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The Distribution of Rainy Days in the Aegean Area

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With 2 Figures

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Summary

The object of this study is the determination of the number of rainy days in the area of the Aegean sea, based on data obtained from 14 observation stations during the period 1950–1975.

The results showed considerable differences from North to South. The seasonal number of rainy days as well as that of rainy spells were examined for the period 1950–1975. The spells of rainy days play an important role in the agricultural activities, especially over the southern part of the Aegean sea basin, where the annual amounts of rainfall are insufficient.

From the data was concluded that during the summer, more than four consecutive rainy days were recorded at the northern most stations only and these of infrequent occurrence; whereas during the winter, it was possible to encounter up to 15 consecutive rainy days.

Finally, we give a theoretical distribution for the rainy spells for each station and for each season and year, using Polya's method. We found that this distribution fitted well the 95% of the confidence level in the majority of the cases.

1. Introduction

This study examines, on one hand the geographical distribution of the number of rainy days and, on the other, the frequency of appearance of consecutive rainy days in the area of the Aegean sea. Data from the 14 stations (Fig. 1) was used for the period 1950–1975.

Thus, the geographical distribution of this meteorological parameter for the area in question, as well as the probability of occurrence of consecutive rainy days examined. It was also possible to obtain informations concerning rain persistence over the area of the Aegean.

Apart from studying the amount of rain, it was also of hydrological and agricultural importance to consider the number of rainy days. The term *rainy* days includes days with shower or rain, hail,

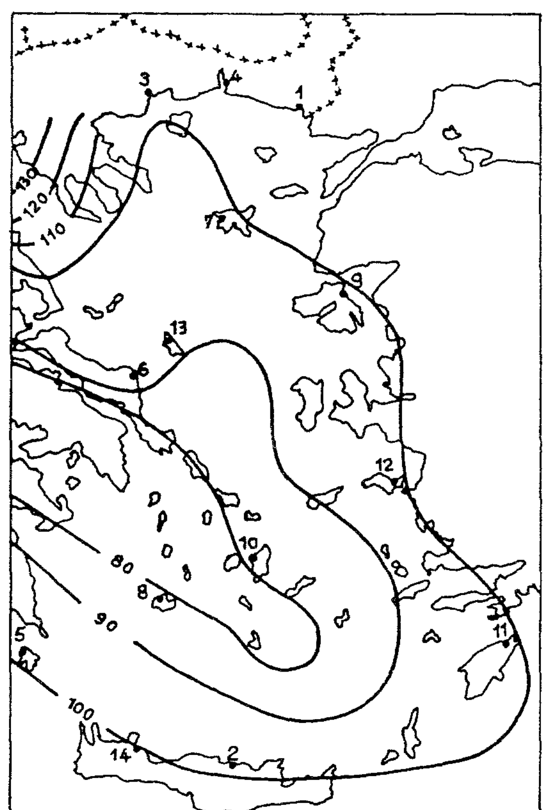

Fig. 1. Mean annual contours of rainy days

sleet, snow, respectivelly whose equivalent amount is equal to or greater than 0.0 mm/day. For this, the geographical distribution of the mentioned parameter over the area of the Aegean sea was initially examined by season and year.

2. Analysis of Number of Rainy Days

Specifically (Table 1), during the spring season the smallest number of rainy days was recorded in the area of the Cyclades Islands (Maheras, 1983; Theoharatos, 1978), gradually increasing to the North and to the East of this area. This behaviour may very well be attributed to the fact that, although the number of thunderstorms during the month May increases. These storms area primarily apparent in the continental areas of Greece and over the bigger north islands. This might be attributed to the fact that low winds prevail over rather large flat areas during that season, thus favouring the generation of thermal storms. That fact is not observed in the area of Cyclades Islands, which are small individual land areas, scattered and of uneven topography.

During the summer season, in the central and southern Aegean, the number of rainy days is very small due to the existence of prevailing Etesian Winds, since, this number is greater for the coasts of northern Greece (Karapiperis, 1953; Maheras, 1976). This is also apparent from the observed amount of rain during the summer season in the area under examination (Maheras, 1983; Theoharatos, 1978). Thus, pleuviometrically, this area, is characterized as Mediterrenean type with continental influence (Jakobaki and Tselepidaki, 1975). The increase in the number of rainy days in the northern Aegean is due to the passing of depressions over northern Greece, at the beginning of the summer season (Karapiperis, 1953, 1956). During the autumn season the average number of rainy days in the examined area exhibits only small fluctuations relative to the latitude. The lowest values were again obtained in the area of the Cyclades Islands, while in the rest of the islands of the East Aegean, Crete and the northern Greek coasts this number was around 20, except for Thessaloniki where the number was greater than 30 days.

The small number recorded for the area of the Cyclades Islands was due to the fact that both months September and October exhibit summer month characteristics. During the month of November the moving of depressions over Crete have only little influence on this part of Greece (Theoharatos, 1978). The higher number in the northern Aegean can be attributed to the fact that sleet and snow incidents that appear in late October are also included in the recorded water.

Finally the mean annual number of rainy days was examined from Fig. 1 where contours of equal number of rainy days were plotted, as well as data obtained from neighbouring area. It was thus observed that the smallest annual number of rainy days was recorded in the Cyclades Islands area, southern Evia, Attica and northeastern Peloponissos, increasing around these areas both over con-

Table 1. *Mean Values of Rainy Days for the Period 1950–1975*

Station	Spring	Summer	Autumn	Winter	Year
1. Alex/polis	34.1	16.1	23.9	40.2	114.2
2. Heraklion	24.8	2.3	22.9	44.8	94.8
3. Thessaloniki	41.6	25.5	31.3	39.3	137.8
4. Kavala	28.5	18.9	21.4	31.6	100.3
5. Kythira	22.9	2.5	23.4	43.9	92.8
6. Kymi	22.3	7.1	22.3	38.9	90.7
7. Limnos	27.5	8.5	22.5	40.9	99.3
8. Milos	21.8	2.4	19.7	41.5	85.4
9. Mytilini	25.6	4.7	20.0	39.8	90.1
10. Naxos	21.6	2.9	17.3	40.7	82.4
11. Rhodos	24.5	1.9	20.7	48.0	95.0
12. Samos	27.6	2.8	22.2	45.8	98.4
13. Skyros	23.0	5.7	21.5	41.4	91.6
14. Chania	24.6	2.4	25.4	47.4	99.8

tinental Greece, and the islands of the eastern Aegean and Crete.

3. Consecutive Number of Rainy Days

For the study of a series of consecutive rainy days the statistical method by G. Polya (Eggemberger and Polya, 1923) was used, a method previously used by many climatologists (Ali Farah, 1970; Angouridakis, 1973; Arléry et al., 1973; Bloutsos and Pennas, 1986). Dependence of successive sampling is the main method. From amongst the various statistical methods, that could have been applied in order to study series of consecutive meteorological phenomena, the Polya method was chosen as it was the one that indicates optimum fit.

The Bernoulli distribution allows for each data sampling to be independent of the previous one. Polya considered that after each sampling and before the next a number equal to μ of similar samples is added to the sample in question. Thus, consecutive samples seize being independent and the probability of obtaining similar samplings is greater.

In Polya's distribution the probability $P(x)$ of consecutive days (x) of a meteorological parameter appearing as:

$$p_1 = 1/(1+d)^{m/d},$$
$$p_2 = p_1 \cdot m/(1+d), \ldots,$$
$$p_x = p_{x-1}\,[m + (x-1)\,d]/x(1+d)$$
$$\text{for } x = 3, 4, \ldots \qquad (1)$$

where $x = 1, 2, 3 \ldots$ the duration of consecutive days,

$$\bar{m} = (N - \Sigma n_x)/\Sigma n_x \qquad (2)$$

the average expected number of days (in series),

with $\Sigma n_x =$ the total number of cases of consecutive days for the meteorological parameter and $N =$ the total number of days when rainy days is occurred.

The parameter d represents the degree of influence of an event on the following and can be found from the relationship.

$$d = (\sigma^2/m) - 1 \qquad (3)$$

$$\text{where } \sigma^2 = [\Sigma\,(n_x \cdot S_x^2)\,/\,\Sigma n_x] - \bar{m}^2 \qquad (4)$$

is the variance of the distribution

where $(S_1 = 0, S_x = x - 1)$

Using these equations it is possible to calculate $P_1, P_2, \ldots$ and then through multiplication of these probabilities, with Σn_i we can find the theoretical values of x consecutive days with rain. Experiments have shown that these theoretical values for small values of x are slightly increased, where as for greater values of x these are slightly decreased.

The calculated theoretical values show little deviation from the real values such that the relationship between real and theoretical values is in general satisfactory and acceptable.

4. Applying the Polya Distribution

By using the Polya statistical method probabilities $P(x)$ of the appearance of consecutive rainy days were calculated for each station, for each season and the year.

During spring (Table 2 a), for example, the values P_1, P_2, ... are given and it is thus apparent that in this area rarely a number of consecutive rainy days greater than nine is observed. The frequency of individual rainy days fluctuate between 0.28 and 0.59, where as over Cyclades Islands the probability of more than six consecutive rainy days is less than 0.1.

During the summer season, the probability of isolated rainy days is relatively high, 0.19–0.9. A number of consecutive rainy days more than 4 is not to be expected, except at stations located on the coast of northern Greece (Alexandroupolis, Kavala and Thessaloniki), where the probability is still quite small (Table 2 b).

During autumn, the probability of appearance of ten or more consecutive rainy days is nearly non-existent, as where the probability of individual rainy days varies between 0.27 and 0.52. Similar to the spring season the probability of appearance of consecutive rainy days for more than seven days is smaller than 0.1 throughout the area examined (Table 2 c).

Finally, during the winter season, due to more frequent occurrence of depressions and frontal systems, which often move slowly and exhibit long duration of stay, the highest number of consecutive rainy days was recorded, sometimes more than 15 days.

The probability of individual rainy days varies between 0.21 and 0.47 and the probability of a number greater than 4 consecutive days is smaller than 0.10 (Table 2 d).

Table 2a. *Spring: Polya's Probabilities P (x), x = 1, 2, ... Days of the Successive Rainy Days*

Station	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
Alex/polis	423	262	147	79	42	22	11	6	3					
Heraklion	504	239	123	65	35	19	10	5	3	2				
Thessaloniki	393	251	150	88	51	29	17	10	6	3				
Kavala	279	136	62	27	12	5	2							
Kythira	592	202	96	50	27	15	8							
Kymi	531	246	116	55	26	12	6	3	1					
Limnos	511	277	125	53	22	9	4							
Milos	539	252	115	52	23	10	5	2						
Mytilini	455	272	141	69	33	15	7	3						
Naxos	497	295	129	50	18	6	2							
Rhodos	307	155	67	27	10	4	1							
Samos	431	273	147	75	37	18	9	4	2	1	1			
Skyros	452	310	146	58	21	7								
Chania	414	287	156	77	36	16	7	3						

The tables 2 a, 2 b, 2 c, 2 d gives P_x in thousandths

Table 2b. *Summer: Polya's Probabilities P (x), x = 1, 2, ... Days of the Successive Rainy Days*

Station	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
Alex/polis	656	190	80	37	18	9	5	3	2	1	1			
Heraklion	782	174	40											
Thessaloniki	617	212	92	43	21	10	5	2						
Kavala	617	231	90	36	14	6	2	1						
Kythira	895	92	11											
Kymi	717	216	53	12										
Limnos	739	211	42	7										
Milos	806	157	30											
Mytilini	737	208	44	8										
Naxos	704	221	56	13										
Rhodos	189	52	15	4										
Samos	854	110	25	6										
Skyros	817	135	34	10	3									
Chania	775	181	36											

Table 2c. *Autumn: Polya's Probabilities P (x), x = 1, 2 ... Days of the Successive Rainy Days*

Station	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
Alex/polis	443	254	140	76	41	22	12	6	3	2	1			
Heraklion	430	255	142	78	42	23	12	6	3					
Thessaloniki	480	234	126	70	39	22	13	7	4	2	1	1		
Kavala	283	130	55	22	9	3	1							
Kythira	461	234	129	73	42	24	14	8	5	3	2			
Kymi	490	242	126	67	36	19	10	5	3	2	1			
Limnos	476	256	131	66	33	16	8	4	2	1	1			
Milos	461	267	138	68	33	16	8	4	2					
Mytilini	429	274	148	75	37	18	9	4	2	1				
Naxos	520	234	117	60	32	17	9	5	3					
Rhodos	266	147	78	40	20	10	5	3	1					
Samos	444	277	145	72	34	16	7	3	1					
Skyros	505	257	124	59	28	13	6	3						
Chania	440	233	133	78	46	27	16	10	6	4	2	1	1	

Table 2d. *Winter: Polya's Probabilities P (x), x = 1, 2 ... Days of the Successive Rainy Days*

Station	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}
Alex/polis	382	227	141	89	57	37	24	15	10	6	4	3	2	1	1
Heraklion	378	216	137	90	60	40	27	18	12	8	5	3	2	1	1
Thessaloniki	407	242	144	85	50	30	18	11	7	4	2	1			
Kavala	274	151	78	39	19	9	4	2	1						
Kythira	369	217	139	91	61	41	28	19	13	9	6	4	3	2	1
Kymi	469	205	118	73	47	31	21	14	9	6	4	3	2	1	1
Limnos	385	228	141	89	56	36	23	15	10	6	4	3	2		
Milos	409	226	136	84	53	34	22	14	9	6	4	3	2	1	
Mytilini	344	234	153	98	63	40	25	16	10	6	4	3	2	1	1
Naxos	350	253	160	97	57	33	19	11	6	3	2	1	1		
Rhodos	208	135	91	62	43	30	21	15	11	8	6	4	3	2	1
Samos	309	227	156	105	70	46	30	20	13	8	5	3	2	1	1
Skyros	402	231	140	86	53	33	21	13	8	5	3	2	1	1	
Chania	338	204	132	91	64	45	32	23	17	12	9	6	4	3	2

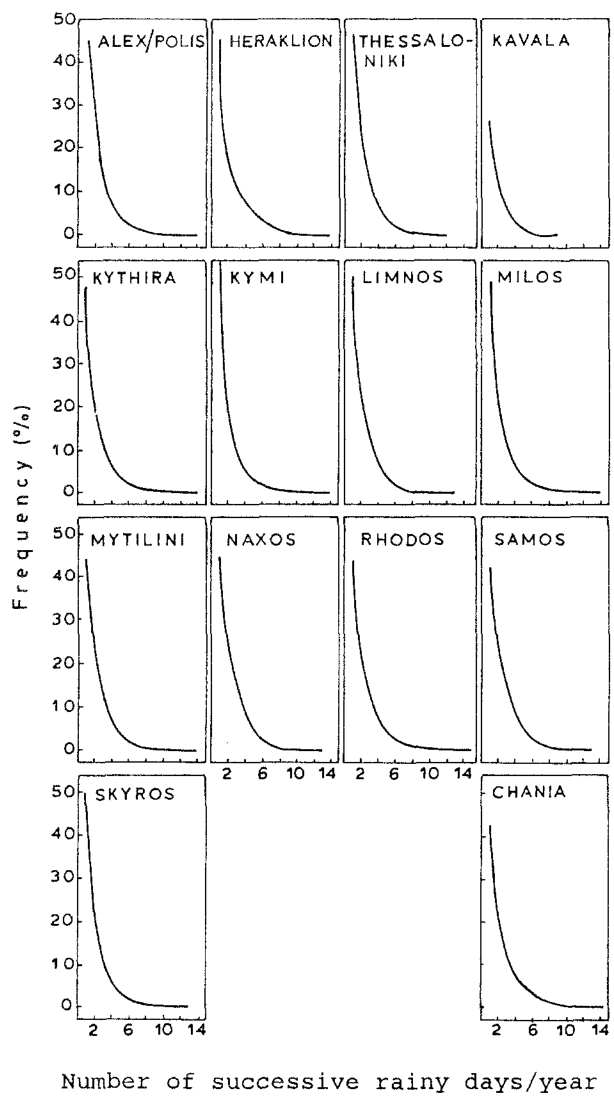

Fig. 2. Polya's distribution curves of the successive rainy days

It was lastly calculated that for the annual total of consecutive rainy days, the series greater than 12 is almost totally improbable as where the probability of a number of consecutive rainy days greater than seven is less than 0.1 (Fig. 2). The probability of individual rainy days is lying generally between 0.27 and 0.54. In conclusion, long series of consecutive rainy days are not often observed, a phenomenon that is also recorded in Athens (Katsoulis et al., 1976).

5. Statistical Verification

To determine whether the Polya distribution is satisfactorily fitted to the observed values, the subordinate deviations of the theoretically calculated values from the real values were taken into account and the x^2 fitting test was applied (Arléry et al., 1973; Spiegel, 1972).

Thus, for each of the stations and for each season, the values of x^2-test are estimated. The conclusions from these values is that the Polya distribution is very satisfactorily fitted to the real values for all the stations (winter data).

During the summer the distribution was very satisfactorily fitted at the data of island stations, but for the stations of Alexandroupoli, Kavala and Thessaloniki the fit was poorer.

For the autumn season the fit is very satisfactory, except for the stations of Kythira, Milos and Skyros where a higher number of 3, 4 and 5 consecutive days of rain are observed resulting in a larger discrepancy between actual and theoretical values.

Finally during spring there is no satisfactory fit to the actual values due to the fact that the number of 3 and 4 consecutive rainy days often appears high, hence deviating appreaciably from the theoretical values.

5. Conclusions

From a statistical analysis of the distribution of rainy days and the frequency of occurrence of consecutive rainy days in the Aegean Sea area we were able to conclude the following:

a. The number of rainy days was higher during spring than during autumn; the lowest number of rainy days for both periods was recorded in the Cyclades Islands area.

b. During summer there were hardly any rainy days at all in the central and southern Aegean area. On the contrary, in the northern Aegean the number of rainy-days is often up to 15 days, due to synoptic systems crossing exclusively this area.

c. The greatest number of rainy days was observed during the winter season both for the northern as well as the southern Aegean.

d. The annual number of rainy days was lowest in the area of the Cyclades Islands and the area of north-eastern Greece, increasing as it moves away from these areas (Fig. 1).

e. The probability of occurrence of isolated rainy days for all seasons, except summer, varies from 0.20 to 0.59, while during the summer this probability is generally greater than 0.62.

f. Long series of consecutive rainy days have a greater occurrence probability during the winter season, followed by the spring and autumn and are highly improbable during the summer.

g. The x^2 statistical control test showed that except for the spring season, the Polya distribution fitted satisfactorily with the recorded values of the number of consecutive rainy days at all stations.

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