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DIURNAL VARIATION OF RAINFALL AMOUNT ON TROPICAL PACIFIC ISLANDS

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DIURNAL VARIATION OF RAINFALL AMOUNT ON TROPICAL PACIFIC ISLANDS

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ABSTRACT

Graphs of diurnal variation of rainfall amount are presented for Nandi, Suva, Apia; for stations on the small islands of Rarotonga, Raoul and Norfolk; and for the four atolls, Tarawa, Canton, Wake and Funafuti. Only Nandi shows a marked afternoon maximum throughout the year. All the stations except Nandi, Suva, Apia and Norfolk have more than half of their rain during the night hours of 20 to 08. Seasonal differences are marked at Nandi and Suva, which both show the greatest tendency to an afternoon maximum in the wet season. However, a seasonal difference of a similar nature is found on Canton and Tarawa, which both have an afternoon maximum only during "wet spells". A possible explanation is given for the seasonal differences at these four stations.

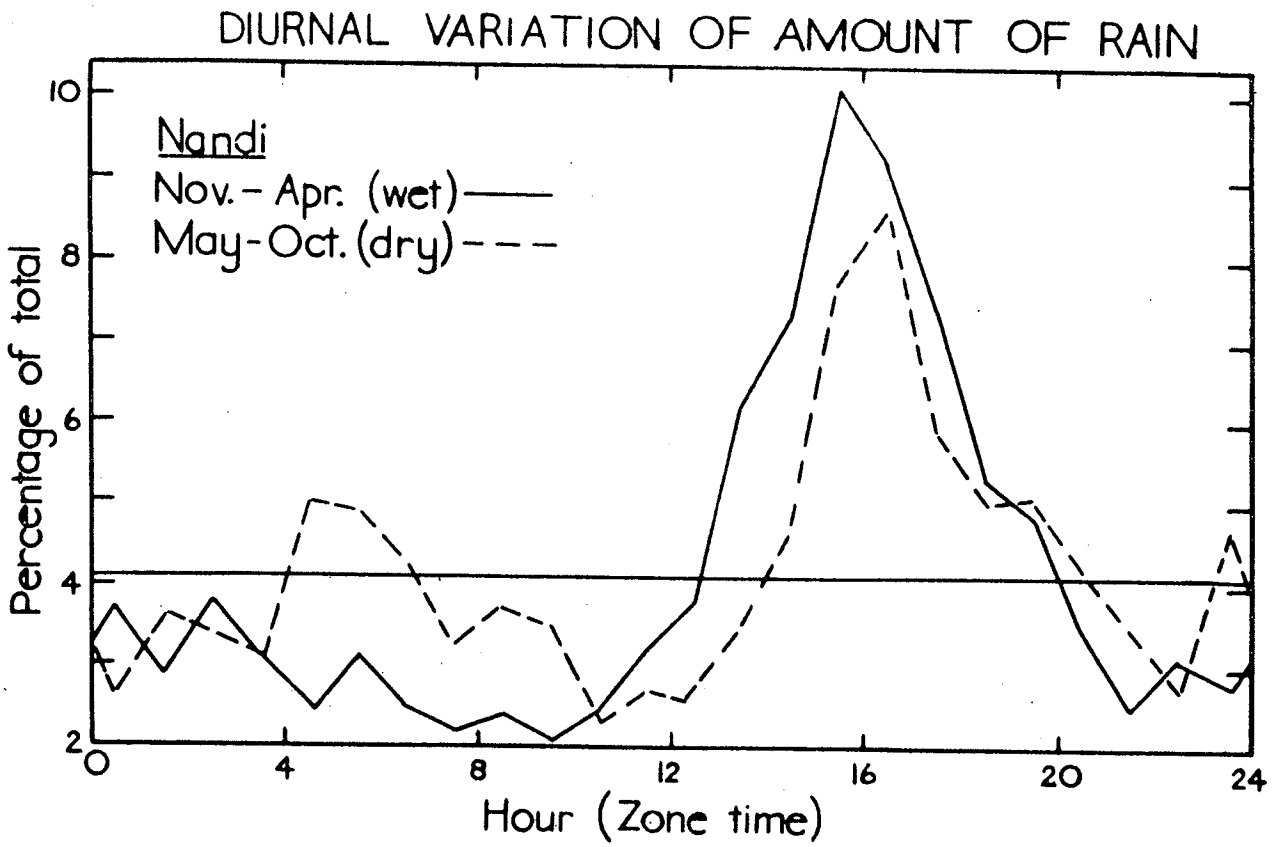
1. INTRODUCTION

Early studies of the diurnal variation of rainfall amount on tropical islands included those of Braak (1925) for many stations in Indonesia and Ray (1928) for San Juan, Puerto Rico. In these studies two main types of maxima were found:

(1) An afternoon maximum, especially pronounced on the lee side of large islands.

(2) A maximum between midnight and dawn, found especially at some stations on the windward side of islands.

Some stations in Indonesia show the afternoon maximum in one of the two main seasons and the pre-dawn maximum in the other. This difference is due to the complete reversal in the general surface wind flow between the seasons - from northwesterly in January-February to southeasterly in July-September. Occasionally two maxima, both quite well marked, appear at the same station in the same season of the year.



Note: Horizontal line at 4·17% is line of no variation.

Fig. 1

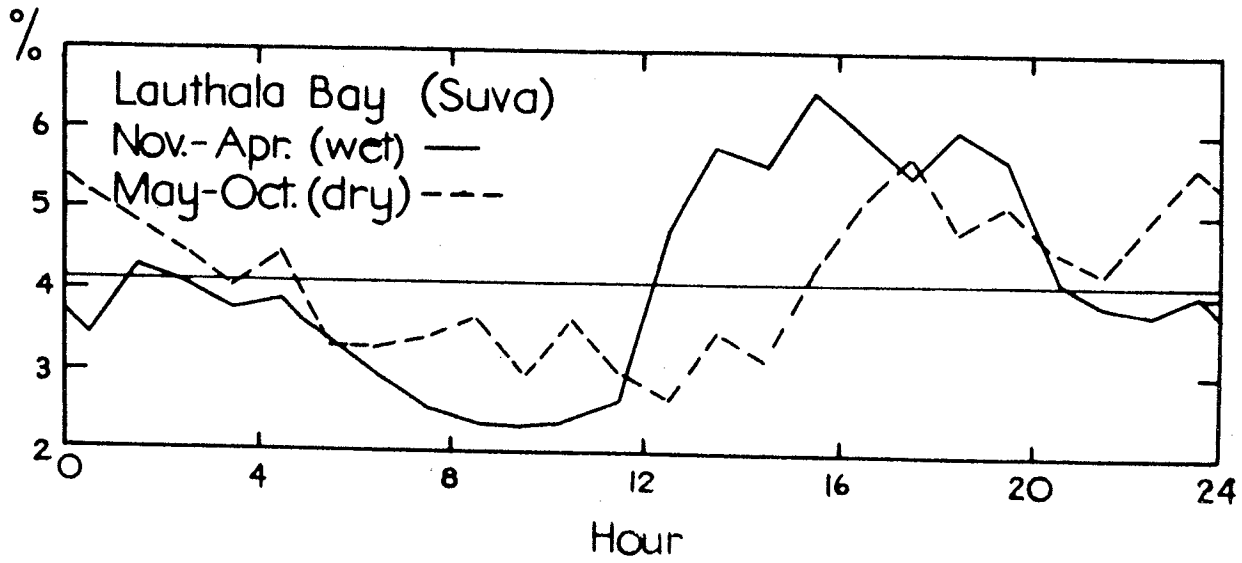


Fig. 2

Results for smaller and lower islands have been obtained in more recent studies, such as those of Jordan (1955) on Guam and Lavoie (1963) on various atolls. However, Lavoie's results refer mainly to rainfall frequency whereas the present study is concerned with the diurnal variation of rainfall amount.

2. THE OBSERVATIONS AND THE STATIONS

Hourly observations of rainfall amount were available for ten Pacific Island stations. Two of these, Nandi and Lauthala Bay (Suva), are on the northwestern and southeastern coast respectively of the fairly large volcanic island of Viti Levu, Fiji. One station, Apia, is on the north coast of the medium-sized volcanic island of Upolu, Western Samoa. Rarotonga, Raoul and Norfolk are quite small volcanic islands. The remaining four stations, Tarawa, Canton, Wake and Funafuti, are on flat atolls.

All of the islands except Wake are in the South Pacific or near the Equator. Raoul and Norfolk are strictly in the sub-tropical zone. One of the atolls, Canton, is in the equatorial dry zone with an average annual rainfall of only 31 in. The monthly and annual variability of rainfall are very high in this zone, Seelye (1950). Tarawa is also in this zone but its average annual rainfall is 78 in. and the rainfall is less variable than that of Canton. Three of the stations have rainfalls of over 100 in. - Funafuti (Ellice Islands), Apia and Lauthala Bay.

For Funafuti, Apia, Rarotonga and the Fiji Stations the year may be divided into two seasons, November-April (wet), and May-October (dry). For Funafuti the length of record available was too short (2¼ years) to attempt a separation of results by seasons. For the other four of these stations, with lengths of record ranging from 19 to 14 years, separate calculations were made for each of the two seasons of the year.

The wind flow in the lowest 3000 feet over the Samoa-Rarotonga-Fiji area is predominantly easterly all the year round. There are, however, two differences in wind flow between the seasons:

(a) The frequency of northerly to westerly winds is much greater in the wet season;

(b) The frequency of southerly and southeasterly winds is correspondingly greater in the dry (trade wind) season.

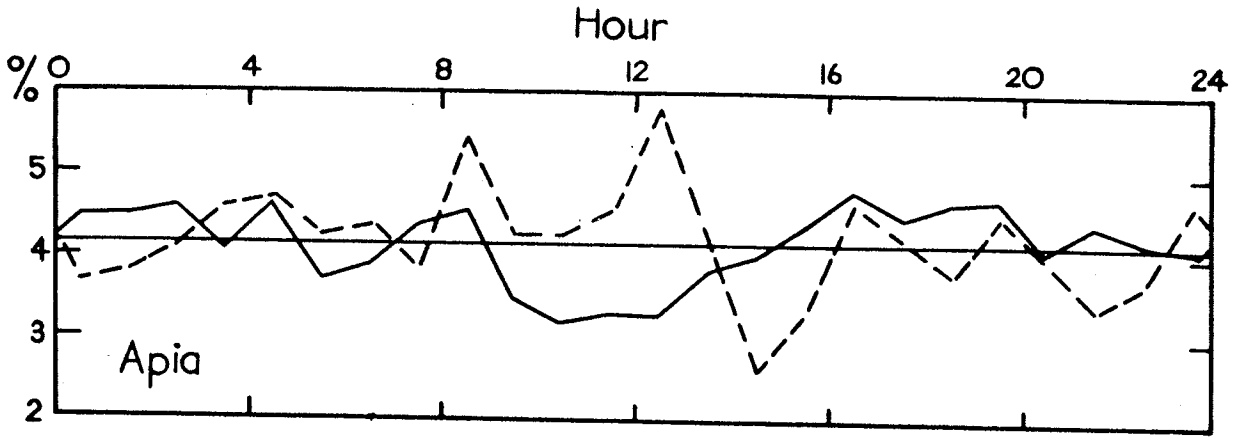


Fig. 3

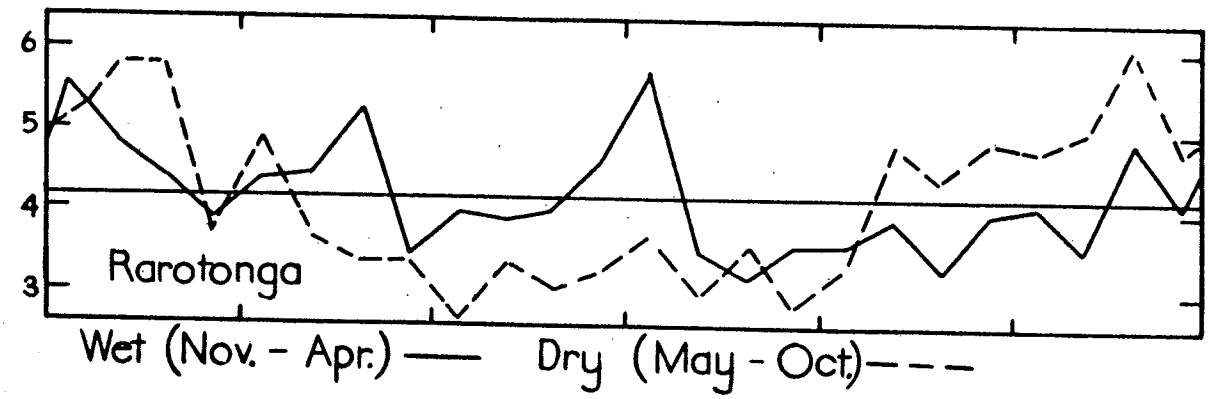


Fig. 4

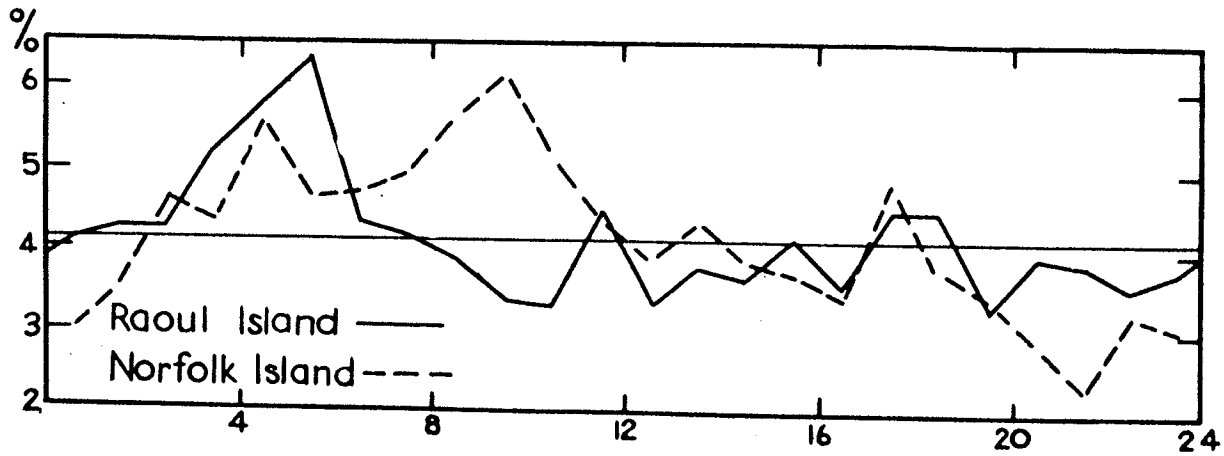


Fig. 5

For Canton and Tarawa a separation of a different nature was made between "wetter months" and "drier months", depending on the rainfall of individual months. In this area the wet months usually occur in spells, such as November 1957 - March 1958, which was studied in some detail by Ichiye and Peterson (1963).

3. DISCUSSION OF RESULTS

The results are shown in Figures 1 to 8. It should be noted that for each station the average hourly amounts are expressed as a percentage of the 24-hourly total; and the horizontal "line of no variation" drawn at 4.17% (= $\frac{100}{24}$) is the line which would result if there were no diurnal variation.

Fiji Stations (Figures 1 and 2)

With the prevailing flow as described above, Nandi has a lee exposure in all seasons and Lauthala Bay a windward exposure in all seasons. Nandi has the most marked diurnal variation of all the ten stations, with a sharp afternoon maximum in both seasons, typical of a lee exposure on a large island. Lauthala Bay also has an afternoon maximum in both seasons, but in the dry season it extends into the early evening and is not as sharp as in the wet season; in the dry season there is also a maximum just before midnight. At Lauthala Bay both the nature of the diurnal variation and its change with season are very similar to those at San Juan, which has a windward exposure on the island of Puerto Rico, an island of about the same size as Viti Levu.

The seasonal difference in diurnal variation is similar at Nandi and Lauthala Bay, with more afternoon rain in the wet season and more night rain in the dry season. This suggests that at these stations the change in diurnal variation with the season is not related to the change in surface winds since this change would have opposite effects on the two sides of the island.

Apia (Figure 3)

The main feature of the diurnal variation at Apia is its feebleness - it has the least diurnal variation of all the ten stations.

The diurnal variation shown is based on 14 years of data. In the dry season it is very different from that quoted by Angenheister (1924), based on about 4 years of data. Such a period was evidently too short to enable a representative sample to be obtained in this season.

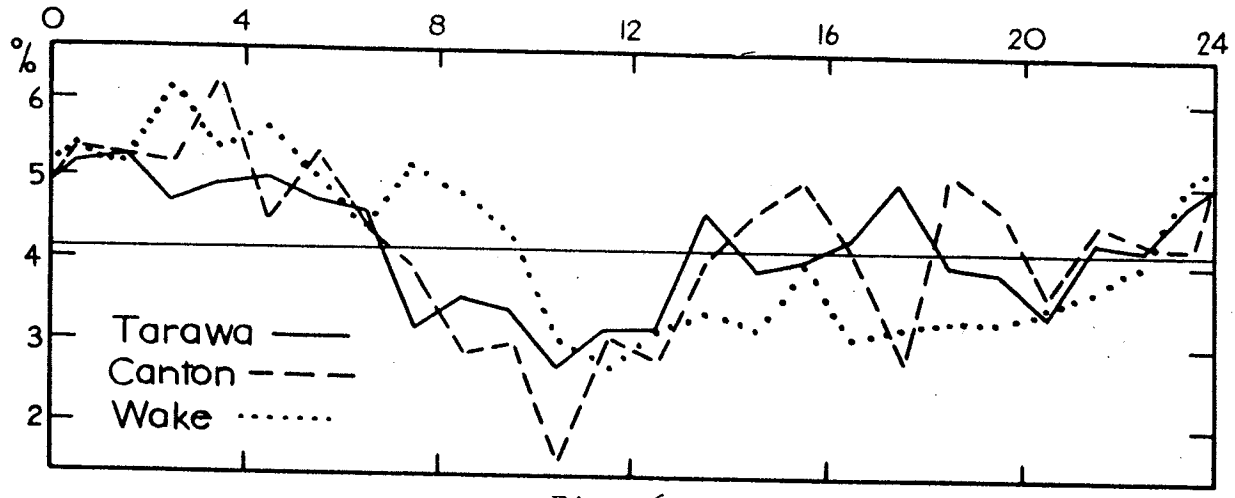


Fig. 6

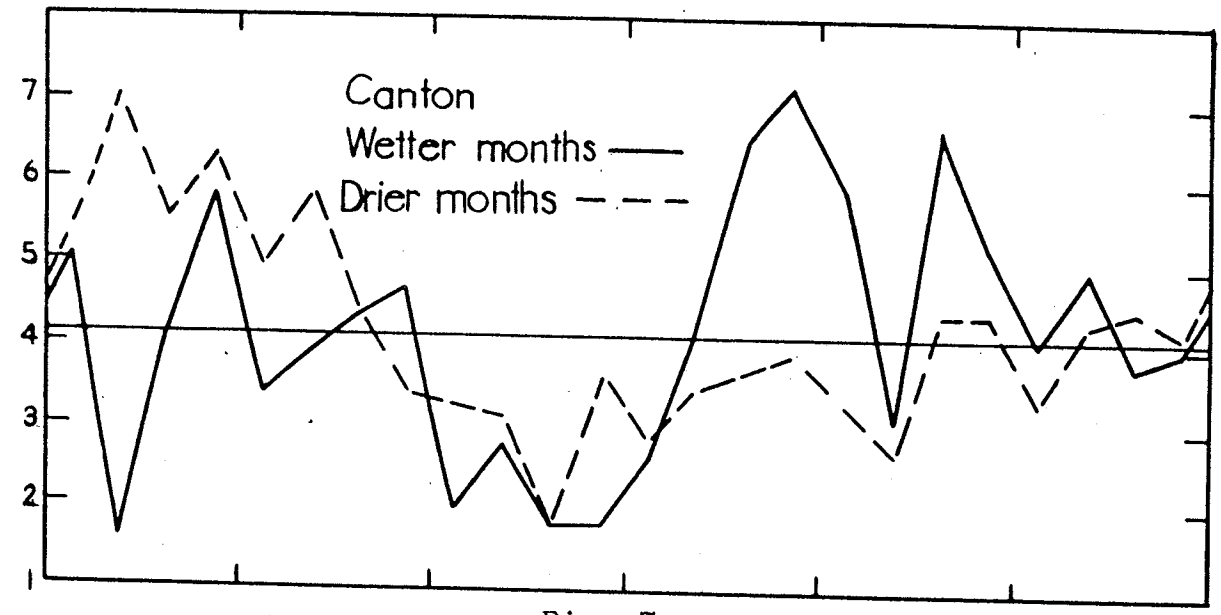


Fig. 7

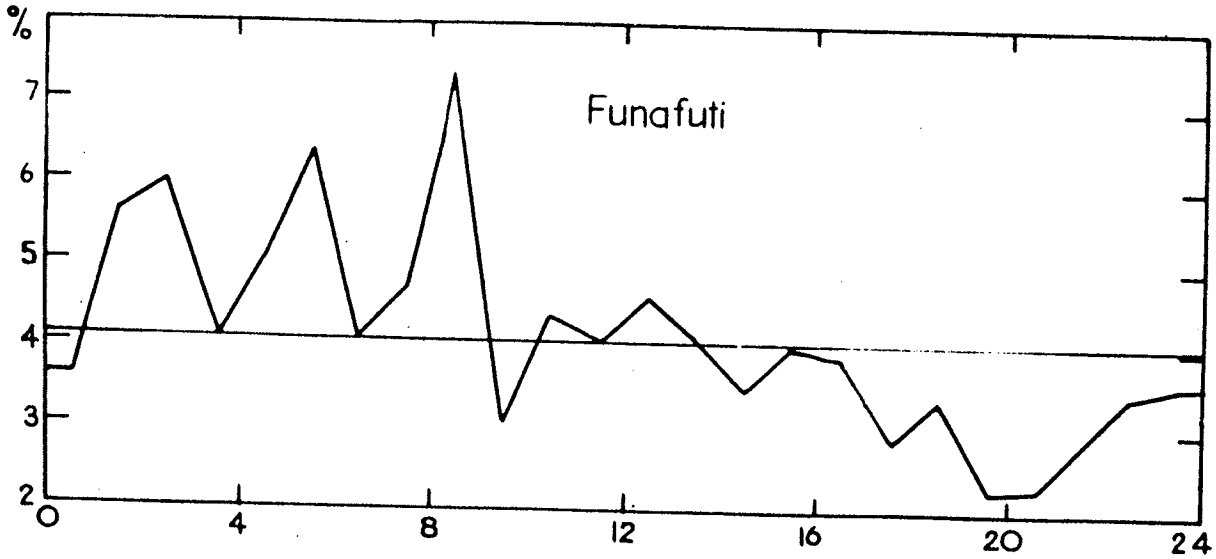


Fig. 8

Rarotonga (Figure 4)

The main maximum is soon after midnight in both seasons. As at the Fiji stations, there is more night rain in the dry season.

Raoul and Norfolk Islands (Figure 5)

These two stations, both on small sub-tropical islands, show a surprising lack of similarity. Raoul has quite a sharp maximum just before dawn; while Norfolk has its main maximum in the late morning.

The Atolls (Figures 6, 7 and 8)

Over the whole period of observation Tarawa, Canton and Wake all show the main maximum between midnight and dawn; but Tarawa and Canton also show subsidiary maxima in the afternoon and early evening. Funafuti has a rather different variation, with the maximum at mid-morning.

Separating the wetter months from the drier months at Canton (Figure 7) shows a rather surprising effect - the wetter months have their main maximum in the afternoon; while the drier months have a correspondingly larger pre-dawn maximum. A similar effect is found at Tarawa. However, at Wake separation by season or by wet spells shows only minor differences, the general nature of the diurnal variation being almost unchanged throughout wet and dry seasons and wet and dry spells.

The fact that two atolls with very similar regimes show similar differences between the diurnal variation in wet and dry spells is some indication of the reality of these differences. At Canton the average percentages of total rainfall during the period 14 - 19 hours were:

Drier periods	19.0
Wetter periods	29.4

The "t" test of significance was applied to the difference between these two, taking account of the standard deviations of each. The calculations showed that the probability of the difference being due to chance was less than 1 in 50 (.02).

In order to obtain some further information on the nature of the difference between the wet and dry spells for Canton, an analysis was carried out of the frequency of (a) all appreciable hourly falls and (b) all hourly falls of at least .10 in., with the following results:

		Wet Spells 00-05 hrs	Wet Spells 14-19 hrs	Dry Spells 00-05 hrs	Dry Spells 14-19 hrs
(a)	Frequency of all appreciable hourly falls (at least .01 in.)	142	152	567	309
(b)	Frequency of hourly falls of at least .10 in.	51	66	145	83
	% b/a	36	43	26	26

There is some evidence here that during the wet spells intensities are greater at the afternoon maximum than at the pre-dawn maximum; while during the dry spells intensities are about the same at the two maxima.

4. FINAL DISCUSSION AND CONCLUSIONS

If we define "night rain" as rain during the hours 20-08, then the percentages (night rain)/(total rain) for the year are as follows: Nandi 38, Suva 47, Apia 50, Rarotonga 54, Raoul 54, Norfolk 46, Tarawa 54, Canton 56, Wake 58, Funafuti 52.

The first three show increasing night rainfall, and all of the remaining seven (small volcanic islands and atolls) except Norfolk show higher values than Apia.

This graduation is consistent with the existence of two separate mechanisms, the relative importance of each varying with the station. The first is convection due to daytime heating, with an afternoon maximum, of most importance on the lee side of a large island. The second mechanism has an overnight maximum, most commonly pre-dawn, and is of most importance on atolls and small volcanic islands.

Mechanism of night rain maximum

It has generally been assumed that the night maximum of (b) is characteristic of rainfall over the open sea. The mechanism has generally been referred to rather vaguely as "cooling of the cloud tops at night". Attempts to work out a somewhat more detailed mechanism have been made recently by Lavoie (1963), Malkus (1963) and Kraus (1963).

The figures obtained for atolls in this investigation could be used to test Malkus' (1963) atmospheric tide-convection hypothesis, but only if it were assumed that the diurnal variation over the open sea is virtually identical with that over an atoll.

While it appears very likely that the main features (the main maximum and main minimum) are very similar over an atoll and over the open sea, it seems doubtful whether secondary features are the same - and in any case there is appreciable variation in the diurnal curves between the atolls.

Seasonal and similar effects

The most marked seasonal effect is the greater tendency for an afternoon maximum at the two Fiji stations during the wet season; but at the other end of the scale the wet spells at Canton Island and Tarawa show an afternoon maximum which does not exist in the dry spells.

A possible explanation for these two similar effects arises from the work of Kraus (1963). He shows that diurnal variation of rainfall over the sea is related to the absorption of radiation. This causes the condensation rate to be appreciably lower during the day than during the night, provided vertical velocities are small. The rain of the dry season in Fiji and of the dry spells of Canton and Tarawa is certainly associated with comparatively small vertical velocities and we might therefore expect a night maximum. On the other hand the rain of the wet season in Fiji and in the wet spells is evidently associated with comparatively large vertical velocities. In these circumstances there is thus little tendency for night rain, and a corresponding greater tendency for an afternoon maximum.

ACKNOWLEDGEMENT

The author is indebted to the National Weather Records Centre of the U.S. Weather Bureau for supplying the hourly rainfall data for Canton Island and Wake Island.