AN EXPLORATION OF PRECIPITATION PATTERNS ACROSS NORTHERN PUERTO RICO

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Abstract

Because of its convective nature, tropical rainfall is variable in both time and space. To better understand rainfall distribution over a selected area, precipitation patterns along the north coast of Puerto Rico were analyzed.

Using various sets of rain occurrences, the authors determine the likelihood of rainfall occurring downstream from a preselected location in a predominantly trade wind regime. Sets include total events, metropolitan area events, day vs night, dry vs wet, and seasonal comparisons. The daily occurrence of rain vs no rain was then tabulated to determine the percent of monthly rain days and summed to obtain an annual average.

The data sets revealed that precipitation occurrences at the upstream station correlate well with all downstream stations. It also concluded that the occurrence of rain was the norm rather than the exception. The study provides forecasters with a better insight of precipitation patterns and geographical distribution of rainfall occurrence across the north coast of Puerto Rico.

1. Introduction

The need to document and understand the variability of climate is well known. In the tropics, this problem is largely one of rainfall variation (White, 1981). The difficulty in documenting tropical rainfall results from its convective nature, being variable in both time and space as illustrated by Riehl (1954). Before one can understand the nature of rainfall fluctuations, one must identify the characteristic rainfall patterns of specific regimes of interest. For this reason, this study is an exploration of precipitation patterns across northern Puerto Rico. The north coast was chosen to study for three reasons: First, the location of the only official National Weather Service (NWS) rain gauge in Puerto Rico is located along the northeast coast; second, the north coast is predominantly under the influence of an easterly trade wind flow throughout the year; third, the United States Geological Survey (USGS) and cooperative observers provide an established network of rain gauges stretching east to west along the entire length of the north coast giving a rather reliable distribution of collective rainfall data.

2. Discussion and Methodology

Precipitation events are analyzed along the north coast of Puerto Rico which coincides with forecast Zone 1 of the NWS (NWS, 1984). Zone 1 includes the city of San Juan, is approximately one hundred miles long and parallels the north coastline in an east to west orientation. The zone extends inland to the interior highlands roughly seven miles from the coast (Fig. 1).

In order to see if any patterns in rainfall distribution would manifest themselves, the following assumptions were tested: If it rains or doesn't rain at the NWS (assumed to be upstream in the chosen zone based on a predominantly easterly trade wind flow), a similar condition would occur downstream at any arbitrary point in the same zone. The San Juan gauge plus nine alternate gauges were used in the study. The ten gauges were spaced east to west along the length of the zone.

The occurrence of rain (or no rain) was determined at San Juan from 0000 UTC to 1200 UTC and 1200 UTC to 2400 UTC on each day during the one year period from May 1989 through April 1990. Total events for each individual station were compared to concurrent events at San Juan (an event is defined as the occurrence of 0.01 inch or more of precipitation somewhere in the zone during each 12 hour period). For example, if it rained in San Juan, and at four of the remaining nine stations during a given time period, the result was a rain event that affected 50 percent of the locations being studied (5 gauges of 10). Smith (1977) used a similar methodology studying point probability and areal coverage of precipitation. The daily totals were used to obtain monthly and yearly averages, then divided into various sets to ascertain if the conclusions derived from each calendar day were valid. The sets include the total events, San Juan metropolitan area, day vs night, dry vs wet, and seasonal comparisons. The daily occurrence of rain vs no rain was then tabulated to determine the percent of monthly rain days and summed to obtain an annual average.

Puerto Rico generally receives abundant rainfall, however, a large portion of the island experienced a significant rainfall deficiency from September 1989 to November 1990 (Burkman and Block, 1990). This may mean the conclusions presented are not representative of more typical years and emphasize the need for further study.

3. Analysis of Data

Over the length of the study period (total events), when it rained at the San Juan gauge (Fig. 2), there was an annual 77 percent conditional probability that a like event occurred at some downstream station. Monthly data revealed a maximum of 85 percent in December to a minimum of 68 percent in January.

The San Juan metropolitan area (Fig. 3) encompassed five of the ten gauges; four were located within fifteen miles of the NWS gauge (refer to Fig. 1). When comparing these four stations to the NWS gauge, there was an 82 percent

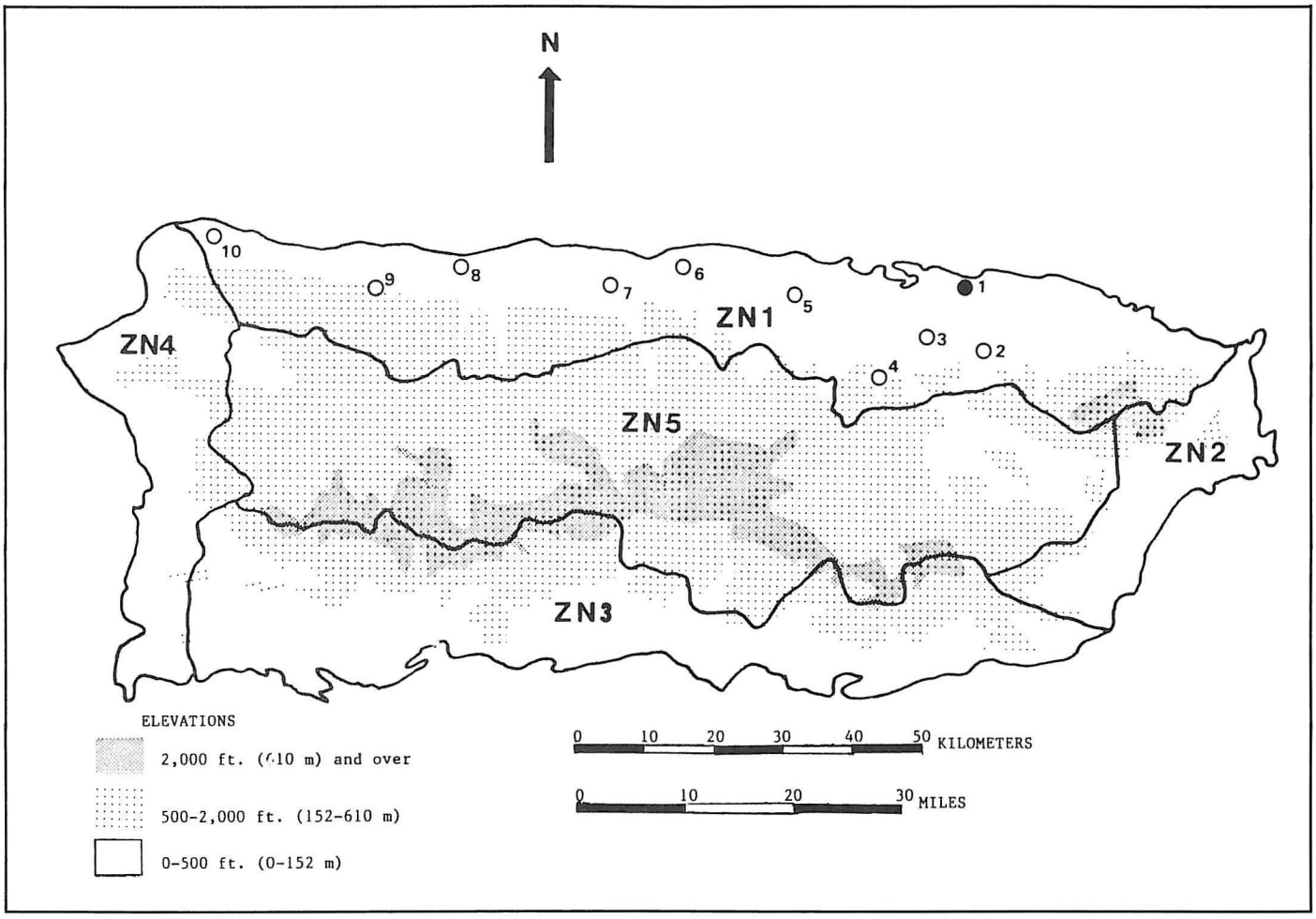

Fig. 1. Map of Puerto Rico depicting forecast zones by zone number (Zones 1 through 5), and the location of the ten stations in the study area. San Juan (1) is the official National Weather Service station. Trujillo Alto (2), Rio Piedras (3), Bayamon (4), Toa Baja (5), Vega Baja (6), Manati (7), Camuy (9) are USGS stations. Arecibo (8) and Isabella (10) are cooperative observer stations.

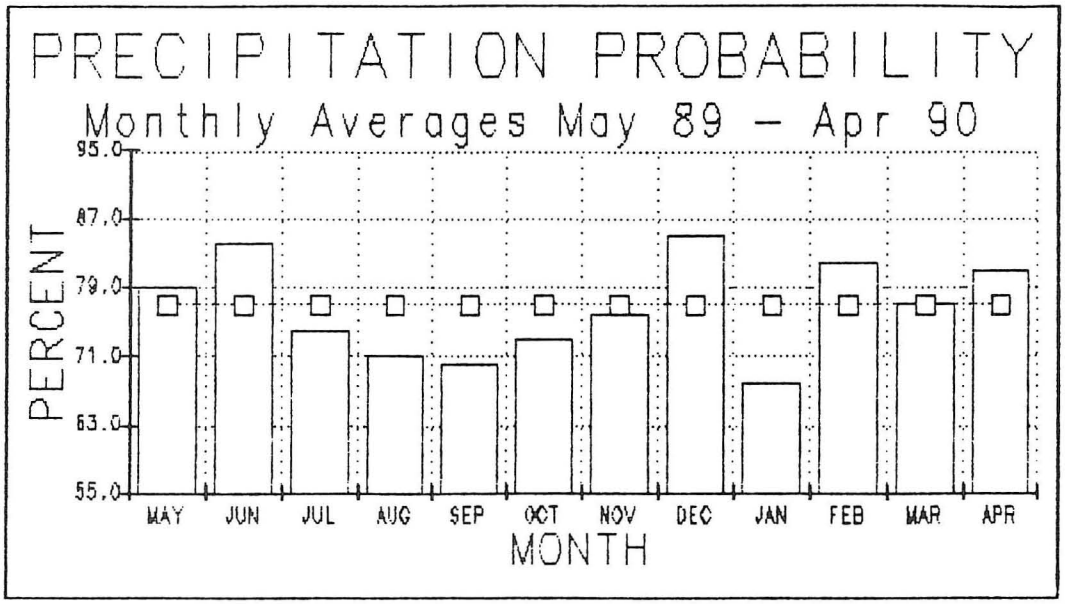

Fig. 2. May 1989 through April 1990 (0000 UTC to 2400 UTC). Average percent of conditional probability of a like event (precipitation) occurring at downstream stations from San Juan. The yearly average of 77 percent is represented by the dashed line.

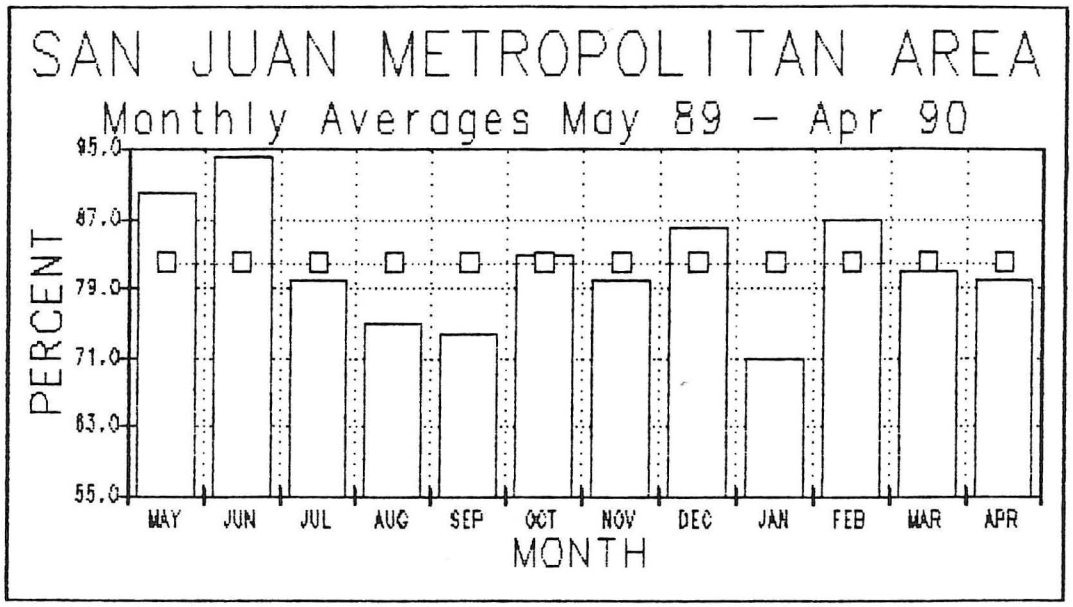

Fig. 3. San Juan metropolitan area events from May 1989 through April 1990 (0000 UTC to 2400 UTC). Monthly averages for the percent of precipitation conditional probability of San Juan metropolitan area. The yearly average of 82 percent is represented by the dashed line.

conditional probability that a like event also occurred at one of these stations.

There was little difference in rain events between day (1200 UTC to 2400 UTC) and night (0000 UTC to 1200 UTC) periods. The yearly average value of precipitation probability was 77 percent (the same as the conditional probability as shown in the total events). During the day the conditional probability of rainfall in Zone 1 ranged from a high of 90 percent in December to a low of 67 percent in July (Fig. 4a). During the night the values ranged from a high of 83 percent in April to a low of 64 percent in January (Fig. 4b).

4. Dry vs Wet Period

There is a wide discrepancy between dry vs wet periods. A wet period is defined as a 24 hour day (0000 UTC to 2400 UTC) when 0.01 inch or more of rain occurred at the San Juan gauge. During wet periods, if rain occurred in San Juan, rain also occurred 67 percent of the time at downstream gauges. Conversely, during dry periods if it did not rain at the San Juan gauge, rain did not occur 83 percent of the time at downstream gauges.

Wet period values averaged from a high of 85 percent in February to a low of 57 percent in May (Fig. 5a). Dry period values ranged from a high of 93 percent in May to a low of 67 percent in September (Fig. 5b). It is interesting to note that May represents both extremes.

The reason for May extremes is attributed to a large variability in synoptic settings during this time of year. May is traditionally the transition period between winter and summer when tropical waves and mid-latitude cold fronts intrude into the tropics battling for control of the local weather regime. In May 1989, surface observations showed two distinct wet periods at each end of the month, an easterly wave in early May and a cold frontal passage in late May. The remainder of the month was dry with high pressure dominating at the surface and a strong ridge prevailed aloft.

5. Seasonal Comparisons

Although there is relatively little monthly precipitation difference, several seasonal trends appear. These are illustrated in Fig. 6. Spring and winter reveal the highest positive relationship of rain occurring at both San Juan and downstream stations while the fall months reveals the weakest. The most pronounced seasonal differences occur during daytime events, conversely little seasonal differences exist between local area and wet events.

During the study period, each day was checked to see if rain or no rain occurred in any of the gauges (occurrence of rain at any gauge was considered a rain day). Both rain and non-rain days were tallied for each month (Table 1). Monthly and annual percentages were then derived. The annual average percent of rain occurring somewhere in Zone 1 was 87 percent.

In the summer months, July through September, rain always occurred somewhere in the zone on any given day. Similar results were found by Naber and Smith (1983) for southern Alabama and northeast Florida. This was attributed to the interaction of such mesoscale features as the sea breeze, differential heating , topographical effects, and synoptic scale features, i.e., cold fronts and tropical waves traversing the region.

6. Summary and Conclusions

The purpose of this study was to obtain some insights into the distribution of rainfall across the northern coast of Puerto Rico during a prevailing trade wind regime. Some of the most interesting findings are summarized here.

In all data sets presented, it was shown that events at the San Juan gauge are highly correlated with events at all other gauges downstream along the north coast. In total events, and other data sets, the monthly rainfall frequencies for rainfall in at least one of the ten gauges, ranged from a high of 93

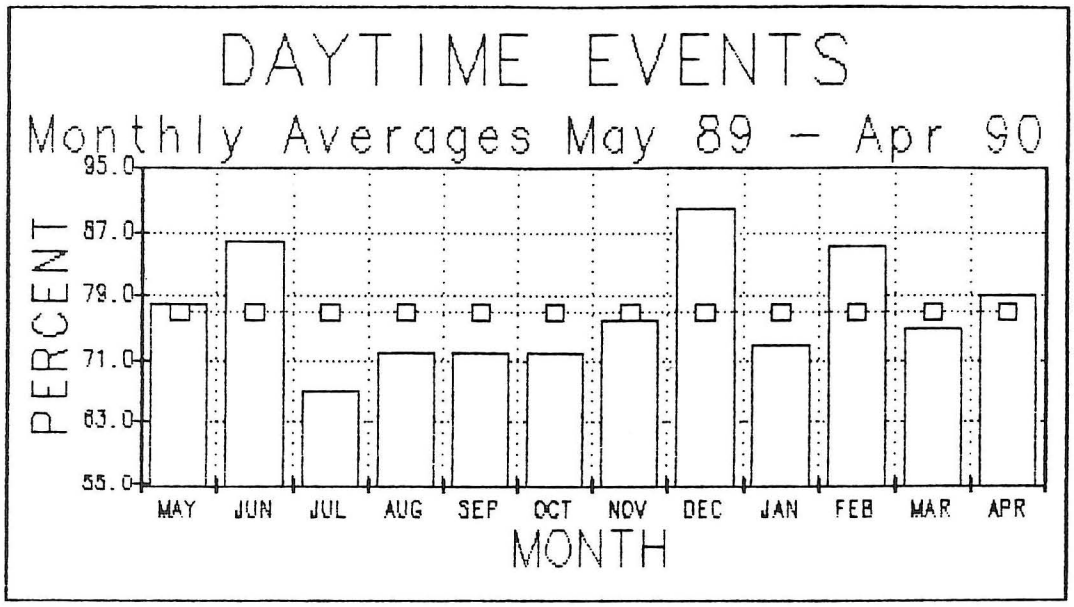

Fig. 4a. Daytime events from May 1989 through April 1990 (0000 UTC to 2400 UTC). Monthly averages for the percent of precipitation conditional probability of daytime events. The yearly average of 77 percent is represented by the dashed line.

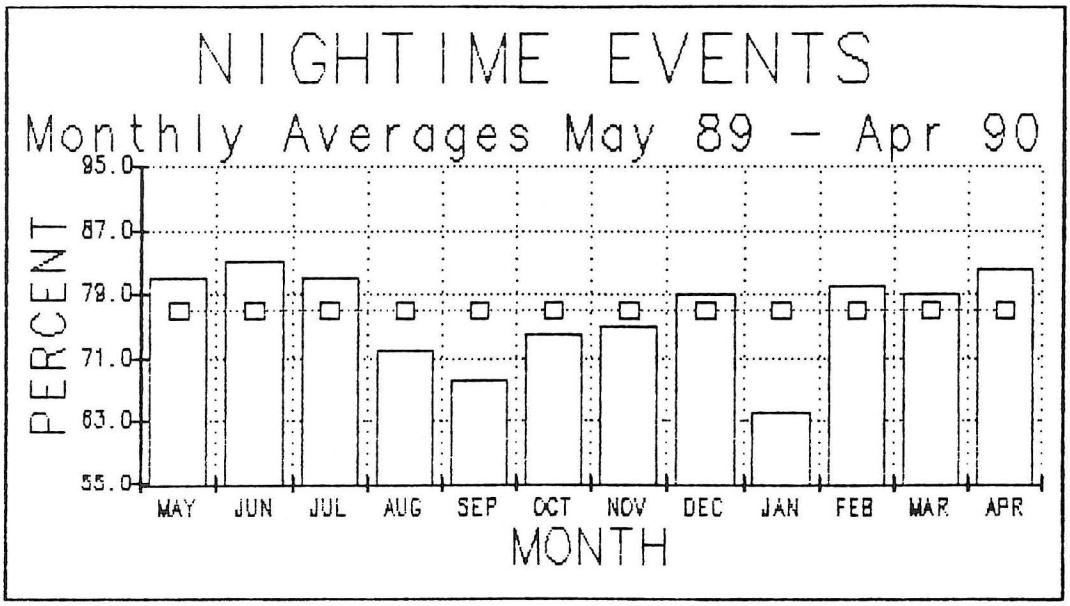

Fig. 4b. Nighttime events from May 1989 through April 1990 (0000 UTC to 2400 UTC). Monthly averages for the percent of precipitation conditional probability of nighttime events. The yearly average of 77 percent is represented by the dashed line.

percent to a low of 64 percent, both occurring in May. The yearly average of any set was no less than 67 percent.

The annual 77 percent conditional probability of precipitation occurring at downstream stations is certainly meteorologically significant given the current level of forecasting skill (Dickey, 1966). We can imply, when given the consistency of a tropical easterly flow pattern across Puerto Rico, if it rains at the NWS Office in San Juan, there is a high probability of a rain occurring downstream along the north coast of Puerto Rico. This is exactly what one would expect with the criteria of a zone being homogeneous throughout (Smith, 1977). However, it must be remembered that the data set is based on only one year's data, and may not be climatologically representative due to an unusually dry period that occurred in Puerto Rico from mid 1989 to late 1990.

The high percentage of precipitation values found across the study area could serve as a forecasting tool by providing the forecaster with a better understanding of geographical and seasonal distribution of rainfall occurrences within the zone.

During the summer months, July through September, it may be concluded there is a 100 percent certainty of rain occurring somewhere in the zone on any given day. Therefore, the forecasting of non-precipitation events rather than precipitation events, may be more meteorologically challenging along the north coast of Puerto Rico.

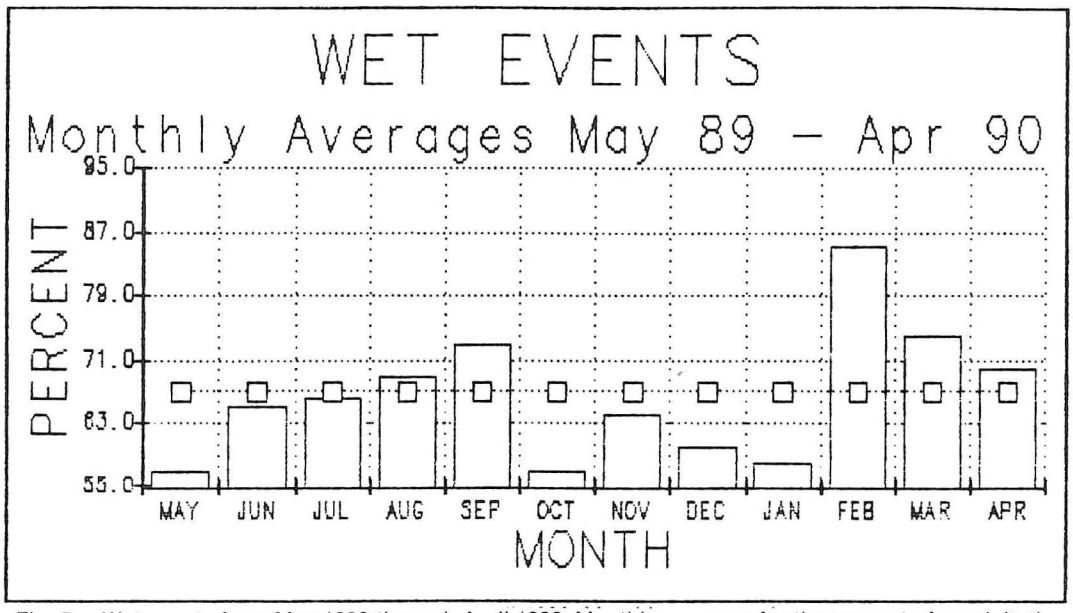

Fig. 5a. Wet events from May 1989 through April 1990. Monthly averages for the percent of precipitation conditional probability of wet events. The yearly average of 67 percent is represented by the dashed line.

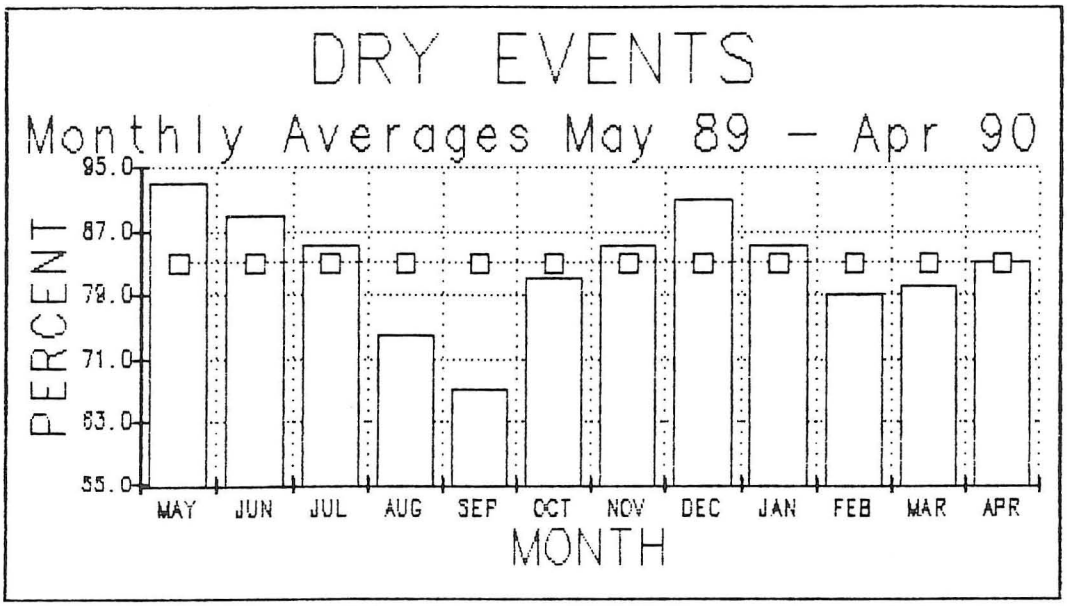

Fig. 5b. Dry events from May 1989 through April 1990. Monthly averages for the percent of precipitation conditional probability of dry events. The yearly average of 83 percent is represented by the dashed line.

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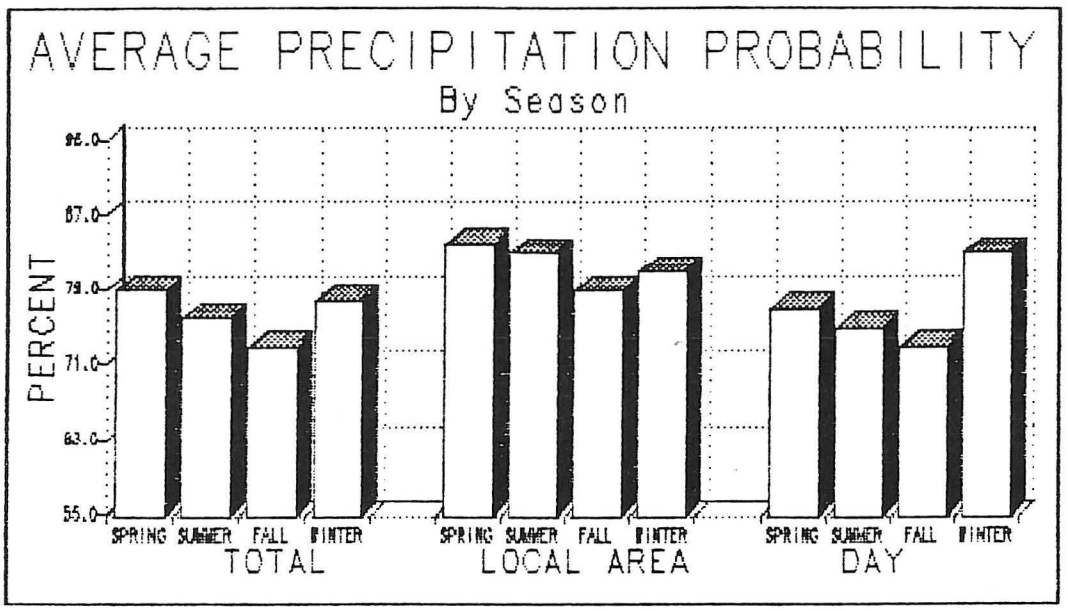

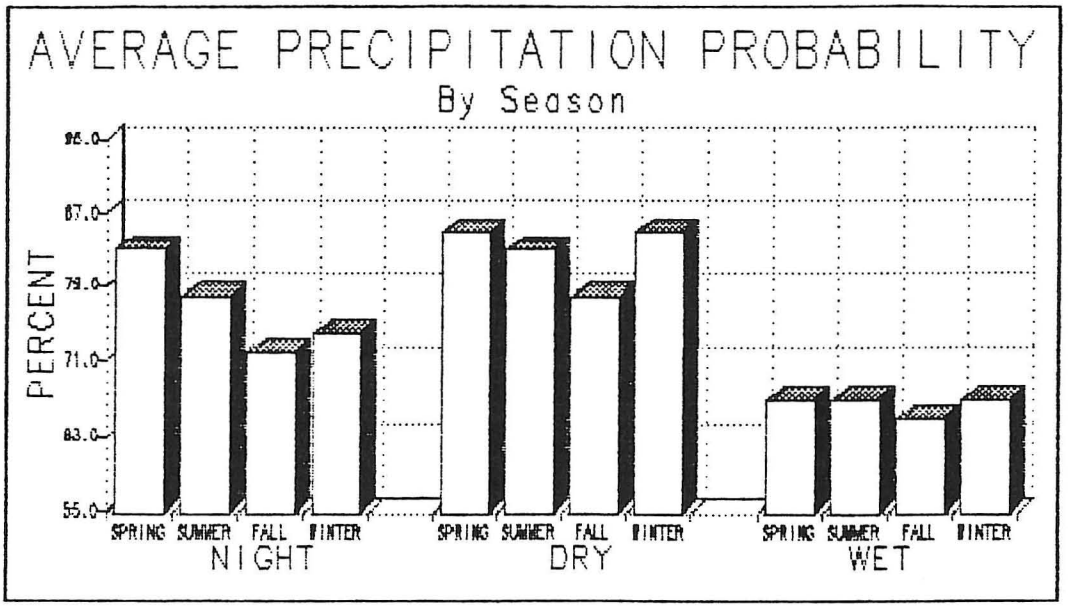

Fig. 6. Season events for May 1989 through April 1990. The seasonal divisions for total, San Juan metropolitan area, day, night, dry and wet events. Spring and winter reveal the highest precipitation conditional probability and fall shows the weakest precipitation conditional probability.

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Table 1. Monthly rainfall days for Zone 1 in Puerto Rico for the period May 1989 through April 1990. Rain fell someplace in the Zone 87 percent of all days studied.

FOR ALL 10 GUAGES - NUMBER OF DAYS IN WHICH RAIN OCCURRRED BY MONTH
for the period May 1989 through April 1990

MONTH	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTAL
DAYS WITH RAIN	22	24	31	31	30	30	27	19	28	25	28	24	319
DAYS WITH NO RAIN	9	6	0	0	0	1	3	12	3	3	2	6	46
PERCENT OF DAYS WITH RAIN	73	80	100	100	100	97	90	61	90	89	93	80	87

FOR THE SAN JUAN GAUGE - NUMBER OF DAYS IN WHICH RAIN OCCURRED BY MONTH
for the period May 1989 through April 1990

MONTH	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTAL
DAYS WITH RAIN	14	8	22	22	23	14	18	11	23	18	20	7	200
DAYS WITH NO RAIN	17	22	9	9	7	17	12	20	8	10	10	23	165
PERCENT OF DAYS WITH RAIN	45	27	71	71	77	45	60	35	74	64	67	23	55