CORRESPONDENCE

Comments on "Comparison of Ocean and Island Rainfall in the Tropical Pacific"

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ABSTRACT

Reed (1980) found that low islands and atolls in the tropical Pacific have a significant effect on measured rainfall. But direct examination of island data leads to the opposite conclusion. Reed and Elliott's (1979) rainfall estimates, the basis of Reed (1980), overestimate dry tropical islands and underestimate wetter islands by a factor of 2 or 3. Further, Reed and Elliott increasingly underestimate the tropical peak toward the west. Other observations are cited, such as satellite cloud analysis, that conflict with Reed (1980). It is concluded that the Reed (1980) analysis is flawed, and that the Reed and Elliott (1980) estimates are in error.

1. Introduction

It has been generally accepted that rainfall measurements at low, small atolls and islands are representative of the open ocean rainfall. Lavoie's (1963) study has supported this fact. But, Reed and Elliott (1979) published an estimate of oceanic rainfall that was generally a factor of 2 to 3 under atoll measurements (except for dry islands). Criticism of these estimates and the method from which they are derived have been made by Dorman (1980). Recently, Reed (1980) further used the Reed and Elliott estimates as an absolute standard to investigate the effect of island measurements on rainfall in the tropical Pacific. Island and other data is reexamined here, showing that Reed's (1980) analysis is seriously flawed and that the more commonly accepted notion concerning island effects is correct.

2. Suitability of low island measurements

Reed concludes that even low, small islands have a significant effect on the measured rainfall. But, the effect of low islands on rainfall is not significant. We can see this when we plot lines of island station measurements crossing large rainfall gradients as we do in Figs. 2, 3 and 4 (see Fig. 1 for location of island stations).

If one considers, for example, the Line Islands in the Johnston–Puka Puka line (Table 1, Fig. 2) one cannot find a significant relationship between the island characteristics and measurements of rainfall. The island measurements fit a smooth and consistent curve. The biggest island, Christmas, has the lowest rainfall. Fanning has the highest maximum elevation (25 m) but does not have the greatest rainfall. The maximum rainfall is at 7°N but neither the island size nor elevation increase as 7°N is approached.

Another way in which we can see that low-island effects do not dominate rainfall is that the above-mentioned curve fits what one would otherwise expect. The peak-fitted curve at 7°N corresponds to a satellite cloudiness peak (Saddler *et al.*, 1976) at 7°N. The minimum at 1°S corresponds to the zone of low cloudiness and low sea surface temperatures (Sverdrup, *et al.*, 1942), both of which are associated with suppression of rainfall. The Wake-Nurakitu line (Table 2, Fig. 3) and the Midway-Kapanga line (Table 3, Fig. 4) are presented to show that the Line Islands are not an anomaly as Reed (1980) implies. All three lines have the same shapes, values and smooth trends. Removal of an island does not significantly change the curves. Many other lines could be constructed with the same features. In spite of the considerable differences between these islands in area, maximum elevation, orientations to the wind,

TABLE 1. Tropical dry islands—precipitation data.

Island	Measured (mm)	Reed and Elliott estimated (mm)
Christmas	710	1500
Curacao	521	<1000
Mindelo	176	400
Prava	217	450
Sal	109	400
San Cristobal	507	<1000

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TABLE 2. Johnston–Puka Puka precipitation data.

No.	Station	Latitude (deg, min)	Longitude (deg, min)	Measured (mm)	Reed and Elliott estimated (mm)
1	Johnston	16, 44N	169, 31W	710	700
2	Palmyra	5, 52N	162, 06W	4162	2400
3	Washington	4, 43N	160, 25W	2903	2500
4	Fanning	3, 55N	159, 23W	2086	2300
5	Christmas	1, 59N	157, 22W	766	1700
6	Malden	4, 01S	155, 01W	689	
7	Penrhyn	9, 01S	158, 03W	1893	
8	Puka Puka	10, 53S	165, 49W	2853	

shape, etc., the measurements at low islands are consistent. This consistency is counter to Reed's thesis that islands have a factor of two effect on the measured rainfall. If such an effect were true, then island measurements would be highly irregular. There should be significant and systematic correlations between island physical characteristics and rainfall, which there is not.

3. Comparison of island measurements to Reed and Elliott's estimates (Figs. 2, 3, 4)

All island measurements used here for comparison to Reed and Elliott's estimates are low and small. I wish to emphasize these characteristics since there seems to be a widespread misconception that all analyses of island rainfall are flawed by including measurements from high islands. Reed's estimates from his 1980 paper will be used since Reed and Elliott's original analysis (1979) is so coarse that values are ambiguous over large areas of the subtropics and tropics. First, Reed and Elliott overestimate all tropical dry zone islands (Table 4), whereas they underestimate wetter islands. In comparison with the three lines (Figs. 2, 3, 4), Reed and Elliott systematically and increasingly underestimate the measured atoll rainfall as the Intertropical Convergence Zone is approached. There also is a tendency for Reed and Elliott to further underestimate the island-measured tropical rainfall peak toward the west.

The underestimation at wetter islands is substantially more than the single 1:2 ratio of measured to

TABLE 3. Wake–Nurakita precipitation data.

No.	Station	Latitude (deg, min)	Longitude (deg, min)	Measured (mm)	Reed and Elliott estimated (mm)
9	Wake	19, 17N	166, 39E	965	800
10	Kwajalein	8, 44N	167, 43E	2630	1100
11	Majuro	7, 05N	171, 23E	3550	1250
12	Jaluit	5, 55N	169, 40E	4110	1400
13	Little Makin	3, 18N	173, 08E	2806	1700
14	Butaritari	3, 07N	172, 48E	3101	1700
15	Marakei	2, 00N	173, 18E	1775	1450
16	Tarawa	1, 21N	172, 56E	1728	1200
17	Maiana	0, 55N	173, 04E	1515	1200
18	Kuria	0, 16N	173, 51E	1274	1100
19	Abemana	0, 21N	173, 51E	1496	1100
20	Aranuka	0, 12N	173, 51E	1043	1100
21	Nonouti	0, 40S	174, 20E	1274	900
22	N. Tabiteuea	1, 10S	174, 45E	1115	
23	S. Tabileuea	1, 32S	175, 00E	1342	
24	Beru	1, 21S	175, 58E	1224	
25	Onotoa	1, 51S	175, 30E	1210	
26	Tamana	2, 29S	175, 58E	1140	
27	Arorae	2, 40S	176, 53E	1431	
28	Nanumea	5, 39S	176, 06E	2776	
29	Niutao	6, 00S	177, 16E	2800	
30	Nanumanga	6, 19S	176, 20E	2434	
31	Nui	7, 16S	176, 10E	3131	
32	Vaitupu	7, 30S	178, 41E	3131	
33	Funafuti	8, 31S	179, 12E	3638	
34	Nukulaelae	9, 23S	179, 00E	3314	
35	Nurakita	10, 45S	179, 30E	3510	

TABLE 4. Midway–Kapingamarangi precipitation data.

No.	Station	Latitude (deg, min)	Longitude (deg, min)	Measured (mm)	Reed and Elliott estimated (mm)
36	Midway	28, 13N	177, 22W	1100	550
9	Wake	19, 17N	166, 39E	965	800
37	Eniwetok	11, 21N	162, 21E	1470	900
38	Ujelang	9, 42N	161, 02E	1980	1000
39	Mokil	6, 41N	159, 47E	3056	1250
40	Kapingamarangi	1, 05N	154, 48E	2808	1700

estimated for all islands reported by Reed. This was obscured by the averaging together of systematic overestimates with underestimates. The distribution of islands was skewed toward moderate rainfall which further obscures the systematic large underestimate at wetter islands.

Reed states that the maximum around 5°N, 155°E in Taylor's (1973) analysis of tropical island rainfall is nonexistent. This maximum is not in Reed and Elliott's analysis. Reed incorrectly states that the maximum is an artifact of Taylor because he uses rainfall from three high islands. But the Midway–Kapingamarangi line (Fig. 4) clearly supports the existence of a peak in the area of 5°N, 155°E. This line is made up of only low islands north of the equator. In addition, other evidence supports the existence of the maximum (see below). Taylor was well justified and correct in his analysis of a rainfall peak around 5°N, 155°E.

4. Comparison with other data

Reed claimed that other evidence supports the amounts and patterns of the Reed and Elliott estimates. A contrary view is presented in Dorman (1980) who suggests that all other evidence indicates that their patterns and amounts are in error. Examination of studies in the tropical Pacific, which Reed states supports their estimates, reveals conflicts rather than agreements.

The Reed and Elliott estimates are in conflict with satellite cloud measurements. Their maximum in the central Pacific is 2° of latitude south of the satellite cloud maximum (Sadler *et al.*, 1976) (note the location of Reed and Elliott's maximum on Figs. 2, 3, 4).

The major rainfall maximum in the tropical Pacific, west of 160°E, is entirely missing in Reed and Elliott's analysis. Monthly satellite cloud analyses do have such a maximum (Sadler and Harris, 1970). Low-level winds derived from cloud motions also indicate convergence during certain months (Sadler and Harris, 1970). Satellite microwave radar measurements (Rao and Elliott, 1977), indicators of general rainfall intensity, show peak values. Ship weather observations (Dorman and Bourke, 1979) and Taylor's (1973) analysis further support this maximum.

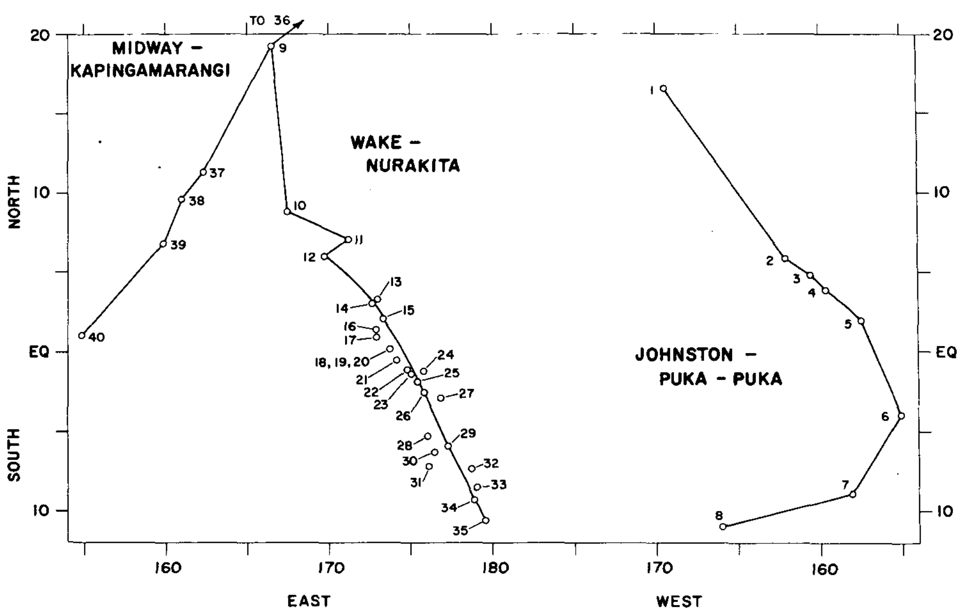

FIG. 1. Location of island stations used.

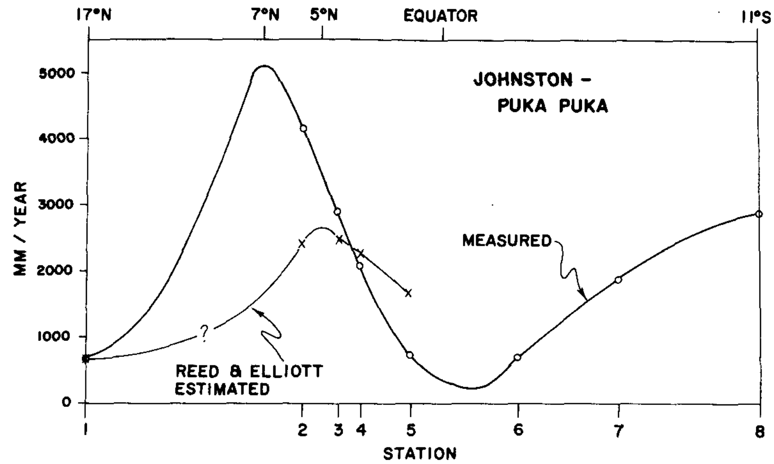

FIG. 2. Johnston to Puka Puka line. Island annual measurements are connected by a smooth line. Reed and Elliott's estimates along the same line are included.

Even if rainfall at atolls and islands was systematically higher than open-ocean rainfall as Reed claims, island measurements and even their vegetation clearly indicate an increased rainfall west of 160°E.

Curiously, Reed cites agreement with latitude-band averages of rainfall estimates by Kilonsky and Ramage (1976). Kilonsky and Ramage made estimates of oceanic rainfall based on satellite-measured cloudiness. But the similarity between latitude-band averages across the Pacific merely confirms that one can get artificial agreement by taking sufficiently large averages over inhomogeneous conditions. The basic assumption behind Kilonsky and Ramage's work was that measurements at low atolls are representative of open ocean rainfall, and so they calibrated their technique on atoll measurements. These measurements are not even in agreement with Reed and Elliott's, being a factor of 2 greater.

Reed cites agreement with Jacobs (1951) estimates. These are based on a computation of the evaporation and the upper salinity structure of the ocean. Jacobs rainfall estimates are a factor of 2 less than low atoll measurements, although his values are similar to Reed and Elliott's. But this general technique has been reapplied by Donguy and Henin (1976) who computed near-surface salinity in the southwestern equatorial Pacific. They assumed that island rainfall measurements are correct, and found a correlation between salinity and rainfall in peak rainfall years. This suggests that Jacobs estimates are an underestimate. This is not surprising considering the difficulty in estimating evaporation and the

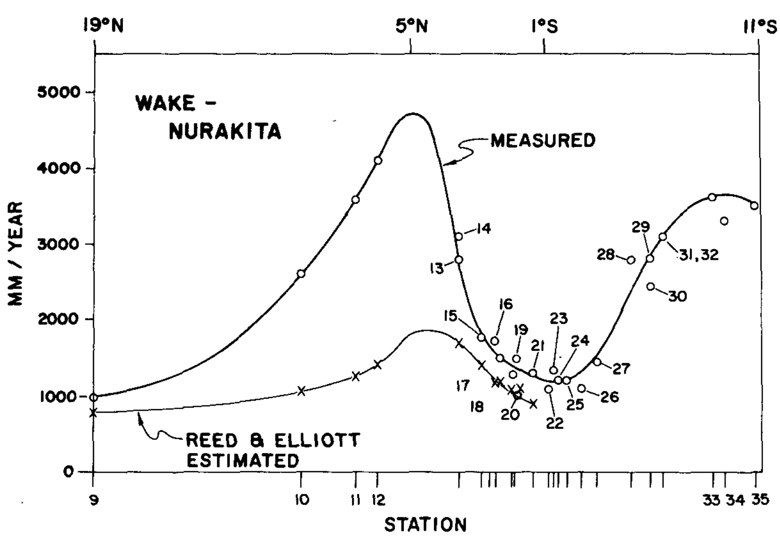

FIG. 3. Wake–Nurakita line. See Fig. 2 caption for explanation.

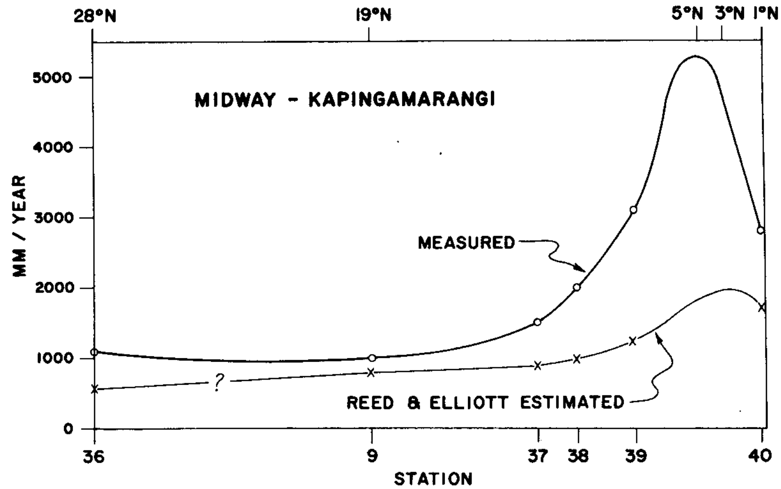

FIG. 4. Midway–Kapingamarangi. See Fig. 2 caption for explanation.

role of diffusion in determining the upper ocean salinity structure.

5. Explanation for differences between measured and estimated rainfall

Reed (1980) cites frictional wind convergence as the explanation for the disparity between measurements at low islands and estimates. This is in conflict with Lavoie (1963) who found no significant correlation between rainfall and the amount of land exposed at Eniwetok Atoll (where an order of magnitude more land is exposed at low tide than at high tide). Presumably, more land area should be associated with more frictional convergence and more rainfall, which it is not. Frictional convergence also does not explain the overestimates at dry islands, and the tendency to increasingly underestimate wetter islands.

A more likely explanation for the differences between low-island measurements and the Reed and Elliott estimates is that the latter are in error. Reed and Elliott's estimates are based on the frequency of rainfall. The frequency of rainfall in the Pacific has been shown to be poorly related to the actual rainfall (Lavoie, 1963).

REFERENCES

Donguy, J. R., and C. Henin, 1976: Relations entre les precipitations et la salinité de surface dans l'ocean pacifique tropical sudouest basees sur un echantillonnage de surface de 156 a 1973. *Ann. Hydrograph.*, **4,** 53–59.

Dorman, C. E., 1980: Comments on "The relationship between the amount and frequency of precipitation over the ocean." *J. Appl. Meteor.*, **19,** 131–133.

——, and R. H. Bourke, 1979: Precipitation over the Pacific Ocean, 30°S to 60°N. *Mon. Wea. Rev.*, **107,** 896–910.

Jacobs, W. C., 1951: The energy exchange between sea and atmosphere and some of its consequences. *Bull. Scripps Inst. Oceanogr.*, **6,** 27–122.

Kilonsky, B. J., and C. S. Ramage, 1976: A technique for estimating tropical open-ocean rainfall from satellite observations. *J. Appl. Meteor.*, **15,** 972–975.

Lavoie, R. L., 1963: Some aspects of the meteorology of the tropical Pacific viewed from an atoll. *Atoll Res. Bull.*, **96,** 1–77.

Rao, M. S. V., and J. S. Theon, 1977: New features of global climatology revealed by satellite-derived oceanic rainfall maps. *Bull. Amer. Meteor. Soc.*, **58,** 1285–1288.

Reed, R. K., 1980: Comparison of ocean and island rainfall in the tropical North Pacific. *J. Appl. Meteor.*, **19,** 877–880.

——, and W. P. Elliott, 1979: New precipitation maps for the North Atlantic and North Pacific oceans. *J. Geophys. Res.*, **84,** 7839–7846.

Taylor, R. C., 1973: *An Atlas of Pacific Islands Rainfall.* Rep. HIG-73-9, Hawaii Institute of Geophys, 7 pp.

Sadler, J. C., and B. E. Harris, 1970: The mean tropospheric circulation and cloudiness over Southeast Asia neighboring areas. Rep. HIG-70-26, Hawaii Institute of Geophysics, 37 pp.

——, L. Oda and B. J. Kilonsky, 1976: Pacific Ocean Cloudiness from satellite observations. Rep. UHMET 76-01, University of Hawaii, 137 pp.

Sverdrup, H. V., M. W. Johnson and R. H. Flemming, 1942: *The Oceans: Their Chemistry, Physics, and General Biology.* Prentice-Hall, 1087 pp.