A COMPARATIVE STUDY OF OKLAHOMA'S PRECIPITATION REGIME FOR TWO EXTENDED TIME PERIODS BY USE OF EIGENVECTORS

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Although the precipitation regimes for Oklahoma during 1910 to 1930 and 1931 to 1952 were quite similar, some discrepancies were noted in the graphed eigenvectors. First, there was relatively less precipitation during the late winter season from 1910 to 1930 with the exception of the Panhandle. This was especially observed from the second eigenvectors, and was more significant for the eastern and southeastern part of the state. The second observed difference was that the 1931-1952 summers were relatively drier with an earlier secondary precipitation maximum. However, this secondary maximum was shorter in duration than in 1910-1930.

INTRODUCTION

From an inspection of mean monthly isohyetal maps of the state of Oklahoma, pronounced temporal and spatial variabilities reflect a rather complex precipitation regime. For example, mean annual precipitation varies from less than 16 inches in the Panhandle to over 56 inches in the southeastern part of the state. Mean monthly amounts range from less than 0.5 inches in the Panhandle during the month of January to over 6 inches during May in the southeast (1). An increased understanding of complex precipitation regimes such as that of Oklahoma may be furnished by use of various mathematical techniques as a type of probe into the basic precipitation data matrix.

One means of gaining insight into the precipitation climatology of Oklahoma is by examining the *relative* amounts and corresponding spatial patterns of mean monthly precipitation. The usefulness of this technique was demonstrated by Skaggs while investigating the precipitation regime of Minnesota (2). This kind of analysis may be fruitful in revealing masked information concerning the types and intensities of climatic controls operating in this area of the United States. Furthermore, if physical processes can be interpreted by examining relative precipitation amounts and their spatial patterns, changes in precipitation processes between two time periods may be suggested.

The purpose of this paper is to compare precipitation regimes of Oklahoma for two different time periods. This comparison will be accomplished by examining graphed eigenvectors and mapped multipliers. In light of this analysis, changes in the relative amounts of mean monthly precipitation for Oklahoma will be discerned. A second objective is to suggest in a summary fashion the physical processes which may be responsible for the differences discerned for the two analyzed time periods.

For this study data were collected from 63 weather stations over the state of Oklahoma for two chosen time periods (see Fig. 1). The choice of stations was dictated by the availability of mean monthly precipitation data for the years 1910 to 1930 and 1931 to 1952. At least twenty years of records were used in calculation of mean monthly precipitation values with three exceptions: Tuskahoma, Hugo, and Idabel. These three stations with fourteen or more years of records were used in view of the paucity of stations in the southeastern part of the state. The 1910-1930 data were obtained from the *U.S. Weather Bureau Climatic Summary of the United States, 1930*

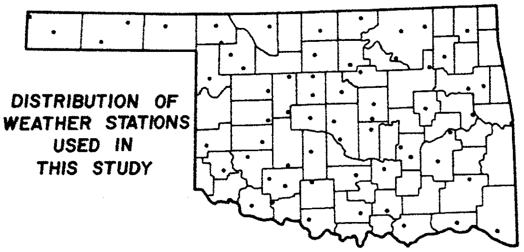

FIGURE 1. Distribution of weather stations used in this study.

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(3) and the 1931-1952 data were chosen from the *Climatic Summary of the United States, Supplement for 1931 Through 1952* (4).

INTERPRETATION AND COMPUTATION PROCEDURE OF EIGENVECTORS AND MULTIPLIERS

Relative mean monthly precipitation values may be obtained from calculated eigenvectors. According to Stidd, these eigenvectors are orthogonal functions which can be arranged in descending magnitude; the first one represents the overall "average" precipitation pattern (5). Successive eigenvectors indicate excursions from the predominant precipitation pattern. Multipliers calculated for each weather station should reflect spatial significance of their corresponding eigenvectors; i.e., the larger the multiplier, the more important is that particular set of eigenvectors in describing the precipitation pattern. These multipliers were plotted for each station for their corresponding eigenvectors, and isarithms drawn at one-unit intervals (see Figs. 3, 4, 5, 7, 8, and 9).

From mean monthly precipitation data for the 63 weather stations selected in this study, a 12 by 63 matrix was prepared and designated A. The following computations were performed on the IBM 360 computer:

A. A subroutine was used to transpose the original data matrix A to A';
B. Data matrix A was multiplied by A' to form a 12 by 12 square symmetrical matrix AA';

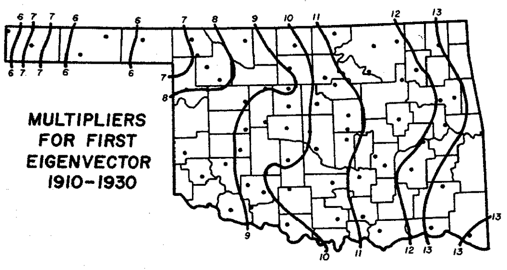

FIGURE 3. Multipliers for first eigenvector, 1910-1930.

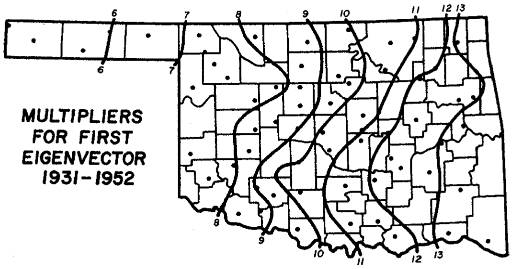

FIGURE 7. Multipliers for first eigenvector, 1931-1952.

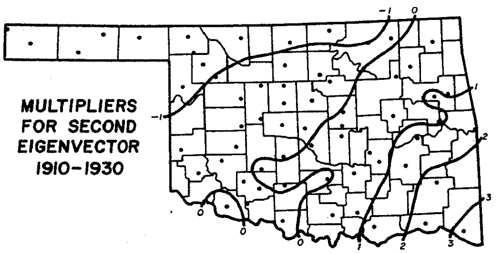

FIGURE 4. Multipliers for second eigenvector, 1910-1930.

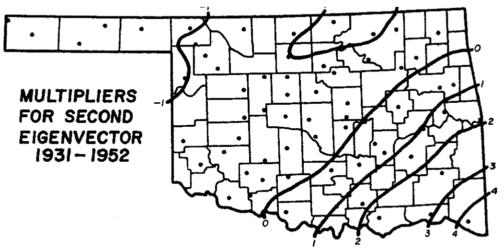

FIGURE 8. Multipliers for second eigenvector, 1931-1952.

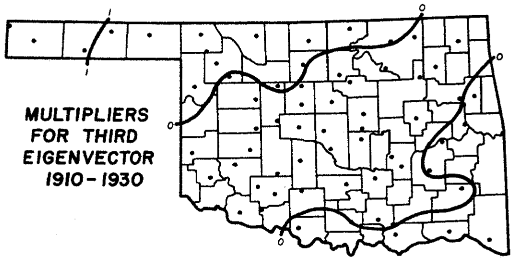

FIGURE 5. Multipliers for third eigenvector, 1910-1930.

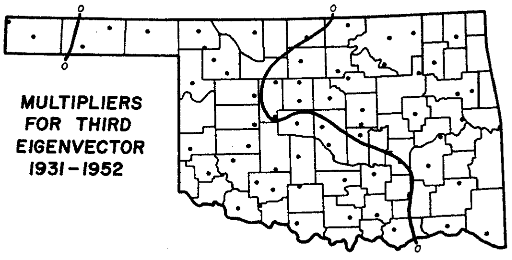

FIGURE 9. Multipliers for third eigenvector, 1931-1952.

C. A subroutine was used to compute eigenvalues, λ_i (or characteristic roots), from the solution of determinant $(AA' - I) = 0$, where I is the identity matrix;

D. With known scalar eigenvalues, twelve eigenvectors, X_j, were computed from the following equation: $AA'(X_j) = \lambda_j (X_j)$;

E. The eigenvectors were then normalized to obtain a matrix E of eigenvectors from $E_j = X_j /(X_j^2)^{½}$;

F. Percentages of each eigenvalue, λ_i , as a ratio to the sum of all eigenvalues, $\Sigma\lambda_i$, were computed to indicate the amount of "variance" explained by each eigenvalue;

G. Finally, multipliers were computed. This matrix equation is $A = EM$ where M is the 12 by 63 matrix of multipliers, E is the matrix of eigenvectors, and A is the original precipitation matrix (6).

DISCUSSION

Although two time periods were investigated in this study, many similarities naturally exist between the two sets of eigenvectors and multipliers. In this section, a general discussion of common features of the first three eigenvectors and multipliers for both time periods is presented.

About 98% of the annual precipitation variation is accounted by the first eigenvector for each of the two time periods (see Table 1). From the first eigenvector, the most outstanding feature is a rapid increase in values beginning in February and March (see Figs. 2 and 6). The highest value is reached in May. June and July reveal a relatively sharp decrease in values followed by a gradual increase in the slope from the months of August to September and October. Finally, during the latter part of fall and all winter months, lower eigenvector values are evidenced. This general description of the two graphs is how one usually characterizes the precipitation

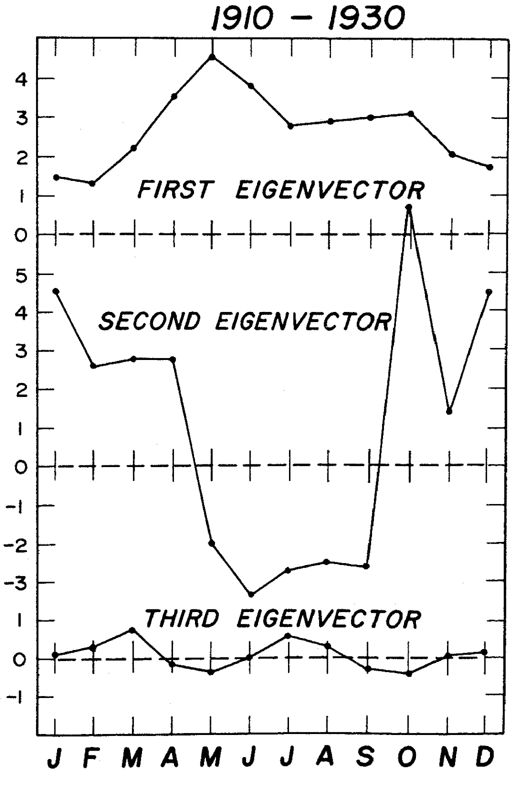

FIGURE 2. First three eigenvectors by months, 1910-1930.

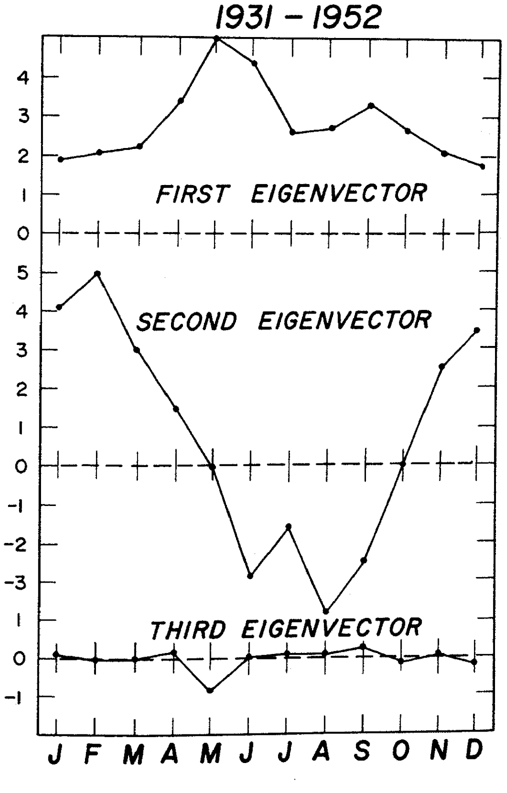

FIGURE 6. First three eigenvectors by months, 1931-1952.

Table 1. *Percentage of annual precipitation variation represented by the twelve calculated sets of eigenvectors.*

1910-1930					
98.06 (1st)	0.99 (2nd)	0.30 (3rd)	0.16 (4th)	0.15 (5th)	0.09 (6th)
0.08 (7th)	0.06 (8th)	0.04 (9th)	0.03 (10th)	0.02 (11th)	0.01 (12th)
1931-1952					
97.79 (1st)	1.18 (2nd)	0.33 (3rd)	0.25 (4th)	0.13 (5th)	0.11 (6th)
0.07 (7th)	0.06 (8th)	0.04 (9th)	0.03 (10th)	0.02 (11th)	0.01 (12th)

regime of Oklahoma, i.e., a wet spring with a dry summer and winter.

However, multipliers for the first eigenvectors corresponding to both time periods generally increase from the western part of Oklahoma to the east. In both cases values range from less than 6 to over 13. This indicates that the eastern part of the state contributes substantially more in explaining the graphed eigenvectors than the western part of the state (see Figs. 3 and 7).

The second set of eigenvectors adds only about 1% in accounting for the variance of the precipitation regimes. However, the variation of magnitudes plotted, both positive and negative, are large (see Figs. 2 and 6). These major excursions from the zero reference line could reveal masked precipitation processes, even though minor in nature, operating over the state throughout the year.

The year begins with high eigenvector values for both time periods. Evidently, with highest multipliers in the southeastern portion of the state, relatively more winter precipitation is received here than would be suspected after examining the first graphed eigenvector. The same conclusion may be interpreted for the latter part of the year, from October through December. Because multiplier values in the Panhandle have a negative sign, one should suspect an inverse relationship; i.e., relatively smaller amounts of precipitation received for these months compared to the average pattern for the state.

From May or June through September, large negative eigenvector values are observed. Again, one might interpret this as representing relatively lesser amounts of precipitation received during the summer season in the southeastern part of the state as compared with the overall average. A slight inverse of this must exist in the Panhandle.

As one inspects the third set of graphed eigenvectors, little variation from the zero reference line is depicted. With only 0.30% and 0.33% of annual precipitation variation represented for the early and late time periods, respectively, little information can be drawn from these graphs. Additionally, the multipliers for both time periods are exceedingly small.

COMPARISON OF VARIATIONS IN PRECIPITATION REGIMES FOR THE TWO TIME PERIODS.

The following discussion will concentrate on major graphed eigenvector differences between the two time periods. Because of the small magnitudes calculated for the third eigenvectors and their relatively insignificant representation of Oklahoma's total precipitation regime, further analysis of these will not be attempted.

First Eigenvectors

The most obvious difference between the two time periods for the first eigenvector is during the summer and autumn seasons. The 1931-1952 time period shows a much clearer secondary maximum due to the depressed July and August values. Furthermore, the secondary maximum occurs in September. For the 1910-1930 time period, the secondary maximum is delayed to October and there is no clear precipitation depression during the summer months. Consequently, a more pronounced dry period during the summer with notable autumn relief is apparent during the 1931-1952 time period. This is not evident on the 1910-1930 graph.

A marked difference between the two time periods is discernible in February. This month represents the lowest annual eigenvector value for the 1910-1930 data. Even though the February value for the 1931-1952 time period is low, a depression of the graphed values does not appear.

This leaves the impression that the transition to the precipitation maximum, which occurs during the spring season, generally started earlier during the 1910-1930 period.

The multiplier values for both time periods are quite similar. Values range from 6 in the Panhandle to 13 in the eastern part of the state, as already noted. Therefore, this analysis should be weighted towards the eastern part of the state.

Second Eigenvectors

One of the most conspicuous differences between the second eigenvectors is observed for February. Greater positive values were calculated for the 1931-1952 time period. Even though the second eigenvector only accounts for about 1% of the annual precipitation variation, the difference is pronounced. The February value is larger than for any other month. According to the distribution of multipliers, this is particularly true in the southeastern part of the state. When the first and second eigenvectors are viewed as a composite, considerably more precipitation was observed in February during the 1931-1952 time period.

Another conspicuous difference between the two time periods for the second eigenvector is depicted for the month of October. A greater magnitude is portrayed on the 1910-1930 graph. This indicates that some process contributed substantially to increased precipitation during October, 1910-1930. The multipliers indicate that this was important in the southeastern portion of Oklahoma.

PROSPECTS FOR FURTHER RESEARCH

Once major differences in relative precipitation values, both apparent and masked, are identified, their origin should be sought. Some of the processes which may be significant in terms of the differences outlined for the two time periods are:

1. Intensity of cyclonic activity with concomitant movement of moist Gulf air over *Central* and *Eastern* Oklahoma during the late winter season;
2. Anticyclonic development with its associated tongue of dry air, particularly in the eastern half of the state during the summer months;
3. Replacement of dry southwestern air flow by moderate Pacific air during the autumn season, and;
4. The time of concurrence of the wintertime circulation pattern characterized by drier air.

If the above climatic controls are scrutinied for the two time periods, differences in their intensity and time of occurrence should furnish a more complete picture as to the reasons for the variations described.

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