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Conditional Probabilities for Sequences of Wet Days at Phoenix, Arizona

PAUL C. KANGIESER

Western Region

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U. S. DEPARTMENT OF COMMERCE
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NATIONAL WEATHER SERVICE

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CONDITIONAL PROBABILITIES FOR SEQUENCES OF WET DAYS AT PHOENIX, ARIZONA

Paul C. Kangieser [1/]
Climatologist for Arizona
Weather Service Forecast Office
Phoenix, Arizona

[1/] Mr. Kangieser retired from the National Weather Service on May 12, 1973. Of his 30-year total Federal service, he had been the Climatologist for Arizona for the past 17 years.

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CONDITIONAL PROBABILITIES FOR SEQUENCES OF WET DAYS AT PHOENIX, ARIZONA

I. INTRODUCTION

Erickson [1] presented data for Washington showing the probability of a thunderstorm day, given the knowledge that a given number of consecutive thunderstorm days have already occurred. Mr. Robert S. Ingram, Meteorologist in Charge of the Weather Service Forecast Office in Phoenix, Arizona, suggested that similar data be prepared for Phoenix using precipitation days.

A good model for such a study seemed to be a study prepared at the National Weather Records Center (now National Climatic Center) for NASA's George C. Marshall Space Flight Center, Alabama [2]. [1] yields only the probability of one more day with a thunderstorm, given that "i" consecutive days with thunderstorms have just occurred, whereas [2] yields the probability of "k" additional days with thunderstorms given that "i" consecutive days with thunderstorms have just occurred.

The method of actually counting the number of consecutive days with thunderstorms was used in [2], which is the most desirable procedure, but is quite laborious without a computer. In processing the Phoenix data, the method of counting <u>runs</u> used by Jorgensen [3] was used. With the thought that similar data may be of value to forecasters in other states, the method is described in some detail below.

Jorgensen's method consists of counting the number of <u>runs</u> of 1-day, 2-days, 3-days, etc., duration and assigning their occurrence to the month in which most of the run's days occurred. The method used in [2] was to actually count the number of times that 1-day, 2-consecutive days, 3-consecutive days, etc., with a given type of weather occurred. The difference in the two methods may be better visualized by realizing that whenever Jorgensen tallied one <u>run</u> of 3 days length, the authors of [2] tallied one period of 3 consecutive days, two periods of 2 consecutive days, and 3 periods of 1 day with a given type of weather. It is a simple matter to convert run data into the type of data used in [2], and if all runs ended on the last day of the month (if that is the unit of stratification used), then the two methods would yield identical results.

II. DATA

Data used for the Phoenix study were the combined record for the 77-year period 1896-1972. These data were divided into two seasonal periods:

(1) July and August, yielding a sample of 4774 days over the 77-year period, and (2) December, January, February and March, giving a total number of 9317 days. The number of runs of various length of days with precipitation were counted, assigning the run to the month in which most of the run's days occurred. A day with "precipitation" was defined as a day on which at least a trace of precipitation occurred in the 24-hour period between midnight and midnight.

III. PROCEDURES AND RESULTS

The method of converting the run data to the number of times precipitation occurred on 1 day, 2 consecutive days, 3 consecutive days, etc., may be illustrated by the following examples using the July and August data in Table 1a. Let F_1 be the number of times precipitation occurred on 1 day and F_2 be the number of times precipitation occurred on two consecutive days. Then

$$F_1 = 343(1) + 224(2) + 111(3) + 52(4) + 28(5) + 11(6) + 4(7) + 3(8) + 1(9) + 1(10) = 1609$$

$$F_2 = 224(1) + 111(2) + 52(3) + 28(4) + 11(5) + 4(6) + 3(7) + 1(8) + 1(9) = 831$$

Continuing in the same manner for the rest of the data in Tables 1a and 1b, yields the data in the F_k columns in Tables 2a and 2b.

To get the data in Tables 3a and 3b, proceed as follows. First, let us define $P(k/i)$ as the probability of "k" additional days with precipitation (trace or more) given that "i" consecutive days with precipitation have just occurred. The solidus, "/", is shorthand notation for "given that".

$P(k/o)$ is the probability of "k" consecutive days of rain, when it is not known whether the previous day was wet or dry. In other words, $P(k/o)$ is the probability of "k" consecutive days of precipitation and may be read simply as $P(k)$ = probability of "k" consecutive days of precipitation occurring anywhere in the whole sample of T days.

$$P(k) = \frac{F_k}{T} \qquad (1)$$

For Table 2a, T = 4774 days, while for Table 2b, T = 9317 days. The values of $P(k)$ from Tables 2a and 2b are transferred to row 1 (i = o) of Tables 3a and 3b.

To complete column 1 in Table 3a using data in Table 2a, note that

$$P(1/1) = \frac{831}{1609} = 0.516$$

$$P(1/2) = \frac{396}{831} = 0.477, \text{ etc.}$$

To complete column 2, we use

$$P(2/1) = \frac{396}{1609} = 0.246$$

$$P(2/2) = \frac{185}{831} = 0.223, \text{ etc.}$$

The remainder of Tables 3a and 3b may be filled out in this manner using values of F_k from Tables 2a and 2b.

After the values of P(k/i) are entered in Tables 3a and 3b, the data may be checked using the following conditional probability formula.

$$P(k/i) = P(1/i) \times P(1/i+1) \times P(1/i+2) \times \ldots . \times P(1/i+k-1) \qquad (2)$$

For example, from Table 3a,

$$P(5/3) = P(1/3) \times P(1/4) \times P(1/5) \times P(1/6) \times P(1/7)$$

$$= (.467)(.459)(.435)(.459)(.471) = 0.020.$$

Thus, every value in Tables 3a and 3b for $k \geq 2$, can be checked using the probabilities in the K = 1 column in each table.

IV. DISCUSSION

The advantage of the method described here over the assumption that the data may be adequately represented by a low-order Markov function (see [4]) is the following: If a tendency exists for the probability of additional precipitation days to increase after several precipitation days have occurred, the method just described will reveal such a tendency. For example, Jorgensen found that a 72% probability existed for at least one more "rain" day in San Francisco if 4 had just occurred, whereas the corresponding probability after only 1 "rain" day was only 58%. Such a probability distribution contains information of great value to the forecaster and would not be revealed by a study such as [4].

The Phoenix data seem to show a tendency for an 8-day sequence of precipitation in both Tables 3a and 3b. Note for example, the relatively larger values in Table 3b of P(1/7), P(2/6), P(3/5), and P(4/4) compared to the values immediately above or below them in the same columns. This pattern is also present to a lesser degree in Table 3a, and may indicate a tendency for precipitation to persist for 8-day periods in Phoenix, a tendency that may warrant a more extensive investigation by spectrum analysis.

V. TABLES

TABLES 1a AND 1b

Table 1a is based on data for July and August 1896-1972.

Table 1b is based on data for December, January, February and March 1896-1972.

X = Length of run of days with precipitation

Y = Number of runs of length X during 77-year period

Table 1a

X	Y
1	343
2	224
3	111
4	52
5	28
6	11
7	4
8	3
9	1
10	1

Table 1b

X	Y
1	473
2	253
3	114
4	49
5	16
6	11
7	3
8	1
9	2
10	1

TABLES 2a AND 2b

Table 2a is based on data for July and August 1896-1972.

Table 2b is based on data for December, January, February and March 1896-1972.

k = Number of consecutive days with precipitation

F_k = Number of times k consecutive days with precipitation occurred during the 77-year period

In Table 2a $P(k) = F_k / 4774$. In Table 2b $P(k) = F_k / 9317$.

Table 2a

k	F_k	P(k)
1	1609	.337
2	831	.174
3	396	.083
4	185	.039
5	85	.018
6	37	.008
7	17	.004
8	8	.002
9	3	.001
10	1	.0002

Table 2b

k	F_k	P(k)
1	1720	.185
2	797	.086
3	347	.037
4	150	.016
5	67	.007
6	33	.004
7	15	.002
8	8	.001
9	3	.0003
10	1	.0001

TABLES 3a AND 3b

Probability, P(k/i), of "k" additional days with precipitation (trace or more) given that "i" consecutive days with precipitation have just occurred. Phoenix WSFO, Arizona.

Table 3a (July and August)

i \ k	1	2	3	4	5	6	7	8	9	10
0	.337	.174	.083	.039	.018	.008	.004	.002	.001	.0002
1	.516	.246	.115	.053	.023	.011	.005	.002	.001	
2	.477	.223	.102	.045	.020	.010	.004	.001		
3	.467	.215	.093	.043	.020	.008	.003			
4	.459	.200	.092	.043	.016	.005				
5	.435	.200	.094	.035	.012					
6	.459	.216	.081	.027						
7	.471	.176	.059							
8	.375	.125								
9	.333									

Table 3b (December, January, February and March)

i \ k	1	2	3	4	5	6	7	8	9	10
0	.185	.086	.037	.016	.007	.004	.002	.001	.0003	.0001
1	.463	.202	.087	.039	.019	.009	.005	.002	.001	
2	.435	.188	.084	.041	.019	.010	.004	.001		
3	.432	.193	.095	.043	.023	.009	.003			
4	.447	.220	.100	.053	.020	.007				
5	.493	.224	.119	.045	.015					
6	.455	.242	.091	.030						
7	.533	.200	.067							
8	.375	.125								
9	.333									

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