A Search for Rainfall Calendaricities

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ABSTRACT

A statistical analysis is applied to 63 years of daily United States precipitation data to determine whether a tendency exists for rainfall anomalies to occur near specific calendar dates. The results clearly indicate no tendency for rainfall anomalies near specific calendar dates.

1. Introduction

Bowen's intriguing ideas (Bowen, 1956, 1957) have caused many meteorologists to re-examine the question of atmospheric calendaricities.[2] Recently Brier (1961a) applied a non-parametric statistical test to the analysis of three sets of rainfall data and reported evidence of calendaricities among the three time series. Some disagreement on the interpretation of the results was aired by the authors (Shapiro and Macdonald, 1961; Brier, 1961b) in an exchange of correspondence. The principal point raised by Shapiro and Macdonald was that when all three time series were compared simultaneously, Brier's results showed a weak tendency for the association of non-anomalies rather than (as Brier claimed) a strong tendency for precipitation anomalies to occur on specific calendar dates. However, Brier re-analyzed the three time series, delineating minor as well as major anomalies. In this re-analysis, a comparison of pairs of time series showed a positive association among the anomalies in two of the three comparisons but a somewhat negative association in the third. The third comparison involved the two time series with the least amount of data and thus subject to greater sampling fluctuations. Since the issues were not resolved by the correspondence, the authors decided to conduct a joint experiment designed to test the reality of rainfall calendaricities. It is the purpose of this paper to report the design and results of the experiment.

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[2] In meteorological terminology, the term "singularities" has been used to describe an anomaly that tends to occur on fixed calendar dates. We feel this term is a poor one because of its possible confusion with mathematical usage and we suggest the term "calendaricity" in its stead.

2. Data and analysis

The basic data in this study consists of 63 years of daily United States precipitation data (1 January 1900 through 31 December 1962). Seven years of these data (1952–1958) were used in the earlier study (Brier, 1961a) in which a comparison was made with the "world-wide" rainfall averages for each day of the year for the period 1880–1950 as published by Bowen (1956, 1957). This study did not use any "world-wide" data since it was not practicable to compute a daily rainfall index for each day of a series sufficiently long for an adequate statistical analysis. The United States precipitation index used here was based on the total amount of precipitation observed each calendar day at approximately 100 stations more or less evenly distributed over the country. The index was normalized to account for any changes in the number of reporting stations.

The method of analysis used here for examining the data for calendaricities is a slight variation of the commonly used superposed epoch method in which the data are arranged in a Buys-Ballot table. The usual method is to put all the events for 1 January in the first column, all those for 2 January in the second column, etc., and then obtain the means for each column. In this study each day was given an index number ranging between 0 and 1 according to its position in the astronomical year of 365.2422 days. In respect to this period, each calendar day advances by $1/365.2422=0.00274$ part of a cycle. 1 January 1900 was given the index number 0.00000, 2 January 1900 was given the index 0.00274, 3 January the index 0.00548, etc. After a year the index number becomes greater than unity but the integer was dropped since we are concerned only with the position of the day with respect to the annual cycle. This pro-

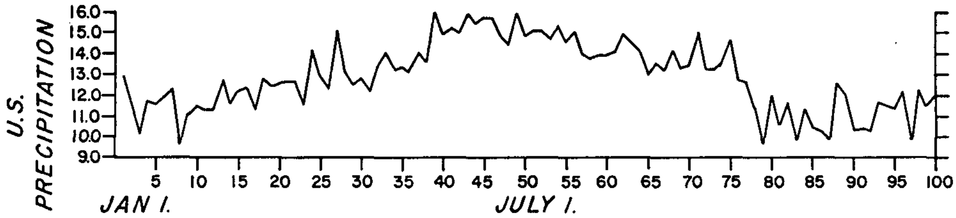

FIG. 1. Original U. S. precipitation data summarized for the annual period divided into 100 classes.

TABLE 1. Statistics computed for the annual period divided into 100 classes.

Class	Mean	s	t	Class	Mean	s	t
1	0.080	0.602	2.01	51	0.003	0.368	0.13
2	−0.014	0.619	−0.35	52	0.006	0.360	0.27
3	−0.088	0.563	−2.37	53	−0.001	0.307	−0.05
4	0.012	0.596	0.30	54	0.034	0.326	1.57
5	0.022	0.555	0.59	55	−0.002	0.340	−0.10
6	0.024	0.638	0.57	56	0.024	0.345	1.06
7	0.061	0.593	1.57	57	−0.019	0.344	−0.82
8	−0.084	0.515	−2.48	58	−0.032	0.361	−1.36
9	−0.044	0.587	−1.13	59	−0.017	0.335	−0.76
10	0.003	0.592	0.08	60	−0.017	0.344	−0.75
11	−0.001	0.576	−0.03	61	0.006	0.322	0.27
12	0.007	0.541	0.18	62	0.060	0.324	2.80
13	0.012	0.646	0.29	63	0.041	0.324	1.93
14	−0.024	0.596	−0.62	64	0.014	0.359	0.59
15	0.036	0.569	0.96	65	−0.042	0.365	−1.74
16	0.008	0.605	0.20	66	−0.037	0.441	−1.29
17	−0.055	0.588	−1.41	67	−0.024	0.413	−0.87
18	0.041	0.579	1.09	68	0.020	0.419	0.72
19	−0.007	0.620	−0.18	69	−0.016	0.408	−0.60
20	0.005	0.593	0.14	70	0.001	0.426	0.04
21	−0.011	0.618	−0.26	71	0.076	0.476	2.43
22	0.004	0.586	0.10	72	−0.003	0.448	−0.09
23	−0.077	0.552	−2.12	73	−0.016	0.499	−0.50
24	0.085	0.573	2.27	74	0.029	0.517	0.86
25	−0.025	0.613	−0.61	75	0.090	0.554	2.46
26	−0.055	0.589	−1.41	76	−0.010	0.536	−0.28
27	0.125	0.554	3.43	77	0.019	0.559	0.51
28	0.024	0.553	0.65	78	−0.001	0.498	−0.03
29	−0.045	0.552	−1.24	79	−0.111	0.495	−3.40
30	−0.047	0.580	−1.23	80	0.016	0.597	0.41
31	−0.072	0.532	−2.04	81	−0.057	0.596	−1.45
32	0.032	0.446	1.09	82	0.018	0.617	0.45
33	0.058	0.457	1.94	83	−0.069	0.561	−1.86
34	−0.013	0.492	−0.40	84	0.041	0.563	1.10
35	−0.031	0.470	−1.02	85	−0.006	0.593	−0.15
36	−0.032	0.423	−1.14	86	−0.070	0.594	−1.79
37	−0.015	0.454	−0.50	87	−0.047	0.567	−1.27
38	−0.039	0.415	−1.43	88	0.098	0.608	2.45
39	0.069	0.435	2.40	89	0.052	0.618	1.27
40	0.019	0.370	0.79	90	−0.044	0.582	−1.15
41	0.024	0.379	0.95	91	−0.026	0.557	−0.72
42	−0.005	0.386	−0.20	92	−0.077	0.602	−1.94
43	0.032	0.393	1.24	93	0.032	0.622	0.78
44	0.013	0.362	0.55	94	0.031	0.578	0.82
45	0.027	0.359	1.14	95	0.018	0.585	0.46
46	0.021	0.384	0.84	96	0.054	0.604	1.37
47	−0.035	0.391	−1.36	97	−0.088	0.569	−2.34
48	−0.036	0.348	−1.57	98	0.022	0.632	0.53
49	0.053	0.342	2.35	99	−0.015	0.632	−0.37
50	−0.026	0.391	−1.02	100	0.047	0.620	1.16

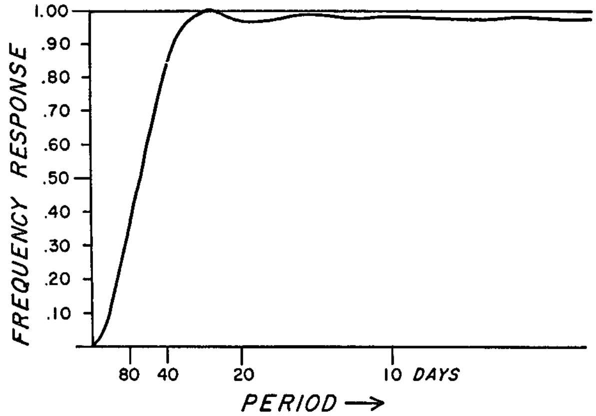

FIG. 2. Frequency response of high pass filter used on precipitation data.

cedure has certain computational and statistical advantages, especially when high-speed electronic computers are used.

After each day was given an index number according to this scheme, all days were sorted into 100 classes. The first class included all days with an index number from 0.00000 to 0.00999. The second class included those days with an index number 0.01000 to 0.01999, etc. This procedure divided the year into 100 parts with the first 3 or 4 days of January falling in class 1, the 4th to 7th day of January falling in the second class, etc. The results of summarizing the original precipitation data in this way are shown in Fig. 1. The seasonal variation is pronounced and it was necessary to remove it before continuing with the remainder of the experiment. Since the frequency distribution of the original daily precipitation data was highly skewed, the data were normalized by means of the well-known cube-root transformation (see Howell, 1960). The seasonal trend was removed by means of a high pass filter which eliminated essentially all periods longer than about 60 days. The frequency response of the filter used is shown in Fig. 2.

The transformed and filtered series was then summarized in the same fashion as that shown in Fig. 1 according to the annual period of 365.2422 days divided into 100 classes. These results are shown in Fig. 3. The peaks and troughs appear in the same locations as in Fig. 1 but the seasonal trend has been removed and the mean of the entire series is now zero. To test whether a particular class mean departs significantly from zero, Student's t was computed for each of the 100 classes by

$$t=\bar{y}\div(S/n^{\frac{1}{2}}),$$

where $\bar{y}=\sum y/n$, $S^2=\sum(y-\bar{y})^2/n-1$, y is the transformed and filtered precipitation data and n is the number of individual days falling into the class. Table 1 shows the results of these computations. It is noticed that 15 values of t exceed 2.00 in absolute value while one would expect only 5 of them to exceed this value by chance. Thus, there is evidence of non-randomness in the data, but its source is not immediately apparent. It would be premature to conclude from this non-randomness that there are a number of calendaricities in the data. If this non-randomness is produced by calendaricities, similar analyses based on periods different from one year should show fewer significant departures.

Table 2 summarizes the results obtained from using a number of "control" periods varying from 361.2422 days up to 369.2422 days. Table 2 also shows the periods

TABLE 2. Number of cases for $t\geq 2.00$ for various trial periods

Period	Cases for $t\geq 2.00$
361.2422	14
361.8422	15
362.4422	8
363.0422	8
363.6422	10
364.2422	8
364.2922	12
364.3422	13
364.3922	14
364.4422	12
364.4922	9
364.5422	6
364.5922	7
364.6422	10
364.6922	10
364.7422	12
364.7922	12
364.8422	9
364.8922	12
364.9422	12
364.9922	9
365.0422	8
365.0922	8
365.1422	12
365.1922	10
365.2422	15
365.2564	13
365.2596	12
365.2922	11
365.3422	12
365.3922	12
365.4422	13
365.4922	10
365.5422	14
365.5922	17
365.6422	12
365.6922	16
365.7422	13
365.7922	11
365.8422	13
365.8922	14
365.9422	18
365.9922	12
366.0422	11
366.0922	11
366.1422	9
366.1922	12
366.2422	9
366.8422	16
367.3650	16
367.4422	9
368.0422	16
368.6422	14
368.8414	13
369.1322	17
369.2422	16

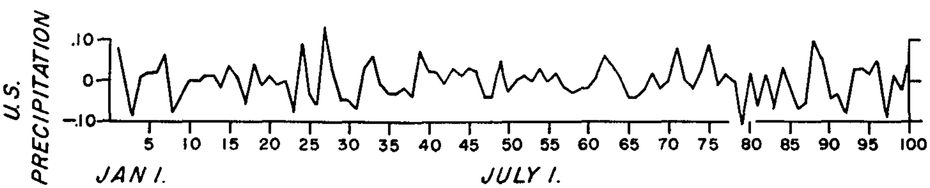

FIG. 3. Mean values for transformed and filtered data according to the annual period divided into 100 classes.

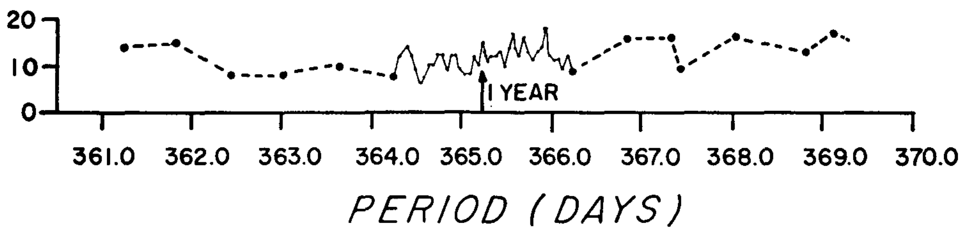

FIG. 4. Number of cases for which Student's $t \geq 2.00$ for various periods near the annual period.

that were used and the number of cases for $t \geq 2.00$. The same data are shown in graphical form in Fig. 4. Although there is a minor maximum at a period of 365.2422 days, numerous other peaks are higher. It is clear that there is nothing particularly unique about the period of 365.2422 days, for many other periods having no particular physical significance produce equivalent results.

3. Discussion

These results give no support to the calendaricity hypothesis, at least as far as the United States precipitation is concerned. There is a non-randomness indicated in Table 1 and Table 2 which requires an explanation. An examination was made to see whether persistence in original precipitation data might be the cause of the nonrandomness. The 15 classes with $t \geq 2.00$ were chosen from Table 1 and the t values were recomputed, using only one observation out of each year in order to insure independence. The average numerical value of t was reduced about 30 per cent and the number of cases with $t \geq 2.00$ became less than 5. Thus there is no evidence of non-randomness in these data.

Hannan (1962) has suggested that the association reported by Brier (1961a), in the paper which served as the impetus for this study, was due to the presence of a sharp peak in the precipitation spectra at a frequency near 18 cycles per year. The data used in the present study are suitable for an examination of this suggestion by Hannan and a report dealing with it is now in preparation. However, from the results presented here, it is clear that the United States precipitation data show no evidence in support of the calendaricity hypothesis.

REFERENCES

Bowen, E. G., 1956: A relation between meteor showers and the rainfall of November and December. *Tellus*, 8, 394–402.

——, 1957: Relation between meteor showers and the rainfall of August, September and October. *Austral. J. Phys.*, **10**, 402–417.

Brier, G. W., 1961a: A test of the reality of rainfall singularities. *J. Meteor.*, 18, 242–246.

——, 1961b: Reply. *J. Meteor.*, 18, 705–707.

Hannan, E. J., 1962: Rainfall singularities. *J. appl. Meteor.*, 1, 426–429.

Howell, W. E., 1960: A comparison between two transformations used in normalizing meteorological data. *J. Meteor.*, 17, 684.

Shapiro, R., and N. J. Macdonald, 1961: A test of the reality of rainfall singularities. *J. Meteor.*, 18, 704–705.