[Proceedings of the Iowa Academy of Science](https://scholarworks.uni.edu/pias)

Volume 94 | Number

Article 7

1987

Variability of Annual Iowa Precipitation During the Past 95 Years

Harry C. Vaughan
Iowa State University

Daniel J. Berning
Iowa State University

Gary R. White

Recommended Citation

Vaughan, Harry C.; Berning, Daniel J.; and White, Gary R. (1987) "Variability of Annual Iowa Precipitation During the Past 95 Years," *Proceedings of the Iowa Academy of Science, 94(3),* 94-104.
Available at: https://scholarworks.uni.edu/pias/vol94/iss3/7

Proc. Iowa Acad. Sci. 94(3):94-104, 1987

Variability of Annual Iowa Precipitation During the Past 95 Years[1]

HARRY C. VAUGHAN[2], DANIEL J. BERNING[2], and GARY R. WHITE[3]

[2]Department of Agronomy, Iowa State University, Ames, Iowa 50011
[3]819 East 6th Street, Leland, Mississippi 38756

With increased consumption of fossil fuels has come warnings that the global atmosphere could be overtaxed with carbon dioxide and other combustion byproducts. The most popular scenario suggests a warming of the subpolar area with an extension of the grain belt. This warming could place the present grain belt in a warmer and drier climate. Each time a portion of the grain belt experiences a temperature or precipitation anomaly, the suggestion of a climatic change is raised.

The present paper addresses the question of medium-term, 95-year change in Iowa annual precipitation as well as linkage between precipitation and temperature anomalies. Similar studies in Europe and the United Kingdom, where unbroken precipitation records extend back almost 300 years, show periods up to 50 or 75 years where a jump in the annual mean has occurred. The fact that such anomalies extend back before the industrial revolution suggests other factors may cause such changes. With only about 100 years of climatological records here in the grain belt, it may not be possible to identify long-term, natural oscillations or a true, long-term trend. Records at four sites, Cedar Rapids, Des Moines, Dubuque, and Storm Lake, were analyzed in search of true jumps or trends in the climatic record. There was no question that the record had dry and wet periods, some extending over a period of ten or fifteen years. The conclusions were that, although extended periods seemed to be above or below the long-term mean, these anomalies had tenuous linkage between sites across the state. Possibly because of the sample size, no statistically significant trends were observed between sites through the years 1890-1984. Several poorly defined single site jumps were observed in the precipitation record, however, these were not clearly linked to companion temperature perturbations.

INDEX DESCRIPTORS: Climate, precipitation

There are two schools of thought regarding long-term climatic change. The first projects a sense of urgency suggesting a world warming trend primarily resulting from increased concentration of atmospheric carbon dioxide (CO_2) due to combustion of fossil fuels. The urgency is related to the potential melting of a portion of the polar ice caps and a projected rise of the seas. It is further suggested that the encroachment of warmer air into the polar regions may influence the length of the growing season and precipitation distribution in the temperate zone which, in turn, could necessitate the modification of types of crops grown in this most productive region (Lamb, 1984; Weller, 1983).

The second, which has received far less public exposure, examined a number of basic parameters including solar radiation, precipitation anomalies, ambient CO_2 concentrations, and natural assimilation of CO_2, along with other industrial effluents. Their findings indicate mesoscale modification associated with large metropolitan areas but show little evidence that any global changes have occurred in these parameters. Both groups agree that the atmospheric CO_2 level has increased and is increasing (Elliott, 1983). The real question is whether this added long-wave radiation screen will result in large-area warming. Recent climatological records have not shown a clear global warming trend. What has been observed is an unexplained increase in temperature fluctuations, both warmer and colder (Palumbo and Mazzarella, 1980, 1984).

Any region of the world that directly depends on renewable natural resources, whether agrarian or marine, tends to be sensitive to the fickle behavior of the ambient climate. Frequently, atypical periods raise the possibility of an imminent climatic shift. There is little question that the earth has undergone, or is undergoing, climatic change. That there are both oil and coal in the polar regions suggests that, at one time, a lush forest existed, possibly supported by a greater ambient CO_2 concentration. During the past 2,000 years we find references to a well-developed agrarian culture in Israel, the Holy Land, and elsewhere throughout the fertile crescent of the near East (Brooks, 1948). Abrupt regional climatic changes in the southwestern United States resulted in abandonment of well-developed cliff dwellings approximately 1,000 years ago (Schulman, 1938).

A number of papers addressing various phases of precipitation variability has appeared in recent literature. The majority deal with long, unbroken (17th Century to the present) precipitation records from European stations. North American climatic studies have a serious limitation, in that few sites in the New World have unbroken records to parallel those of Europe and the United Kingdom (Vaughan and White, in press). Researchers using these single-site precipitation records have been able to address the various aspects of change, shifts, or variability in annual and seasonal precipitation records (Gregory, 1955; Senior, 1969; Craddock, 1979; Burroughs, 1980; Camuffo, 1984).

Craddock (1979) has investigated statistical techniques for combining parallel, nearby, precipitation records to provide additional long, unbroken annual rainfall records for climatic purposes. These techniques suggest a method for combining a number of separate raingauge records if the two nearby sites have sufficiently long, overlapping records.

In our work none of the records were sufficiently long, with extended overlapping periods to fully utilize Craddock's techniques. However, we did use some of his methods when possible to test movement of sites.

Senior (1969) examined British rain records at 100 sites (1916 through 1960), in an attempt to identify and stratify precipitation over the British Isles. His conclusions were that the variability of rainfall itself fluctuates by a significant amount from one period of years to another. However, these periods are not cyclic nor of similar amplitude. This variability will be discussed later in our work.

Burroughs (1980) was concerned with the number of atypical British winters during the decade of the 1970's. Four years were considered extremes, in that they fell outside the 90th percentile level of a 250-year wintertime precipitation-temperature analysis. As in the study by Senior (1969), Burroughs found extended periods (5 to 15 years) where the temperature or precipitation record departed from the long-term mean. Although such anomalies were interesting, these quasi-periodic events were not of statistical significance.

---

[1] Journal Paper No. J-12072 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project 2704. A portion of this paper was presented at the 97th Annual Meeting of the I.A.S.

The present investigation, regarding short- and long-term variability of area precipitation, was prompted by the conflicting statements, both in the literature and national news media, regarding climatic change. Historically, Iowa has retained an enviable record in agricultural production. During the past decade, a number of unrelated constraints (climatic and economic) have placed great stress on the agricultural community. Whether there is an ongoing climatic shift, as suggested by some, or a natural period of variability, is of more than academic interest to people both in and outside the agricultural community.

SCOPE OF THIS STUDY

Five diverse objectives have been pursued in this work: (a) to examine the annual temperature and precipitation records for any continuous long-term trend, (b) to analyze subsections (segments) of the precipitation records to identify "climatic jumps", (c) to examine annual precipitation records using spectral analysis techniques to see whether any periodicity could be identified, (d) to examine annual temperature-precipitation (relationship) at select sites to see whether there was large area similarity in years with extreme values. Finally, using a Monte Carlo simulation algorithm tailored to Iowa precipitation, an attempt was made to compare real climatic records to those of a computer-generated, random number source.

Climatic perturbations may be divided into five subclasses or time scales: (a) true large-area (or global) climatic change, which may be of a very small magnitutde per unit time on a scale of geological time, generally identified by archeological or geological records; (b) changes ranging from 100 to 1,000 years, which may be documented by dendro- chronological methods (Meko *et al.*, 1985; Trefil, 1985); (c) changes in the 25- to 300-year range, which may be documented by absolute, rain-gauge observations; (d) climatic jumps occurring for periods of 5 to 25 years, which may be documented by absolute methods, (3) manmade perturbations, or bogus changes, resulting from the "heat island effect" developed within large industrial cities (Palumbo and Mazzarella, 1980, 1984).

With only 95 years of unbroken precipitation and temperature records from four selected sites at our disposal, it is not possible to address the two, longer time scales with any precision. However, the third scale ranging from 25 to 300 years may be identified by using standard statistical techniques as suggested by Bunting *et al.* (1976), Burroughs (1980), and Gregory (1955). The most straightforward means of analysis of a single-site precipitation or temperature record is to compute the mean and plot the annual departures. If a continuous change occurred, which is highly unlikely, the majority of annual values would be above or below the mean during the early sampling period and would cross the mean value line during the later years. Clearly, such a technique would require that a significant slope be identified over the relatively short period of 95 years. A slight variation of the techniques is to plot the accumulated residual and show any short- or long-term departure from the mean. This technique has been described in detail by Gregory (1979).

SITE SELECTION AND HISTORY

The ideal ingredients for site selection in this study would be 3 or 4 equally-spaced National Weather Service (NWS) stations at fixed site locations, each with an unbroken record in excess of a century. In addition, each station should be climatologically representative of the general territory within 4,000 km^2. If this were not possible, a volunteer climatological station with a minimum number of site and observer changes would be chosen. The Cedar Rapids and Storm Lake sites both had long, unbroken cooperative climatological records and both sites remained within a few km of the original location.

Des Moines, a first-order NWS station, was moved five times from 1878 to 1939, always within 0.5 km until July 1939 when it moved 1.5 km to the present airport site. The city office was retained at the Federal Court House until 1973. During the 35 years since the Des Moines airport station has been operational, some or all of the instruments have been relocated a total of 5 times.

The Dubuque NWS office originated as a cooperative station in 1851. In 1873 the U.S. Army Signal Corps took over the station until June 1894, when it again became a cooperative station until January 1902. At this time the then-Weather Bureau maintained the station with three site changes, all within 4 blocks until January 26, 1951, when the station was relocated to its present airport site. During part of 1981 and 1982 the station reverted to a cooperative station but was reopened November 1, 1982. The airport station was 11.0 km southwest of the city office and 130 meters above the old site. The present airport site is an excellent location, far more representative of the general plateau west of the Mississippi River. In addition, the U.S. Corps of Engineers retain a cooperative station at Lock and Dam Number 11 at the north edge of the city (4.8 km NE of the last city office site).

The Dubuque site was included in this study because of its very long, unbroken record. It was not until well into the study that we realized the serious difference between the city office and the airport site. T-tests for the years 1937 through 1951 beween the Lock and Dam site and the NWS city office show the two sites to be similar. Tests of the NWS airport office and the Lock and Dam 1951 through 1981 show the sites are statistically different. Three of the four sites (Cedar Rapids, Des Moines, and Storm Lake) were equidistant and considered representative of the general area. Dubuque, with one of the longest records in the state, was representative of the river-bottom land.

There is one further note regarding the stability of observing sites within the state of Iowa. All of the present four National Weather Service sites have been relocated and their instruments moved on site at least twice. Of the 163 published climatic, volunteer, observing sites only the Sheldon, Iowa site has totally retained its site and instrument location.

PROCEDURE AND ANALYSIS

Many of the analytical procedures employed in this paper parallel previously-mentioned British and Italian climatic studies of events of the past century. Originally, 105 years of precipitation and temperature records were compiled. Because of some concern for breaks in early temperature records necessitating the substitution of neighboring site data, together with on-site inspection of current as well as historical sites, it was thought advisable to limit the study to 95 years (1890 through 1984). The analytical study followed in the order outlined in Section 2, the scope of the study. Simple regression analyses of the four annual temperature and precipitation records were performed. In each case the 95 percent confidence band for the prediction of the Y value were drawn (Fig. 1). It is interesting to note that, within the 95 percent confidence level, the most conservative estimate (a line drawn from upper left to lower right of the confidence bounds) will predict over the next 100 years an increase in annual precipitation in eastern, and a decrease in western, Iowa. Specifically, the projected increase for Cedar Rapids is 3.25 cm and 5.44 cm for Dubuque. Des Moines and Storm Lake will show a decrease of -8.38 cm and -16.93 cm, respectively. When the standard deviation of annual precipitation is computed, we find it broader with a more positive slope at Dubuque and Storm Lake, while Cedar Rapids and Des Moines both show a near neutral slope and a narrower confidence band (Fig. 2). In the case of Dubuque, this may be explained by the site relocation, but no explanation can be given in the Storm Lake record where the site has not undergone any significant relocation.

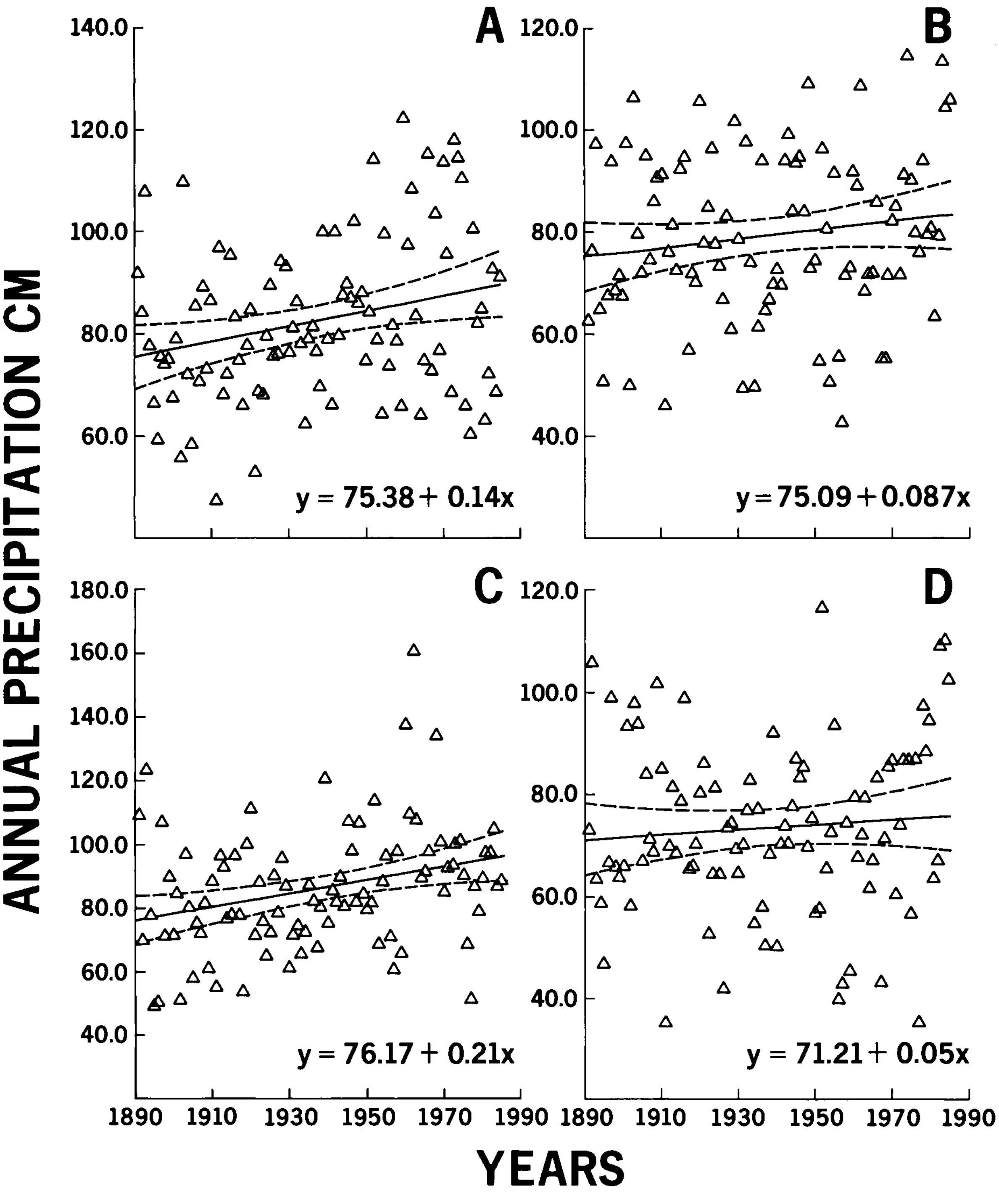

Fig. 1. Ninety-five year annual precipitation totals in cm. A. Cedar Rapids, IA, annual mean 82.47. B. Des Moines, IA, annual mean 79.29. C. Dubuque, IA, annual mean 86.53. D. Storm Lake, IA, annual mean 73.63.

Regression analysis of the annual temperature record, which is a more conservative parameter, has two perturbations both which may be explained by human intervention (Fig. 3). In Dubuque it was the major relocation of the site to the bluff southwest of the city; in the case of Storm Lake, it was a change of observation time from 1800 local time to 0700 after 1 April 1958. The Storm Lake observation time change can be seen clearly as a discrete data group indicating lower annual temperatures. This problem in data collection is well documented and only further compounds climatic trend studies (Mitchell, 1958).

The site records do show groupings of dormant and active periods in the annual temperature profile. The first 25 years of the Cedar

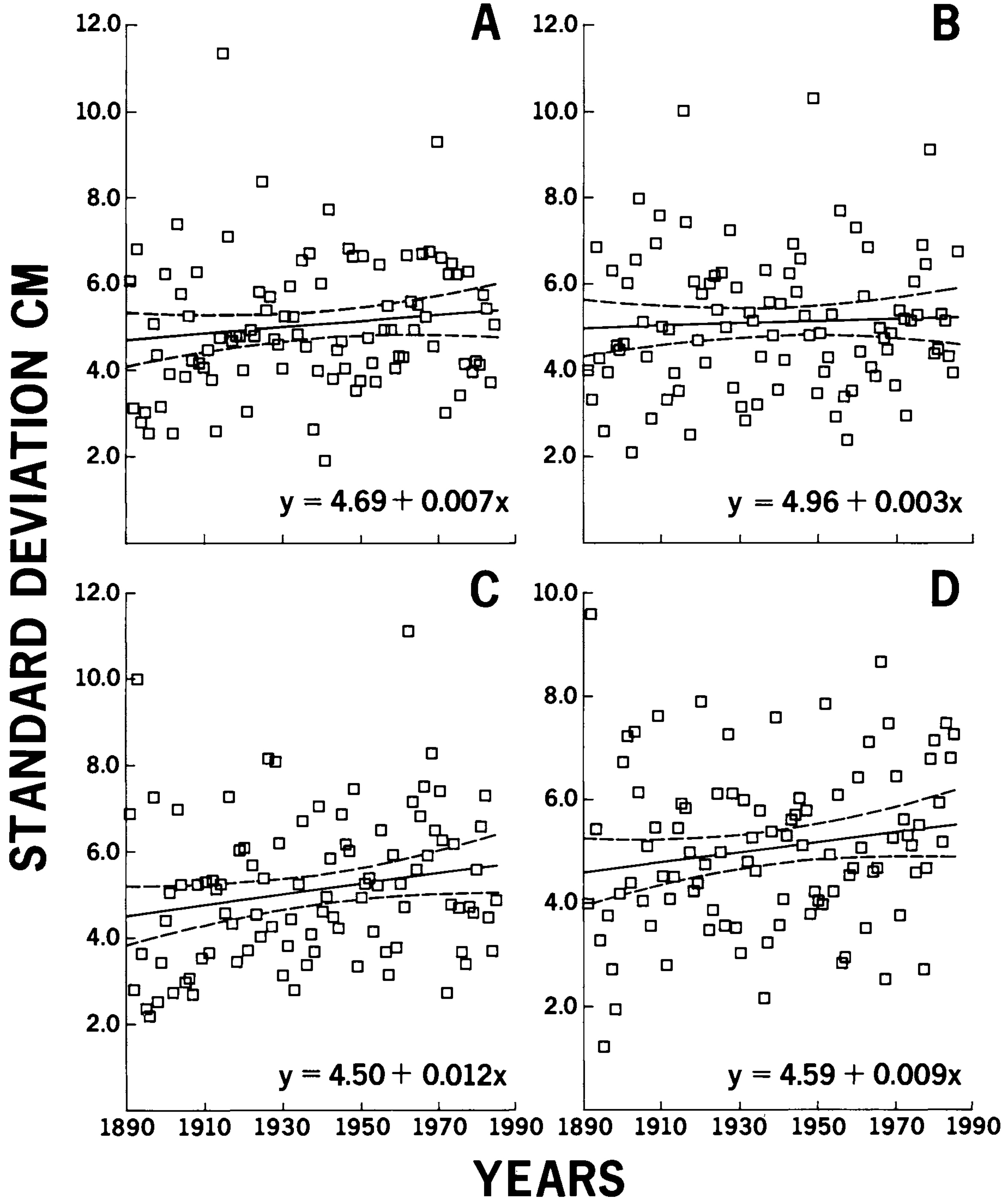

Fig. 2. Ninety-five year standard deviations of annual precipitation in cm. A. Cedar Rapids, IA, 15.78 B. Des Moines, IA, 16.48. C. Dubuque, IA, 19.41. D. Storm Lake, IA, 17.06.

Rapids record show far less range as do the last 38 years; however, the 32 years between 1916 and 1948 experienced seven warm annuals and two colder years. The Des Moines records are much more active similar to the center portion of the Cedar Rapids record. Dubuque seems to have experienced a warming trend, possibly as the city grew. The trend changed abruptly one year after the site relocation resulting in the large negative slope of the regression line. Similarly, Storm Lake seems to show a cooler early history followed by a majority of warm years until the time of observational change in 1958.

Abrupt changes of time average over a few decades have been observed by a number of researchers (Burroughs, 1980; Craddock, 1979). Yamamoto (1985) has proposed the concept of "climatic jump" for such abrupt perturbations in a seemingly well ordered climatic record. He further proposed a specific numerical definition using grouped time means and confidence limits for equal periods before and during the period in question. No clear explanation for these perturbations has been given. Craddock (1979) suggested that site data should be examined to identify instrument and exposure

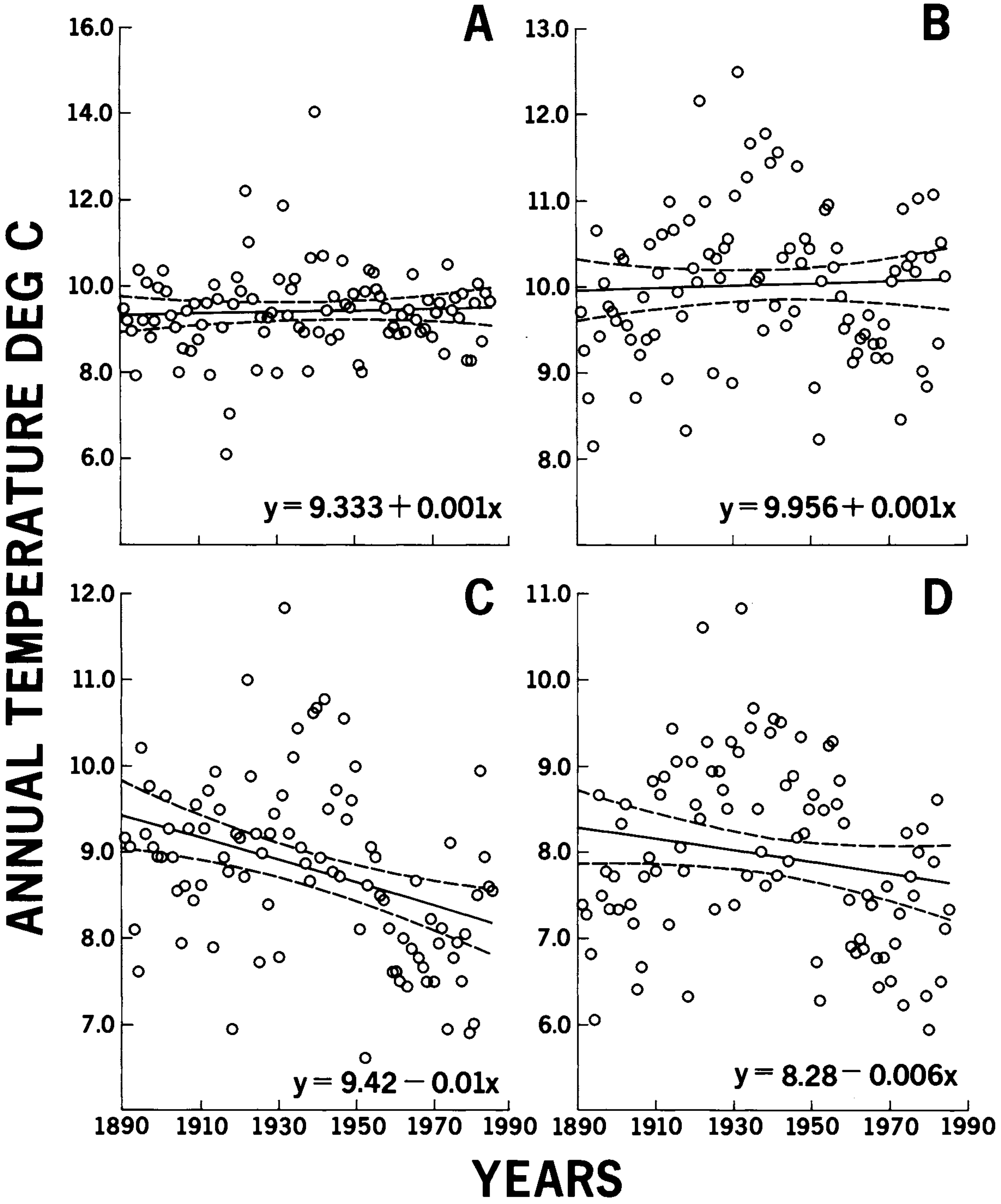

Fig. 3. Ninety-five year annual temperature record in Celsius degrees. A. Cedar Rapids, IA, 9.42. B. Des Moines, IA, 10.01. C. Dubuque, IA, 8.79. D. Storm Lake, IA, 7.95.

problems early on in such apparent climatic changes. However, he acknowledges true short-term (3- to 30-year) changes in area rainfall. It is this unexplained "jump" or "shift" which is most troubling, particularly when such perturbations are interpreted as the true area mean.

The present work identified such an unexplained departure in the Cedar Rapids annual precipitation records. Using an arbitrary 15-year grouping of records starting in 1890, it was observed that after the third period (1935) both the mean and the standard deviation changed suggesting an increase in area precipitation (Fig. 4). No such clear excursion could be identified at Des Moines or Storm Lake. As previously stated, the Dubuque precipitation data cannot be regarded as totally homogenous for such a study.

The fact is that dry or wet, as well as warm or cold, periods of up to 3 decades occur at single sites and in some cases do not extend more than a few hundred square kilometers. Intuitively, any sustained

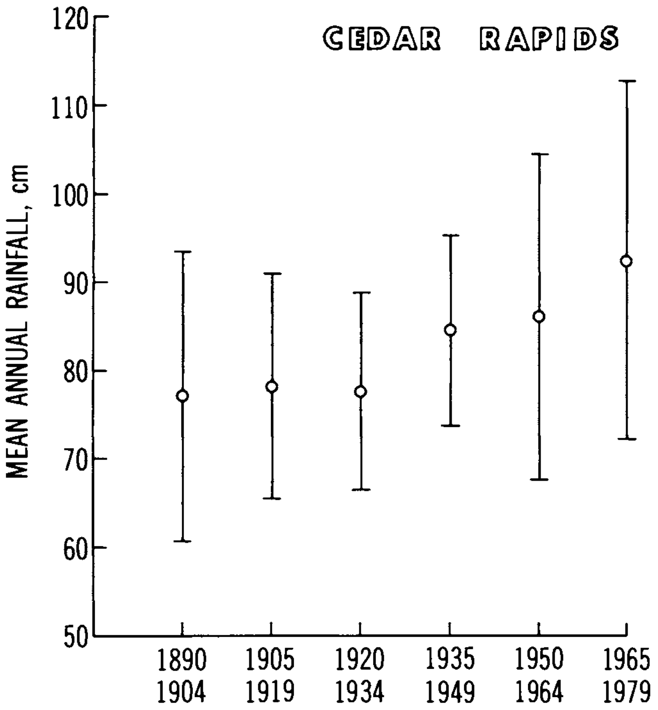

Fig. 4. Six 15-year mean annual precipitation values observed at Cedar Rapids, IA, with plus and minus one standard deviation as the error bars.

anomaly at one site should be the result of large-scale meteorological factors. However, as illustrated by Gregory (1979), this is not necessarily the case. He computed a single-site mean rainfall for the years 1726-1975 and then the accumulated residual resulting from subtracting the mean from the 250 station annuals. A similar plot (1890-1984) for the four Iowa sites, normalized to a single range, shows a rather interesting track (Fig. 5). Dubuque, which has the highest mean rainfall in the state, had a progressive decline after the third year, reaching a minimum in 1938. To some extent, Cedar Rapids tended to follow a similar track, with a less well-defined minimum at about the same time, followed by a second minimum in 1941. Des Moines and Storm Lake records, after the first 15 years, diverged, with a well-defined Des Moines minimum of 150 percent in 1941. After that, the two traces seem to be in good agreement but show little relationship to the Cedar Rapids or Dubuque records (Fig. 5). It must be remembered that this is a long-term algebraic sum of the residual and does not imply long dry or wet periods. A similar temperature plot (1890-1984) for the same four Iowa sites, normalized to a single range, shows a much different track. Clearly, there is no large scale departure from the mean at Cedar Rapids or Des Moines. In the case of Dubuque, the site change occurred 26 January 1951 which is the minor minimum two years after the 87 percent maximum. Human intervention contributed to the sharp change in slope of both Dubuque and Storm Lake temperature tracks; however, there is no clear explanation for the two-year delay in the case of Dubuque.

Comparisons of the temperature and precipitation records show little or no interrelationship. Independent correlation of annual mean temperature and annual precipitation records show no relationship using 95 years of Des Moines records. What it does suggest is that local temperature and precipitation variations do occur, which cannot be accounted for by large-scale atmospheric pollution such as an increased CO_2 concentration.

Spectral analyses of 94 years (1890-1983) of annual precipitation records show no significant periods present at the four sites (Fig. 6). The ordinate of Fig. 6 "wavenumbers" may be converted into frequency, in this case years, by dividing the wavenumber into the total sample size which must be an even number. Thus, the two Cedar Rapids peaks wavenumbers two and 22 represent a recurrence with an increase in precipitation every 47 and 4.27 years counting from wavenumber one or 94 years. With the exception of wavenumber two, 47 years, which is also prominent in the Dubuque record, there were no similarities in the remaining total percent of variance suggesting no meaningful annual cyclic precipitation events were present. This does not address the possibility of some monthly or seasonal periods, but with a small sample (94 years), it is doubtful whether it could be found given the natural fluctuations of annual precipitation records.

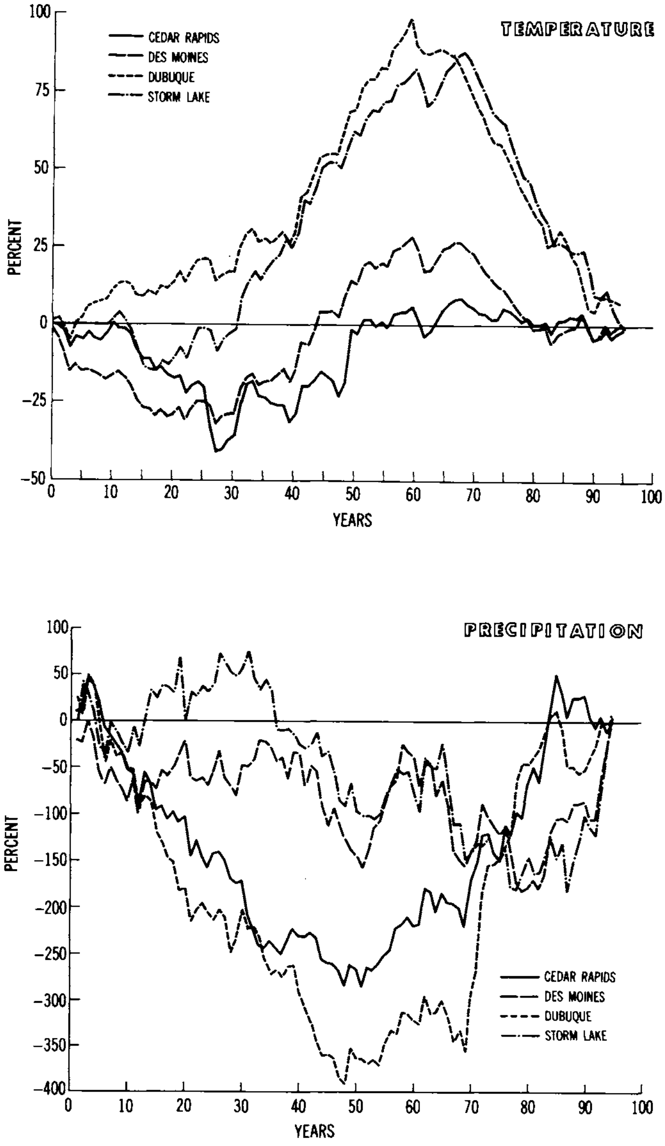

Fig. 5. Normalized accumulated departures from the mean annual precipitation and the departures from the mean annual temperature at each of the four sites.

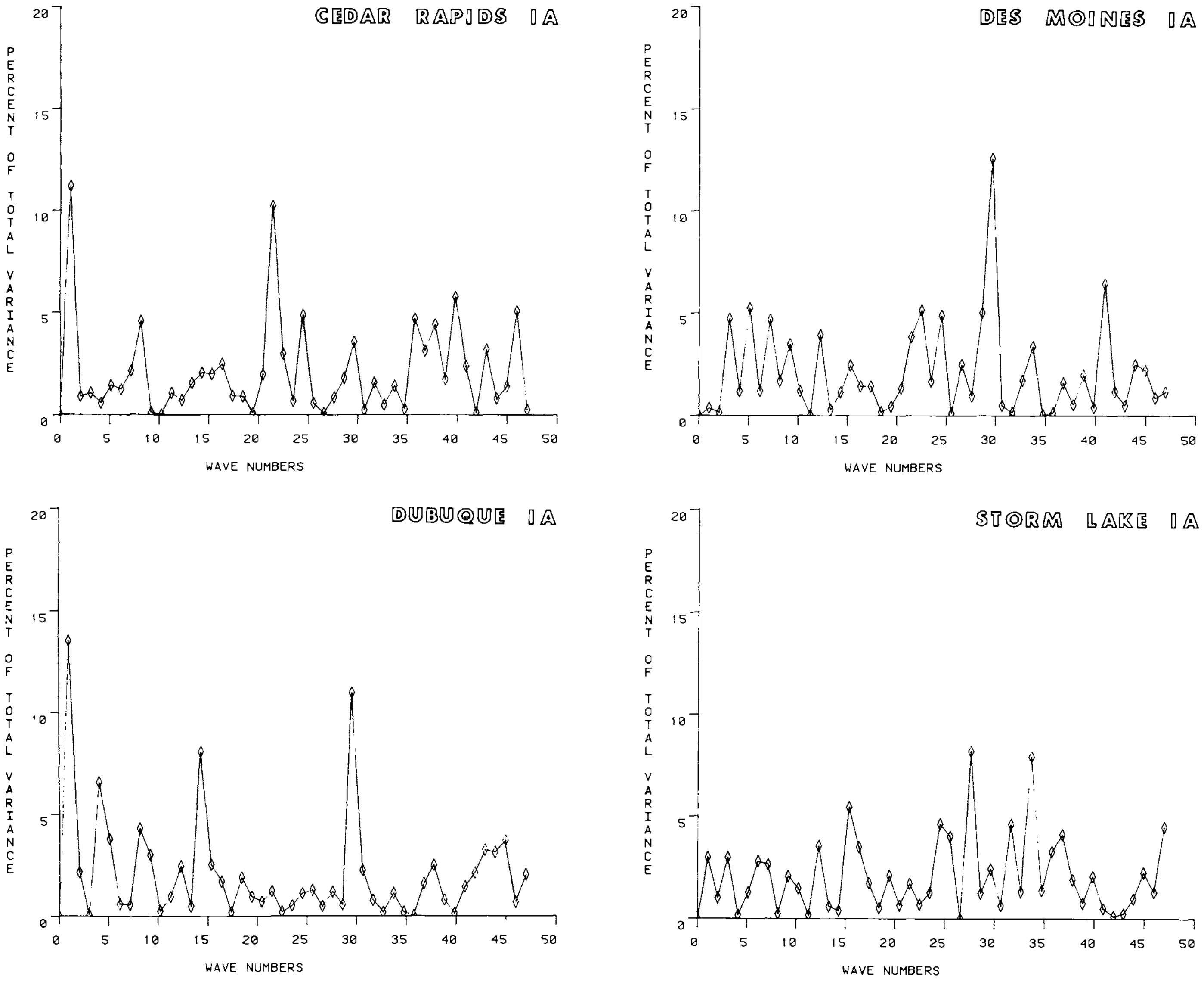

Fig. 6. Ninety-five year spectral analysis of annual precipitation record.

Although not illustrated here, spectral analysis values were computed from annual temperature records. With the exception of wavenumber one having a value of 25.5 percent at Dubuque and 35.0 percent at Storm Lake, the remaining percent of total variance at the four sites were well below a statistically significant value. Unless one considers the nature of spectral analysis, it is hard to explain apparent periodicity at two sites 254 km apart where the two intermediate sites show little or no response. This topic will be discussed further in the section regarding simulated data. The final topic relates a grouping of annual temperature-precipitation data to see whether cooler-wetter or warmer-drier sets could be identified. If the statewide climate were to shift or if it were coming out of a more homogenous period in the late 1800's, we would expect clustering of the data. Two sites (Dubuque and Storm Lake) were chosen specifically because of their maximum separation across the state. If some statewide homogenous climatic shift were occurring, the 10 percent extreme cases should be observed at both sites. The extreme years were defined simply as lying the greater distance from the mean temperature-precipitation intersection line and excluded from the group by a hand-drawn boundary to enclose approximately 90 percent of the data. With the exception of 1931 and 1951, the two site extremes were mutually exclusive. In fact, several extremes at one site were very close to the mean intersection line at the other site (Fig. 7).

Correlations of all site combinations, as well as t-test computations of precipitation records, show no strong evidence that the 95-year standard deviation differs between locations; that is, the variance is homogeneous. The t-test for all pair-wise comparisons of precipitation data indicate a difference must be at least 4.0 cm to be considered statistically significant at P 0.05 (Table 1). It is not clear whether these statistical site differences are an artifact of local exposure, observer technique such as time-of-day of observations as made at volunteer sites or true territorial differences.

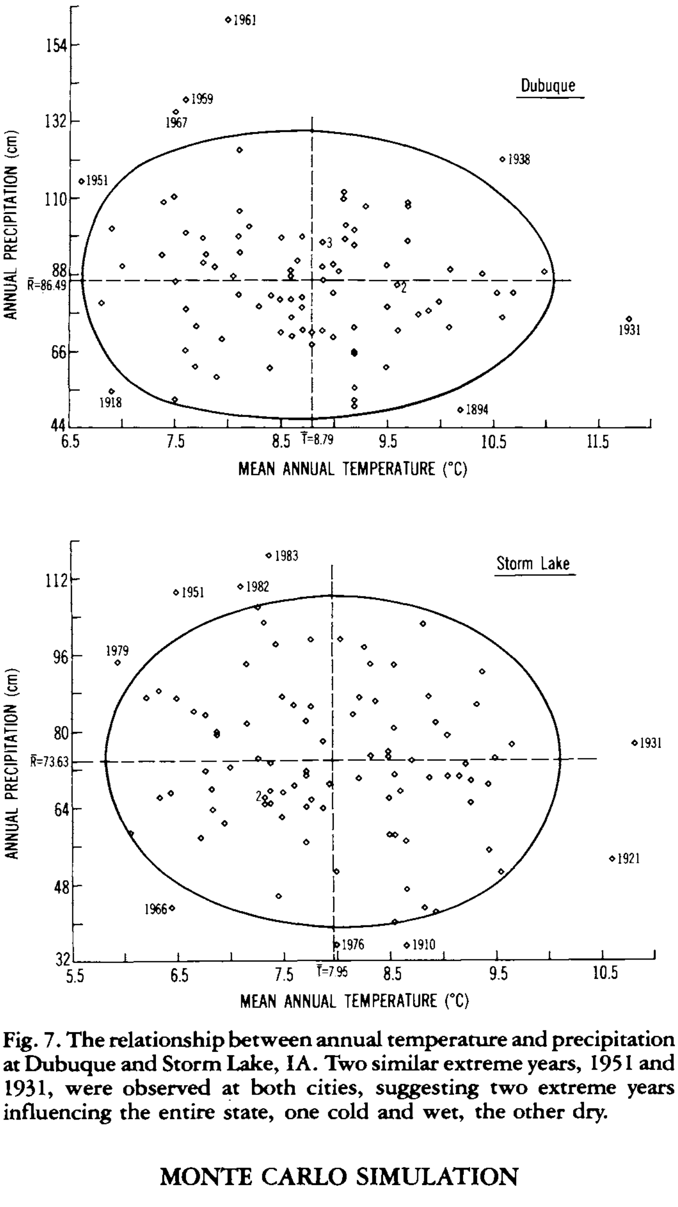

Fig. 7. The relationship between annual temperature and precipitation at Dubuque and Storm Lake, IA. Two similar extreme years, 1951 and 1931, were observed at both cities, suggesting two extreme years influencing the entire state, one cold and wet, the other dry.

MONTE CARLO SIMULATION

Because of the fickle nature of precipitation, a discontinuous function as opposed to temperature a continuous parameter, we find a number of unexplained perturbations. It was thought appropriate to make some comparisons between real observations, annual precipitation records, and random numbers tailored to simulate monthly and annual precipitation events. Frequently these simulated data, tailored to a specific parameter, are referred to as Monte Carlo simulation. With the development of the high speed electronic computer has come a powerful tool in the form of the pseudorandom number generator which is suitable for programming between arbitrary limits but still retains the attributes to real observations. These numerical values are frequently referred to as "white noise" (Knuth, 1980). Briefly, "white noise" may be defined as having a uniform distribution analogous to the spectrum of white light, which is also flat and featureless (Bloomfield, 1976).

The algorithm as employed here was originally assembled from 80 years of monthly mean precipitation records at Cedar Rapids, Des Moines, and Sioux City, Iowa. The sums of each of the monthly means were divided by three and multiplied by a factor approximating the mean standard deviation of the three above-mentioned sites, for each of the twelve months. The resulting program generated a monthly value analogous to a monthly rainfall ranging in amount from zero to approximately the product of the computed three site mean and their mean standard deviation. The raw random numbers ranged from 0 to .99 carried to 13 decimal places setting the upper limit to these data. As a point of interest, 10^{15} random numbers would have to be generated to get a recurring sequence. The primary algorithm passes the standard test for randomness (Kendall, 1976; Knuth, 1980). The algorithm was run in blocks of 80 years, that is, 960 simulated months, with the annual total and standrd deviation computed for each simulated year (Table 2).

A total of 20 blocks of 80 simulated years (19,200 months) were compiled along with annual amounts, 80-year means, standard deviations and the "year" of extreme maximum and minimum value. In addition, Fourier analysis of the annual totals was computed. The results provide some insight into both spurious peaks in the "percent of total variance" observed in both the real and simulated data. The twenty, 80-year random data sets show a range of mean annual simulated precipitation of 71.04 cm to 80.95 cm. The annual range for individual years was 117.7 cm down to 30.48 cm, which is quite comparable to the range of annual values from our real sites over their history of approximately 100 years. Examination of one group cataloged 1900-1980 for bookkeeping purposes shows the first 15 years to have more below normal annual simulated precipitation with only three above the 95 percent confidence line. The next three 15-year blocks were about neutral, with the final block (1960-1975) having six years below the 95 percent boundary. The 80-year mean being 76.45 cm is slightly above the 1600-year mean of 75.77 cm annual (Fig. 8). The simple regression plot of the 80 annual standard deviations show high values (more erratic) during the latter part of the sample period, and both plots show a downward slope (Fig 8). As might be expected, about half of the 20 data sets show a positive and half a negative slope. The two extremes are as follows: (catalog years 380-459) was the wettest period with positive slope +0.076; the driest period (catalog years 1821-1900) had a negative slope of −0.07.

To establish a bench mark for meaningful judgement of the observed "total percent of variance" as used in Fourier analysis of annual precipitation time series whether real or simulated, all of the 1600 simulated precipitation data were processed using a routine Fast Fourier algorithm (Bloomfield, 1976). The resulting values of total percent of variance for the 1600 years have been tabulated and are given in Table 3. There is one point which should be made in the use

Table 1. Correlation of 80 Years of Annual and Monthly Precipitation Records Between Selected Iowa Cities

Correlation between Cities	Distance between Cities, km	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
Cedar Rapids-Des Moines	187.7	.82	.74	.82	.55	.64	.52	.51	.53	.79	.49	.83	.66	.51
Cedar Rapids-Dubuque	110.9	.88	.84	.75	.49	.66	.58	.42	.42	.69	.75	.88	.73	.63
Cedar Rapids-Storm Lake	332.6	.29	.54	.77	.32	.56	.23	.40	.31	.58	.34	.51	.40	.45
Des Moines-Dubuque	297.7	.81	.64	.62	.50	.57	.52	.27	.35	.55	.26	.66	.45	.36
Des Moines-Storm Lake	193.1	.39	.59	.74	.46	.52	.34	.48	.32	.57	.63	.57	.68	.52
Dubuque-Storm Lake	413.6	.29	.47	.58	.27	.40	.26	.41	.20	.50	.19	.33	.33	.34

of Fourier analysis results. The Harmonic wavenumbers, which range from 1 to N, or one-half the raw data value, suggest a linear scale. However, the true or simulated time series (in this case, years) is a logarithmic plot arrived at by dividing the wavenumber into the total number of data points. Clearly, if a peak occurs on the right half of the abscissa, the event has been present through a number of cycles at least equal to half the sample size. In the case of those values ranging from wavenumber one to 15 (in a sample of 80), the statistical validity may be questioned because only one or two recurring cycles were observed. Needless to say, the three 16 percent values, along with all values above 10 percent of the total percent of variance given in Table 3, were related to wavenumbers no greater than 26. This would translate into 3.08 years in an 80-year sample which means the annual total had to be larger and similar every third time in 80/1600 simulated years. With these facts at our disposal, it was much easier to evaluate the real data with respect to large peaks.

REMARKS AND CONCLUSIONS

Visual examination of a long, 95-year, unbroken single site meteorological record seems to hold an implicit message of active and dormant periods. For example, the first seven years of the Dubuque (Fig. 1c) precipitation record (1890-1896) has five years exceeding ± one standard deviation ($\sigma = 19.35$) followed by a relatively dormant period of 57 years when only nine years exceeding $\pm 1\sigma$. The final 31 years had 13 extreme years, four years with +one σ, three years experienced more than $+2\sigma$, while the remaining nine cases extended one σ below the mean one of which extended more than 2σ below the mean. Although such analysis is interesting for comparison, it has little statistical substance. The simulated 80-year precipitation record for Randomville has similar groupings of active and dormant periods (Fig. 8a). The first 13 simulated years had only one case exceeding $\pm\sigma$, where $\sigma = 13.84$ cm for the Randomville data between the catalog years 1900 and 1979, while the next 13 simulated years experienced five cases falling outside $\pm\sigma$, one of which outside -2σ.

A more objective approach to the real or random properties of both temperature and precipitation records presented here might be Fisher's "runs test". Fisher (1926) suggested a simple runs test in which the sign of the first derivative changes every third or, in rare cases, fourth period (in this case, years). If the sign does not change, that portion of the data exceeding three periods may be considered non-random. Inspection of Figs. 1 and 3 shows one run exceeding three years without a sign change. The years 1960-1964 show continuous temperature increase at Des Moines (Fig. 3b). This represents a single case out of a total of 760 years of data for the two parameters, temperature and precipitation. A second test for randomness was made by using an autocorrelation computation; the first 10 lags of the 95-year record at each site yielded a statistically insignificant value, indicating no year-to-year persistence in the precipitation records. Such a result suggests that these data are composed of "white noise" (Bunting *et al.* (1976)).

The only clear site trend was found in the Cedar Rapids record; here, six 15-year means and standard deviations with error bars were computed. After 1934, the mean rainfall seems to increase progressively (Fig. 5). This figure illustrates the type of phenomenon that has been seen in climatological records since records were first kept. The fact is, dry or wet periods occur at single sites in some cases, and these extend for several decades or more with no explanation.

Because of the regional nature of such excursions of a single site parameter, it is difficult to suggest a physical cause of the phenomenon. The annual precipitation records are strongly influenced by the months of May through September, where the majority of rain is of a convective nature. Such rains are discrete events and seldom cover more than a small fraction of the state (Jensen, unpublished manuscript). It is within the realm of probability that Cedar Rapids received a "lucky draw" for the majority of 40 years starting in 1934.

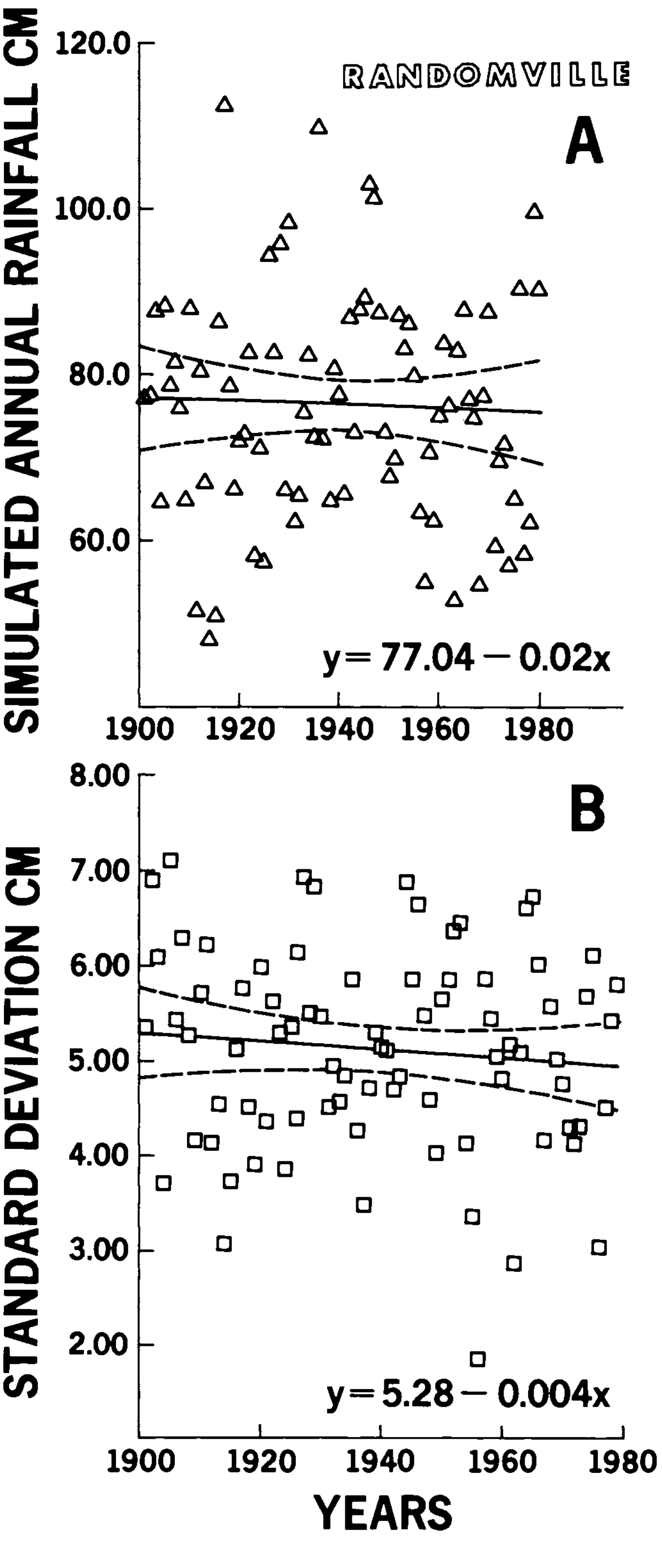

Fig. 8. Eighty simulated annual rainfalls for Randomville, IA. A. Annual total. B. Standard deviation.

Table 2. Statistical Summary of the Equivalent of 80 Years of Simulated Precipitation Data at Randomville, IA

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
MEAN	2.74	2.54	5.00	7.04	9.82	12.73	8.36	8.00	8.86	4.75	3.56	2.77	76.23
SDEV	1.37	1.50	2.97	4.04	5.94	6.27	5.23	5.11	5.21	2.90	2.13	1.63	13.84
CVAR	49.93	58.11	59.33	57.31	60.43	49.23	62.55	63.72	58.60	60.98	59.95	58.96	18.17

	JAN/YR	FEB/YR	MAR/YR	APR/YR	MAY/YR	JUN/YR	JUL/YR	AUG/YR	SEP/YR	OCT/YR	NOV/YR	DEC/YR	ANN/YR
MAX	4.95/52	5.21/17	9.45/69	13.84/65	19.34/23	22.12/76	17.09/65	17.35/70	17.78/27	10.54/37	7.49/42	5.33/41	112.17
MIN	0.00/23	0.05/45	0.03/54	0.03/01	0.03/31	0.05/35	0.48/51	0.20/11	0.15/75	0.05/51	0.18/34	0.03/67	48.21/14
RANGE	4.95	5.16	9.42	13.82	19.35	22.07	16.61	17.15	17.63	10.52	7.32	5.31	64.54

*NOTE: Randomville is the Reference Name for the Monte Carlo algorithm used to generate simulated precipitation data. All values in cm, except for coefficient of variation which is expressed as a percentage.

The identification of both linkage and shift in precipitation patterns was not found, nor was any clear cyclic relationship observed, at least at the annual level. Time-series analysis at the four sites shows no statistically significant periodicity. Clearly, the variability of each site makes it difficult to identify trends. Gregory (1975) suggested that the study of short-term extremes at a single site is nonproductive and, further, that grouping of nearby sites provides a better climatic picture. In this study, we were more interested in the unexplained 15- to 30-year change at a single site; one might think such change, if real, should be controlled by large-scale meteorological factors. However, such factors would influence most, if not all, sites in Iowa. The Monte Carlo simulation, with similar mean values and annual standard deviations, only supports the proposition that, within a single century, no true shift can be identified. That is to say, the natural variability is much greater than any small, real, or hypothetical change. The thought that we are experiencing a climatic change seems to be linked to lack of research into past records and the real or chance reoccurrence of passive or active years.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the help of Paul Waite, State Climatologist, and his staff for their generous assistance in assembling early history of sites and in compiling early climatic records from a number of sites. Also, thanks to Professor David F. Cox, Department of Statistics, for our many discussions and for his help in the statistical testing of our data sets.

REFERENCES

BLOOMFIELD, P. 1976. "Fourier Analysis of Time Series: An Introduction." John Wiley & Sons, New York.

BROOKS, C.E.P. 1948. "Climate Through the Ages." Dover Publications, Inc., New York, 2nd Revised Edition, 1948.

BUNTING, A.H., M.D. DENNETT, J. ELSTON and J.R. MILFORD. 1976. "Rainfall trends in the West African Sahel." *Q.J.R. Meteorol. Soc., 102,* 59-64.

BURROUGHS, W.J. 1980. "Average Temperature and Rainfall Figures in British Winters." *Weather, 35:3,* 75-79.

CAMUFFO, DARIO. 1984. "Analysis of the Series of Precipitation in Padova, Italy." *Climatic Change, 6,* 57-77.

CRADDOCK, J.M. 1979. "Methods of Comparing Annual Rainfall Records for Climatic Purposes." *Weather, 34:9,* 332-346.

ELLIOTT, W.P. 1983. "A note on the Historical Industrial Production of Carbon Dixoide," *Climatic Change,* 5:2, 141-144.

FISHER, R.A. 1926. "On the Random Sequence." *Q.J.R. Meteorol. Soc. 52:219,* 250.

GREGORY, S. 1955. "Some Aspects of the Variability of Annual Rainfall over the British Isles for the Standard Period, 1901-30." *Q.J.R. Meteorol. Soc., 81:348,* 257-262.

GREGORY, S. 1975. "On the Delimitation of Regional Patterns of Recent Climatic Fluctuations." *Weather, 34:9,* 363-369.

GREGORY S. 1979. "The Definition of Wet and Dry Periods for Discrete Regional Units." *Weather, 34:9,* 363-369.

KENALL, M. 1976. "Time-Series." Charles Griffin and Company Ltd., London and High Wycombe, Second Edition.

KNUTH, D.E. 1981. "The Art of Computer Programming." Addison-Wesley Publishing Co., Reading, Massachusetts, Vol. 2/Seminumerical Algorithms, Second Edition.

LAMB, H.H. 1984. "The Future of the Earth-Greenhouse or Refrigerator?", *J. Meteorol.-UK, 9:92,* 237-242.

MEKO, D.M., C. W. STOCKTON and T.J. BLASING. 1985. *Science, 229,* 381-384.

MITCHELL, J.M., JR. 1958. "Effect of Changing Observation Time on Mean Temperature." *Bull. Amer. Meteor. Soc.* Vol. 32:2, pp. 83-89.

PALUMBO, A. and A. MAZZARELLA. 1980. "Rainfall Statistical Properties in Naples." *Mon. Weather Rev., 108:7,* 1041-1045.

PALUMBO, A. and A. MAZZARELLA. 1984. "Local Recent Change in Extreme Air Temperature." *Climatic Change, 6:3,* 303-309.

SCHULMAN, EDMUND. 1938. "Nineteen Centuries of Rainfall History in the Southwest." *Bull. Am. Meteorol. Soc., 19:5.*

Table 3. Summary of Fast Fourier Analysis from 1600 Years of Randomville Simulated Precipitation Data

	Percent of Total Variance														
	PERCENTAGE														
Wave Numbers	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1-5	15	13	7	7	4	0	0	5	0	0	0	0	0	0	2
6-10	12	6	3	12	4	1	0	0	0	1	0	0	0	1	0
11-15	14	16	11	5	4	2	0	3	0	0	0	1	1	0	0
16-20	13	11	9	7	2	1	0	0	0	0	0	0	0	0	0
21-25	16	13	7	3	3	1	1	0	1	0	0	0	0	0	0
26-30	17	18	4	6	4	2	0	0	0	0	0	0	0	0	1
31-35	6	14	5	1	2	2	1	1	0	0	0	0	0	0	0
36-40	14	12	6	2	1	0	0	3	0	0	0	0	0	0	0

The values in this table are the sum of Percent of Total Variance grouped in increments of five wave numbers, left-hand column.

SENIOR, M.R. 1969. "Changes in the Variability of Annual Rainfall over Britain." *Weather, 24:9,* 354-359.

TREFEL, J.S. 1985. "Concentric Clues from Growth Rings Unlock the Past." *Smithsonian, 16:4,* pp. 46-52.

VAUGHAN, H.C. and G.R. WHITE. (In Press). "Is the Agricultural Community Expecting Too Much from the Weather?". *J. Climate Appl. Meteorol.*, Boston, MA.

WELLER, G., D.J. BAKER, JR., W.L. GATES, M.C. MACCRACKEN, S. MANABE and T.H. VANDERHAAR. 1983. *Changing Climate,* Ch. 5, National Academy Press, Washington, D.C.

YAMAMOTO, T., T. IWASHIMA and N.K. SANGA. 1986. "An Analysis of Climatic Jump." *J. of the Meteor., Soc. of Japan,* 64:2, pp. 273-280.