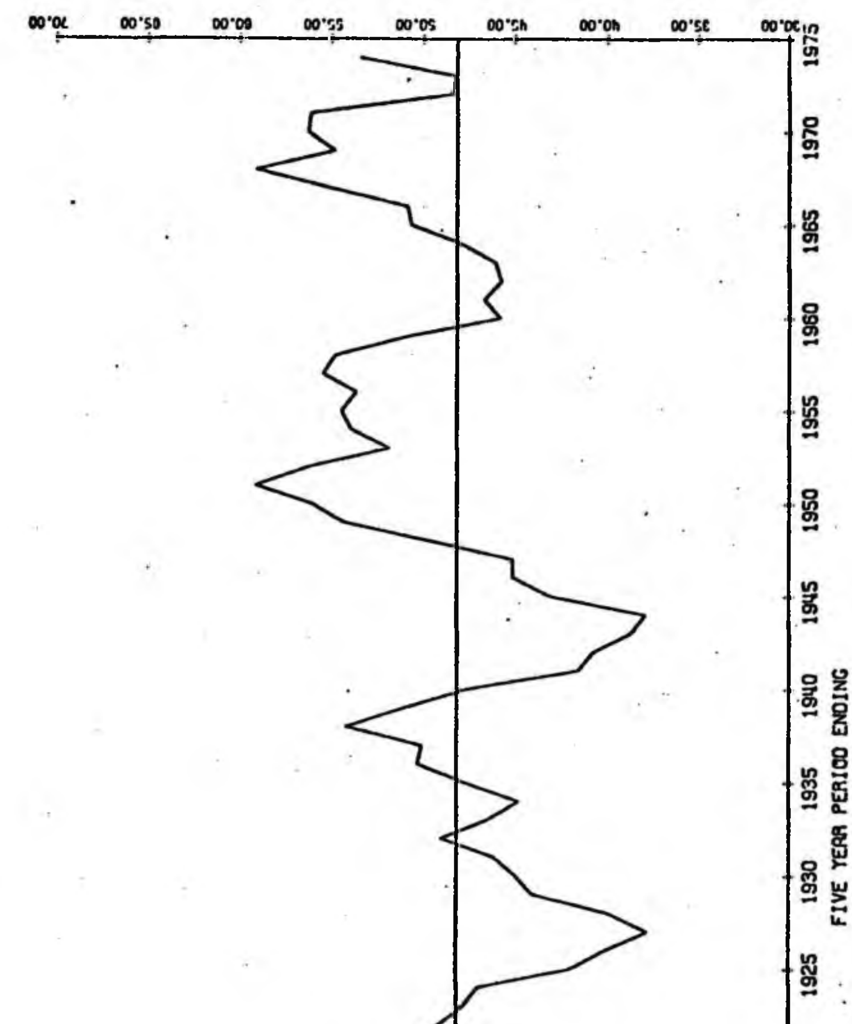
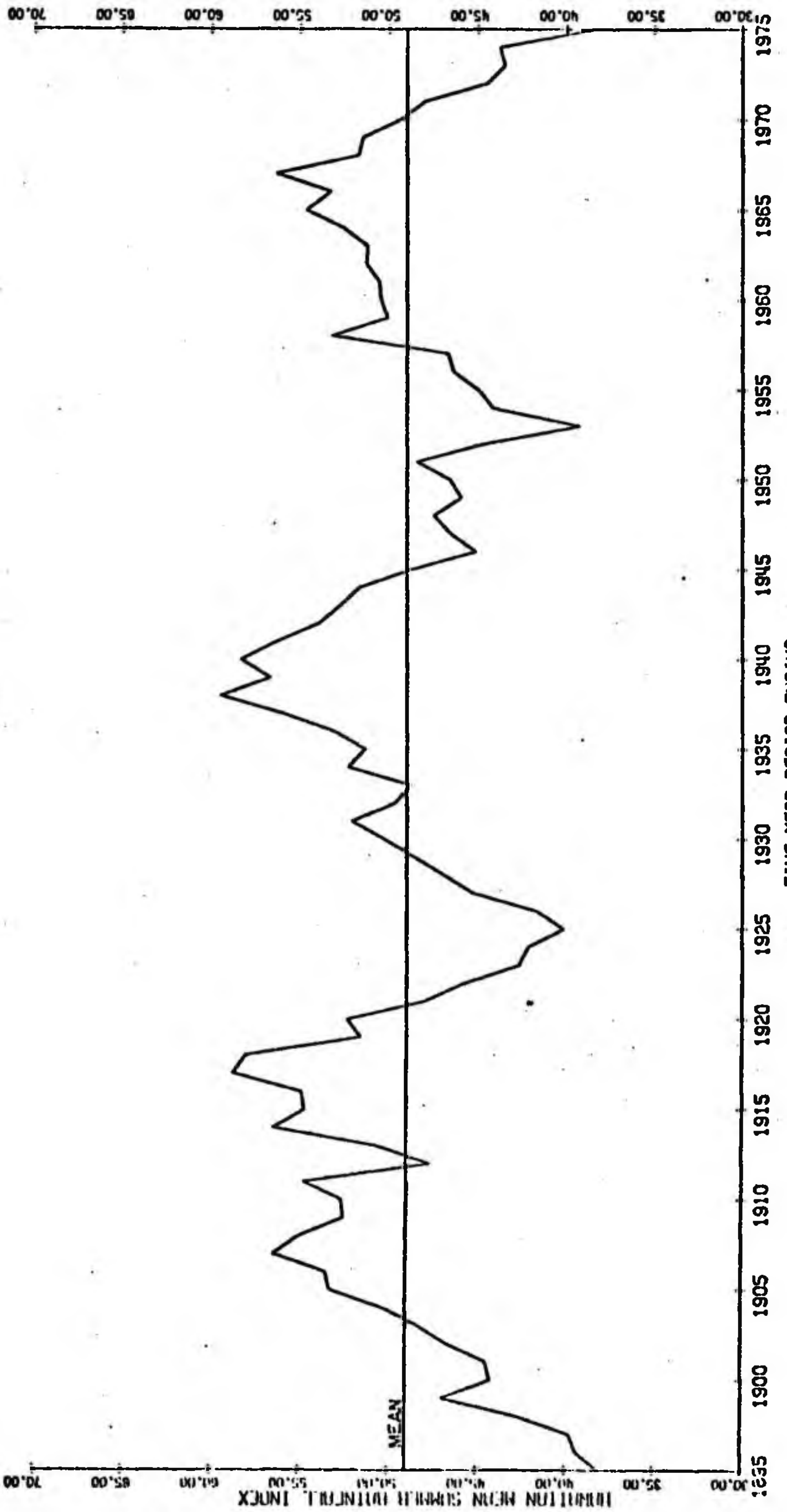

MEAN
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
FIVE YEAR PERIOD ENDING

Figure 21. Secular variation in Hawaiian mean summer rainfall index.


FIVE YEAR PERIOD ENDING
MEAN
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00

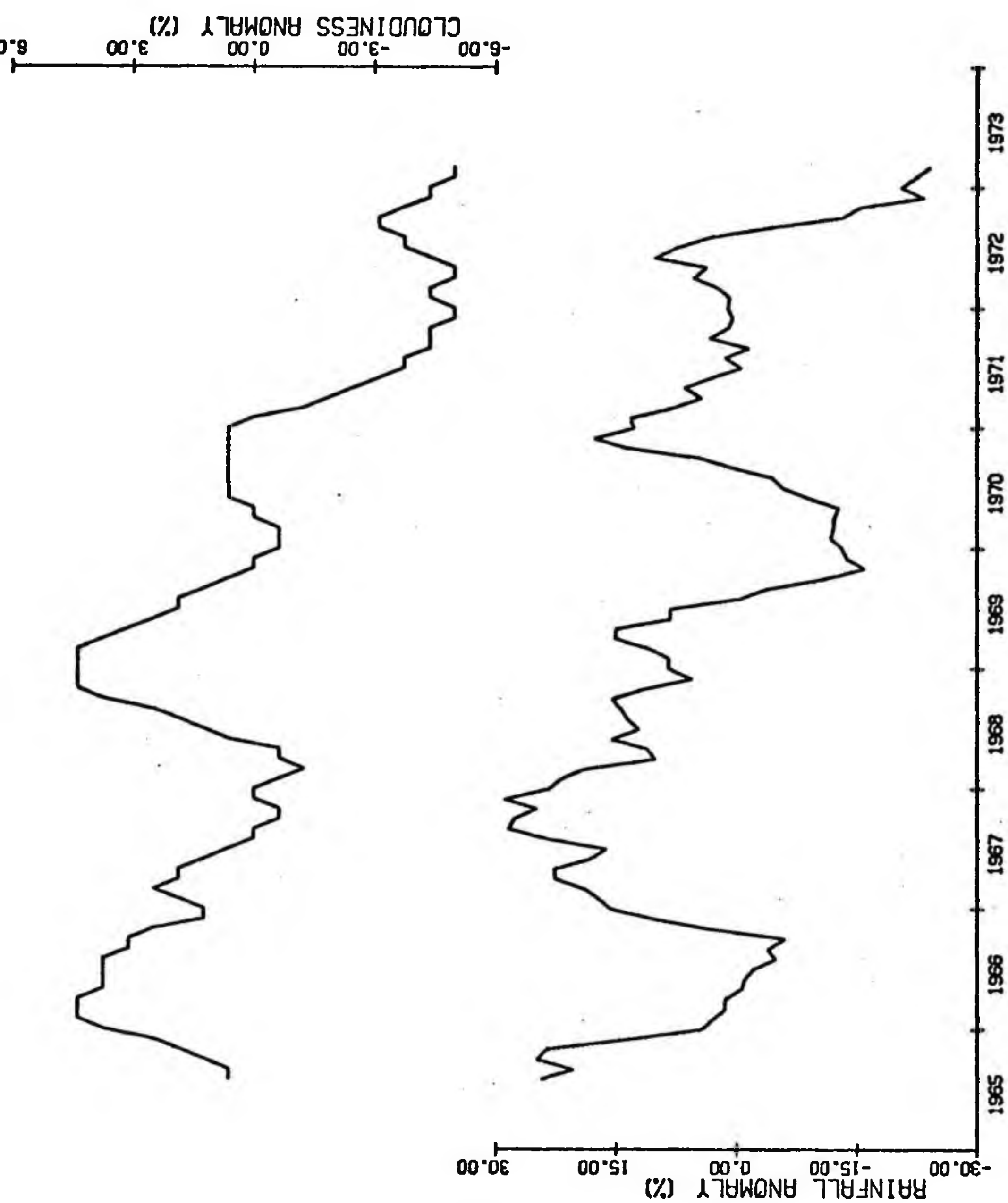
autocorrelation of both the winter and summer indices for the entire period of record with a lag of one year gives no significant results. Using only the last ten years of data (1966-1975) gives larger magnitudes of both autocorrelation coefficients ($r = -.248$ for winter and $r = -.384$ for summer), but the results are still only significant at about the 25% level.

In a study of East African rains, Rodhe and Virji (1976) found a similar cycle which they attributed to the biennial oscillation in the circulation of the tropical stratosphere. These cycles appear to be of a different period than that found in the Line Islands rainfalls, however, which will be discussed below.

The long term cycle in the Hawaiian summer rainfalls, with previous minima occurring in 1895, 1925 and 1953, may be unique to the Hawaiian chain. Of interest is the fact that we are at or near another minimum and that this past summer was one of drought throughout the islands. Only one-seventh of the monthly reports of the operating stations used in this study were above the monthly medians for that period and the mean summer index was the lowest for the entire period of record.

One must ask if this cycle is a local response to some global phenomenon or something on a smaller scale. Satellite cloudiness data is the only data of truly global coverage. In the period from February 1965 to July 1973, the seasonally adjusted monthly mean cloudiness in the tropics (30°N-30°S) showed a decline similar to that of the Hawaiian rainfall (Figure 22). Comparison of the two factors yielded a correlation coefficient of 0.329, which is significant in the one

Figure 22. Comparison of the variation in the twelve month running means of global tropical cloudiness and Hawaiian rainfall index.


CLOUDINESS ANOMALY (%)
-6.00
-3.00
0.00
3.00
6.00
RAINFALL ANOMALY (%)
-30.00
-15.00
0.00
15.00
30.00
1965
1966
1967
1968
1969
1970
1971
1972
1973

percent level. Certainly more work needs to be done in this area before any definite conclusions can be drawn.

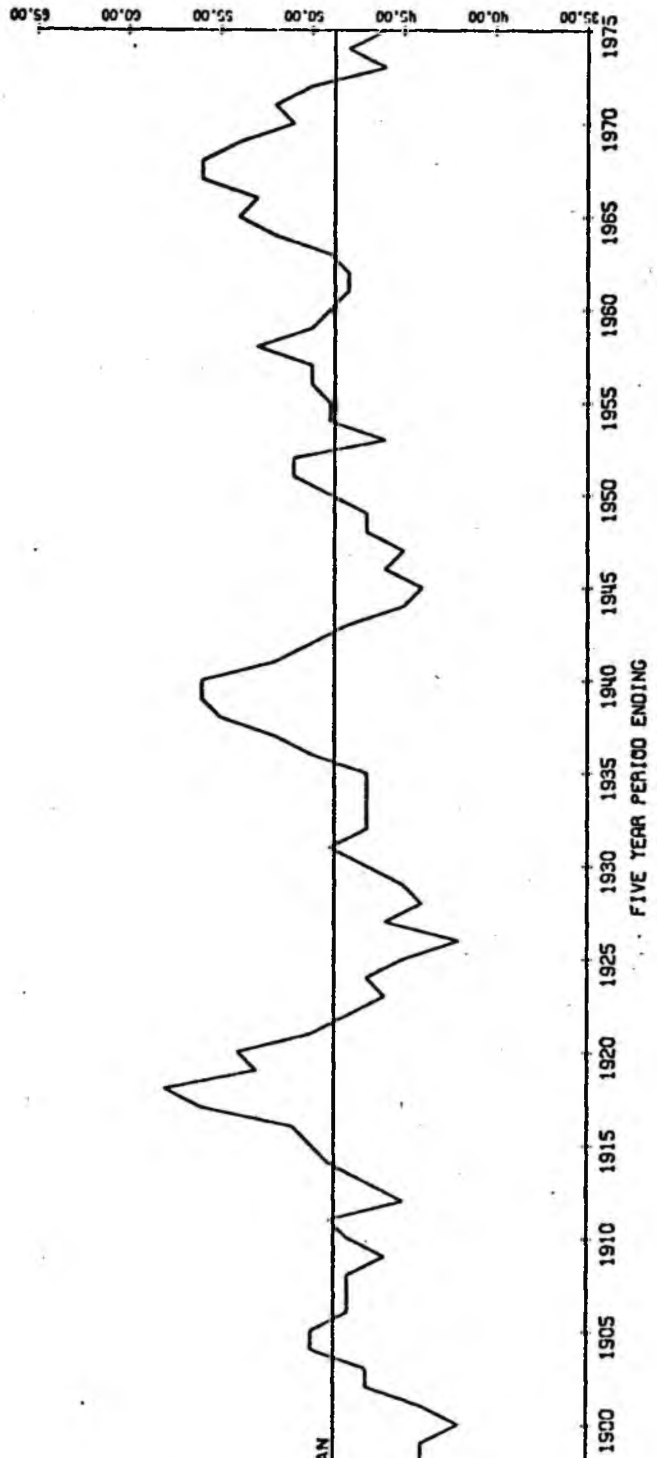
Wentworth (1949) found a secular variation in the direction of the prevailing trade winds as measured in Honolulu. Comparison of our data with his gave no significant results, as the cycles are neither in phase nor of the same period. We also compared the Hawaiian summer rainfalls with the monthly mean 300 mb. heights at both Lihue, Kauai and Midway Island in order to examine any effects due to the location or intensity of the Mid-Pacific Trough. Again, no significant results were found.

Examination of Figure 20 for the winter months shows both a short term cycle with a period of about 17 years and also a general increase in the amount of winter precipitation since 1944, which may be part of a much longer cycle. Again, this area needs further study before any conclusions can be drawn.

It is necessary to separately consider the summer and winter rains, particularly if the apparent cycles are real. As shown above, for most regions of the islands most rain falls during winter. Both the amount of ground water available for irrigation and public consumption and the amount of flooding are related to the winter rains. On the other hand, the amount of summer rainfall determines the demand on the existing ground water. A successful prediction of either season's rainfall could have dramatic impact on both agriculture and the general public.

Figure 23 depicts the secular change in the annual rainfall, computed by taking the mean of the monthly indices for any given year.

Figure 23. Secular variation in Hawaiian mean annual rainfall index.


MEAN
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
FIVE YEAR PERIOD ENDING
35.00
40.00
45.00
50.00
55.00
60.00
65.00

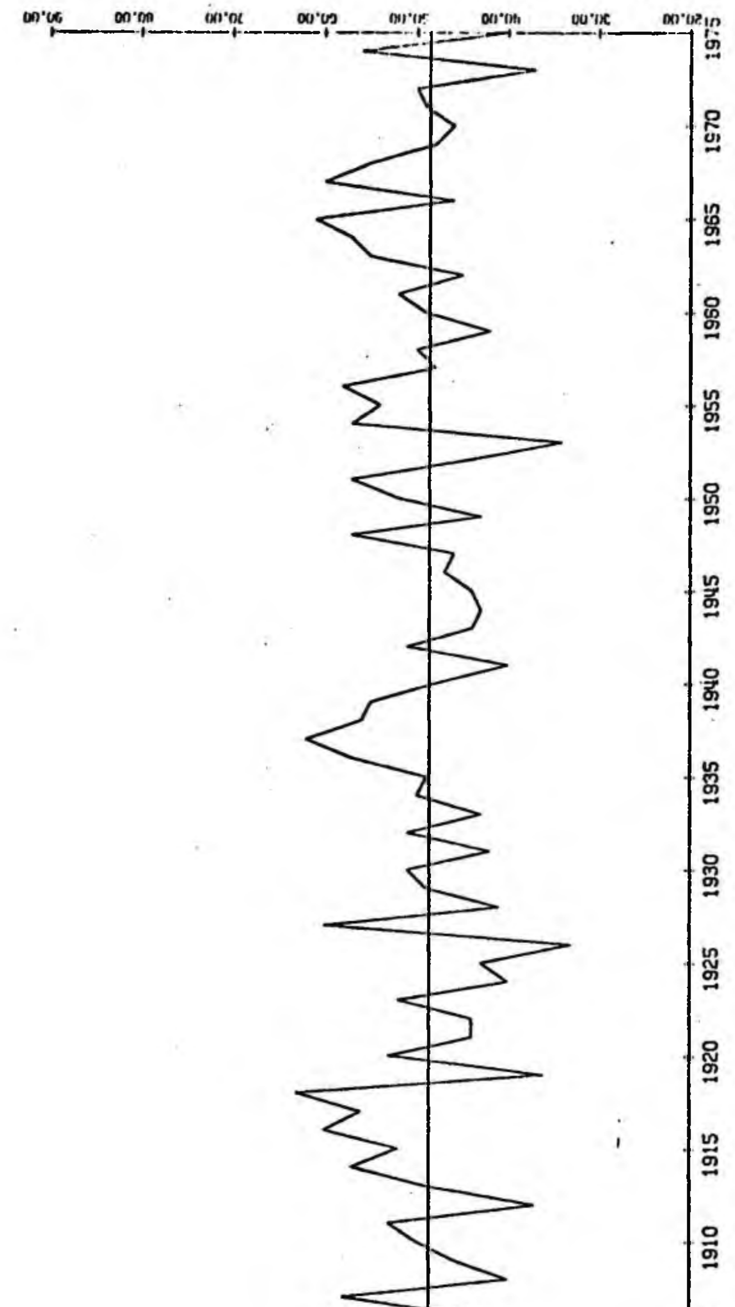
As to be expected, it closely resembles a summation of the summer and winter curves. The 1920's were very dry, as both the winter and summer rains reached the minima of their respective cycles within two years of each other. Precipitation increased throughout the 1930's, followed by a decrease until 1945--mainly due to the decrease in the winter rains. The annual rainfall then began a general increase until about 1968. Since that time both the winter and summer rainfalls have begun to decrease. If these trends continue, one might expect the 1970's to resemble the 1940's, when the annual index remained below average for seven out of eight consecutive years (Figure 24).

Hastenrath (1970) found a similar pattern in the annual precipitation in the Central American and Caribbean areas. Unfortunately, he did not separate the summer and winter rainfalls. It would be of interest to compare the Hawaiian patterns with other areas in the tropics.

2.7 Comparisons with Sea Surface Temperature (SST) Anomalies

In the tropics, where both pressure and temperature gradients are generally very small, large anomalies in the sea surface temperature (SST) can have profound effects upon the distribution of pressure and the corresponding winds and weather. With this in mind I compared the anomalies in monthly sea surface temperature during the Northern Hemisphere winter months at both Canton Island and Peru with the Hawaiian rainfall index. I tried many different comparisons based on both the sign and magnitude of the anomalies. I also tried the comparisons with a one month lag in the rainfall to test the speed of

Figure 24. Secular variation in Hawaiian annual rainfall index.


MEAN
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970

the atmospheric response to the SST anomaly. The results are presented in Tables 17 and 18. To give a better feeling for the significance of the relationship between these quantities, the data for all winter months, along with the best fit lines using the method of least squares, are plotted for each location in Figures 25 and 26. Although the scatter is significant, particularly with the small anomalies, one can see that in all cases there is a negative relationship between the sea surface temperature anomalies and the Hawaiian rain. That is to say, higher sea surface temperature at either of these two locations generally corresponds with less rain in Hawaii, while cooler water corresponds to more rain. Statistically these results are significant at the 0.5% level. Also the negative correlation with Canton Island, which is the closer of the two to Hawaii, is the larger.

3.0 THE LINE ISLANDS

3.1 The Rainfall Index

For the Line Islands, one station each on Washington, Fanning and Christmas Islands will be used to represent the rainfall regime south of the near-equatorial trough. The periods of record for each station are listed in Table 19.

Using the same method as for the Hawaiian stations, the mean index value was calculated for each month from January 1910 to December 1975. These are presented in Table 20. One can see that the range of values for the index is much larger than for the Hawaiian stations by this may, in great part, be due to the smaller number of stations involved.

TABLE 17. SEA SURFACE TEMPERATURE ANOMALIES AT PERU CORRELATED WITH HAWAIIAN RAIN

Anomaly	Number of Months	Correlation Coefficient	Level of Significance
Major El Nino	29	-0.284	10%
Major El Nino (one month lag*)	29	-0.299	10%
Winter anomalies > +1.0°C	40	-0.263	5%
Winter anomalies > +1.0°C (one month lag)	40	-0.207	10%
Winter anomalies < -1.0°C	85	-0.295	.5%
Winter anomalies < -1.0°C (one month lag)	85	-0.137	10%
Winter anomalies > +1.0°C or < -1.0°C	125	-0.414	.5%
All winter anomalies (1933-1973)	287	-0.242	.5%
All winter anomalies (1925-1973)**	343	-0.223	.5%
All anomalies (1933-1973)	492	-0.186	.5%
All anomalies (1925-1973)**	588	-0.168	.5%

*Example: January SST compared with February rain.

**The data from 1925-1933 may not be accurate.

TABLE 18. SEA SURFACE TEMPERATURE ANOMALIES AT CANTON ISLAND CORRELATED WITH HAWAIIAN RAIN

Anomaly	Number of Months	Correlation Coefficient	Level of Significance
All winter anomalies (1950-1974)	97	-0.340	.5%
Winter SST	97	-0.364	.5%

Figure 25. Comparison of Hawaiian rainfall with Peruvian sea surface temperature anomalies.

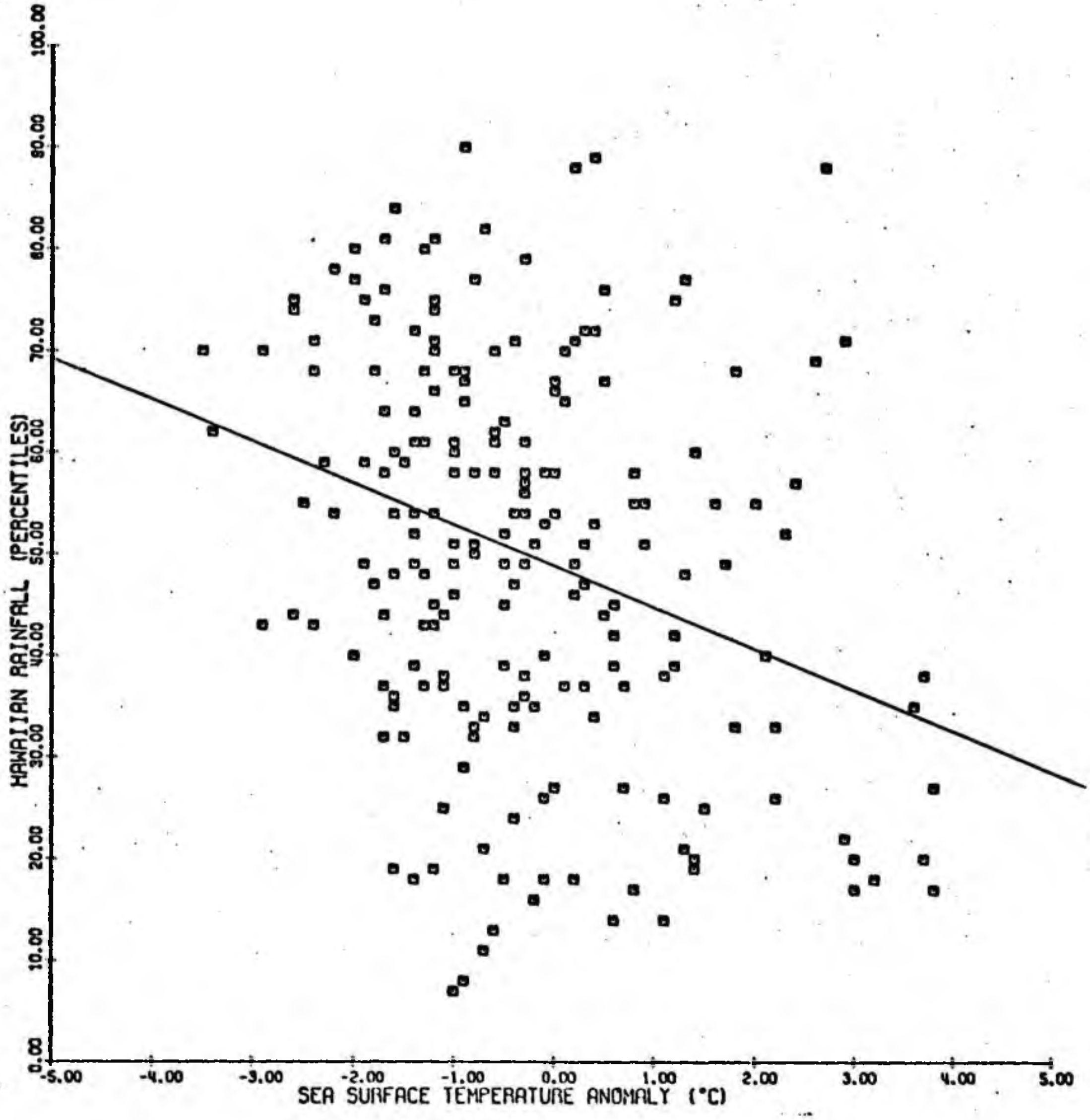
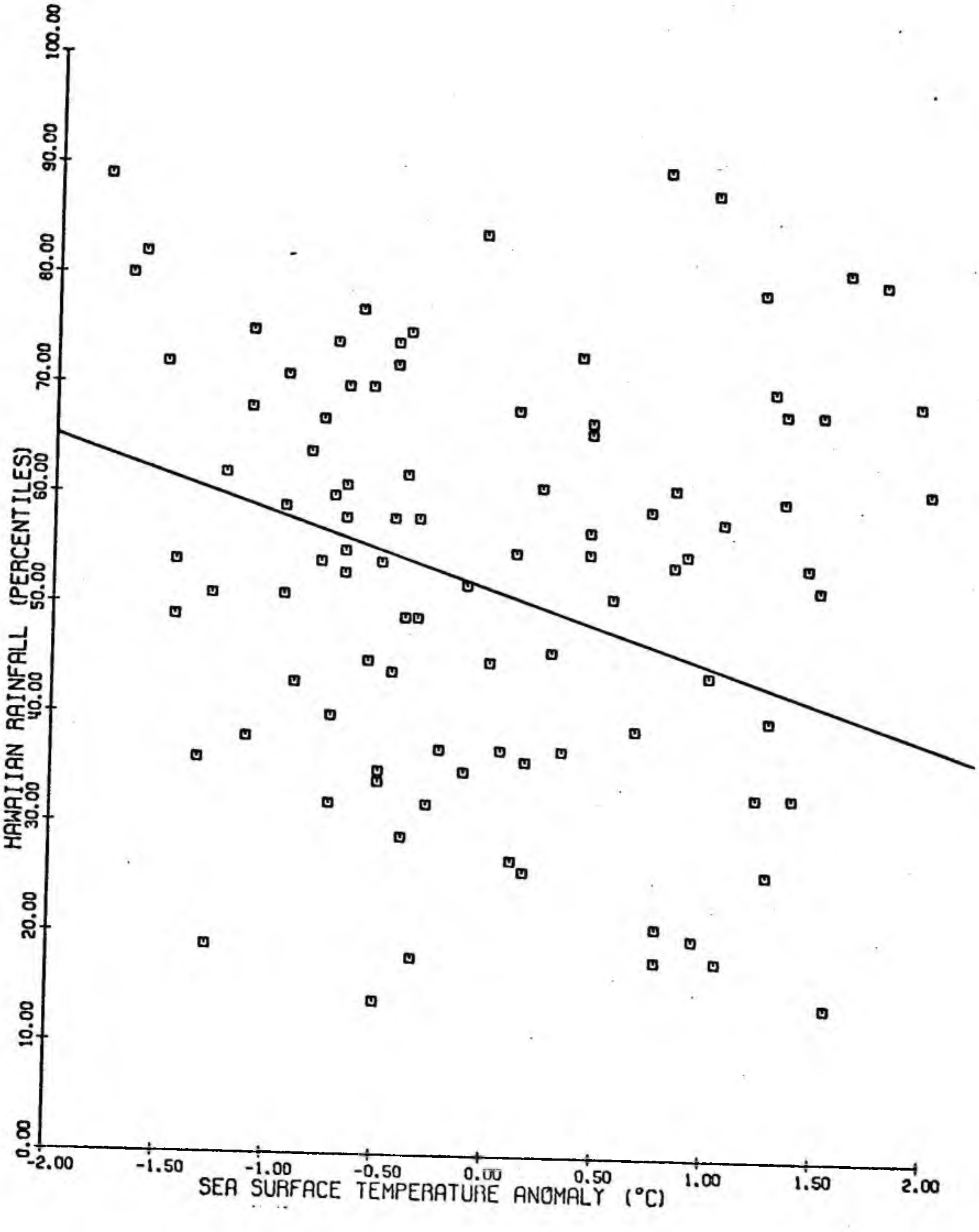

HAWAIIAN RAINFALL (PERCENTILES)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
SEA SURFACE TEMPERATURE ANOMALY (°C)

Figure 26. Comparison of Hawaiian rainfall with Canton Island sea surface temperature anomalies.



HAWAIIAN RAINFALL (PERCENTILES)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
-2.00
-1.50
-1.00
-0.50
0.00
0.50
1.00
1.50
2.00
SEA SURFACE TEMPERATURE ANOMALY (°C)

TABLE 19. LIST OF LINE ISLANDS STATIONS

Station	Period of Record
Washington Island	1910 - 1911
	1927 - 1933
	1936 - 1937
	1940 - 1943
	1945 - 1975
Fanning Island	1910 - 1972
	1973 - 1975
Christmas Island	1916 - 1919
	1935
	1937
	1939
	1941 - 1975

TABLE 20.
CALENDAR OF LINE ISLAND RAINFALL INDEX

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1910	26	23	48	35	59	80	72	26	16	33	53	17	1910
1911	18	17	14	33	53	46	74	63	99	92	89	95	1911
1912	98	98	89	95	78	21	5	38	56	74	56	66	1912
1913	33	57	83				50	54	84	77	75	83	1913
1914	93	90	92	30	91	77	78	84	83	96	83	89	1914
1915	87	87	95	90	99	43	96	72	32	14	9	15	1915
1916	5	11	20			17	19	10	53	57	44	53	1916
1917	7	10	18	16	48	48	67	18	31	25	59	35	1917
1918	25	24	9	8	62	87	91	96	92	89	71	88	1918
1919	94	86	79	71	77	44	68	50	65	6	27		1919
1920	51	84	72	71	5		26	60	2				1920
1921								45	69	51	24	36	1921
1922	45	62	65	77	59	76	31	7	42	6	15	47	1922
1923	6	3	2	14	35	58	92	62	77	84	65	80	1923
1924	80	80	63	50	3	7	9	23	18	50	21	5	1924
1925	14	48	33	51	77	66	42	53	72	86	74	86	1925
1926	90	93		83	75	53	60	90	35	57	2	2	1926
1927	27	11	35	7	37	29	30	44	80	39	28	55	1927
1928	89	85	71	58	12	30	34	39	41	59	66	35	1928
1929	33	51	76	61	19	64	66	72	55	66	44	71	1929
1930	76	82	64	17	72	63	90	82	90	88	84	94	1930
1931	77	67	36	35	33	64	27	31	31	41	44	27	1931
1932	22	22	72	50	65	40	36	42	21	65	31	28	1932
1933	60	52	61	20	42	61	50	26	23	13	20	14	1933
1934	9	12	42	48	50	75	36	42	8	12	38	26	1934
1935	31	65	35	16	37	51	55	65	44	62	34	56	1935
1936	56	60	53	44	80	47	84	24	42	68	66	19	1936
1937	60	32	25	52	41	92	71	53	92	62	31	34	1937
1938	65	15	8	24	46	16	17	74	6	36	50	35	1938
1939	67	22	26	56	71	40	78	61	84	86	91	86	1939
1940	80	96	56	94	76	93	73	79	75	97	90	81	1940
1941	89	94	97	59	77	63	64	84	88	67	85	66	1941
1942	90	59	80	56	41	27	10	29	12	30	20	23	1942
1943	29	37	10	42	41	43	67	57	57	26	35	62	1943
1944	67	53	28	49	53	70	56	34	39	63	23	42	1944
1945	35	32	42	27	48	29	65	55	27	15	24	62	1945
1946	52	43	37	44	33	50	42	68	25	38	57	13	1946
1947	72	65	41	76	66	50	60	52	40	33	44	70	1947
1948	56	51	58	76	94	64	38	24	29	27	46	41	1948
1949	33	81	69	37	60	55	42	25	34	31	19	25	1949
1950	11	5	9	21	25	22	13	25	38	40	9	47	1950
1951	29	42	47	56	77	84	55	87	78	53	58	68	1951
1952	65	56	67	84	35	64	37	53	66	21	73	59	1952
1953	69	74	50	61	63	47	49	38	68	69	90	47	1953
1954	43	49	50	33	13	28	25	19	33	26	39	20	1954
1955	44	52	39	49	30	52	48	11	49	30	11	15	1955
1956	17	4	62	89	75	74	35	73	73	55	45	34	1956
1957	27	6	40	58	84	81	75	44	77	90	93	95	1957
1958	88	90	84	85	91	61	74	73	56	42	28	63	1958
1959	45	67	68	83	65	70	35	41	50	70	41	33	1959
1960	50	56	66	50	56	48	24	74	38	72	54	53	1960
1961	58	82	15	35	46	41	48	62	44	51	65	30	1961
1962	57	42	57	42	38	27	61	34	57	32	67	42	1962
1963	36	41	27	46	32	56	81	90	82	87	71	77	1963
1964	90	91	79	27	13	6	7	30	47	53	47	46	1964
1965	41	37	63	36	38	82	51	92	97	85	84	89	1965
1966	89	72	90	67	51	32	53	37	35	37	51	67	1966
1967	39	42	35	4	17	45	64	30	38	76	69	37	1967
1968	18	9	8	12	7	8	69	33	51	69	87	54	1968
1969	62	50	66	80	84	80	31	76	65	57	77	63	1969
1970	63	51	60	72	72	10	7	11	50	22	13	31	1970
1971	15	36	28	29	23	41	22	65	27	26	15	65	1971
1972	32	30	22	52	34	86	94	93	95	92	97	89	1972
1973	85	73	69	78	81	19	6	41	35	18	6	25	1973
1974	21	55	23	16	20	39	94	27	38	54	30	62	1974
1975	49	53	87	68	37	41	28	13	50	60	23	51	1975

The annual variation in rainfall for each station is presented in Figures 27-29. This is a simple pattern with a single maximum and minimum corresponding to the meridional movement of the trough. During a normal year the center of the rainfall belt associated with the trough moves between 5°N in April and 8°N in September (Ramage, 1975). When the trough is closest to the equator the rainfalls are largest; when the trough is farthest from the equator the rainfalls are smallest. This is also reflected in the annual variation of correlation between the stations (Table 21). As expected the values are highest for the Washington-Fanning comparison and lowest for the Washington-Christmas--the farther apart the stations, the less we expect their rainfalls to be related.

The Washington-Fanning rains are least similar in May and September. In May, with the trough nearly over Washington, its rains are more influenced by the intensity of the trough. In September, Washington is still under the influence of the trough while Fanning is not--the rainfalls at Washington are much larger than those at Fanning.

Both the Washington-Christmas and the Fanning-Christmas correlations are least in June. During that month the rains at both Washington and Fanning are decreasing as the trough moves northward. Christmas remains under less influence from the trough and the rains there are the same as in May, with no decrease.

3.2 Persistence

As with the Hawaiian index, I examined the Line Islands index to determine when, if ever, persistence was a major factor in the

Figure 27. Annual variation in rainfall: Washington Island.

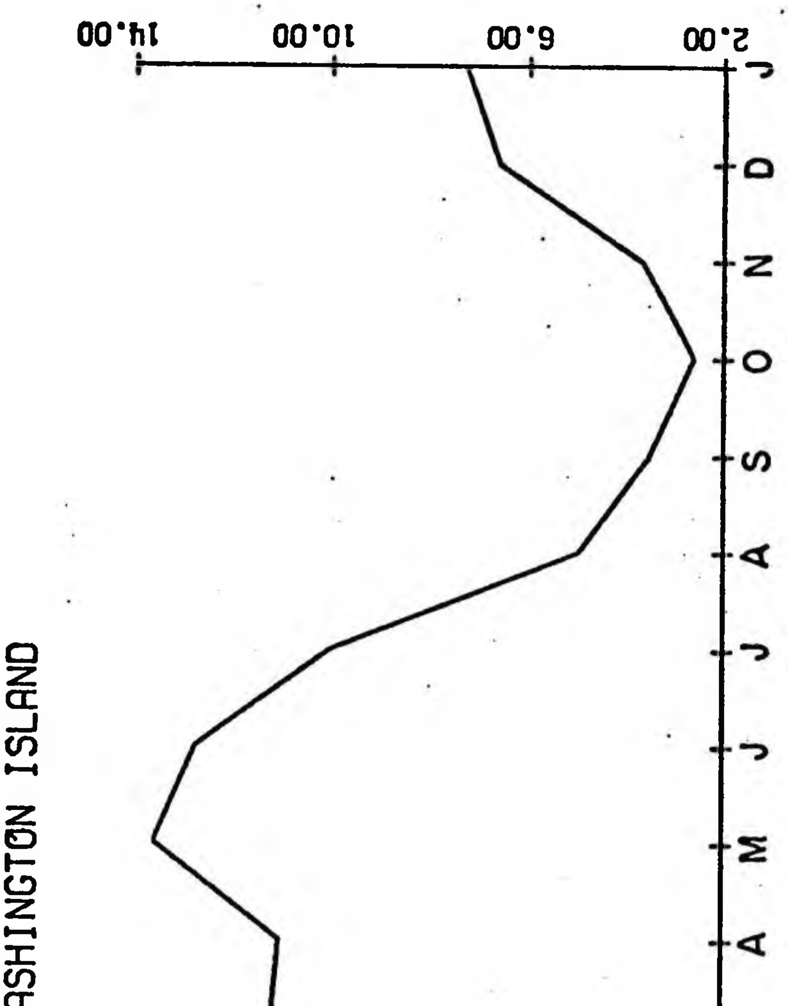

WASHINGTON ISLAND
RAINFALL (INCHES)
2.00
6.00
10.00
14.00
J
F
M
A
M
J
J
A
S
O
N
D
J

Figure 28. Annual variation in rainfall: Fanning Island.

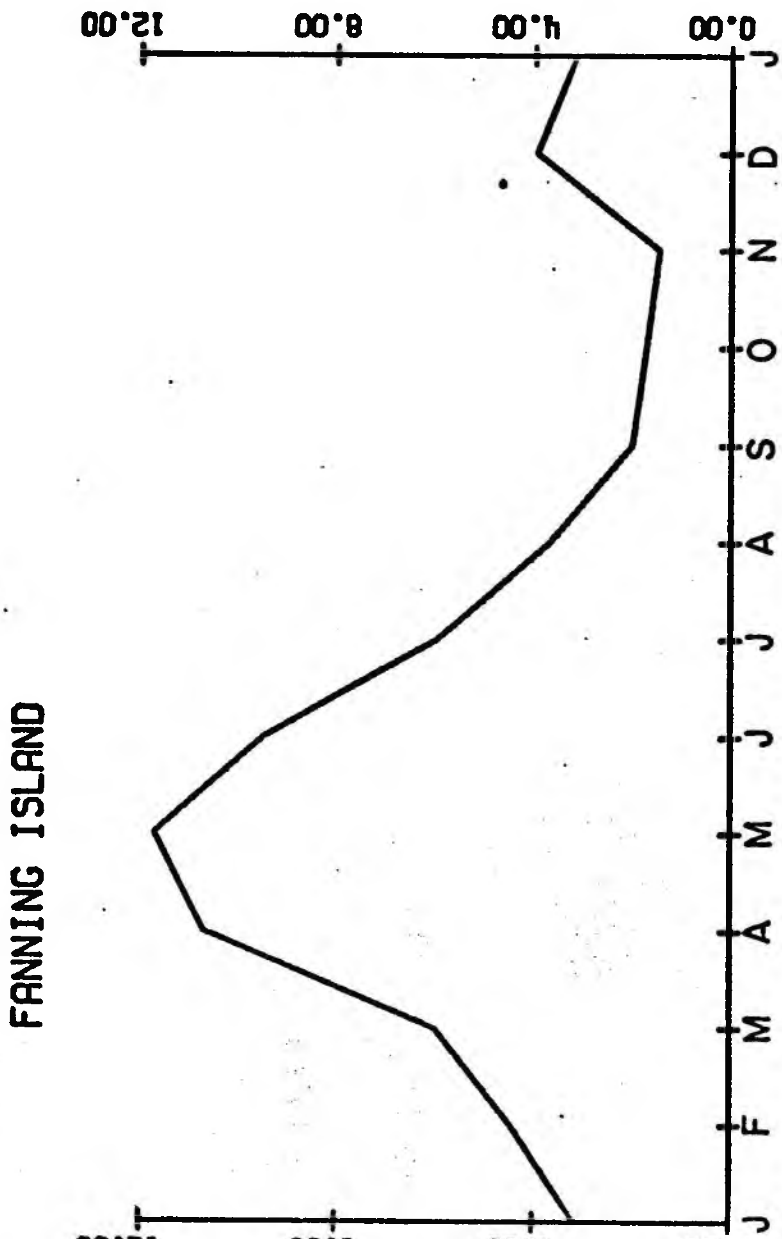

FANNING ISLAND
RAINFALL (INCHES)
0.00
4.00
8.00
12.00
J
F
M
A
M
J
J
A
S
O
N
D
J

Figure 29. Annual variation in rainfall: Christmas Island.

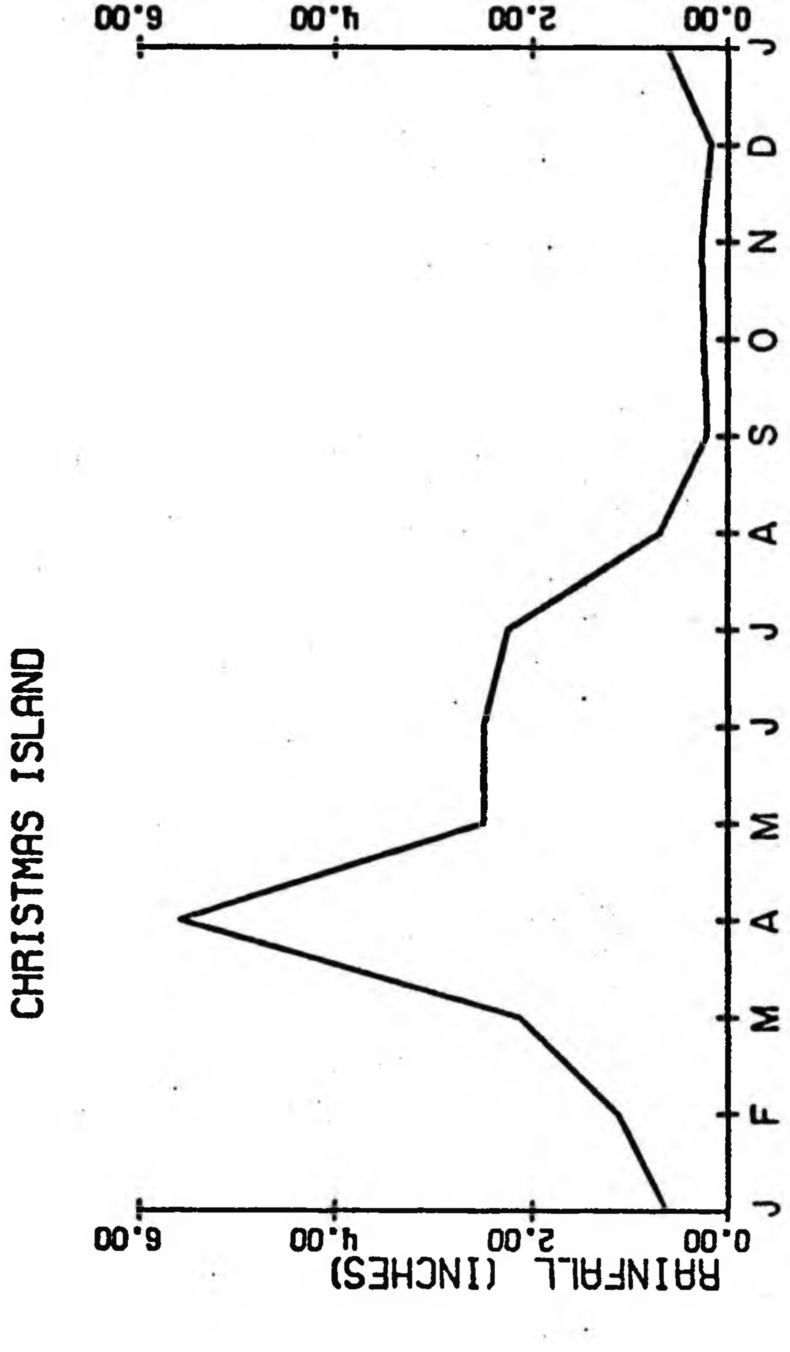

CHRISTMAS ISLAND
RAINFALL (INCHES)
0.00
2.00
4.00
6.00
J
F
M
A
M
J
J
A
S
O
N
D
J

TABLE 21. CORRELATION BETWEEN LINE ISLANDS STATIONS

Month	Washington-Fanning	Fanning-Christmas	Washington-Christmas
January	0.776 (0.5%)	0.576 (0.5%)	0.494 (0.5%)
February	0.745 (0.5%)	0.741 (0.5%)	0.493 (0.5%)
March	0.718 (0.5%)	0.675 (0.5%)	0.466 (0.5%)
April	0.793 (0.5%)	0.473 (0.5%)	0.184 (20%)
May	0.503 (0.5%)	0.614 (0.5%)	0.329 (2%)
June	0.610 (0.5%)	0.175 (30%)	0.138 (40%)
July	0.621 (0.5%)	0.542 (0.5%)	0.494 (0.5%)
August	0.753 (0.5%)	0.601 (0.5%)	0.270 (10%)
September	0.456 (0.5%)	0.694 (0.5%)	0.312 (5%)
October	0.701 (0.5%)	0.523 (0.5%)	0.528 (0.5%)
November	0.741 (0.5%)	0.720 (0.5%)	0.781 (0.5%)
December	0.766 (0.5%)	0.512 (0.5%)	0.406 (1%)

Note: Numbers in parentheses indicate level of significance (student's t-test).

month-to-month rainfalls. The annual variation in persistence here appears to be just the opposite to Hawaii, with persistence occurring most often in winter and least in summer (Tables 22-33). The winter persistence is a reflection of the effect El Nino has on the equatorial central Pacific, causing large rainfalls month after month in that region. The summer minimum in persistence may be due to fluctuation in the intensity of the near-equatorial trough and the variation in the number of tropical depressions in the vicinity.

Stratification of the data by island shows no pattern--there is no meridional variation in persistence.

3.3 Trends in Precipitation

Using the same definitions as before, I divided the monthly indices into winter and summer and found that there is a good correlation between summer and winter rains ($r = 0.634$, significant at 0.5% level). For the Line Islands it appears that wet summers are followed by wet winters and dry summers are followed by dry winters. The converse is not true. While this may be the result of the selection of our "seasons" (a better division for these stations would probably be February to June for the wet season and August to December for the dry), one should remember that month-to-month persistence is not significant for these stations. Because of this lack of persistence, one probably could not argue that a year in which the trough is particularly strong or weak would affect both seasons. El Nino might be an adequate explanation for this phenomenon.

There appears to be no long period cycles in either the Line

TABLE 22. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
JANUARY - FEBRUARY

JANUARY	FEBRUARY 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	8	1	1	0	0
20-39%	2	6	6	1	1
40-59%	0	1	7	3	2
60-79%	1	2	5	3	1
80-100%	0	0	1	2	11

MEAN ABSOLUTE CHANGE 12.08

STANDARD DEVIATION 12.13

TABLE 23. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
FEBRUARY - MARCH

FEBRUARY	MARCH 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	6	2	2	1	0
20-39%	2	4	2	2	0
40-59%	0	7	4	6	3
60-79%	0	2	3	3	1
80-100%	1	0	1	7	5

MEAN ABSOLUTE CHANGE 17.00

STANDARD DEVIATION 16.51

TABLE 24. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
MARCH - APRIL

MARCH	APRIL 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	4	4	1	0	0
20-39%	4	2	8	0	0
40-59%	0	3	5	3	1
60-79%	1	4	4	6	4
80-100%	0	1	2	2	3

MEAN ABSOLUTE CHANGE 20.12

STANDARD DEVIATION 16.81

TABLE 25. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
APRIL - MAY

APRIL	MAY 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	2	4	1	2	0
20-39%	2	4	6	1	1
40-59%	2	5	6	5	2
60-79%	2	1	2	4	2
80-100%	0	1	0	5	3

MEAN ABSOLUTE CHANGE 18.14

STANDARD DEVIATION 15.63

TABLE 26. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
MAY - JUNE

MAY	JUNE 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	3	2	1	1	0
20-39%	0	4	7	2	2
40-59%	1	3	5	4	2
60-79%	1	1	7	5	3
80-100%	1	0	2	3	2

MEAN ABSOLUTE CHANGE 19.71

STANDARD DEVIATION 15.73

TABLE 27. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
JUNE - JULY

JUNE	JULY 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	6	0	0	1	0
20-39%	3	3	1	2	1
40-59%	0	4	6	8	4
60-79%	0	7	3	4	1
80-100%	0	1	2	4	2

MEAN ABSOLUTE CHANGE 19.52

STANDARD DEVIATION 15.69

TABLE 28. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
JULY - AUGUST

JULY			AUGUST		
	0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	2	5	1	1	0
20-39%	3	3	5	5	0
40-59%	1	5	2	3	2
60-79%	1	4	6	5	3
80-100%	0	2	0	2	4

MEAN ABSOLUTE CHANGE 21.67

STANDARD DEVIATION 15.85

TABLE 29. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
AUGUST - SEPTEMBER

AUGUST	SEPTEMBER 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	0	2	5	0	0
20-39%	3	9	6	1	0
40-59%	1	3	3	5	3
60-79%	2	4	4	4	2
80-100%	0	1	0	1	7

MEAN ABSOLUTE CHANGE 19.59

STANDARD DEVIATION 15.49

TABLE 30. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
SEPTEMBER - OCTOBER

SEPTEMBER	OCTOBER 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	1	3	1	0	0
20-39%	4	7	4	4	0
40-59%	1	5	5	7	0
60-79%	1	1	4	1	4
80-100%	0	1	0	3	8

MEAN ABSOLUTE CHANGE 16.30

STANDARD DEVIATION 12.49

TABLE 31. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
OCTOBER - NOVEMBER

OCTOBER	NOVEMBER 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	3	4	0	0	0
20-39%	4	4	7	2	0
40-59%	2	4	5	3	0
60-79%	0	5	4	3	3
80-100%	0	0	0	4	8

MEAN ABSOLUTE CHANGE 16.52

STANDARD DEVIATION 11.73

TABLE 32. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
NOVEMBER - DECEMBER

NOVEMBER	DECEMBER 0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	3	3	2	1	0
20-39%	2	6	4	4	0
40-59%	2	5	4	5	0
60-79%	1	3	2	2	4
80-100%	0	0	2	1	8

MEAN ABSOLUTE CHANGE 17.64

STANDARD DEVIATION 12.93

TABLE 33. MONTH TO MONTH VARIATION IN LINE ISLANDS RAINFALL INDEX

LINE ISLANDS
DECEMBER - JANUARY

DECEMBER	JANUARY				
	0-19%	20-39%	40-59%	60-79%	80-100%
0-19%	5	1	0	2	0
20-39%	3	7	5	3	0
40-59%	2	3	4	2	1
60-79%	0	3	4	4	2
80-100%	0	0	0	1	11

MEAN ABSOLUTE CHANGE 13.95

STANDARD DEVIATION 13.67

Islands summer or winter rains (Figures 30-31), nor does any quasi-biennial oscillation appear. There is some evidence for a five-year cycle in the annual rainfall (Figure 32).

3.4 Comparisons with Sea Surface Temperature (SST) Anomalies

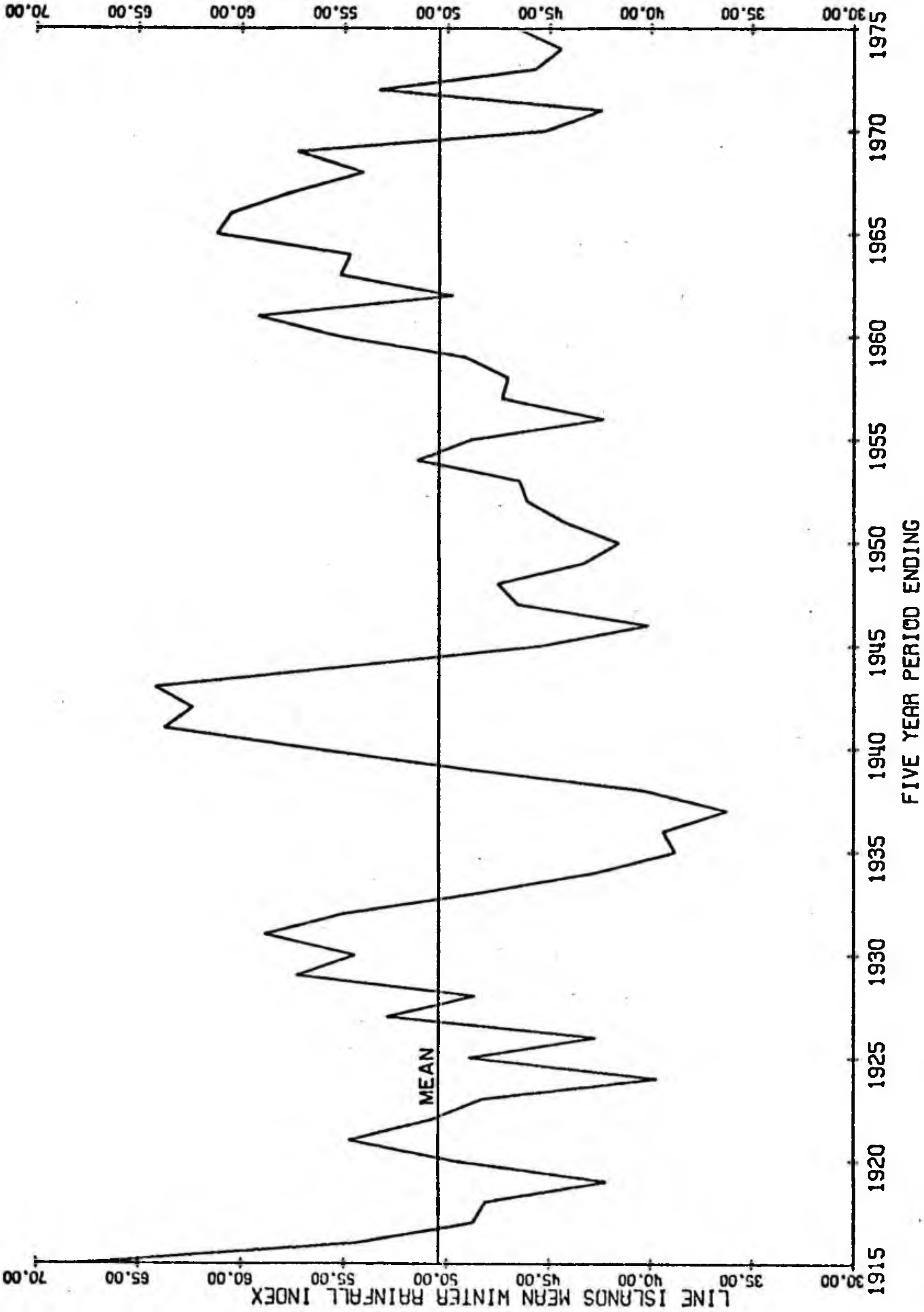
In comparing the Line Islands rainfall index with anomalies in sea surface temperature at both Canton Island and Peru, we again find that the scatter is significant (Figures 34-35), but a positive correlation exists. That is to say, warmer water at either of these locations generally corresponds to more rain falling in the vicinity of the Line Islands, while cooler water corresponds to less rain. Again, one should remember that it is the effect of the water temperature on the pressure and wind distribution, not the amount of evaporation, which is of importance. Ramage (1975) has explained the wind distributions near the equator as a result of the amount of cooler water upwelled there, and our data agrees with his.

4.0 COMPARISON BETWEEN HAWAIIAN AND LINE ISLANDS RAIN

Having treated both the Hawaiian and Line Islands rainfalls separately, we are now in a position to compare the two. There are 66 years in which data are available for both. The results are plotted in Figures 36-37.

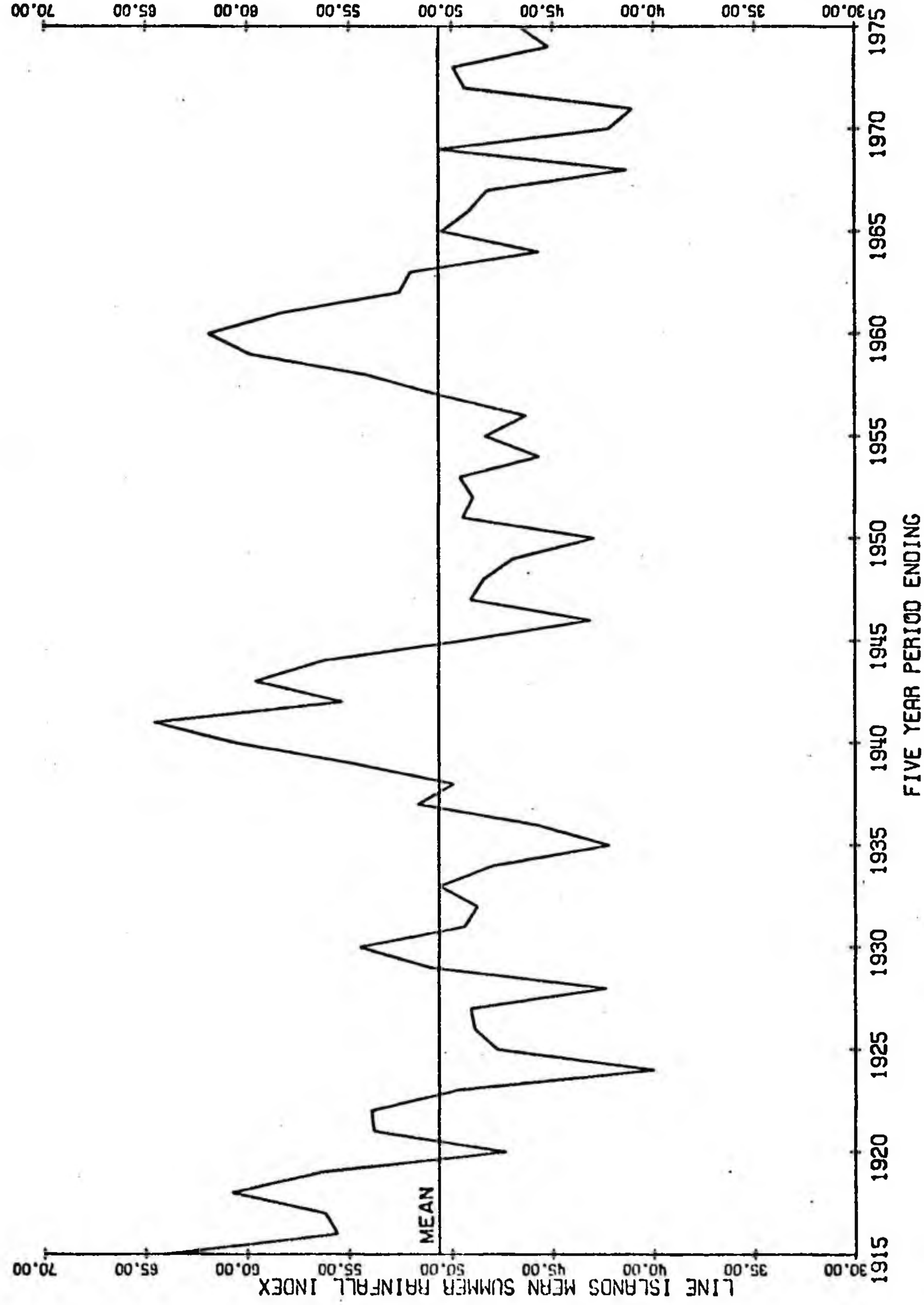
Of interest here is that there is a positive correlation (r = .217, significant at 10% level) in summer rainfall between the two and a larger negative correlation (r = -.570, significant at 0.5% level) in winter rainfall. The primary source of winter rain in the Line Islands

Figure 30. Secular variation in Line Islands mean winter rainfall index.



LINE ISLANDS MEAN WINTER RAINFALL INDEX
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
FIVE YEAR PERIOD ENDING
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
MEAN

Figure 31. Secular variation in Line Islands mean summer rainfall index.



LINE ISLANDS MEAN SUMMER RAINFALL INDEX
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
MEAN
FIVE YEAR PERIOD ENDING
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975

Figure 32. Secular variation in Line Islands annual rainfall index.

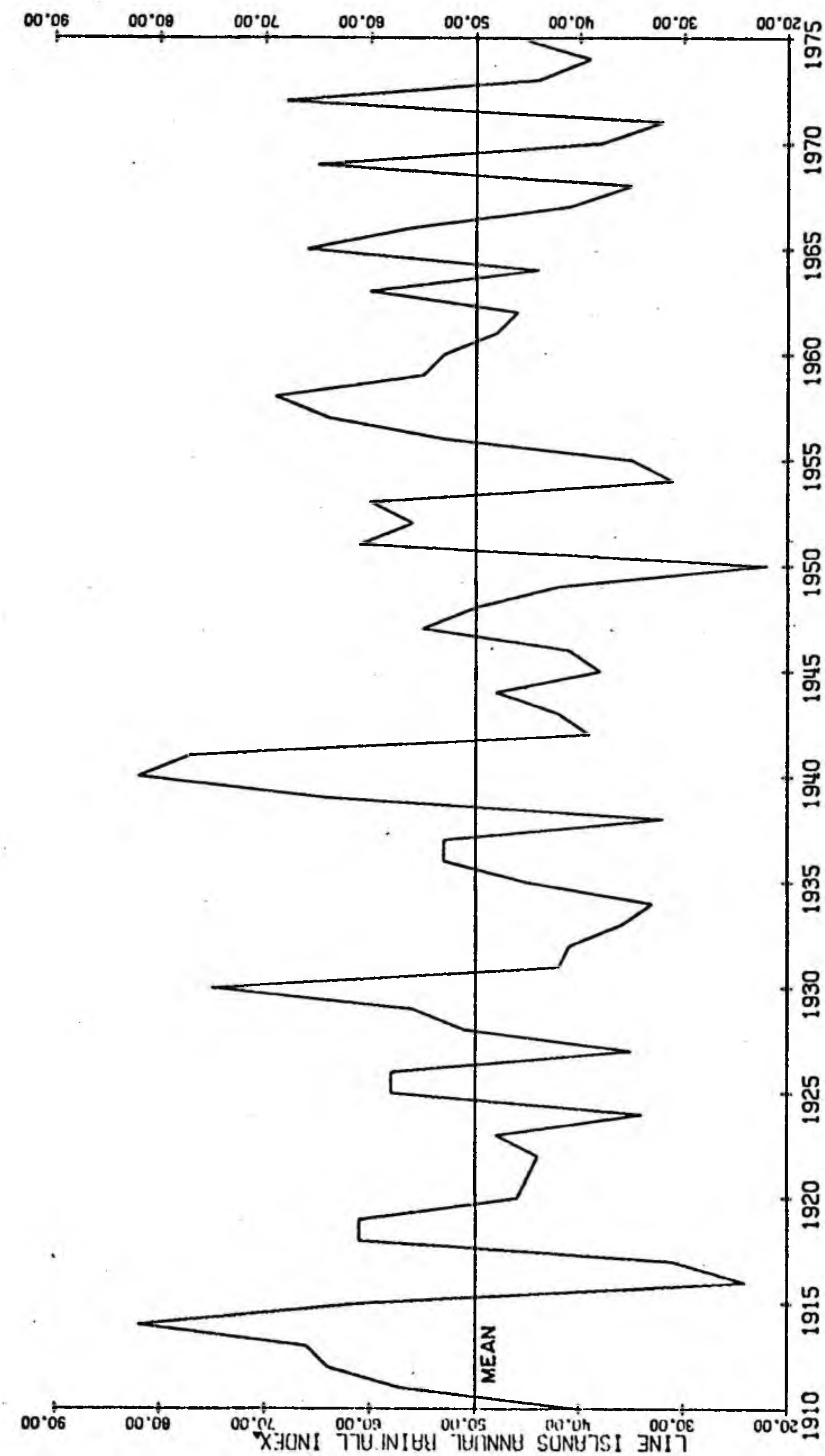

LINE ISLANDS ANNUAL RAINFALL INDEX
MEAN
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975

Figure 33. Secular variation in Line Islands mean annual rainfall index.

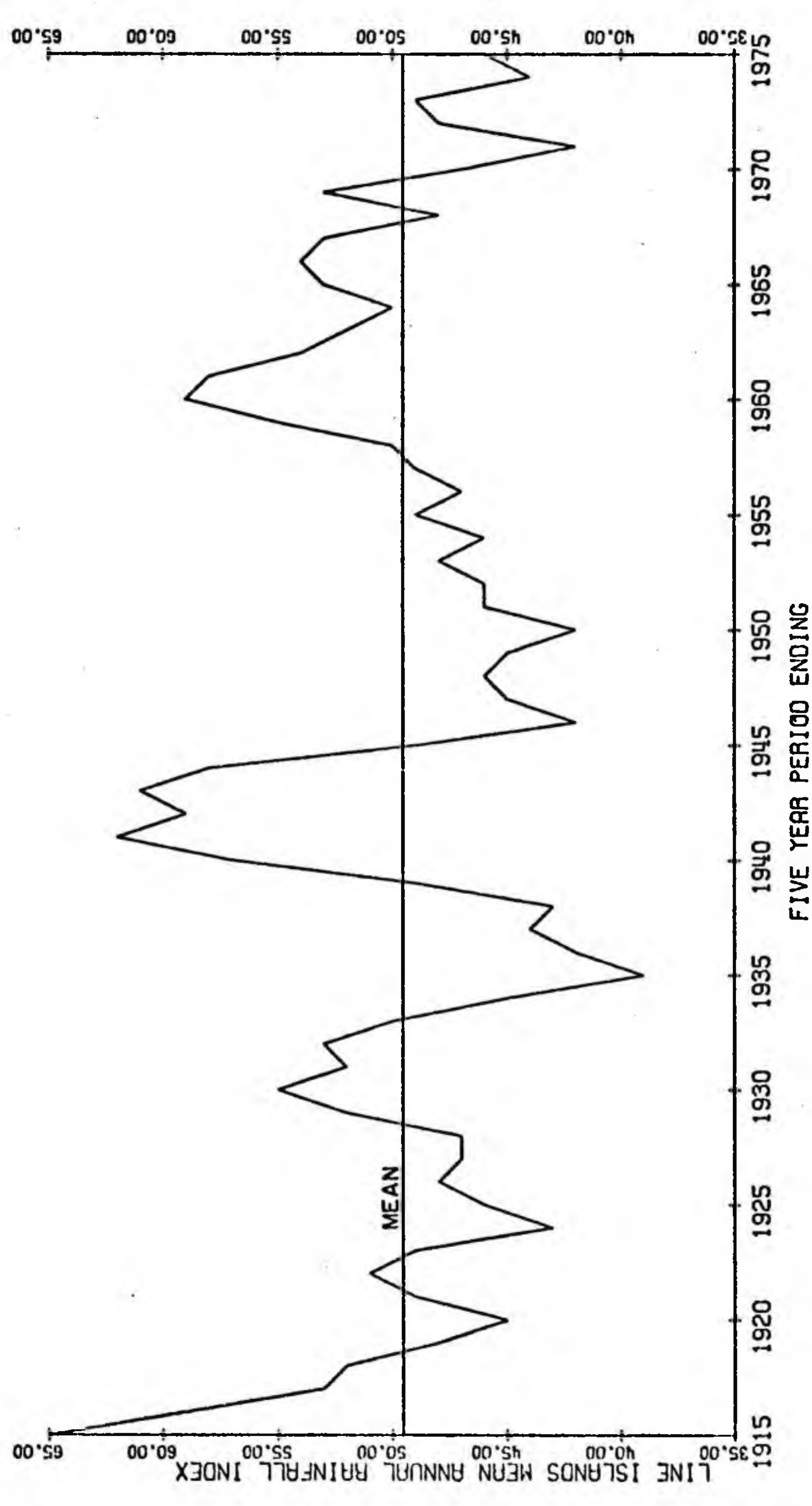

LINE ISLANDS MEAN ANNUAL RAINFALL INDEX
35.00
40.00
45.00
50.00
55.00
60.00
65.00
MEAN
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
FIVE YEAR PERIOD ENDING

Figure 34. Comparison of Line Islands rainfall with Peruvian sea surface temperature anomalies.

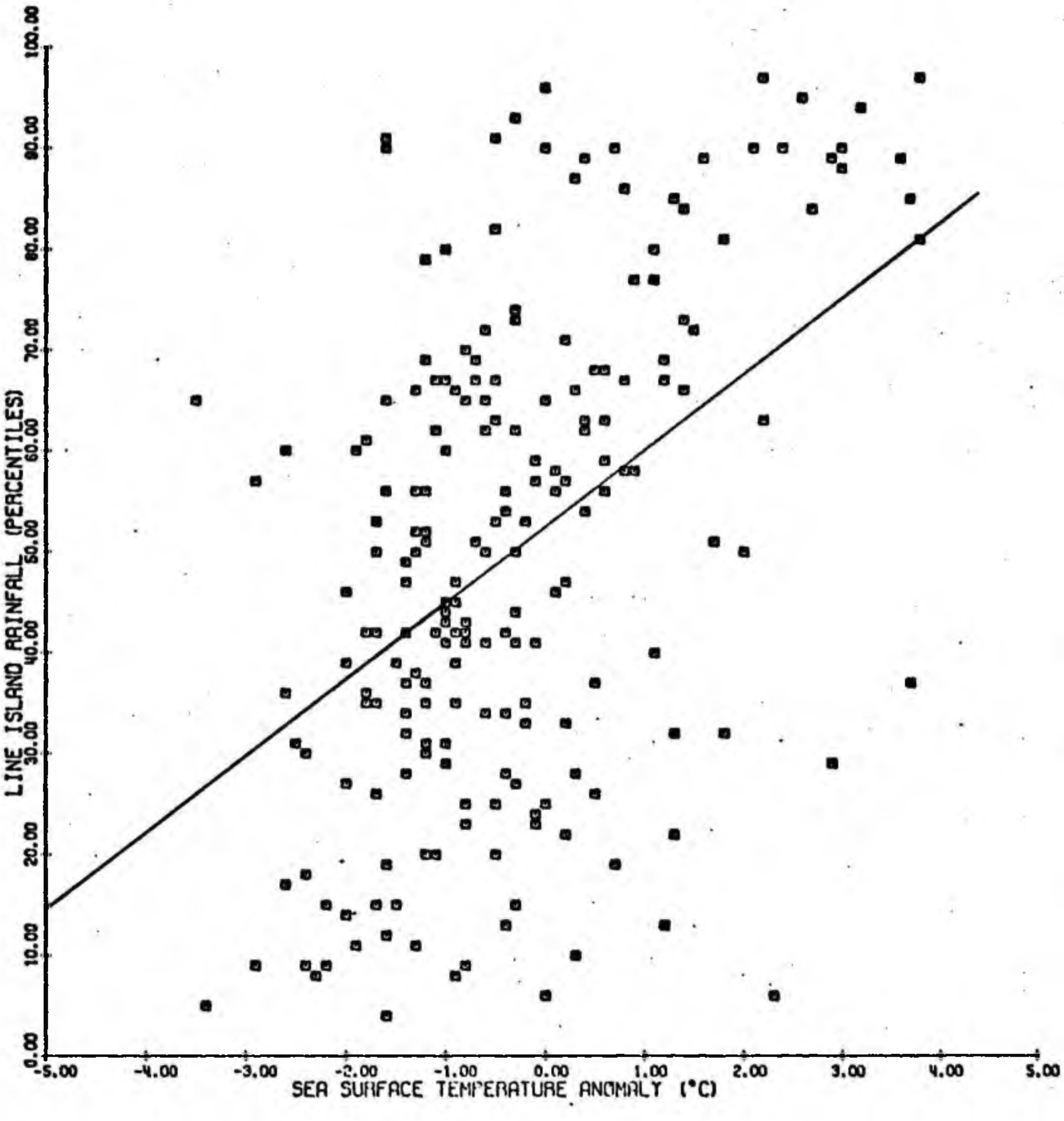

LINE ISLAND RAINFALL (PERCENTILES)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
SEA SURFACE TEMPERATURE ANOMALY (°C)

Figure 35. Comparison of Line Islands rainfall with Canton Island sea surface temperature anomalies.

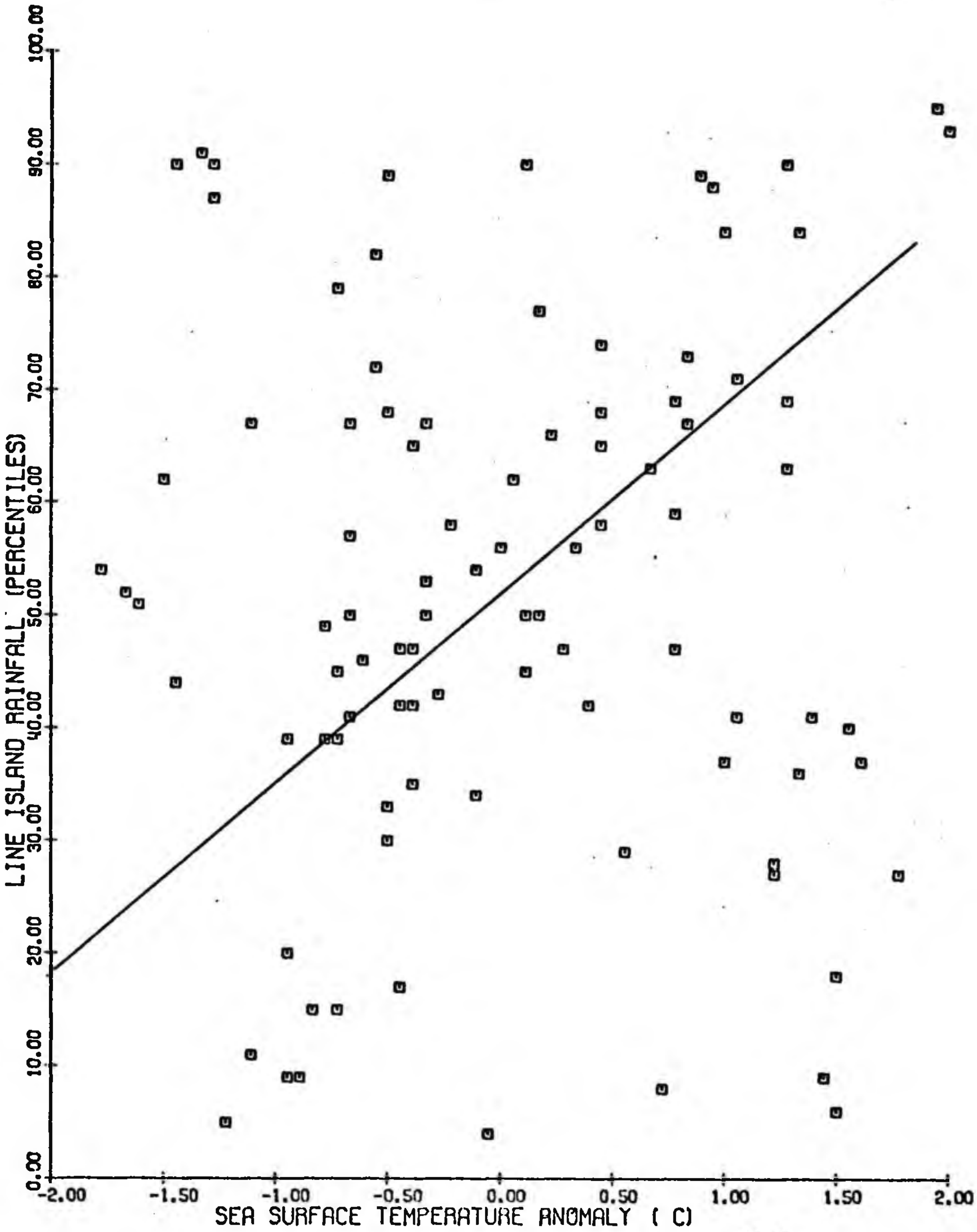

LINE ISLAND RAINFALL (PERCENTILES)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
-2.00
-1.50
-1.00
-0.50
0.00
0.50
1.00
1.50
2.00
SEA SURFACE TEMPERATURE ANOMALY (C)

Figure 36. Comparison of Hawaiian Island and Line Islands summer rainfall indices.

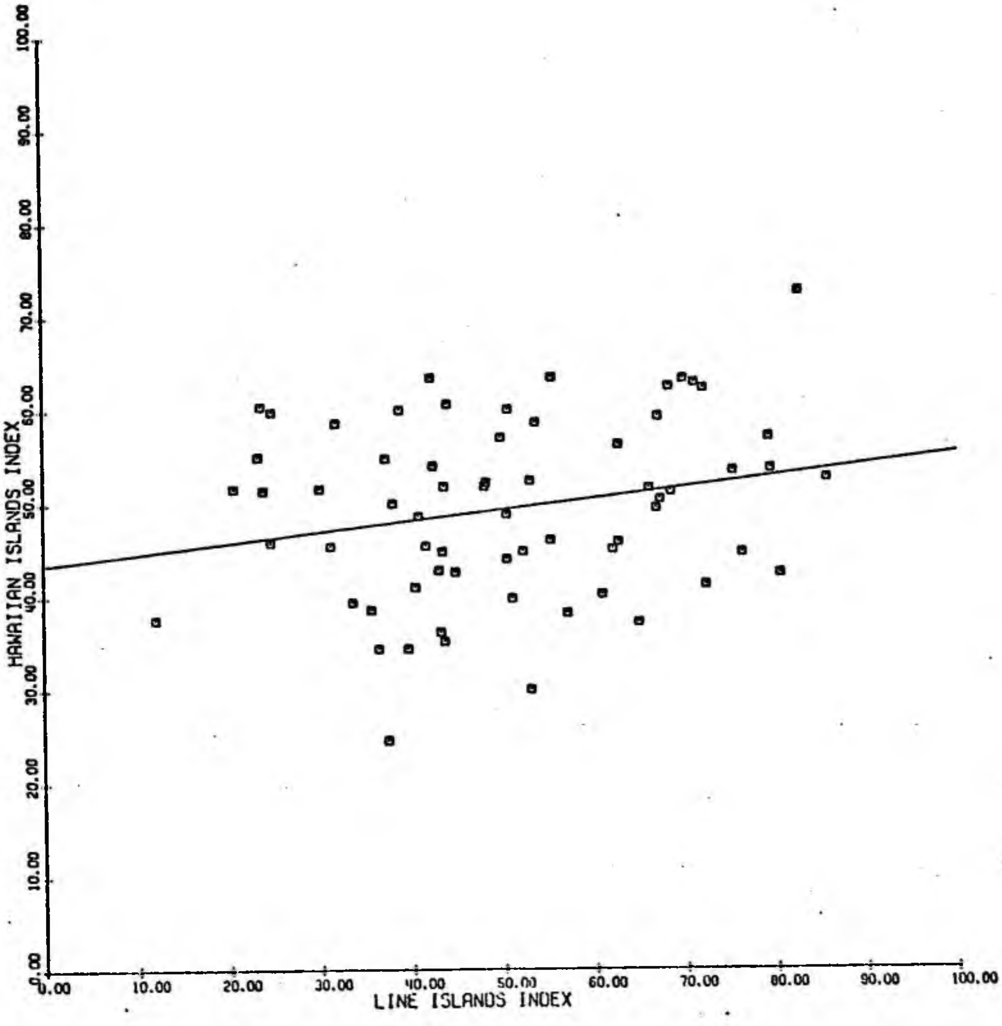
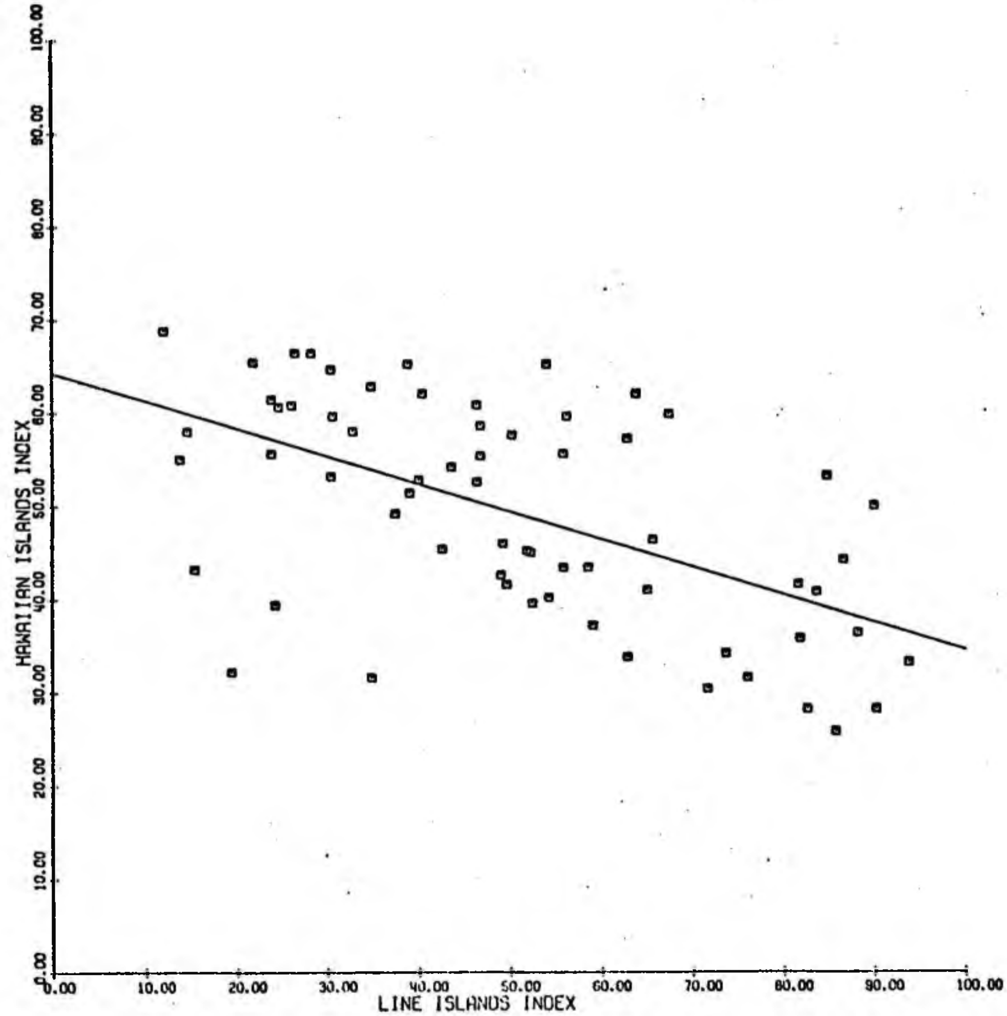

HAWAIIAN ISLANDS INDEX
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
LINE ISLANDS INDEX

Figure 37. Comparison of Hawaiian Island and Line Islands winter rainfall indices.



HAWAIIAN ISLANDS INDEX
LINE ISLANDS INDEX
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

is the near-equatorial trough, as shown above. The intensity of the trough will determine the amount of rain falling in the vicinity of the Line Islands. The trough, in turn responds to the strength of the trade winds in both hemispheres. The primary source of winter rain for the Hawaiian Islands is the passage of fronts and cyclonic disturbances. These would tend to disrupt the trade winds, thereby reducing the intensity of the near-equatorial trough and the Line Islands rainfall.

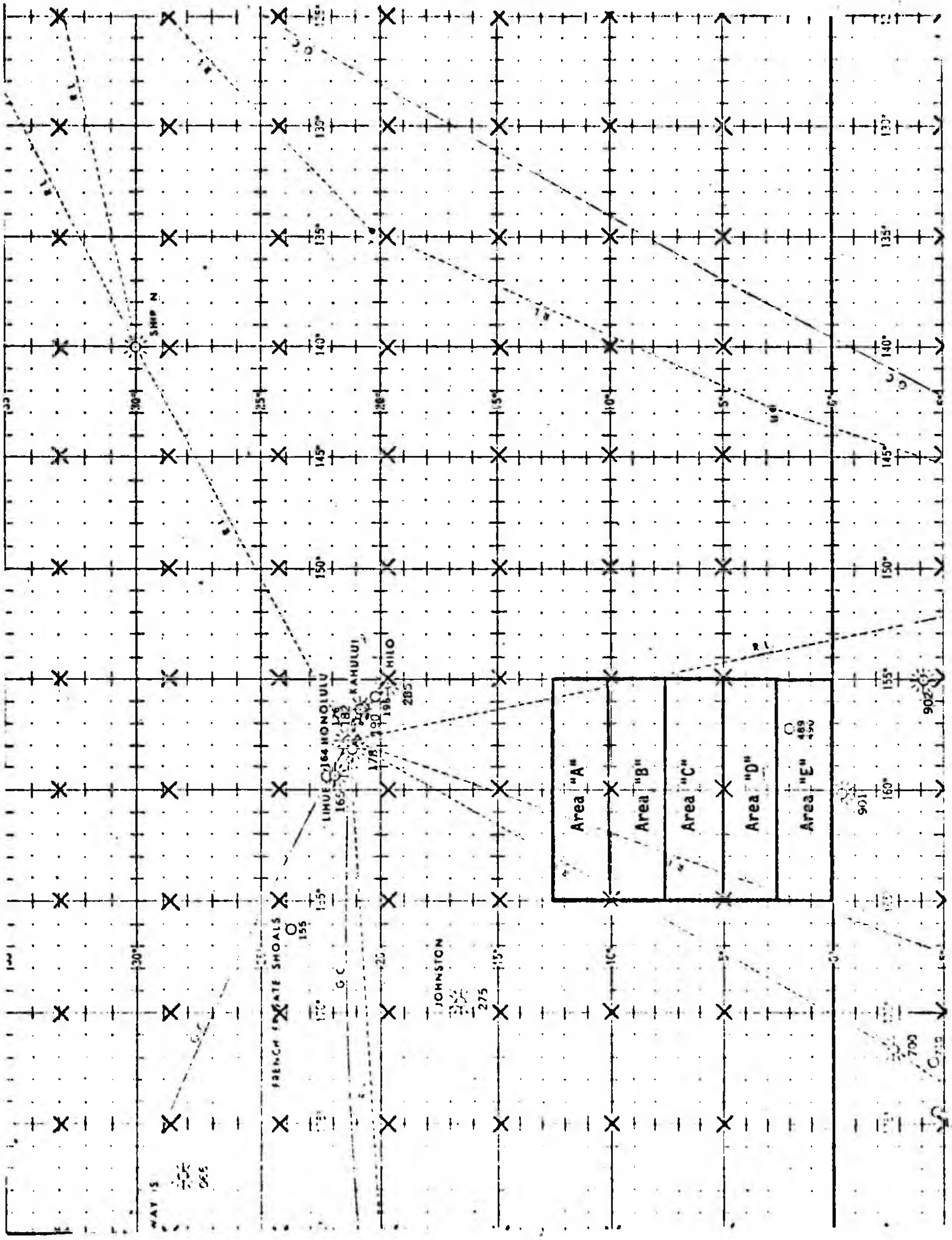
Similarly in summer, in a year when the trade winds are stronger than normal, we can expect more than the normal amount of orographically-induced rain to fall in the Hawaiian chain, the near-equatorial trough will be correspondingly stronger, and thus more rain will also fall in the Line Islands. Also, tropical depressions moving westward between Hawaii and the Line Islands might increase the rainfall at both locations.

As a simple test of these hypotheses, I correlated Hawaiian rainfall with total cloudiness in a number of 2½ degree by 10 degree strips in the vicinity of the Line Islands (Figure 38). The results are presented in Table 34.

One can see that the summer rain in Hawaii correlates positively with cloudiness in the region 0-5°N and negatively with cloudiness in the region 7½-10°N. Just the opposite is true in winter, when the correlations are even more significant.

Examination of film loops of daily cloudiness from the SMS-2 satellite has shown that, in winter, as cold fronts pass over the Hawaiian chain, the cloudiness in the vicinity of the Line Islands decreases substantially. This could be the result of pre-frontal

Figure 38. Location of areas of total cloudiness used in study.



SHIP N
HONOLULU
HILO
KAHULUI
LIHUE
FRENCH FRIGATE SHOALS
JOHNSTON
Area "A"
Area "B"
Area "C"
Area "D"
Area "E"

TABLE 34. CORRELATION OF HAWAIIAN RAINFALL WITH TOTAL CLOUDINESS IN THE VICINITY OF THE LINE ISLANDS

Cloudiness in Area	Correlation Coefficient Summer	Winter
A only	-0.15 (40%)	0.35 (5%)
B only	-0.18 (30%)	0.36 (5%)
C only	-0.04	-0.08
D only	0.15 (40%)	-0.57 (0.5%)
E only	0.18 (30%)	-0.40 (1%)
A and B	-0.18 (30%)	0.38 (2%)
B and C	-0.12	0.17 (30%)
C and D	-0.07	-0.39 (2%)
D and E	0.17 (30%)	-0.52 (0.5%)
A, B and C	-0.15 (40%)	0.23 (20%)
B, C and D	0.00	-0.13
A through D	-0.06	-0.02
B through E	0.05	-0.22 (20%)
A through E	-0.01	-0.12

Note: Numbers in parentheses indicate level of significance (student's t-test). If no number appears, significance is less than 40%.

subsidence or the interaction between the trade winds and the frontal winds, either case resulting in a diminished near-equatorial trough in that region. Some similar process may be acting in the summer, in this case the Hawaiian Islands may be in a region of subsidence resulting from increased convective activity in the region 7½-10°N.

5.0 SUMMARY

Using the monthly rainfall data from 27 stations in the Hawaiian Islands, representing the various climatic regimes, and 3 stations in the Line Islands, representing the region to the south of the near-equatorial trough, a rainfall index for each island chain has been computed.

The resulting Hawaiian indices have confirmed that general rainfall is characteristic of the winter months and that the sources of rain in the summer months are more dependent on mesoscale events. It has been shown that month-to-month persistence occurs more often in the summer than the winter, and that the degree of persistence is latitude dependent in the chain. It has also been shown that there is no relationship between the amount of winter and summer rainfalls for any given year.

There appears to be a definite cycle in the summer rainfall and we are currently approaching a minimum in that cycle. There is evidence for a cycle of shorter period in the winter rainfall.

There is also a significant negative correlation between the sea surface temperatures at both Peru and Canton Island and the northern hemisphere winter rainfalls at Hawaii.

The Line Islands indices show that month-to-month persistence is only significant during the winters of El Nino years, and that there is no variation in persistence among the islands. There is a good correlation between the amounts of summer and winter rainfalls, again probably related to El Nino.

There appears to be no long period cycles in either the summer or winter rains, although there may be a five-year cycle in the annual rainfall.

There is a positive correlation between the sea surface temperatures at both Peru and Canton Island and the northern hemisphere winter rainfalls in the Line Islands.

In comparing the rainfall of the Hawaiian and Line Islands, it has been shown that there is an inverse relationship in the winter and a direct relationship in the summer. Cyclonic storms and frontal passages interfering with the northeast trade winds in winter and fluctuations in the strength of the trade winds in summer seem to account for these relationships.

APPENDIX

CALENDAR OF HAWAIIAN RAINFALL BY STATION CLASSIFICATION

In each of the following tables, blank spaces indicate months in which none of the stations in that particular classification were operating.

TABLE 36.
CALENDAR OF HAWAIIAN RAINFALL INDEX
OAHU STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1891		48	13	6	21	18	30	24	47	25	31	26	1891
1892	77	55	3	61	92	89	40	55	17	44	17	60	1892
1893	56	92	48	75	19	7	38	20	34	17	86	22	1893
1894	48	92	37	32	5	23	36	14	35	24	92	16	1894
1895	39	41	18	16	49	40	66	44	93	65	62	82	1895
1896	33	28	92	70	75	58	14	89	23	37	64	61	1896
1897	20	10	16	13	47	85	28	48	89	76	56	16	1897
1898	26	85	91	32	28	79	55	36	24	16	17	19	1898
1899	15	51	60	37	82	45	56	19	32	70	3	27	1899
1900	7	25	25	65	21	42	74	76	23	66	96	23	1900
1901	23	91	42	74	84	62	59	20	31	57	37	81	1901
1902	2	36	83	52	25	78	57	35	82	60	73	84	1902
1903	29	45	25	51	43	52	51	40	50	40	48	17	1903
1904	32	96	85	41	9	28	42	91	62	36	77	58	1904
1905	24	2	20	13	38	44	71	73	75	41	57	27	1905
1906	51	7	30	24	52	19	40	64	57	44	80	85	1906
1907	92	78	48	35	71	75	57	78	76	33	31	37	1907
1908	9	64	86	18	26	50	16	43	71	18	16	22	1908
1909	48	50	69	41	41	61	67	19	35	37	11	79	1909
1910	48	38	27	46	53	84	55	77	83	28	59	47	1910
1911	56	81	48	28	58	47	44	50	80	35	23	34	1911
1912	16	57	35	45	36	38	54	60	22	50	37	44	1912
1913	25	29	37	51	86	95	23	73	54	58	65	22	1913
1914	49	24	68	63	76	61	56	48	92	34	46	58	1914
1915	18	38	29	84	40	75	69	29	57	55	86	87	1915
1916	96	46	65	55	77	58	67	66	51	59	61	77	1916
1917	81	47	92	72	79	70	43	54	75	48	64	66	1917
1918	80	78	73	92	37	50	58	87	46	53	84	61	1918
1919	35	13	22	37	35	59	46	32	64	49	19	31	1919
1920	55	10	73	47	63	63	68	56	44	35	50	82	1920
1921	87	26	21	33	39	28	56	41	46	65	26	65	1921
1922	64	42	44	30	45	40	30	35	86	52	39	6	1922
1923	88	83	71	83	18	20	24	27	51	34	13	80	1923
1924	12	28	37	89	30	17	62	35	33	60	20	50	1924
1925	35	18	59	53	35	54	62	28	49	46	53	33	1925
1926	24	11	15	25	12	89	42	63	46	56	17	22	1926
1927	58	41	83	81	80	63	70	48	77	24	71	95	1927
1928	25	17	26	65	44	43	63	30	25	35	69	29	1928
1929	30	56	17	34	53	30	40	68	41	51	83	84	1929
1930	76	45	62	35	20	65	41	41	91	71	74	14	1930
1931	13	18	31	42	70	28	44	83	81	62	39	29	1931
1932	43	93	43	53	56	69	43	57	51	27	65	36	1932
1933	49	80	81	20	39	42	45	27	36	4	22	58	1933
1934	37	46	17	61	60	87	51	47	88	57	49	30	1934
1935	63	81	50	14	27	45	57	38	75	76	49	15	1935
1936	35	50	34	50	53	58	59	83	73	91	39	61	1936
1937	69	85	54	63	79	50	83	62	53	44	39	70	1937
1938	42	84	62	65	78	59	60	90	13	42	33	36	1938
1939	37	60	72	78	59	57	44	40	72	94	54	14	1939
1940	46	32	40	49	82	26	33	67	36	39	78	16	1940
1941	16	11	23	5	44	65	24	58	53	88	5	18	1941
1942	10	53	59	62	37	71	60	50	46	79	47	81	1942
1943	82	45	43	20	85	38	31	34	25	23	8	36	1943
1944	6	70	83	23	35	70	33	25	19	30	29	37	1944
1945	7	24	20	89	14	27	62	66	39	22	29	56	1945
1946	67	51	32	30	9	58	69	23	13	37	59	69	1946
1947	20	10	50	24	69	62	40	70	63	26	55	43	1947
1948	81	59	42	51	52	47	49	58	56	30	69	53	1948
1949	92	69	28	16	15	60	54	27	14	9	26	48	1949
1950	87	48	37	85	72	26	35	75	42	36	52	65	1950
1951	47	64	95	48	23	30	20	64	52	88	37	68	1951
1952	61	29	51	36	40	53	40	24	27	82	54	13	1952
1953	28	54	63	29	30	43	26	21	15	28	25	48	1953
1954	32	67	51	56	43	64	87	59	34	53	78	68	1954
1955	47	94	73	39	55	33	35	69	49	28	67	72	1955
1956	73	84	24	35	50	63	28	58	35	66	66	56	1956
1957	93	43	14	68	26	36	44	69	11	17	71	72	1957
1958	23	50	89	23	49	59	91	95	57	87	24	42	1958
1959	59	59	11	44	41	14	34	88	39	13	42	16	1959
1960	33	40	60	33	79	58	42	45	63	58	43	48	1960
1961	57	47	15	43	55	69	61	51	38	66	68	27	1961
1962	47	58	80	59	67	38	31	38	51	60	6	37	1962
1963	83	30	89	94	86	66	68	30	73	43	14	28	1963
1964	57	25	73	53	45	31	79	47	48	52	72	84	1964
1965	50	61	17	75	90	36	82	53	50	87	95	76	1965
1966	32	77	21	22	41	37	69	51	28	74	90	36	1966
1967	36	51	82	61	65	59	77	86	45	45	60	85	1967
1968	77	47	78	74	46	30	31	8	60	68	67	83	1968
1969	81	57	46	29	52	46	64	30	54	31	60	45	1969
1970	57	18	4	54	39	43	85	34	45	59	83	31	1970
1971	78	33	68	75	28	84	21	25	60	33	35	52	1971
1972	68	76	51	72	28	44	12	55	43	67	30	35	1972
1973	17	27	28	36	47	58	56	32	40	57	49	53	1973
1974	77	51	63	87	61	67	78	14	64	58	67	13	1974
1975	4	73	55	31	23	21	29	10	11	28	87	28	1975

TABLE 37.
CALENDAR OF HAWAIIAN RAINFALL INDEX
HAWAII STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1890	84	80	84	58	66	77	93	71	53	89	47	51	1890
1891	60	42	37	55	35	22	59	72	79	84	9	47	1891
1892	72	36	32	24	24	32	35	37	27	49	24	44	1892
1893	34	67	59	55	43	29	40	10	11	12	59	28	1893
1894	59	85	53	25	1	19	37	29	17	33	59	45	1894
1895	31	51	26	64	41	47	49	67	74	56	59	47	1895
1896	46	55	58	43	48	30	32	61	33	20	27	25	1896
1897	27	26	21	12	15	22	20	47	29	40	64	40	1897
1898	71	49	86	19	30	41	50	20	46	24	31	37	1898
1899	20	34	67	59	71	64	34	41	14	70	7	7	1899
1900	12	52	12	34	67	36	45	62	29	82	57	12	1900
1901	45	77	71	51	44	23	31	27	38	39	73	66	1901
1902	25	13	91	24	63	64	66	59	73	68	57	76	1902
1903	56	40	33	61	39	15	76	49	57	24	61	13	1903
1904	67	82	35	88	63	64	62	71	78	42	18	26	1904
1905	16	18	19	20	53	56	49	68	81	44	66	43	1905
1906	37	7	10	39	55	47	49	73	31	28	71	72	1906
1907	50	79	58	31	33	82	60	83	90	64	37	16	1907
1908	35	54	43	52	32	26	32	46	50	38	25	51	1908
1909	30	62	62	42	68	41	48	24	44	35	8	80	1909
1910	76	24	38	31	44	67	53	58	45	40	39	49	1910
1911	69	71	66	65	64	74	42	50	70	47	56	55	1911
1912	7	52	39	53	30	47	29	26	31	67	39	47	1912
1913	64	34	26	50	65	68	37	48	30	38	83	36	1913
1914	61	34	50	43	78	74	66	91	80	32	78	81	1914
1915	16	43	6	57	25	79	65	20	48	75	92	71	1915
1916	71	8	50	53	80	56	52	55	46	53	51	80	1916
1917	56	35	56	51	55	54	32	23	26	41	43	42	1917
1918	72	91	75	86	51	59	80	61	37	45	70	41	1918
1919	25	23	37	33	28	30	30	32	28	36	20	32	1919
1920	51	29	78	21	38	35	34	24	63	65	23	48	1920
1921	89	31	20	41	32	17	37	37	25	39	51	69	1921
1922	73	64	58	49	21	17	33	37	59	39	57	21	1922
1923	87	56	79	77	56	47	51	58	50	49	21	78	1923
1924	12	54	28	71	40	35	48	41	40	59	42	42	1924
1925	35	10	69	38	54	47	22	65	60	39	39	24	1925
1926	18	22	16	9	26	47	43	70	31	41	24	46	1926
1927	53	16	50	69	41	47	46	52	74	55	55	90	1927
1928	29	35	22	31	33	49	60	48	48	39	38	55	1928
1929	63	79	47	66	46	42	47	53	42	33	78	73	1929
1930	64	27	54	56	38	65	39	50	65	52	61	19	1930
1931	10	33	29	54	51	22	65	52	67	51	51	20	1931
1932	64	84	31	55	57	39	50	25	39	18	44	61	1932
1933	59	58	44	60	37	50	14	23	40	9	31	13	1933
1934	53	32	23	36	79	81	59	43	76	65	47	47	1934
1935	53	59	43	45	35	58	56	27	56	69	67	21	1935
1936	45	50	66	47	45	40	72	68	77	78	31	60	1936
1937	87	76	61	40	81	48	72	64	53	60	42	54	1937
1938	60	64	66	68	78	65	50	50	39	61	42	36	1938
1939	59	75	80	80	22	72	61	25	53	51	60	14	1939
1940	27	32	60	35	48	39	47	82	57	65	61	25	1940
1941	32	24	35	36	72	65	43	52	81	83	36	23	1941
1942	7	37	70	48	43	51	32	66	53	59	24	58	1942
1943	54	36	63	42	45	84	49	57	47	25	16	38	1943
1944	16	73	50	48	64	67	51	37	44	60	25	65	1944
1945	13	50	67	63	39	77	39	57	42	46	54	58	1945
1946	76	66	43	47	27	36	42	28	41	54	29	76	1946
1947	26	18	56	48	65	45	38	67	48	40	47	57	1947
1948	55	59	62	45	54	47	58	45	61	50	72	65	1948
1949	79	43	45	21	24	39	45	31	19	44	52	55	1949
1950	59	59	36	86	51	25	60	32	26	27	73	57	1950
1951	56	85	80	36	40	55	55	61	38	82	69	54	1951
1952	75	45	64	35	49	55	41	17	41	49	48	24	1952
1953	6	66	58	31	64	47	27	19	27	29	21	50	1953
1954	33	40	59	25	71	66	65	72	57	43	48	79	1954
1955	47	85	54	45	50	49	58	40	49	21	48	60	1955
1956	71	81	47	56	77	67	57	76	40	75	77	44	1956
1957	56	40	20	64	48	29	59	70	30	70	53	60	1957
1958	21	35	64	20	59	52	66	82	31	69	44	40	1958
1959	75	61	20	45	45	18	49	62	39	34	78	47	1959
1960	38	60	49	42	60	35	15	44	60	46	35	37	1960
1961	28	56	47	57	56	45	33	27	29	83	71	59	1961
1962	39	22	49	31	60	33	38	22	53	29	23	30	1962
1963	43	31	64	87	69	58	72	56	77	25	31	30	1963
1964	18	31	68	50	47	58	32	49	53	49	52	69	1964
1965	50	45	48	63	72	59	40	58	58	51	77	38	1965
1966	53	66	22	28	31	33	52	48	59	65	70	47	1966
1967	38	58	57	57	43	55	72	74	41	44	76	69	1967
1968	63	53	41	90	27	40	67	39	49	51	23	91	1968
1969	76	50	36	51	41	34	60	80	49	24	30	39	1969
1970	39	25	9	54	55	45	44	73	45	44	63	56	1970
1971	86	48	40	64	22	12	45	19	50	22	75	45	1971
1972	61	61	50	61	27	44	59	49	43	50	34	47	1972
1973	28	18	29	15	27	23	10	5	55	40	59	55	1973
1974	56	34	58	53	42	59	36	21	49	72	46	57	1974
1975	70	81	48	26	42	25	24	25	25	42	46	54	1975

TABLE 34.
CALENDAR OF HAWAIIAN RAINFALL INDEX
WINDWARD STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1890	76	84	80	32	67	95	95	89	56	87	86	77	1890
1891	90	43	35	33	32	11	42	45	73	41	17	41	1891
1892	76	25	23	28	64	54	19	36	26	40	17	51	1892
1893	63	76	37	53	31	31	25	16	27	21	39	12	1893
1894	22	85	44	16	4	19	29	26	15	22	80	44	1894
1895	26	41	29	45	23	23	40	69	83	73	57	39	1895
1896	48	55	47	43	78	74	39	73	13	36	29	41	1896
1897	19	25	7	11	31	47	19	52	56	38	47	22	1897
1898	65	52	88	30	42	72	63	26	31	23	18	19	1898
1899	16	24	75	45	68	46	42	42	28	77	8	12	1899
1900	12	48	12	38	50	26	36	53	29	73	73	17	1900
1901	39	77	65	48	49	35	44	24	28	57	65	70	1901
1902	12	37	92	30	57	76	50	65	75	70	73	91	1902
1903	35	40	25	60	20	33	50	24	49	45	50	21	1903
1904	58	80	43	72	25	32	57	74	63	20	42	40	1904
1905	23	17	25	40	53	57	62	73	83	50	74	43	1905
1906	28	7	17	37	56	38	50	76	52	36	59	77	1906
1907	62	77	64	35	51	72	68	88	76	52	36	33	1907
1908	26	69	62	42	46	44	32	62	70	46	22	37	1908
1909	42	52	82	53	53	56	70	29	44	46	11	80	1909
1910	69	33	39	45	67	81	52	64	55	55	65	57	1910
1911	76	80	53	43	78	70	59	58	89	37	43	38	1911
1912	13	50	49	56	40	42	41	45	33	55	39	48	1912
1913	43	41	35	47	58	88	16	48	41	38	83	41	1913
1914	51	16	57	55	91	76	76	66	95	31	60	69	1914
1915	14	46	14	82	16	74	61	32	50	64	87	77	1915
1916	79	25	59	39	84	67	71	60	60	49	64	88	1916
1917	68	36	77	57	53	67	27	23	35	33	59	39	1917
1918	72	84	83	95	62	61	69	80	27	44	72	72	1918
1919	30	18	32	37	26	45	41	28	46	44	25	41	1919
1920	48	15	81	40	36	43	48	51	61	59	46	62	1920
1921	91	21	30	38	28	30	47	43	40	63	51	76	1921
1922	73	58	53	46	53	29	29	39	86	56	63	8	1922
1923	91	66	69	70	28	37	34	38	49	56	19	80	1923
1924	9	41	20	86	47	23	54	35	28	75	27	32	1924
1925	48	30	62	49	46	60	39	43	65	37	38	22	1925
1926	24	19	9	16	18	74	29	57	52	37	20	33	1926
1927	68	30	72	74	58	48	67	59	68	30	66	91	1927
1928	35	28	18	49	41	36	72	43	59	40	51	44	1928
1929	45	60	41	37	45	24	61	49	17	35	67	70	1929
1930	67	45	52	60	37	79	59	73	90	57	80	22	1930
1931	14	32	25	41	51	24	55	71	86	66	51	37	1931
1932	64	95	27	58	67	55	54	42	41	18	52	52	1932
1933	67	67	64	26	51	47	35	21	45	5	25	40	1933
1934	48	35	19	58	61	77	52	25	85	71	47	36	1934
1935	53	76	37	28	28	51	53	36	74	48	48	28	1935
1936	42	30	62	50	56	50	71	86	71	88	36	65	1936
1937	81	75	76	56	82	37	88	65	59	62	49	57	1937
1938	58	74	70	63	72	63	50	64	15	43	41	46	1938
1939	53	70	74	82	50	56	50	25	36	78	58	13	1939
1940	27	38	35	38	72	31	56	82	55	66	45	20	1940
1941	29	18	31	14	56	71	37	67	70	89	23	27	1941
1942	19	47	74	71	43	67	41	49	46	45	37	70	1942
1943	66	45	43	30	60	69	41	42	34	17	9	41	1943
1944	11	75	55	28	51	60	58	25	22	39	33	39	1944
1945	7	24	52	69	12	41	29	56	18	49	30	58	1945
1946	65	57	42	53	13	48	61	25	23	35	54	80	1946
1947	24	11	52	27	54	60	49	74	67	40	56	55	1947
1948	66	41	64	66	59	38	37	67	61	42	70	66	1948
1949	84	63	36	14	31	36	32	26	22	24	41	48	1949
1950	67	57	36	86	67	22	38	53	24	36	50	59	1950
1951	46	68	81	42	14	20	39	65	42	83	56	62	1951
1952	61	47	65	30	51	63	41	28	37	74	59	16	1952
1953	18	55	57	13	37	32	20	21	13	15	26	36	1953
1954	29	61	54	33	56	62	82	71	43	38	51	74	1954
1955	48	87	49	43	59	41	39	56	48	38	63	51	1955
1956	71	88	38	38	57	64	17	59	34	77	61	41	1956
1957	77	55	13	62	32	33	59	73	19	41	60	76	1957
1958	24	40	50	21	40	50	91	89	57	82	37	39	1958
1959	50	52	18	51	50	21	34	72	57	19	58	45	1959
1960	47	54	68	48	70	57	36	47	70	59	41	47	1960
1961	39	59	18	52	47	56	42	39	43	84	64	45	1961
1962	41	41	70	39	62	39	25	27	41	23	13	24	1962
1963	56	21	70	85	83	73	61	22	59	55	18	25	1963
1964	60	44	67	49	59	36	67	36	59	65	76	69	1964
1965	62	54	32	78	81	45	65	37	51	72	89	65	1965
1966	41	66	17	20	39	50	61	58	52	77	76	38	1966
1967	48	67	72	57	70	52	70	76	42	39	70	85	1967
1968	58	40	69	72	40	45	35	18	52	53	43	88	1968
1969	63	72	56	45	51	41	62	43	61	21	40	47	1969
1970	57	17	12	66	69	49	77	66	46	51	75	57	1970
1971	74	42	67	74	24	52	29	22	55	21	53	63	1971
1972	62	79	27	75	30	51	42	55	39	64	38	24	1972
1973	18	33	54	37	56	33	35	16	42	60	84	50	1973
1974	61	38	59	80	62	42	44	14	50	44	58	44	1974
1975	84	68	47	38	15	9	19	17	15	42	51	28	1975

TABLE 39.
CALENDAR OF HAWAIIAN RAINFALL INDEX
NEUTRAL STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1890	92	77	88	84	66	59	91	54	50	92	8	25	1890
1891	31	36	10					57	81	90	6	48	1891
1892	69	49	28	36	20	38	42	35	20	58	35	41	1892
1893	21	71	67	65	49	17	43	11	12	12	89	36	1893
1894	86	91	45	34	1	22	32	24	24	38	57	29	1894
1895	33	54	10	53	49	53	54	67	74	58	52	69	1895
1896	36	43	58	55	32	4	12	60	19	7	37	21	1896
1897	29	21	30	13	15	26	20	37	33	55	75	44	1897
1898	60	62	90	13	18	26	43	19	52	18	37	39	1898
1899	30	47	56	81	82	65	38	31	9	51	1	14	1899
1900	6	52	12	43	56	39	56	77	28	86	52	7	1900
1901	36	85	62	53	73	52	52	31	23	58	67	68	1901
1902	10	31	88	42	34	48	47	47	61	64	62	65	1902
1903	32	31	24	77	36	42	70	37	63	31	36	11	1903
1904	50	89	44	54	39	42	50	88	56	53	26	36	1904
1905	8	10	19	19	46	56	43	66	69	54	73	34	1905
1906	42	7	10	25	51	37	33	78	35	22	69	72	1906
1907	82	67	69	20	47	82	68	89	61	35	36	28	1907
1908	12	73	71	49	34	32	5	33	58	33	7	14	1908
1909	42	49	78	46	31	37	49	17	32	32	8	79	1909
1910	49	20	34	42	41	76	42	60	68	35	64	46	1910
1911	70	81	57	36	64	60	46	24	77	18	22	41	1911
1912	14	34	33	37	32	26	30	26	18	49	27	47	1912
1913	43	40	24	42	84	79	15	45	41	58	82	12	1913
1914	46	24	46	44	80	83	68	71	93	39	58	64	1914
1915	17	42	16	73	37	75	59	37	52	80	79	86	1915
1916	83	36	68	51	83	56	55	50	52	67	66	83	1916
1917	72	51	86	68	73	64	49	43	50	45	44	51	1917
1918	68	77	76	86	28	45	80	64	34	49	73	50	1918
1919	23	15	32	34	35	31	39	31	54	60	28	39	1919
1920	66	19	68	42	64	49	45	55	64	53	45	76	1920
1921	91	26	21	43	26	36	49	35	49	42	17	57	1921
1922	64	60	48	31	50	18	18	22	73	56	47	9	1922
1923	88	68	78	73	45	30	37	33	46	34	15	76	1923
1924	15	29	32	86	41	31	76	36	32	72	25	44	1924
1925	39	23	69	58	33	58	61	34	53	35	41	33	1925
1926	20	15	10	13	19	62	30	50	34	35	11	45	1926
1927	56	23	82	71	81	57	60	47	69	28	53	93	1927
1928	24	25	23	66	48	25	69	39	43	40	67	29	1928
1929	35	57	24	37	42	21	56	55	39	39	77	64	1929
1930	58	32	54	44	31	64	45	48	85	68	60	14	1930
1931	15	23	27	29	61	22	40	75	79	61	35	19	1931
1932	58	89	32	47	47	45	36	40	45	25	67	46	1932
1933	62	66	72	39	39	51	39	18	29	10	20	36	1933
1934	45	29	13	48	55	87	49	32	76	53	48	38	1934
1935	53	77	54	29	22	50	47	53	80	60	56	24	1935
1936	52	47	50	38	54	50	74	85	70	85	27	67	1936
1937	69	79	62	56	75	29	77	80	49	53	36	58	1937
1938	58	81	57	62	69	66	59	75	24	41	54	33	1938
1939	39	76	78	79	49	70	54	30	46	75	44	13	1939
1940	34	22	41	45	71	27	48	76	51	61	57	16	1940
1941	17	13	19	11	56	56	30	61	73	81	23	21	1941
1942	15	36	55	53	41	73	39	45	54	52	49	77	1942
1943	77	39	47	21	72	63	33	61	37	33	12	38	1943
1944	12	81	73	16	53	67	50	28	28	27	27	54	1944
1945	10	34	40	86	25	39	32	65	37	38	45	58	1945
1946	64	72	40	48	9	45	54	31	20	31	49	67	1946
1947	23	12	41	27	63	46	42	65	47	30	54	48	1947
1948	56	46	54	57	66	64	57	54	58	31	68	65	1948
1949	91	70	41	12	22	59	48	24	14	25	42	68	1949
1950	75	67	40	79	62	24	42	66	44	20	46	43	1950
1951	54	76	91	30	24	31	28	66	52	87	57	71	1951
1952	65	31	67	40	45	47	50	20	36	62	51	20	1952
1953	20	61	58	25	43	39	22	23	16	21	35	45	1953
1954	33	62	57	62	44	73	76	64	53	51	84	73	1954
1955	48	82	66	50	47	37	42	58	55	38	72	65	1955
1956	71	87	32	48	59	76	42	58	45	79	64	58	1956
1957	81	53	12	59	32	32	50	81	22	35	67	74	1957
1958	22	44	56	23	55	60	83	91	52	76	34	32	1958
1959	60	52	15	43	41	13	42	83	41	18	45	31	1959
1960	35	33	57	44	69	48	28	50	66	66	40	47	1960
1961	32	38	30	57	66	69	56	43	36	78	63	65	1961
1962	58	43	74	71	74	43	37	40	46	47	14	19	1962
1963	68	27	81	94	78	63	67	37	72	34	14	26	1963
1964	58	44	82	56	53	60	55	40	57	55	67	83	1964
1965	54	42	19	79	91	41	72	45	56	64	86	60	1965
1966	23	70	13	22	34	41	67	64	51	61	80	45	1966
1967	30	62	76	49	66	45	63	72	41	37	81	80	1967
1968	70	49	65	79	28	42	67	10	52	75	57	86	1968
1969	77	76	35	37	47	27	64	45	57	29	57	32	1969
1970	54	16	3	61	63	50	60	48	49	51	70	64	1970
1971	88	45	63	84	20	46	20	13	56	35	51	74	1971
1972	59	63	43	82	20	47	23	38	47	70	39	16	1972
1973	19	13	32	30	49	42	29	21	48	44	66	63	1973
1974	68	36	80	68	56	66	58	25	34	67	63	50	1974
1975	80	77	59	32	20	15	29	9	11	33	67	44	1975

TABLE 40.
CALENDAR OF HAWAIIAN RAINFALL INDEX
LEEWARD STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1891		58	19	1	14	35	34	47	24	46	41	17	1891
1892	78	69	1	68	89	90	61	79	24	41	4	67	1892
1893	48	91	65	80	6	7	61	15	21	6	96	33	1893
1894	57	90	50	59	25	44	54	27	43	28	91	35	1894
1895	66	49	32	44	63	69	87	19	92	36	83	86	1895
1896	48	31	49	61	53	45	40	86	49	32	86	58	1896
1897	23	21	44	25	59	82	41	63	77	70	51	19	1897
1898	17	90	86	34	25	87	46	42	21	15		32	1898
1899	4	55	48	50	81	79	52	27	26	81	13	54	1899
1900	11	45	39	49	6	50	89	62	56	51	91	28	1900
1901	38	93	62	66	90	57	76	27	65	29	44	82	1901
1902	26	29	90	37	49	62	69	30	59	61	57	67	1902
1903	55	45	25	47	67	37	51	74	68	36	49	14	1903
1904	39	95	76	72	51	79	43	78	75	63	35	39	1904
1905	21	3	12	22	51	36	52	77	71	28	56	26	1905
1906	58	11	30	38	49	30	36	63	38	49	81	77	1906
1907	83	81	59	41	65	80	57	68	68	28	38	32	1907
1908	15	46	81	30	29	39	28	46	50	13	16	33	1908
1909	42	57	57	35	55	56	49	29	40	27	7	81	1909
1910	51	22	20	41	40	72	51	51	80	28	49	37	1910
1911	63	66	57	35	33	53	52	39	74	42	27	38	1911
1912	14	41	29	36	33	42	41	46	16	51	31	49	1912
1913	31	29	29	57	84	86	53	62	43	71	67	6	1913
1914	46	23	58	57	73	54	24	55	80	13	44	60	1914
1915	6	18	18	55	31	78	60	31	78	51	84	83	1915
1916	86	47	55	51	61	51	57	49	34	63	52	64	1916
1917	62	49	74	64	85	50	66	61	70	66	38	56	1917
1918	67	78	74	85	28	30	51	71	55	42	83	37	1918
1919	26	21	25	41	41	50	60	33	46	44	24	46	1919
1920	76	20	54	35	72	73	65	47	59	54	42	73	1920
1921	89	36	14	35	46	29	49	37	33	49	24	79	1921
1922	53	33	37	42	41	41	34	45	65	45	39	13	1922
1923	83	71	77	74	37	20	48	35	38	45	15	77	1923
1924	11	45	31	71	28	33	46	26	27	37	35	63	1924
1925	19	16	60	46	39	22	43	46	36	54	39	43	1925
1926	23	22	28	16	16	87	61	59	39	45	18	38	1926
1927	45	45	64	76	67	56	55	46	66	41	63	94	1927
1928	22	29	32	52	39	46	61	41	17	33	71	28	1928
1929	41	63	19	49	52	48	52	77	59	58	85	64	1929
1930	77	31	57	21	23	55	15	34	68	55	63	9	1930
1931	13	25	37	50	53	29	42	74	56	45	42	22	1931
1932	28	86	53	60	67	41	56	55	39	37	64	40	1932
1933	47	76	68	52	36	64	46	45	52	18	30	44	1933
1934	36	43	22	36	65	92	59	53	88	53	49	37	1934
1935	61	55	52	30	34	50	60	30	65	76	57	19	1935
1936	52	72	38	33	47	29	68	61	71	81	42	48	1936
1937	74	76	51	40	79	54	69	63	45	58	44	59	1937
1938	44	79	69	50	66	83	63	76	38	54	33	16	1938
1939	30	67	76	80	67	68	56	35	52	79	54	25	1939
1940	54	22	57	41	70	51	51	71	42	58	70	17	1940
1941	21	23	32	29	45	45	27	52	58	74	17	14	1941
1942	17	44	45	58	38	63	53	59	56	63	49	83	1942
1943	69	31	52	29	67	67	32	62	48	28	26	36	1943
1944	11	71	89	40	47	75	36	38	21	33	17	49	1944
1945	6	41	42	90	48	49	71	65	51	49	45	58	1945
1946	68	74	35	57	24	57	53	30	39	55	45	79	1946
1947	27	14	46	40	73	56	50	79	54	34	57	48	1947
1948	72	62	55	44	52	61	65	65	54	37	72	51	1948
1949	89	71	40	27	45	65	51	45	18	22	30	56	1949
1950	83	62	53	79	58	38	46	67	35	28	56	48	1950
1951	53	75	96	58	41	53	48	68	75	90	53	67	1951
1952	72	34	52	42	37	51	42	13	41	57	52	17	1952
1953	24	53	51	39	43	47	32	24	33	35	20	58	1953
1954	35	41	64	51	50	63	80	52	39	52	63	65	1954
1955	52	73	61	36	48	37	54	62	67	36	68	75	1955
1956	80	78	41	54	57	46	56	63	42	68	79	58	1956
1957	81	47	17	55	33	30	53	55	16	26	56	57	1957
1958	16	37	73	14	41	47	68	83	39	77	28	47	1958
1959	68	60	9	41	45	19	52	84	21	27	55	31	1959
1960	27	47	59	22	74	40	33	37	55	55	25	53	1960
1961	40	40	47	59	72	62	52	54	46	67	59	51	1961
1962	72	46	66	56	61	56	44	44	36	58	27	42	1962
1963	78	48	86	92	66	65	68	55	68	20	22	28	1963
1964	46	24	73	67	40	44	69	53	45	37	73	79	1964
1965	58	39	28	69	85	55	62	73	66	72	88	44	1965
1966	35	74	24	13	23	29	49	41	38	62	87	34	1966
1967	40	49	77	62	59	45	69	74	55	48	62	78	1967
1968	74	67	47	82	30	29	54	33	54	72	54	91	1968
1969	76	43	24	45	51	43	64	52	44	29	57	38	1969
1970	48	21	6	45	38	40	49	34	51	42	68	23	1970
1971	82	45	55	75	37	46	41	41	67	35	45	42	1971
1972	70	70	69	68	38	45	46	46	63	68	23	60	1972
1973	23	12	22	19	37	37	24	23	13	41	54	63	1973
1974	78	58	54	69	52	75	77	17	86	71	67	21	1974
1975	57	82	45	40	54	36	46	26	25	25	62	53	1975

TABLE 41.
CALENDAR OF HAWAIIAN RAINFALL INDEX
HIGH STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1901	48	96	88	63	97	63	86	31	52	42	85	86	1901
1902	27	44	97	45	39	50	68	48	59	61	68	66	1902
1903	47	46	7	66	50	28	73	67	74	37	38	20	1903
1904	63	93	38	50	35	60	28	82	52	90	12	36	1904
1905	18	5	13	27	60	23	48	77	81	49	74	44	1905
1906	38	9	14	37	52	26	33	57	40	47	66	78	1906
1907	76	77	63	40	50	79	52	85	80	53	45	35	1907
1908	28	60	64	45	43	44	13	55	69	38	22	45	1908
1909	42	59	73	49	65	45	64	34	41	33	13	84	1909
1910	64	40	47	56	58	88	49	68	70	47	59	51	1910
1911	79	75	51	50	61	76	57	57	84	44	47	51	1911
1912	12	53	58	54	40	44	53	39	29	58	45	57	1912
1913	52	36	40	69	71	88	37	62	32	62	79	36	1913
1914	54	25	49	65	82	74	64	79	84	37	75	70	1914
1915	22	61	25	69	33	83	72	25	66	74	82	81	1915
1916	82	32	54	41	88	77	69	70	62	79	75	82	1916
1917	66	43	78	74	75	64	54	46	51	50	55	51	1917
1918	73	88	86	82	47	50	78	70	34	60	73	61	1918
1919	30	28	29	40	29	37	43	31	45	44	10	29	1919
1920	55	23	71	30	52	62	55	40	56	59	51	75	1920
1921	93	24	15	40	41	26	48	40	42	47	59	69	1921
1922	73	54	48	47	46	30	29	40	72	48	52	15	1922
1923	90	68	68	73	34	32	34	37	51	44	17	85	1923
1924	17	39	31	79	49	33	56	36	32	64	27	44	1924
1925	39	19	67	67	53	52	51	58	53	43	47	26	1925
1926	19	17	23	16	14	76	39	65	39	44	21	30	1926
1927	64	31	77	78	69	45	60	51	79	33	63	94	1927
1928	36	32	26	56	44	44	64	43	42	38	64	44	1928
1929	38	66	34	40	44	27	41	51	34	44	66	74	1929
1930	59	36	58	50	26	60	27	45	78	62	56	13	1930
1931	17	29	25	34	47	19	41	69	76	50	45	25	1931
1932	53	90	38	54	52	49	51	42	42	27	62	45	1932
1933	65	69	64	37	31	50	43	22	40	7	19	32	1933
1934	46	38	16	54	64	83	51	40	76	56	48	39	1934
1935	58	70	41	31	25	43	55	30	75	55	51	18	1935
1936	44	52	48	40	59	32	82	83	79	84	27	64	1936
1937	84	80	68	42	78	42	78	72	50	54	50	60	1937
1938	50	80	65	65	76	75	52	73	25	51	46	27	1938
1939	46	71	72	78	55	69	55	30	44	75	48	19	1939
1940	34	26	38	48	74	39	47	76	53	49	51	12	1940
1941	21	19	31	17	43	60	31	53	72	78	20	28	1941
1942	13	38	59	57	29	60	40	51	59	49	35	76	1942
1943	69	39	43	27	62	71	35	47	40	28	14	32	1943
1944	10	74	74	31	51	73	52	25	20	37	27	44	1944
1945	5	33	51	81	29	45	47	51	41	45	34	54	1945
1946	65	63	40	52	13	47	53	33	33	37	46	65	1946
1947	23	9	46	34	68	57	52	73	55	23	51	52	1947
1948	64	40	58	55	65	57	50	68	57	35	70	68	1948
1949	91	70	47	19	31	50	48	35	13	21	37	67	1949
1950	74	63	40	85	66	28	43	59	30	23	47	40	1950
1951	50	73	94	41	29	42	30	64	61	83	70	67	1951
1952	70	46	69	41	40	60	48	22	33	62	53	23	1952
1953	22	55	56	27	44	47	29	31	27	31	29	49	1953
1954	22	55	50	40	46	72	76	61	51	51	56	70	1954
1955	50	82	55	48	44	42	60	61	57	36	67	65	1955
1956	72	87	37	41	65	64	50	59	37	72	62	41	1956
1957	80	56	12	50	32	22	56	71	17	31	59	63	1957
1958	24	30	59	23	46	54	79	86	55	78	36	37	1958
1959	53	54	15	42	41	19	43	81	46	17	47	33	1959
1960	39	53	63	40	70	42	27	41	60	54	35	48	1960
1961	33	51	36	49	56	50	35	42	38	72	62	56	1961
1962	53	35	65	56	58	44	31	34	39	41	14	31	1962
1963	61	33	85	90	70	73	58	42	63	40	16	21	1963
1964	51	39	84	65	55	44	60	41	45	61	72	81	1964
1965	54	36	19	75	85	44	68	50	59	66	89	56	1965
1966	33	59	21	13	18	32	47	45	48	66	82	30	1966
1967	31	60	79	52	62	39	66	67	46	37	71	83	1967
1968	63	48	59	71	16	23	46	19	51	60	53	84	1968
1969	68	59	33	31	42	28	52	38	42	32	52	32	1969
1970	48	18	4	51	49	50	47	38	52	47	73	51	1970
1971	72	37	66	87	31	42	18	19	57	28	48	55	1971
1972	63	74	47	63	32	32	31	29	41	65	28	33	1972
1973	15	18	29	25	37	36	21	14	28	45	60	57	1973
1974	72	49	61	58	58	58	53	17	72	64	66	39	1974
1975	72	75	51	44	38	25	38	7	12	34	69	54	1975

TABLE 42.
CALENDAR OF HAWAIIAN RAINFALL INDEX
MIDDLE STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1890	84	80	84	58	66	77	93	71	53	89	47	51	1890
1891	60	42	37	55	35	22	59	88	83	79	12	47	1891
1892	75	40	34	32	34	13	28	31	25	37	27	54	1892
1893	48	67	63	40	30	28	56	14	11	8	44	28	1893
1894	42	82	54	24	2	24	49	41	10	27	72	45	1894
1895	32	52	30	65	36	50	49	79	74	46	63	39	1895
1896	50	58	59	38	47	42	46	77	39	25	34	31	1896
1897	22	29	16	11	16	29	16	55	24	34	59	33	1897
1898	70	38	86	21	31	46	57	24	48	19	30	48	1898
1899	24	22	76	55	60	61	64	35	14	49	12	11	1899
1900	16	60	9	54	52	33	39	54	12	74	60	21	1900
1901	38	81	70	41	49	24	16	32	29	43	55	63	1901
1902	22	17	88	27	55	56	41	49	61	68	53	70	1902
1903	44	40	31	67	42	29	62	51	58	36	48	9	1903
1904	44	81	49	88	66	61	52	74	64	46	22	34	1904
1905	18	11	19	29	59	49	40	68	76	43	57	32	1905
1906	35	8	7	32	47	40	40	78	31	31	65	75	1906
1907	65	71	62	32	41	77	78	87	72	32	38	28	1907
1908	12	61	67	38	37	38	25	48	52	21	14	32	1908
1909	34	56	64	46	47	55	57	18	41	36	7	78	1909
1910	62	21	30	44	45	74	50	55	65	38	48	41	1910
1911	66	77	52	38	47	57	40	35	75	26	32	39	1911
1912	11	44	35	35	35	25	23	44	23	51	27	44	1912
1913	32	29	23	49	77	85	24	43	37	57	83	19	1913
1914	42	18	50	37	83	70	48	62	89	27	55	57	1914
1915	5	29	11	66	23	69	51	31	62	68	88	78	1915
1916	84	30	60	44	74	57	55	36	42	50	55	80	1916
1917	62	46	74	52	65	55	37	39	47	48	46	47	1917
1918	61	78	72	90	39	38	66	70	34	47	74	50	1918
1919	22	13	27	29	32	31	47	23	39	44	21	49	1919
1920	65	15	70	35	63	52	39	52	64	58	45	69	1920
1921	89	28	24	33	25	28	55	40	48	53	27	72	1921
1922	60	56	43	25	46	28	20	30	73	52	44	8	1922
1923	87	72	79	63	42	23	33	27	41	42	14	72	1923
1924	10	33	19	80	37	30	52	27	25	56	28	40	1924
1925	33	25	68	52	30	43	41	38	49	37	42	34	1925
1926	23	16	13	12	14	80	24	44	35	32	19	40	1926
1927	63	35	71	74	62	60	67	51	63	33	63	90	1927
1928	29	30	23	56	45	28	70	40	39	28	62	24	1928
1929	38	60	25	39	39	24	49	63	34	41	78	61	1929
1930	68	38	51	38	35	73	34	55	81	68	70	13	1930
1931	14	26	29	40	56	26	47	74	78	59	39	24	1931
1932	49	90	40	55	66	36	39	39	38	27	59	52	1932
1933	57	69	72	41	43	59	47	32	50	18	33	39	1933
1934	44	31	21	43	55	87	43	26	87	63	48	32	1934
1935	56	71	43	33	31	52	52	42	75	54	55	24	1935
1936	48	46	56	38	58	46	69	75	64	85	40	62	1936
1937	73	79	62	47	76	37	83	69	49	57	35	56	1937
1938	49	74	65	58	64	62	52	73	20	44	42	35	1938
1939	43	69	74	82	62	65	55	26	47	82	53	14	1939
1940	35	34	41	37	69	31	54	78	53	62	61	18	1940
1941	22	20	29	15	52	58	32	55	76	84	18	18	1941
1942	15	48	60	57	33	71	28	47	47	49	41	76	1942
1943	72	43	52	25	67	63	36	63	41	22	19	41	1943
1944	12	75	74	27	47	57	48	31	26	30	23	47	1944
1945	10	39	50	82	27	41	43	70	36	55	35	53	1945
1946	64	69	49	56	16	57	56	22	30	40	53	84	1946
1947	25	13	48	32	67	56	43	67	49	41	55	56	1947
1948	66	45	57	50	60	45	58	59	61	45	75	72	1948
1949	81	67	45	21	23	51	47	31	22	30	46	50	1949
1950	73	54	46	79	59	29	53	58	39	37	53	52	1950
1951	55	76	85	43	28	31	43	70	62	86	55	65	1951
1952	65	33	63	45	51	56	60	14	35	64	53	17	1952
1953	21	59	43	24	38	45	20	20	15	25	33	44	1953
1954	34	50	55	55	51	73	84	64	49	53	69	75	1954
1955	45	83	61	40	54	49	44	65	59	38	66	62	1955
1956	68	85	43	49	58	76	33	62	30	75	64	45	1956
1957	79	49	19	68	38	39	55	69	28	30	60	73	1957
1958	23	42	64	19	51	57	83	90	52	77	34	39	1958
1959	59	62	13	52	49	12	42	86	29	20	47	37	1959
1960	38	41	56	42	73	54	25	50	65	51	35	49	1960
1961	38	47	33	63	62	77	55	45	46	78	65	48	1961
1962	57	49	63	59	63	33	39	38	47	46	17	26	1962
1963	70	33	71	89	78	72	76	28	73	39	19	24	1963
1964	57	40	73	53	48	58	61	48	61	46	71	71	1964
1965	56	51	29	75	81	59	63	53	55	62	85	54	1965
1966	38	77	16	21	28	48	57	57	52	70	75	51	1966
1967	44	36	72	53	65	40	66	76	51	48	73	78	1967
1968	71	52	61	80	35	44	48	19	43	65	46	90	1968
1969	73	68	40	55	58	37	66	56	56	27	48	40	1969
1970	51	16	8	66	56	42	64	53	43	41	69	54	1970
1971	84	50	62	71	22	37	35	22	54	29	51	56	1971
1972	60	67	43	70	30	41	39	59	51	67	37	35	1972
1973	21	18	43	26	53	44	32	27	44	50	70	56	1973
1974	69	48	69	75	56	63	55	15	40	69	67	48	1974
1975	73	74	44	37	22	16	25	19	20	32	46	41	1975

TABLE 43.
CALENDAR OF HAWAIIAN RAINFALL INDEX
LOW STATIONS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1891		48	13	6	21	18	30	35	55	46	23	33	1891
1892	74	46	11	44	63	83	43	53	22	54	18	48	1892
1893	40	84	48	79	35	15	29	13	26	18	87	24	1893
1894	61	92	42	42	14	26	33	18	36	31	78	31	1894
1895	46	46	20	38	49	48	66	44	86	69	58	78	1895
1896	40	36	48	60	58	40	22	71	31	25	59	45	1896
1897	25	19	33	19	44	63	32	48	70	65	57	28	1897
1898	42	81	90	26	28	63	48	28	30	19	25	21	1898
1899	13	46	56	57	82	56	35	34	25	79	6	27	1899
1900	8	44	22	38	42	33	53	64	43	69	76	16	1900
1901	35	82	53	56	67	49	58	25	39	51	53	74	1901
1902	10	36	89	40	43	67	59	46	69	59	69	78	1902
1903	36	35	26	58	37	45	51	34	57	37	44	17	1903
1904	47	90	61	56	24	42	55	84	68	33	46	41	1904
1905	16	14	22	26	39	65	62	72	70	42	71	30	1905
1906	48	7	29	32	56	39	46	81	51	30	74	74	1906
1907	81	74	66	26	64	77	65	79	59	39	31	32	1907
1908	18	67	78	40	33	36	25	42	63	38	14	16	1908
1909	49	46	81	43	36	50	53	27	37	37	8	80	1909
1910	51	21	24	33	51	72	49	56	68	38	72	51	1910
1911	68	75	61	31	69	57	62	39	84	33	22	31	1911
1912	18	35	29	46	33	46	42	37	19	49	31	46	1912
1913	39	44	31	36	74	83	26	55	51	51	71	14	1913
1914	48	20	61	57	80	69	59	55	95	21	38	68	1914
1915	12	20	16	76	26	77	61	39	56	55	80	87	1915
1916	82	44	66	54	71	47	62	58	49	54	57	76	1916
1917	76	47	87	66	71	65	52	42	55	45	43	49	1917
1918	76	75	79	92	38	53	60	75	46	32	80	54	1918
1919	29	17	34	44	40	56	48	39	62	60	43	44	1919
1920	66	17	64	50	54	52	64	58	63	50	38	68	1920
1921	90	30	24	44	37	39	42	35	32	53	21	70	1921
1922	61	44	49	51	51	29	32	38	80	57	57	7	1922
1923	85	64	75	82	34	33	50	43	44	48	18	79	1923
1924	11	43	34	84	34	25	67	35	30	65	33	54	1924
1925	35	24	57	39	40	46	52	33	54	47	32	36	1925
1926	23	22	14	16	25	69	57	61	49	43	11	43	1926
1927	45	32	71	71	75	54	54	50	65	32	57	95	1927
1928	18	22	23	55	39	38	66	40	39	47	62	36	1928
1929	44	57	28	44	55	39	75	64	45	47	82	65	1929
1930	72	33	55	39	30	62	56	53	84	52	74	17	1930
1931	11	25	34	43	61	29	48	76	68	62	44	28	1931
1932	51	89	34	54	60	56	55	55	44	26	63	40	1932
1933	56	70	68	39	49	52	30	28	33	6	21	47	1933
1934	40	38	17	46	62	86	64	44	84	56	48	40	1934
1935	53	68	57	24	27	55	53	47	70	72	55	29	1935
1936	52	49	48	44	41	52	63	77	71	86	37	56	1936
1937	68	71	61	63	82	39	73	67	54	61	44	58	1937
1938	61	79	65	53	67	75	67	69	31	43	41	34	1938
1939	36	74	80	80	47	61	50	34	44	75	55	18	1939
1940	46	21	55	40	70	39	54	76	42	74	59	22	1940
1941	24	16	22	22	60	53	31	71	53	83	25	15	1941
1942	24	41	55	69	60	72	66	55	50	62	59	79	1942
1943	72	33	45	28	69	65	34	56	38	28	15	41	1943
1944	12	79	69	25	53	73	46	36	25	33	27	51	1944
1945	8	27	32	82	30	43	42	66	30	36	51	67	1945
1946	68	71	29	49	17	46	59	30	19	44	49	76	1946
1947	27	16	44	27	55	50	47	78	63	41	61	44	1947
1948	65	64	58	61	52	60	51	59	54	30	66	43	1948
1949	92	67	25	13	44	61	37	30	20	21	30	54	1949
1950	79	69	44	79	61	27	32	70	35	25	52	57	1950
1951	49	72	89	46	23	33	43	64	48	92	42	68	1951
1952	64	32	52	28	41	44	27	25	46	66	54	14	1952
1953	19	56	59	27	41	29	26	17	22	18	20	46	1953
1954	41	57	70	53	51	54	79	61	36	39	75	68	1954
1955	52	76	60	41	54	26	31	51	56	37	70	65	1955
1956	81	81	32	52	51	47	33	60	53	77	78	69	1956
1957	79	50	12	59	28	34	51	58	13	40	64	71	1957
1958	14	49	58	16	41	46	79	87	39	81	29	41	1958
1959	67	50	13	41	45	21	43	74	41	27	64	36	1959
1960	31	39	65	30	70	50	48	42	68	78	35	50	1960
1961	43	37	30	57	70	61	62	49	42	79	59	56	1961
1962	64	47	77	63	75	62	36	40	37	43	25	29	1962
1963	74	33	81	94	77	54	62	49	63	24	18	36	1963
1964	53	30	62	56	46	37	71	43	54	45	73	79	1964
1965	65	47	32	75	93	40	67	59	62	83	89	56	1965
1966	30	75	20	20	49	36	69	56	37	63	90	33	1966
1967	45	60	75	65	65	64	72	80	43	41	66	83	1967
1968	70	62	56	82	46	44	61	29	66	76	56	92	1968
1969	76	56	38	42	49	51	73	46	60	21	56	44	1969
1970	59	21	9	49	58	45	66	55	51	54	71	32	1970
1971	86	44	55	76	29	65	39	39	68	34	49	64	1971
1972	69	71	53	89	30	69	46	51	59	69	34	39	1972
1973	25	20	29	32	48	28	32	19	46	49	69	62	1973
1974	69	40	59	81	55	67	76	24	71	52	58	22	1974
1975	72	80	55	31	41	24	38	25	19	28	61	42	1975

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