

Precipitation Features of Climate for Selected Locations in Missouri

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Preface

Before reviewing this report, take a moment to formulate your concept of annual amounts of precipitation that characterize the climate of a locality with which you are familiar. Then open the report to Figure 2a on page 13 and assemble your thinking of what the graphical portrayal of a century of annual amounts of precipitation tell you about the climate of Columbia, Mo.

Understanding characteristics of climate for a locality is a concept usually derived from remembered performances in the past but seldom set forth in the concrete form of their occurrences in closely related clusters of years.

There are configurations of various physical structures on the earth that resonate to the harmonics and subharmonics of a cyclic pacemaker within the overriding annual cycles of the earth-moon system as it orbits about the sun.

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Precipitation Features of Locations in Missouri

Climate of a locality is a property provided by its position on the surface of the earth. Climate of the midwestern Corn Belt of the United States, fluctuating at uncertain intervals between wet and dry conditions during the growing season, is identified as being subhumid. Precipitation and the lack thereof are elements of climate. Floods and droughts that accompany excessive and deficit amounts of effective precipitation, when they occur during the summer growing season, are dominant features of crop production for the region.

Features of precipitation for a locality are provided by a century or more of recorded data for amounts and frequencies of occurrences, each of daily, monthly, seasonal and yearly events. Amounts of precipitation for each of the respective events present an apparently chaotic distribution with respect to the passage of time (see Figure 2). A mean amount for a succession of annual events over an extended period of time identifies a central tendency about which measures of variability establish limits and working ranges for each that characterizes past performances of precipitation.

Efforts to identify causative agents of recurring climatic events from precipitation records have been pursued by numerous investigators with doubtful success. Likely occurrences of future droughts and floods are estimated from historical records, which in many localities seldom exist for more than a century.

Amounts, frequencies and absences of precipitation, as elements of climate for a locality, express the focus of numerous vectors of physical forces operating at a location. Precipitation, except at the instant of a stroke of lightning during a thunderstorm, as a record of physical processes, is identified with interruptible segments of time. Physical processes, whose properties as a function of time are characterized by a property mean that is identified with a mean position in time, are dynamic processes of which rates, frequencies, amplitudes and directions of changes are parameters.

Occasional occurrences of excessive and deficit amounts of precipitation, made evident in longer segments of passing time, have been attributed to various causes. These causes, which include sunspot cycles, positions of the orbiting moon and global, man-made changes in arable land, remain subject to speculations as to their possible causes. The purpose of this report is to present characteristic features of precipitation with respect to the years of their occurrences at various locations in Missouri. Those entering the 21st century may, from past records, anticipate possible developments in the future. Extension of evaluations to other locations would be informative.

Precipitation Features of Subhumid Regions

The atmosphere that surrounds the earth, unlike living organisms, is an inactive, pliable mass that responds to vector forces of various agencies. It is subject to both incoming and outgoing radiation with respect to the location of each position on the surface of the earth. Air temperatures, densities, humidities, wind directions and velocities, and evaporation and condensation of water as intermixed with occurrences and lack of occurrences of precipitation, are elements of the climate of a locality.

The atmosphere is penetrated, obstructed, deflected and channelized by sea and land masses that support it. These elements, combined with daily rotation of the earth in its annual orbit about the sun, contribute to the fundamental attributes of climate for each locality. Embedded within the climate of each locality are recognizable, repeating, quasi-periodic, changing amounts of precipitation of an undocumented nature that are common characteristics of various locations throughout a region.

Amounts and frequencies of precipitation in subhumid regions are consequences of interactions among sources of supply and avenues of disposition. That portion of the maritime water vapor remaining in the atmosphere, upon arrival at the arid and semiarid Western High Plains of the Missouri and Mississippi River Basins, provides a nucleus of precipitation that wets the soil and generates a sparse growth of xerophytic vegetation. Evapotranspiration from the arid land adds its component to enrich arriving vapor of the atmosphere that introduces the hydrological cycle to the Great Plains.

Hydrological cycles of land areas moving eastward from the High Plains accumulate recycled supplies of evapotranspired water vapor that support mesic and, with insufficient drainage, even hydrophobic types of vegetation. Rates of precipitation in excess of rates of consumption of water from land areas escape as runoff through the drainage system. Such losses from the Great Plains area are replenished at intervals by maritime water vapor moving in from southern and southwestern areas of the river basins.

Chaotic distributions of annual amounts of precipitation and deficits thereof, when treated as isolated, random events suggest that such events are not synchronized with the harmony of the system. In contrast, clusters of successive sequences of annual events occupy orderly arrays of changing, annual positions in time. Embedded within the magnitude of each position are measures of amounts and directions of change that are made more evident as recurring events over extended segments of time. Associated annual clusters of events are revealed with moving averages of sequential events.

Character of Measured Amounts of Precipitation

During each year of recorded amounts of precipitation, there are days when it rains and days when it doesn't. When it does rain, amounts of rain that fall are caught in a single, suitable rain gauge maintained at a location over an extended period of years. Amount of rain entering a gauge represents a sample of amounts falling on an ill-defined area of land surrounding the gauge. Amount of rain entering a gauge is determined by the intensity of rainfall during the period of time that it is raining. Amounts of annual precipitation for a particular season or year are subject to random fluctuations associated with samplings of spatial distributions of irregular amounts of falling precipitation during rain events. By any measure, the precise amount of water in a gauge is only an estimate of amounts of rain that have fallen. Conversely, days of empty gauges provide precise measures of a lack of precipitation.

Deficits in amounts of annual precipitation are deduced from differences between mean amounts for the period of record and lesser amounts that occur during clusters of dry seasons. Amounts of deficits are estimated more precisely as scheduled amounts of supplemental irrigation required when amounts and frequencies of precipitation are inadequate. As such, the timing of occurrences of droughts are more precise than are those of floods during consecutive successions of the respective events.

Amount of precipitation identified within a particular year in a chronological sequence of years, represents numerous vectors of physical forces brought to focus during that year. Daily rotation of the earth and the seasonal configuration of its orbit about the sun are incorporated in amount of annual precipitation tabulated with respect to each year in the flux of passing years. Amounts of measured annual precipitation vary year to year as consequences of errors in measurement, random atmospheric turbulence, segmented character of seasonal events, and regular and fortuitous occurrences of external and unexplained random events.

Frequencies of tabulated data that do not coincide with periodic frequencies of gravitational fields produced by an unidentified agent appear as random fluctuations for events tabulated on an annual scale. Initially, fluctuations in mean amounts of annual precipitation were effectively stabilized by closely related clusters of annual amounts of precipitation. A stable mean amount of annual precipitation was provided by a moving average of three consecutive annual successions each of eight chronological sequences of annual precipitation amounts. Eighteen of 24 amounts of annual precipitation remain unchanged for a 3-year succession.

Types of Information Derived from U.S. Weather Bureau Records

1. Individual storm periods.

Amounts, intensities, durations and frequencies are obtained by recording rain gauges at some locations. Such information is utilized in design of systems for disposal of storm runoff and to establish requirements for protecting land from flooding and loss of soil by sheet and gully erosion.

2. Annual amounts of daily, monthly, seasonal and yearly precipitation, including their average values.

Summarized data provide measures of variabilities, ranges and limits as contributions to knowledge of the climate of a locality. Average amounts of precipitation for each month over an extended period of years, when distributed to one inch incremental classes for each month, identify numbers of occurrences in each numerical class. Numbers of occurrences in each class for a span of years may be converted to frequencies of percentages whose incremental sums, distributed from zero to 100, portray graphically the frequency distribution of amounts of precipitation for each month of the year.

3. Mean amounts of annual precipitation for successive clusters of years during a period of record.

Character of precipitation, in whatever manner it is expressed, is a dynamic, irregular reoccurrence of a phenomenon that has persisted through the years. A feature to be considered is that of the annual performance of chronological sequences of clusters of closely related years. A cluster consisting of eight chronological sequences of annual amounts of precipitation, assembled into three consecutive annual successions (A, B and C, whose sum equals $(A+B+C)/(3 \times 8)$), identifies the mean amount of annual precipitation for the cluster.

Each year of a century or more of recorded data provides, in graphical form, a precise identification of mean annual amounts of precipitation. Mean annual rates and directions of change advance each year from positions occupied the previous year.

Mean amounts of annual precipitation (expressed alphabetically) that involve three annual successions each of eight annual sequences are identified with the mid-position between the fifth and sixth year of the 10-year span of time (a through j). Positions in time and their distributions throughout time identify regular features of change that have occurred during years of recorded precipitation.

Portraying Features of Information Incorporated in Yearly Distributed Amounts of Annual Precipitation

The chaotic distribution of amounts of annual precipitation over a century or more of recorded information are expressions of contributions by various agencies, some of whose contributions also vary as a function of time. Variations during the course of passing time are revealed in chronological sequences of sufficient number of years to encompass the range of variability of the system of record (Figure 2). After investigating averages of 3, 5 and 7 years, 8-year chronological sequences of data were used.

A chronological sequence of 8 years represents a cluster of closely related years. Random fluctuations about the mean are incorporated in the mean amount of precipitation at a position in time between the fourth and fifth year of the sequence. Changes in incremental amounts of precipitation from year to year in response to modifications of the environment by unidentified agencies are too small to isolate from values of adjacent means.

Three consecutive annual successions each of eight chronological sequences of amounts of annual precipitation

The initial annual succession of a three-member consecutive succession consists of an 8-year alphabetic chronological sequence (**a** to **h**) of amounts of annual precipitation of sum **A**.

The second succession, **b** to **i**, consists of annual amounts of precipitation of sum **B**. The sum of amounts of annual precipitation in succession **B** differs from that of **A** by the difference between the dropped year, **a**, and the added ninth year, **i**. Otherwise, 6 years of the two sequences are identical. They form a cluster of two closely related sequences of years.

The third succession consists of the sequence, **c** to **j**, of annual amounts of precipitation of sum **C**. Sum **C** differs from that of sum **B** by the difference between dropped year, **b**, and added 10th year, **j**. Otherwise, 6 years of each of the three successions remain identical. One-third of the sum of three consecutive successions of annual precipitation amounts identifies a 3-year mean of sums of three 8-year chronological sequences of annual precipitation amounts. Three successions, as clusters of closely related years, collectively possess a mean per sequence of $(A + B + C)/3$. They represent an annual mean of, $(A + B + C)/(3 \times 8)$, for the position between the fifth and sixth years of the 10-year span. Utilizing the fifth year as the initial mean, then each 24-member succession follows annually to the last 4 years of record, which consist of two rather than three successions of 16 amounts of annual precipitation.

Alphabetical Anatomy of a Dynamic Cluster of Years

Amounts of annual precipitation for a locality, tabulated in an alphabetical succession from first to last year of record, may be analyzed as clusters of consecutive annual successions of years. Each cluster consists of three consecutive annual successions. Each annual succession consists of eight chronological sequences of amounts of annual precipitation. Mean amount of annual precipitation for each cluster of years advances year by year as a consecutive succession with respect to the annual flux of passing time.

a	-	-
b	b	-
c	c	c
d	d	d
e	e	e
f	f	f
g	g	g
h	h	h
-	i	i
-	-	j
A	B	C

Mean amounts of precipitation (**P**) per year (**Y**) consist of the sum of three consecutive annual successions, **A+B+C**, each of eight chronological sequences, **a**, **b** and **c** through **h**, **i** and **j**, of annual amounts of precipitation from which, $P/Y = (A+B+C)/(3 \times 8)$. Time of the mean is located between fifth and sixth year of the ten year span of time from **a** to **j**.

Change Per Year in Mean Amount of Annual Precipitation by Clusters of Advancing Years

a	-	-	-
b	b	-	-
c	c	c	-
d	d	d	d
e	e	e	e
f	f	f	f
g	g	g	g
h	h	h	h
-	i	i	i
-	-	j	j
-	-	-	k
A	B	C	D

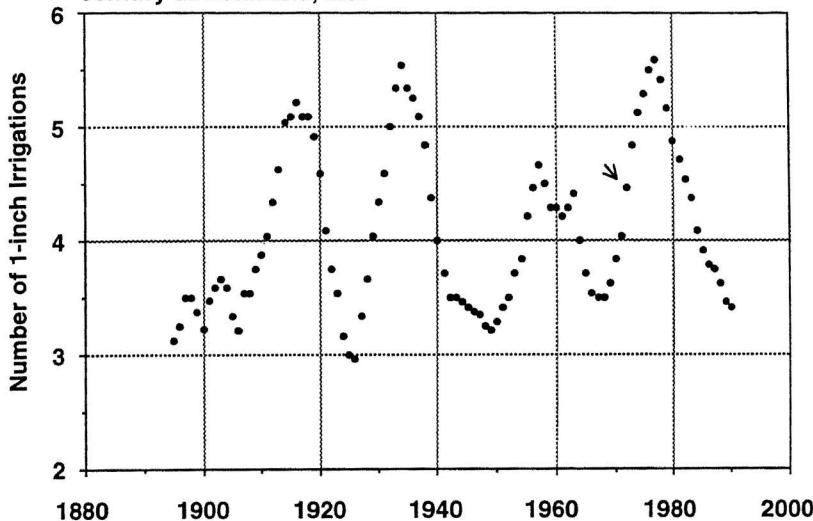
Cluster **BCD** that follows cluster **ABC** one year later share **BC**. The difference, $(D - A)/(3 \times 8)$, in mean amount of annual precipitation, as either an increase or decrease, is a rate of change per year, hence, a derivative of the process that it represents.

Drought and Flood Trends at Columbia, Mo.

Successions of yearly precipitation and of droughts and floods in summer growing seasons, like flights of water fowl, flocks of starlings, schools of fish, herds of cattle, swarms of bees, colonies of ants, and communities of people, so too, are they held together by some common bond.

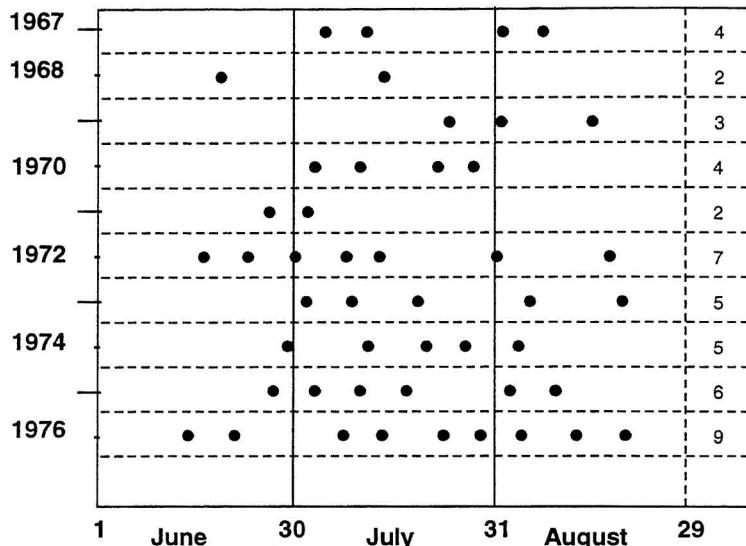
The four, 20-year swings between deficits in effective annual summer season precipitation for Central Missouri during the past century appear to be associated with the 20-year synodical, elliptical path of precession by the rotating moon. The orderly development of each annual deficit, its rate and direction of movement (see Figure 1) are more apparent as averaged numbers of annual irrigations that would have been required for each year during the period of inquiry. Values of each annual position identify a moving average of three consecutive successive 8-year sequences of annual irrigations, each of which may vary from zero to nine irrigations per year.

Figure 1. Average irrigation deficits for each year of a century at Columbia, Mo.



The arrow in Figure 1 identifies a sequence of eight seasons centered about 1972 with an average requirement of 4.46 inches of applied water per summer growing season.

Figure 1a. Dates and numbers of 1-inch irrigations required per year for corn in Columbia, Mo.



Distributions of applications during the 10 seasons that include an initial and final season were as follows:

Table 1. Computations of a 1972 annual moving average for three successive 8-year sequences of annual irrigations.

Year	A	B	C	Calculations:
1967	4	—	—	$32 + 34 + 41 = 107 \div 3 = 35.67$
1968	2	2	—	$35.67 \div 8 = 4.46 \text{ in./yr. at 72 yr.}$
1969	3	3	3	
1970	4	4	4	$\frac{A + B + C}{3} = \frac{(a + j) - (b + i)}{3}$
1971	2	2	2	
1972	7	7	7	
1973	5	5	5	$(4 + 9) - (2 + 6)$
1974	5	5	5	$35.67 = 34 + \frac{3}{3}$
1975	—	6	6	
1976	—	—	9	$35.67 = 34 + (5 \div 3)$
Sum	32	34	41	

Five Consecutive Annual Successions Each of Five Chronological Sequences of Annual Precipitation

A cluster of closely related amounts of annual precipitation, assembled about a mean position in time, is characterized by a mean amount of annual precipitation that waxes and wanes with the flux of passing time.

A cluster of 25 annual elements, distributed symmetrically about a mean element, e, consists of five consecutive annual successions each of five chronological sequences of annual amounts of precipitation assembled within a span of nine chronological sequences, a to i, inclusive. A 5x5 structure of the assembled cluster (expressed alphabetically) identifies the mean annual position in time with the fifth member, e, and the mean amount of annual precipitation for the cluster of 25 elements. with one twenty-fifth of the sum, A to E, of the assembled elements.

Computationally, an annual succession of amounts of annual precipitation is achieved by a 5-year moving average of five consecutive successions, each of five chronological sequences.

Table 2. A 5 x 5 cluster of annual precipitation amounts.

Five Successions Each of Five Chronologic Sequences				
a	-	-	-	-
b	b	-	-	-
c	c	c	-	-
d	d	d	d	-
e	e	e*	e	e
-	f	f	f	f
-	-	g	g	g
-	-	-	h	h
-	-	-	-	i
Succession Sum				
A	B	C	D	E

*Mean year of a cluster

$$\text{Mean Annual Amount of Precipitation per Cluster} = \\ (A+B+C+D+E) \div 25$$

Extension of Analytical Methods for Measured Deficits of Annual Summer Precipitation Amounts to Measured Amounts of Annual Precipitation

The precipitation records first utilized were those at the Columbia, Mo., location. Only the summer growing season of corn that extended from the first of June to the 29th day of August was considered. Cyclic swings in results, as presented in Figure 1, identified the experienced droughts of 1916, 1934, 1936, 1955 and 1980. Accompanying the droughts were the floods of the Missouri River. One in 1903 left marks of the river at Lexington, Mo. Floods of 1925 and 1926 left the north end of the new Lexington bridge in the center of the river. The flood of 1951 washed out the rail yards in Kansas City and broke all levies downriver. Floods of 1993 and 1995 are remembered by all. Both droughts and floods are well-documented by numbers of required irrigations.

The records of annual precipitation investigated first were those for Columbia. They were followed by analyses of those for Fulton and Mexico in adjacent counties. Records of precipitation for deep soils of Maryville, Mo., were examined in terms of irrigation frequencies, but will not be presented.

Questions Raised in Developing Figure 1

- What information will an analysis of yearly precipitation records reveal for Columbia?
- Will other locations reveal similar responses?
- What contribution to the yearly total does each of the four seasons of the year provide?
- Will results of early years, where available, agree with what happened during the present century?
- Is there evidence that associates precipitation features with influences of the moon?
- Are there recent developments of special interest?

Some answers to questions that were raised are presented in the section of the report that follows:

Amounts and Sequential Clusters of Annual Precipitation in Columbia, Mo., at Elevation of 784 feet

Chaotic distributions of annual precipitation characteristic of localities in the Central Upland Plains of Missouri preclude their utilization as predictive values of succeeding events with one exception: extreme deviations from the mean seldom occur in a succeeding year (see Figure 2). Mean annual precipitation for Columbia, Mo., for the 109 years of record, as presented in Fig. 2, is 38.4 inches. Of the 109 years, seven exceeded 50 inches per year and 14 provided less than 30 inches per year. Clusters of years with less than 30 inches of annual precipitation were usually associated with mid-summer droughts in Central Missouri.

Changes in year to year amounts of annual precipitation at Columbia, Mo., during the period of record are expressed in Figure 2a. Changes in amounts of annual precipitation above and below the long-term annual mean of 38.4 inches are obvious. Each annual amount of precipitation is a resultant of complex interacting and overlapping forces operating at various periodic scales. One such period approaches the 20-year elliptical orbit of precession by the rotating moon. Consequences of such an association are expressed by moving averages of five successions, each of five sequential amounts of annual precipitation (see Figure 2b).

Included in deviations of annual amounts of precipitation from the century mean are those contributed by the gravitational field of the precessing moon. This mean annual contribution to the total for the century of record is expressed in Figure 2c. Deviations of both operate with respect to the same average annual mean. Differences between the two, then, express the residual variability attributable to other vector forces of the process (see Figure 2d).

Persistent regularities of distributions about the average annual mean suggest feedback effects between positive and negative interactions. Neglecting the variability of seasonal distributions through the year and variations of supplies of stored water in soils, amounts of precipitation in excess of that utilized are lost as runoff. Thus, an unloaded atmosphere requires sufficient time to replenish its supply through evapotranspiration from the land and from extraneous sources of the prevailing winds. As a consequence of interactions and feedback, linear effects of modifications identified with lunar features cannot be isolated completely from residual effects that remain.

The expression of Figure 2b was reformatted as Figure 2e to accommodate comparisons between various localities whose data were presented in 3 x 8 configurations.

Figure 2. Random distributions of a century of annual precipitation at Columbia, Mo., and standard deviations from the mean of 38.4 ± 7.7 inches.

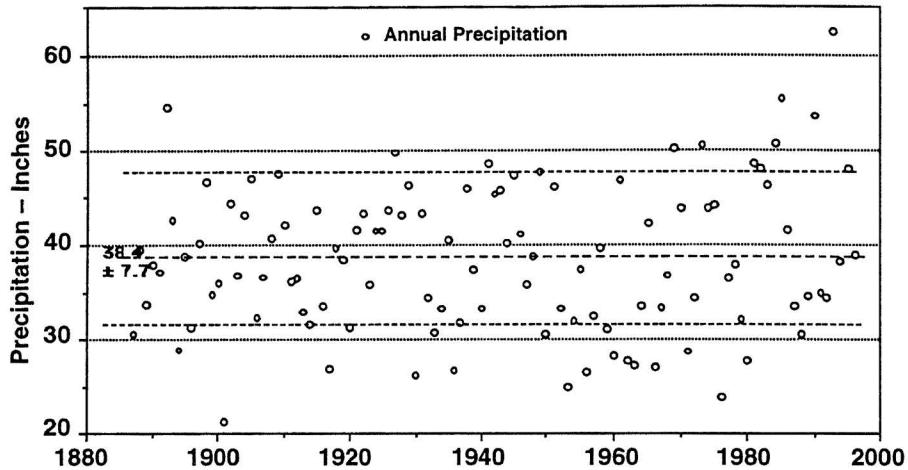


Figure 2a. A century of changes in annual precipitation at Columbia, Mo.

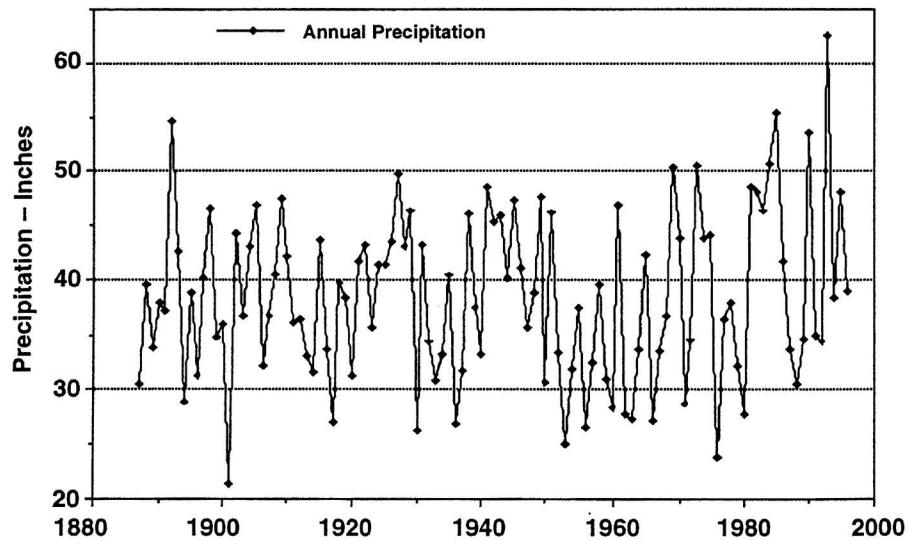


Figure 2b.* Five successions each of five chronological sequences of annual precipitation at Columbia, Mo.

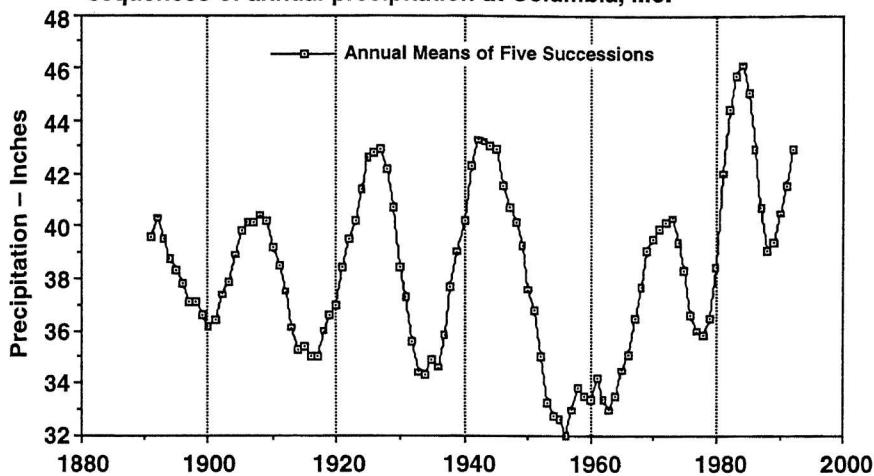
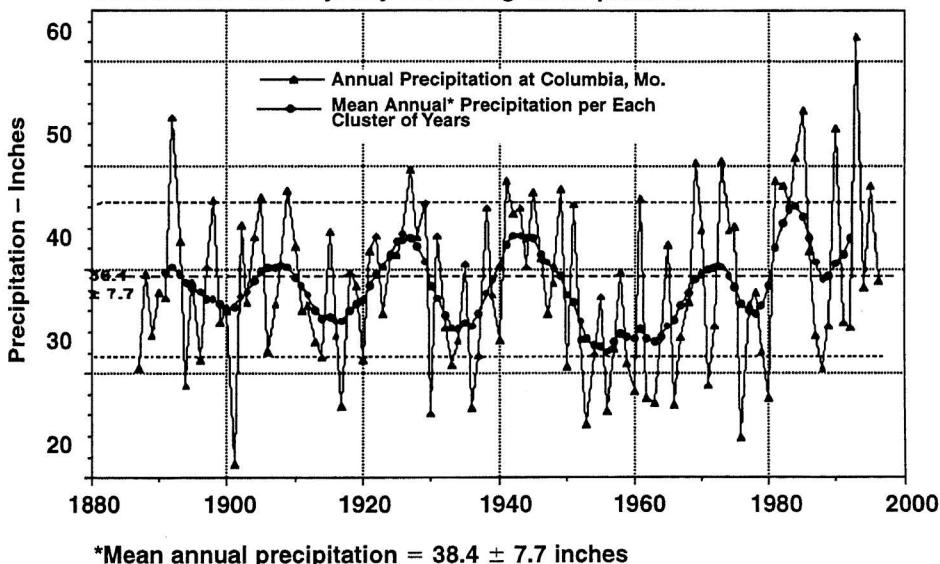


Figure 2c.* A century of precipitation at Columbia, Mo., for each of five successions of five yearly chronological sequences.



$$* \text{Mean annual precipitation} = 38.4 \pm 7.7 \text{ inches}$$

*Figures 2b and 2c were derived as 5×5 structures.

Figure 2d. Distributions about mean of annual precipitation for Columbia, Mo., after removal of annual means of 5×5 clusters.

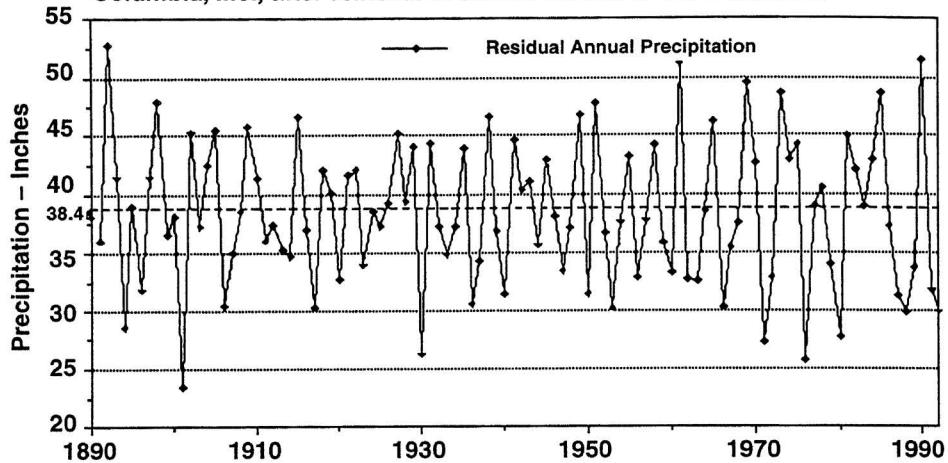
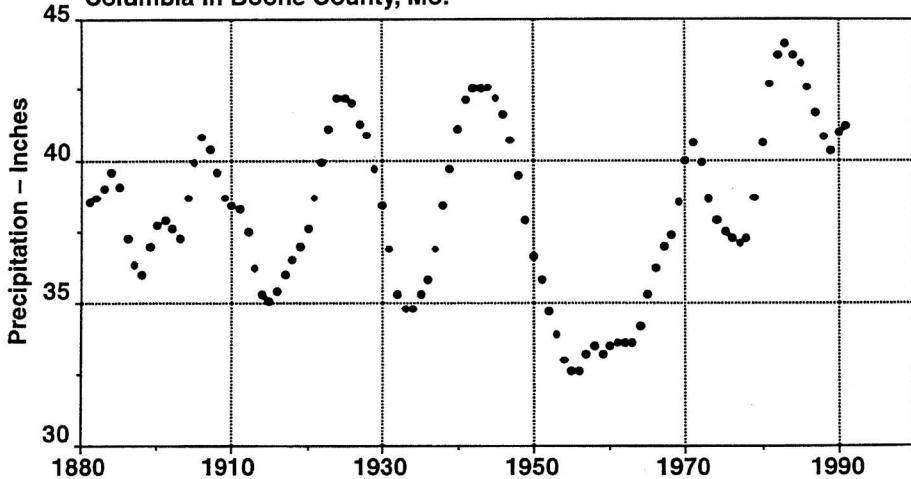


Figure 2e. Mean annual precipitation for sequential 8-year clusters at Columbia in Boone County, Mo.



Similarities and Dissimilarities in Precipitation Amounts for Selected Locations in Northern Missouri

Fulton, Mexico, Bethany and Conception, Mo.

Weather records of county seats in two contiguous counties, Fulton and Mexico, at elevations of 818 and 800 feet, respectively, were examined. Results are presented in Figure 3 and 4. Results for Columbia and Fulton, which are 20 miles apart, are essentially identical. Those for Mexico (Fig. 4) present evidence of the same periodicity but at reduced amplitudes during the initial 40 years of the record. A constant feature of the three locations is the fortuitous dryer 10-year sequence from 1955 to 1965. With no other explanation, it will be pointed out that annual amounts of precipitation at Bethany, Mo., some 150 miles to the northwest, increased from 31 inches in 1951 to 39 inches in 1960 (see Fig 5). Similar features developed at Conception in Nodaway County, Mo., with some uncertainty from 1965 to 1973 (see Fig. 5a). Excesses in some locations are accompanied by losses in other areas. However, the droughts of 1934 and 1936 appear to have been universal at all locations.

Oregon in Holt County, Mo., at Elevation of 1,048 feet

Records of annual amounts of precipitation for Oregon, Mo., date back to 1856. and were continued to 1981. Oregon is located in the River Hills 20 miles northwest of St Joseph, Mo. This set of records conveys information heretofore not observed (see Fig. 6). These observations are noted:

1. Cyclic swings of the past century extend to the previous century.
2. Dry years of the cycles tend to be distributed at 20-year intervals.
Wet years of the cycles tend to be distributed at more irregular intervals than are the dry years.
3. An initial trend toward increasing dryness during the first 80 years appears to have reversed during the past 20 years.
4. If the 20-year periodicity of the dry end of the cycles is attributable to the 20-year synodical precession of the rotating moon, then linear increases and decreases in amplitudes of the cycles must reflect the elliptical orbit of the precessional path of the moon. The results suggest that the turbulent atmosphere in a sensitive subhumid climate responds to changes in gravitational fields of atmosphere, earth, moon and sun.

The linearity of the ascending and descending changes in amounts of precipitation exhibited in Figure 6 suggests that the same process was included in processes responsible for creations of figures for each location in Northern Missouri.

Figure 3. Mean annual precipitation for sequential 8-year clusters at Fulton in Callaway County, Mo.

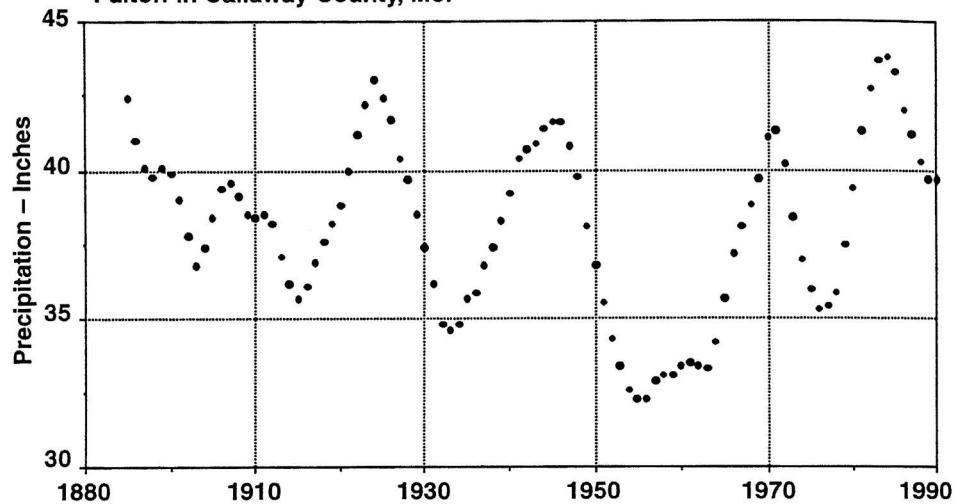


Figure 4. Mean annual precipitation for sequential 8-year clusters at Mexico in Audrain County, Mo.

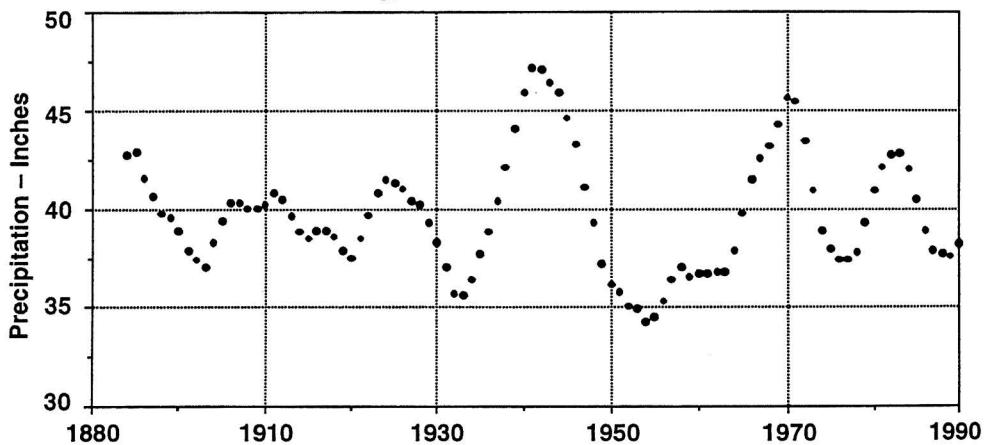


Figure 5. Mean annual precipitation for sequential 8-year clusters at Bethany in Harrison County, Mo.

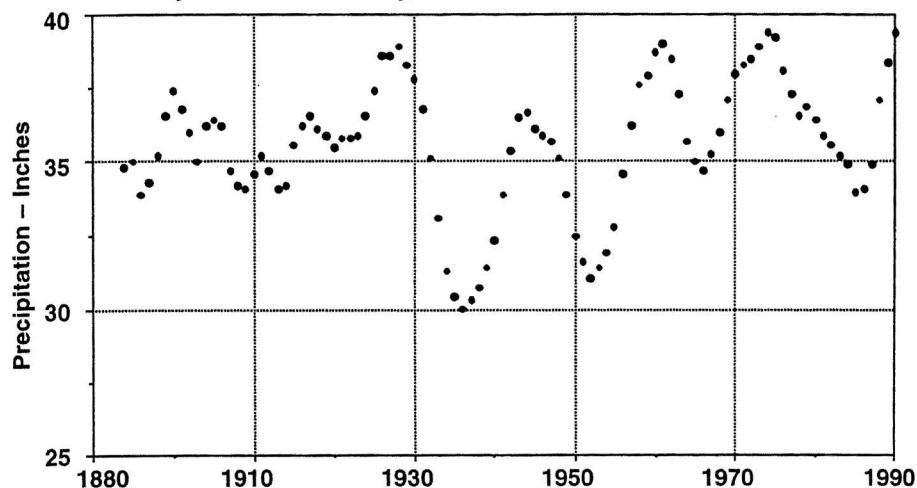


Figure 5a. Mean annual precipitation for sequential 8-year clusters at Conception in Nodaway County, Mo.

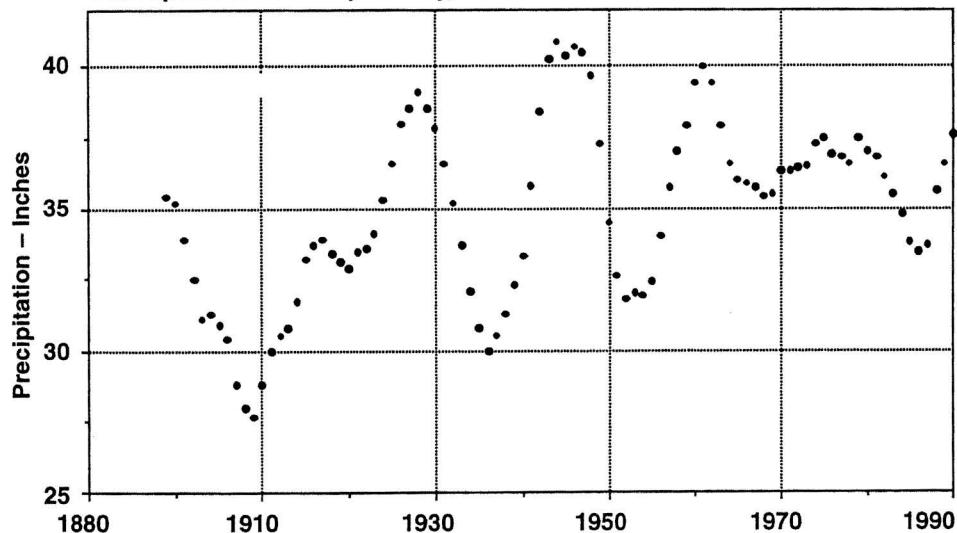
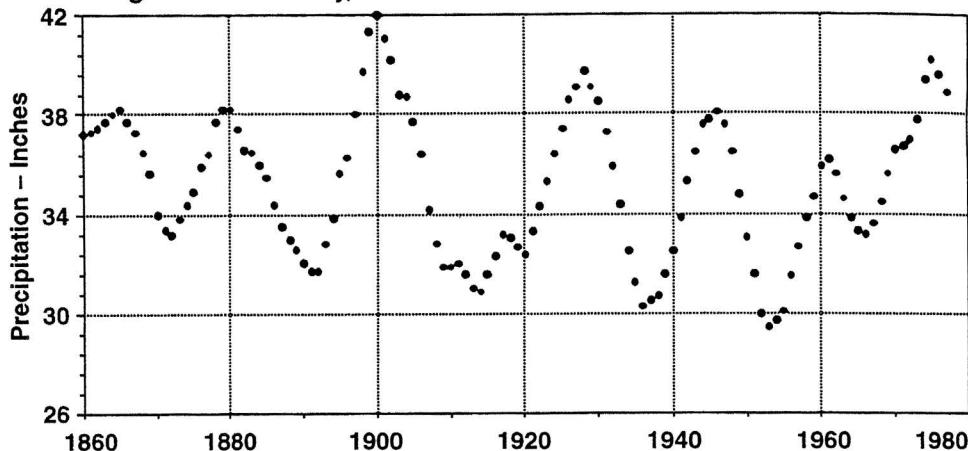


Figure 6. Mean annual precipitation for sequential 8-year clusters at Oregon in Holt County, Mo.



Precipitation Features of the High Semiarid Plains of Central Kansas - Hays, Kan., at Elevation of 2,000 feet

There being no better place to introduce the subject of the dry Plains of Central Kansas, results of measured amounts of precipitation at Hays, Kan., will be presented (see Figure 6a). Hays, at an elevation of 2,000 feet and an annual precipitation of 23 inches, exhibits the sharp, cyclic characteristics and periodicities of the Oregon location in Missouri. The truncated peak of the 1960s must exhibit a response to the same agent that produced the persistent sequence of dry years at Columbia, Fulton and Mexico. Until another operating agent has been identified, cause of the sequence of dry years must be considered as unknown.

Contributions of Seasonal Amounts of Precipitation to Annual Features of Climate That Characterize a Locality

Amounts of annual precipitation involve all seasons of the year. Separation of the annual amounts of precipitation into the six summer months from April 1 to September 30 and the six winter months from October 1 to March 31 (see Figure 7), indicate that, with two-thirds of the annual precipitation occurring during the six summer months, the cyclic swings of the annual pre-

cipitation follow closely those of the summer period. Precipitation during the winter half of the year, although minor with respect to the summer half of the year, tends to support the swings of the summer half. An exception to this observation is the wetter winter months of the 20-year period from 1970 to 1990 that led to flooded rivers in the spring seasons of 1993 to 1996.

Annual records for Columbia were subdivided into four seasons of the year: the winter season of December, January, and February, and the spring planting season of March, April and May (see Figure 8), the summer growing season of June, July and August, and the autumn harvest season of September, October and November (see Figure 9). The linear reversals in directions of change noted at Oregon, Mo., (see Figure 6) are apparent during the summer solstice at Columbia (see Figure 10). Both the apparent linearity and the sharp peaks of changes in directions, in contrast to curvilinear responses produced by other physical processes, suggest a causative agent that is operating in an elliptical orbit. Because the period between the precipitation minima appears to be close to 20 years, the monthly orbit of the moon is rejected in favor of the elliptical path of precession by the spinning moon. Existence of such a path would account for minor fluctuations in the gravitational fields among the earth, moon and atmosphere, of which amounts of precipitation in some locations become sensitive indicators.

Figure 6a. Mean annual precipitation for sequential 8-year clusters at Hays in Ellis County, Kan., at elevation of 2,000 feet.

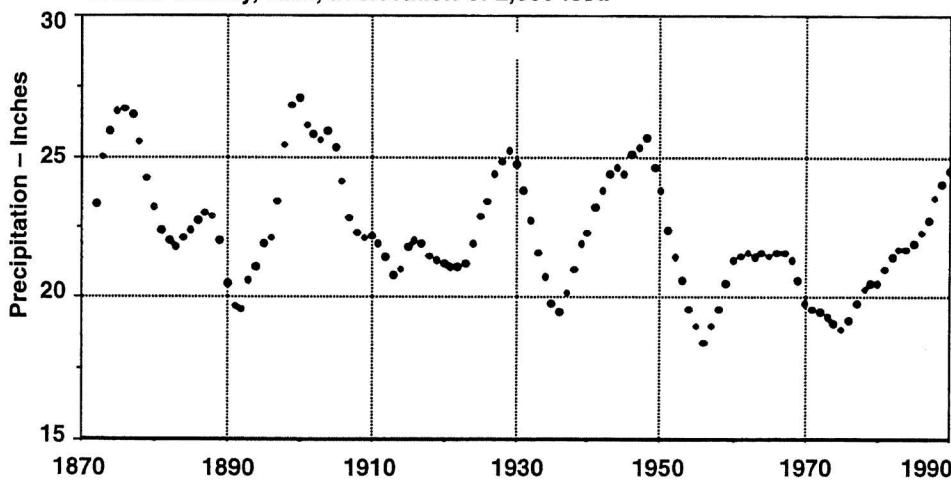


Figure 7. Annual, summer and winter mean annual precipitation at Columbia, Mo.

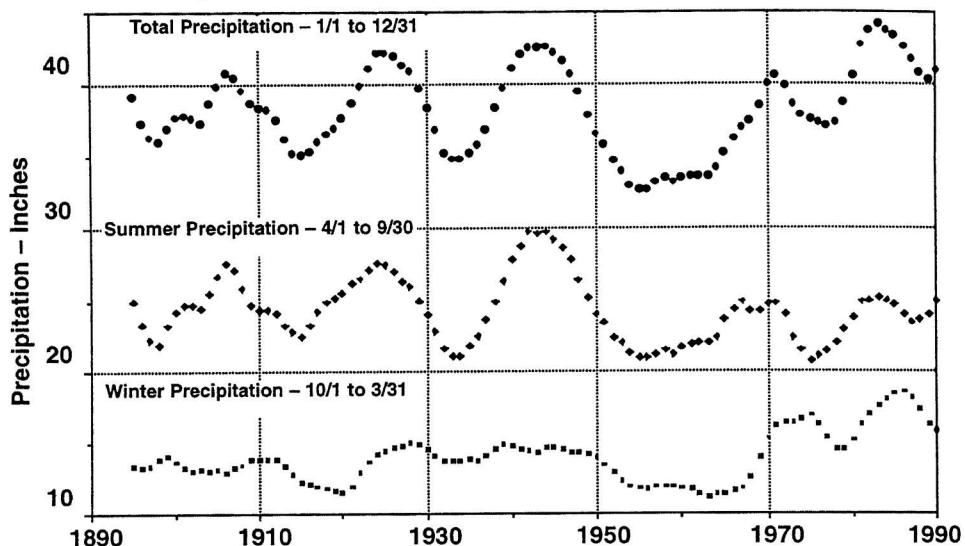


Figure 8. Winter and spring annual precipitation at Columbia, Mo.

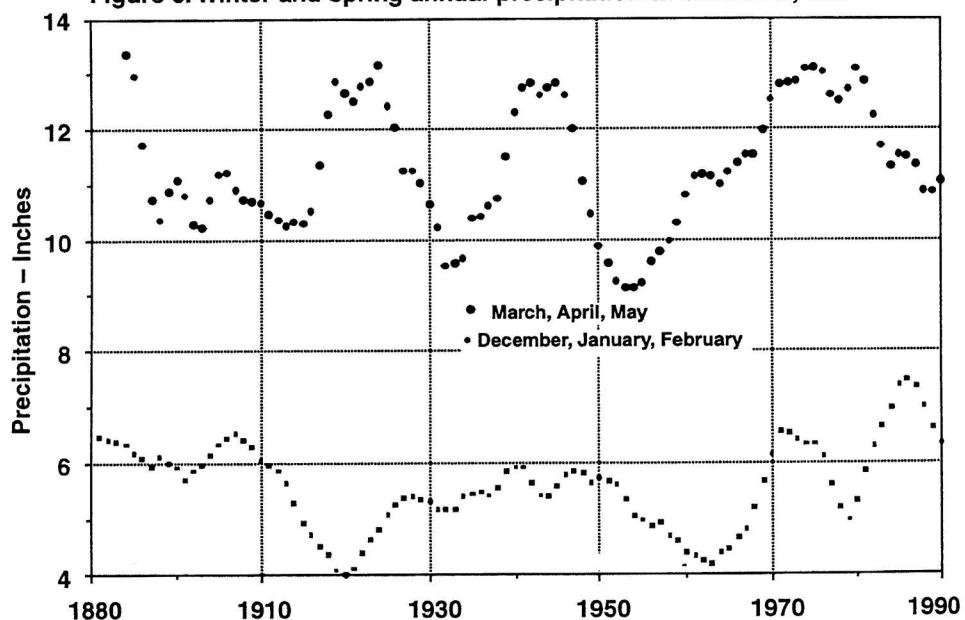


Figure 9. Summer and autumn annual precipitation at Columbia, Mo.

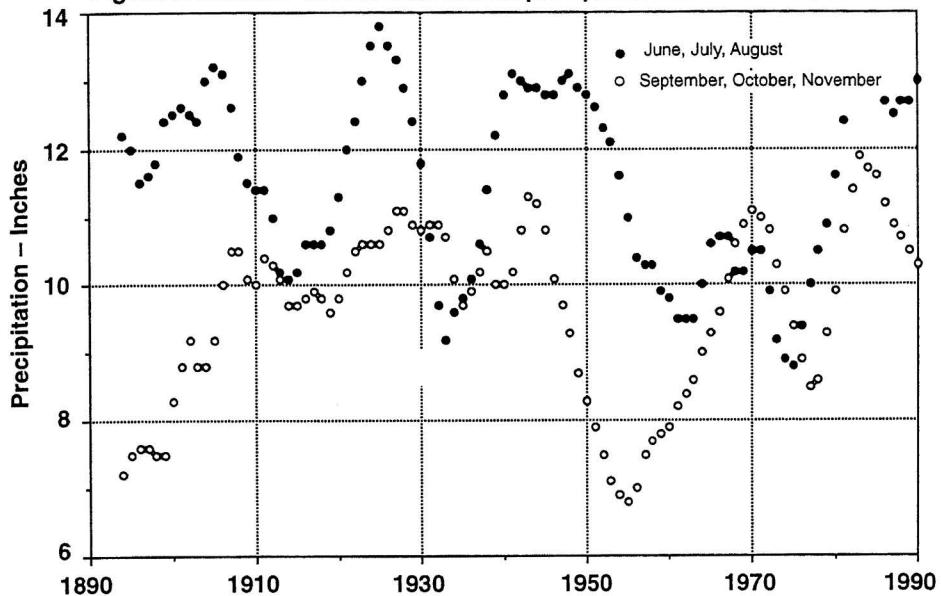
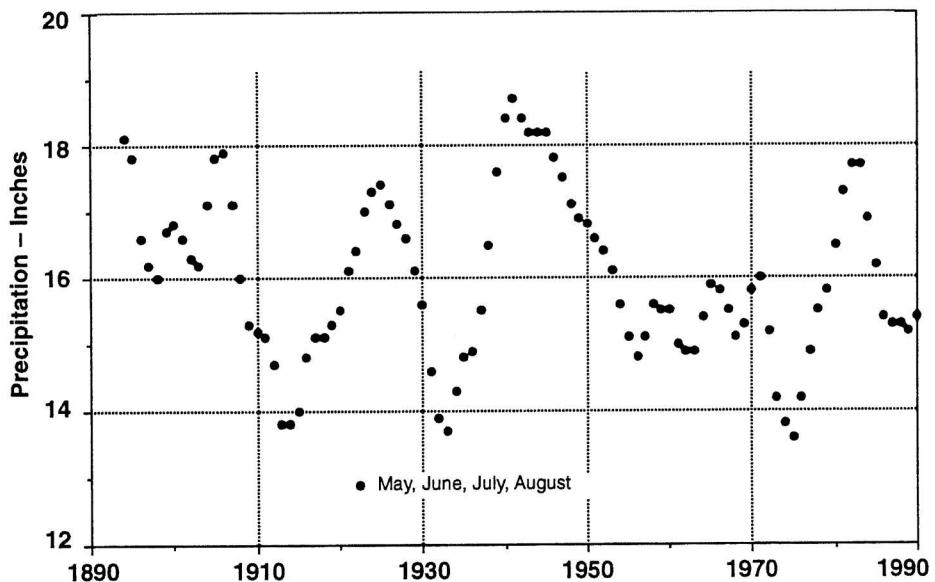


Figure 10. Mean annual precipitation in Columbia, Mo., for months surrounding the summer solstice.



Precipitation Features for Locations in the Western Prairie Counties of Southern Missouri

The Western Prairie counties of southern Missouri, from Newton County that borders Oklahoma on the west through Jasper, Barton, Vernon, Bates and Cass County, which border Kansas on the west, are serviced by the prevailing westerlies of the Great Plains. The subhumid climate of 35 to 45 inches, annually, tends toward increasing intensities of droughts during the first 80 years of records, with increases above normal during the last 20 years of record. All locations investigated exhibit the droughts of 1934 and 1936, and again in 1955. Why should annual precipitation of counties bordering Kansas on the west approach 50 inches per year while that of Neosho in Newton County remains below that of the decade of the 1920s and the decade of the 1940s? As a tentative suggestion, evapotranspiration from corn irrigated from deep wells in central and western Kansas may have recharged the passing breezes entering Missouri along the western border.

Precipitation features of Neosho in Newton County, Mo., are presented in Figure 11. The two uncluttered cyclic swings of 10 inches between maxima and minima have appeared in results of plotted data for most locations in northern Missouri. Annual precipitation at Springfield, Mo., which is in Green County at the foothills of the Ozarks some 80 miles east of the border, were investigated (see Figure 12). Records initially reflect a downward trend in annual precipitation, followed by a rapid rise during the last 10 years. It must be remembered that the year represented by the position of each solid circle is the fifth year of a 10-year sequence of years that extends 4 years beyond the end member of the reported data.

Lamar in Barton County, Nevada in Vernon County and Butler in Bates County, Mo., were known for their production of native prairie hay during their early history. Harrisonville in Cass County, south of Independence, Mo., is today a more suburban setting than formerly. Annual precipitation for the period of record are presented in Figures 13 for Lamar, 14 for Nevada and 15 for Harrisonville. The figure for Lamar reflects the downward trend in precipitation until the rapid rise that started in 1980. It also reflects the uncertainties of the early 1860s. Figure 14 for Nevada reflects droughts of 1914, 1934 to 1936, 1955 and 1980 with excesses since 1980. Results for Harrisonville (see Figure 15), reflect the droughts and swings in precipitation with the recent excesses.

Figure 11. Mean annual precipitation for Neosho in Newton County, Mo.

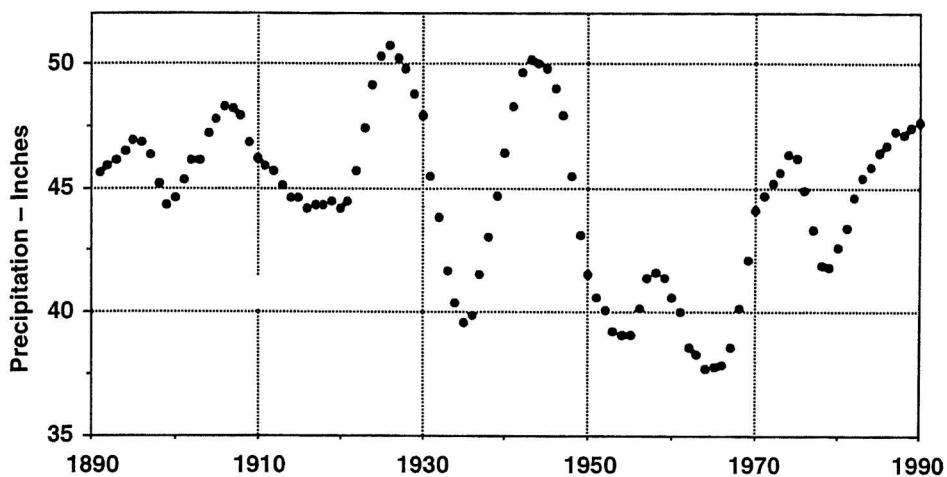


Figure 12. Mean annual precipitation for Springfield in Green County, Mo., 80 miles east of the Kansas border.

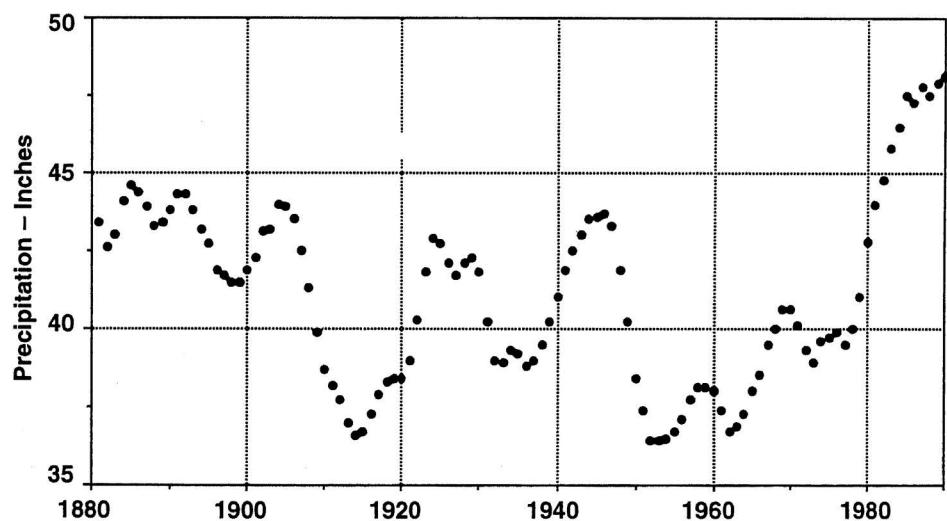


Figure 13. Mean annual precipitation for Lamar in Barton County, Mo.

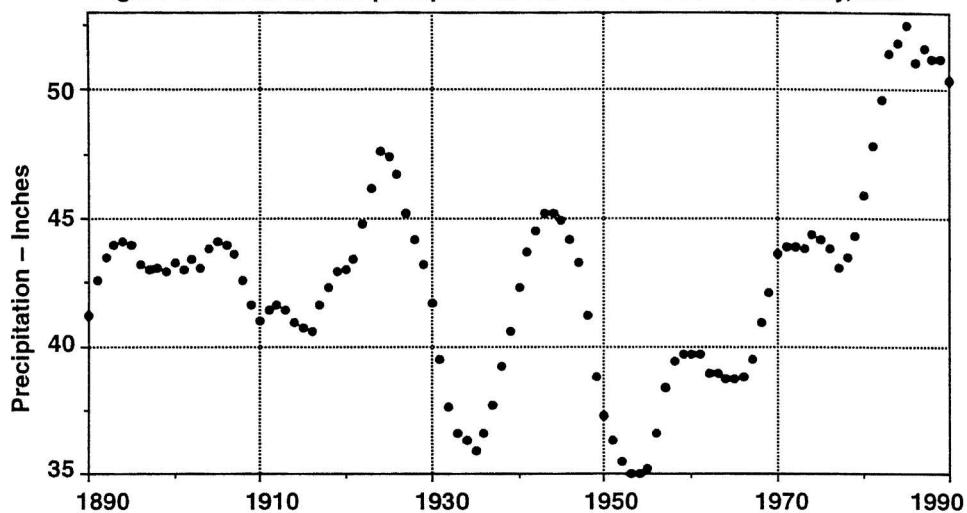


Figure 14. Mean annual precipitation for Nevada in Vernon County, Mo.

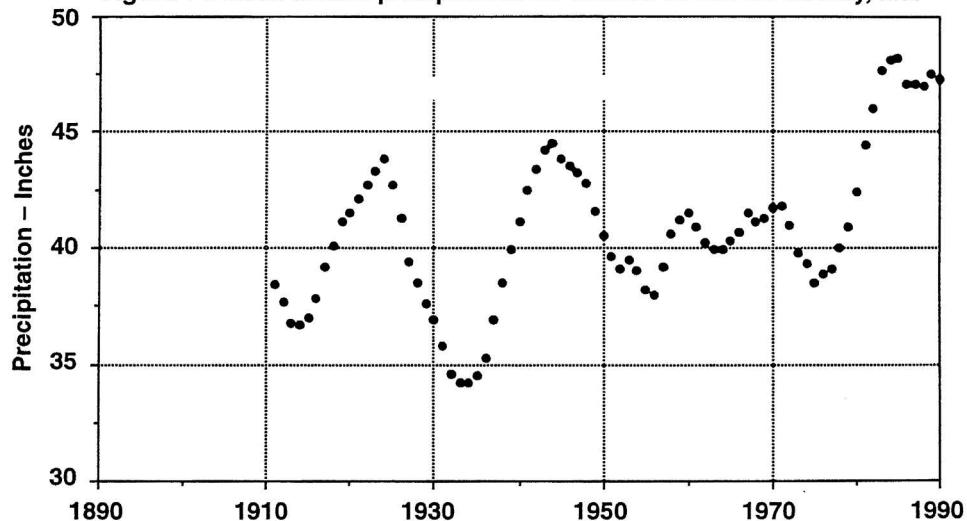
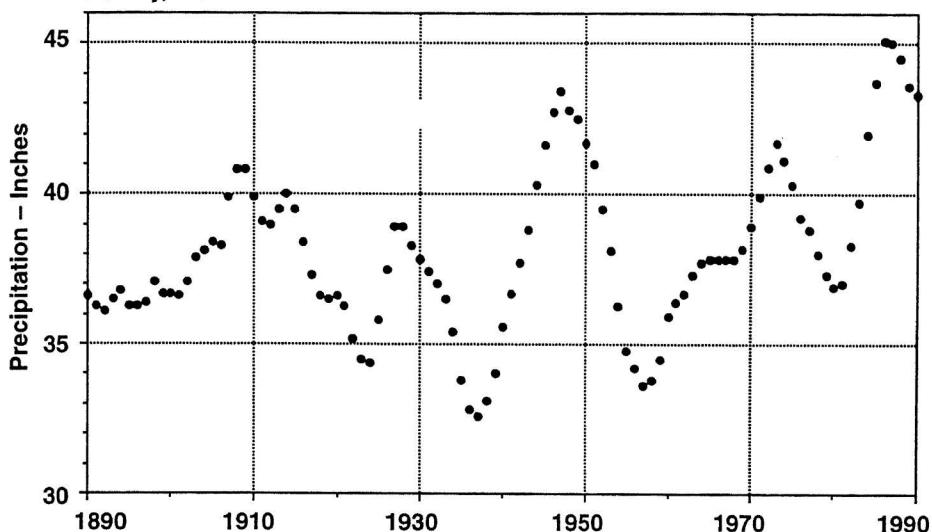


Figure 15. Mean annual precipitation for Harrisonville in Cass County, Mo.



Early Records of Precipitation at River Locations

Records dating back to earlier years were sought to verify the patterns of precipitation observed at Columbia, Fulton and Mexico. Records for Miami, Mo., date back to 1847, but terminate in 1904. Those for Brunswick, Mo., 8 miles away on the north side of the Missouri River, did not agree with those for Miami, suggesting that presence of the river influenced differently the features of precipitation at the two locations. The records for Oregon in Holt County date back to 1856 (see Figure 6).

Uncertainties in distributions of precipitation features along large bodies of flowing rivers, which include the Missouri and Mississippi Rivers in Missouri, and the Delaware River in Pennsylvania, date back to the 1830s. They turn attention to effects of activities of man on hydrology of land. Much of the land two centuries ago remained in native timber and prairie. Measurements of runoff by the USDA Soil Erosion Experiment Stations (1, H.H. Bennett), revealed losses of water approaching 30 percent of the incidental precipitation from arable crop land, compared with less than 10 percent from land in a constant cover of living vegetation. Corn, soybean and cotton land, combined with paved highways, parking lots and roofed-over buildings of today, provide little stored water for return to the atmosphere by evapotranspiration.

Leavenworth, Kan., on the Banks of the Missouri River, 20 Miles Northwest of Kansas City, Mo.

Records for the Leavenworth location (see Figure 16), are complete from 1836 to date. With an exception of one 20-year period from the mid-1930s to the mid-1950s, cyclic trends are not evident. The droughts of the '30s and '50s, separated by wet years of the '40s, were so sufficiently intense that they overcame the smoothing effect of storms that follow the rivers. A consistent trend downward in annual precipitation is evident from 1870 to 1960, followed by a rise from 28 to 50 inches during the next 15 years.

St. Louis on the Banks of the Mississippi River

Records at St. Louis date back to 1837 (see Figure 17). Unlike records for Leavenworth, Kan., these records decline in an erratic fashion from 1850 to 1960 and exhibit wet sequences in the 1940s and 1980s. A first interpretation was that precipitation declined as pioneers cut the timber and plowed the prairie sod.

Philadelphia, Pa., on Banks of the Delaware River

Records at Philadelphia date back to 1829, (see Figure 18). Mean annual precipitation attained 50 inches during years of the Civil War, then switched from 37 to 45 inches three times during the past century with no defined evidence of droughts.

Figure 16. Mean annual precipitation for Leavenworth in Worth County, Kan.

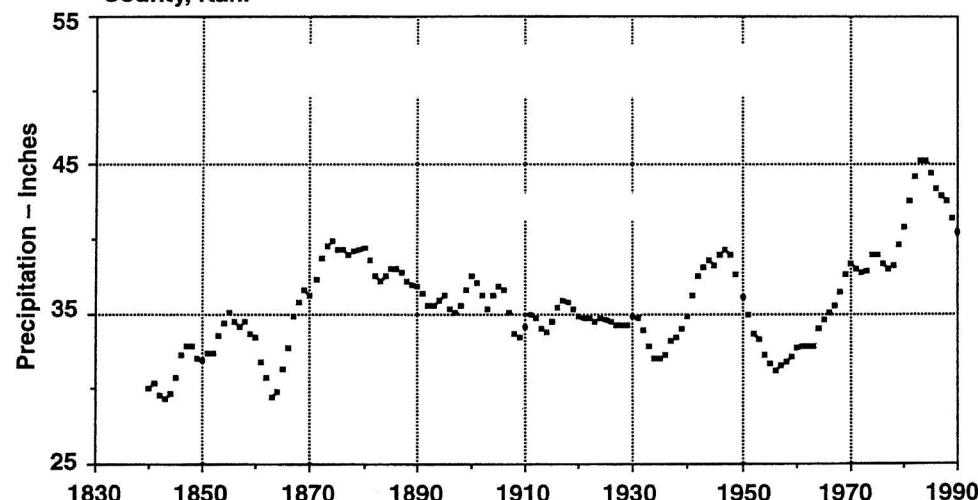


Figure 17. Mean annual precipitation for Saint Louis, Mo.

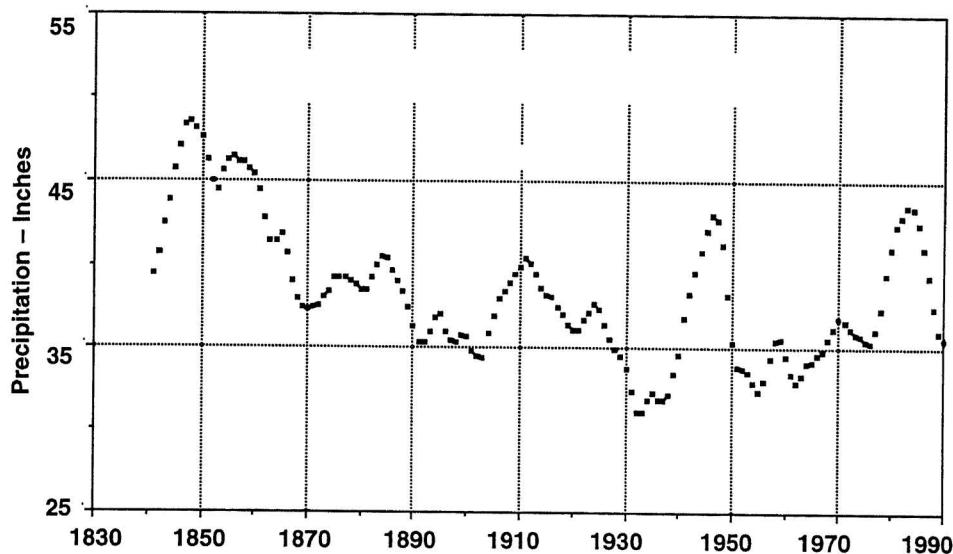
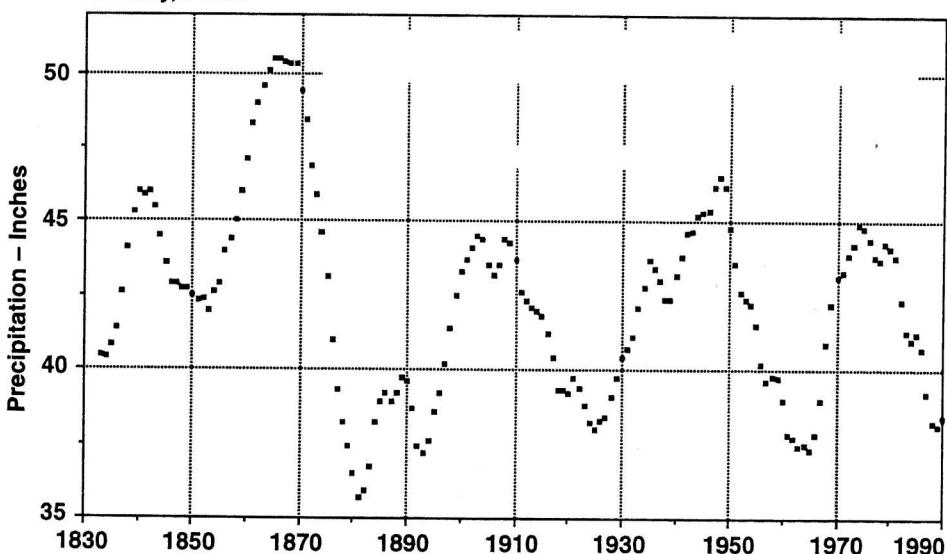


Figure 18. Mean annual precipitation for Philadelphia in Philadelphia County, Penn.



Summary

An analysis of annual precipitation for selected upland sites in Missouri was initiated due to 20-year deficits in annual precipitation for crop production during the summer growing season at Columbia, Mo. Consecutive days with empty rain gauges provide a more precise measure of precipitation deficits than do measured amounts and frequencies of precipitation. That lost as runoff when it rains is helpful only when it is stored in impoundments for later application as supplemental irrigation or for other uses.

Organizing deficits in summer precipitation into three consecutive successions, each of eight chronological sequences of annual data, revealed 20-year, repeating cycles. These cycles were then expressed as the numbers of irrigations required to keep the moisture profile of the soil in condition for a developing corn crop. Successful development of irrigation for corn and soybean production on claypan prairie soils of Missouri suggested applying similar methods of analyses to the century of precipitation for Columbia. Results of the analyses revealed repeating cycles emerging from a turbulent mass of influences that were superimposed upon the environment by clearing of land and, more recently, by supplemental irrigation of the dry western prairies of Kansas.

Records of precipitation for river sites in Kansas, Missouri and Pennsylvania, extending back into the early 1800s, were investigated. Results provide indirect evidence of changing amounts of annual precipitation because of changing hydrological characteristics of land areas. Land areas originally in native vegetation are today arable, crop-producing land. That which is not is paved or roofed-over.

References

1. Bennett, H. H. 1939. Soil Conservation, pages 125 to 168. McGraw- Hill Book Company, Inc. New York and London.
2. United States Department of Agriculture - Weather Bureau. Climatic Summary of the United States - to 1930.
3. U. S. Department of Commerce - Weather Bureau Climatic Summary of the United States - 1931 to 1952.
4. U. S. Department of Commerce - Weather Bureau. Climatological Data, National Summary - 1950 to 1974.
5. U. S. Department of Commerce - National Oceanic and Atmospheric Administration (NOAA). Climatological Data - 1973 to 1995.
6. U. S. Department of Commerce, Missouri Data, Vol. 6 to 94.
7. Ikerd, J. E. and Woodruff, C. M. - June 1996, Dry Times Ahead. Missouri Ruralist, Volume 137, No. 9.



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