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ABSTRACT

Precipitation data for Macomb (Illinois) for the period 1912-1981 were the bases for developing classroom exercises that offered college students experience in collecting such data. After students collected the data, they reduced them to manageable proportions, and then examined average long-term relations which may have emerged among yearly, monthly, and daily values. This approach makes the study of weather and climate more relevant to students by utilizing local sources of data that students may find appealing and informative. Examples of the many figures, questions, and discussion topics that can be used in exercises to help students reflect on how the climate and weather conditions influenced the precipitation patterns are presented. For example, to get a concise summary of the general precipitation pattern in their community, the students placed on a graph yearly precipitation values for the entire period of record. To examine possible precipitation trends, students calculated a 5-year running mean for the Macomb data. The resulting graph helped to smooth the yearly fluctuations evident in their initial graph of yearly precipitation values, making the interpretation of dry and wet periods easier. (RM)

CLASSROOM EXERCISES UTILIZING PRECIPITATION DATA

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Introduction

Precipitation data are available from numerous sources for use in the classroom. One possible source often overlooked is the precipitation amounts recorded at the local water treatment or sewage treatment plants. Usually all that is required to collect such data is plenty of time and patience. A form for collecting the data should be prepared in advance to facilitate the collection process. A table with 31 days across the top and 12 months along the side works well for collecting one year's data on a single sheet of paper. This form can be drawn on a ditto and then run as often as needed.

If precipitation amounts are not available in your community a copy of the Local Climatological Data prepared by the National Weather Service for a nearby community may serve as an acceptable substitute. This source of precipitation data is usually available at an university library or may be obtained through interlibrary loan. As a last resort this data could even be purchased from the National Weather Service, although the cost of even 30 years of data could be prohibitive.

Precipitation types could include rain, snow, hail, sleet and freezing rain or a combination of any of these five. Originally rain and snow data were considered for this study but a paucity of the latter prevented its inclusion and restricted the study almost entirely to rainfall. The exceptions occurred during the winter because it was not always possible to separate rain from snow, sleet or freezing rain.

Precipitation data for the city of Macomb, Illinois were collected at the local water treatment plant for the period 1912-1981. Yearly, monthly and daily values were prepared for use in the classroom exercises. Even though organizing data for 70 years was time consuming and tedious it ultimately provided a format from which data could be quickly tabulated for a variety of exercises. Such a format could, in fact, be part of a classroom exercise in which data acquisition is divided among students in an introductory synoptic climatology course. This activity is as valuable as the actual use of the data since it provides students with the experience needed to efficiently acquire and process data for other research projects.

The precipitation data for Macomb were first tabulated chronologically by year and month. They were then ranked by year and month for the entire 70 year period. Finally, the number of days receiving .01 inch of precipitation or greater was recorded for the same time period.

Results

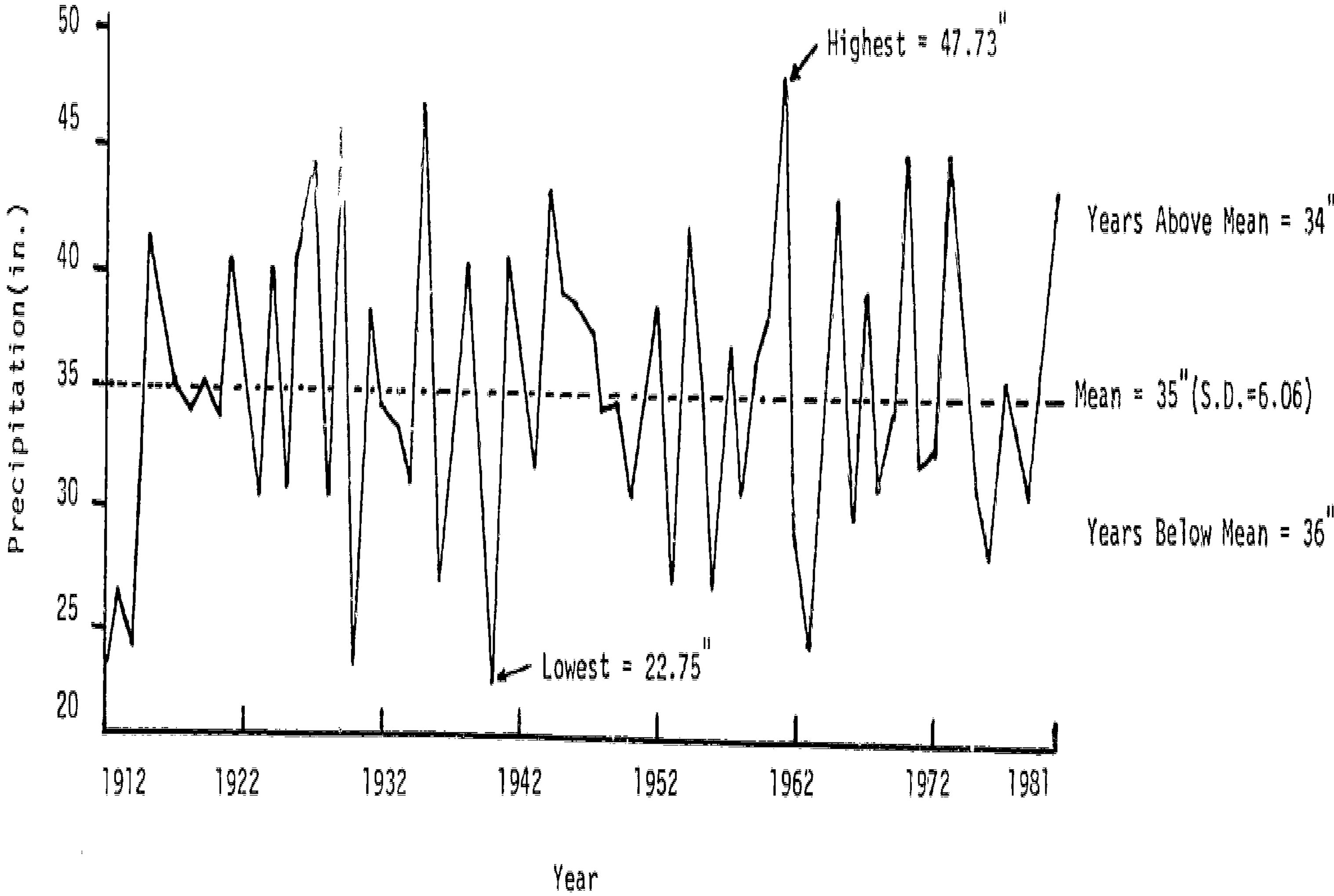
Yearly precipitation values were placed on a graph for the entire period of record(Figure 1). The mean value was represented by a dotted line on the graph so that all years could be compared to average conditions. The mean of 35 inches was equaled only twice in 70 years even though the number of years above and below the mean were almost equal. The considerable fluctuations in precipitation from year to year were supported by a standard deviation of just over six inches. The highest precipitation total for any year was 47.73 inches which was more than twice the lowest value of 22.75 inches. A graph of this sort provides students with a concise summary of the general precipitation pattern in their community.

The fluctuations around the mean from year to year make it difficult to detect possible dry or wet period for Macomb. One method of examining possible precipitation trends involved calculating a five-year running mean for the

FIGURE 1

·RLY PRECIPITATION VALUES

·ACOMB, ILLINOIS 1912-1981



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Macomb data(Figure 2)[1]. The resulting graph helped to smooth the yearly fluctuations evident in Figure 1, making the interpretation of dry and wet periods easier.

Notice that this procedure revealed distinct periods of above and below average precipitation. What effect these "cycles" might have locally could be investigated. Average crop yields might be compared to the wet and dry periods to determine whether precipitation influences production. The effect of extended dry periods on local surface and ground water supplies could also be examined. Finally, students could discuss the advantages and disadvantages of using Figures 1 and 2. Actually, the use of both is recommended to more fully comprehend the long-term trends in local precipitation.

Another exercise investigated long-term precipitation trends by dividing the study period in half and calculating the means and standard deviations(Figure 3). The mean precipitation for the first half of the study period(34.98 inches) was almost the same as the figure for the latter half of the study period(35.02 inches). Even though the 1947-1981 period had a slightly higher average it would be very risky to conclude that a wetter trend was in effect because errors in measurement could easily account for this small difference. The standard deviations for the two periods revealed greater variability from year to year during 1912-1946 than during 1947-1981. These periods could be compared to Figures 1 and 2 so that students could observe how the same data can be represented in a variety of ways.

Another way to clarify precipitation patterns for Macomb involved calculating the mean and standard deviation for seven, ten year intervals(Figure 4). Three of the seven intervals had ten year means below the 70 year average of 35 inches. Notice that each of the three drier periods was followed by a wetter than average interval. This may indicate that wet and dry periods

FIGURE 2

YEARLY PRECIPITATION VALUES

FIVE-YEAR RUNNING MEAN 1914-1979

MACOMB, ILLINOIS

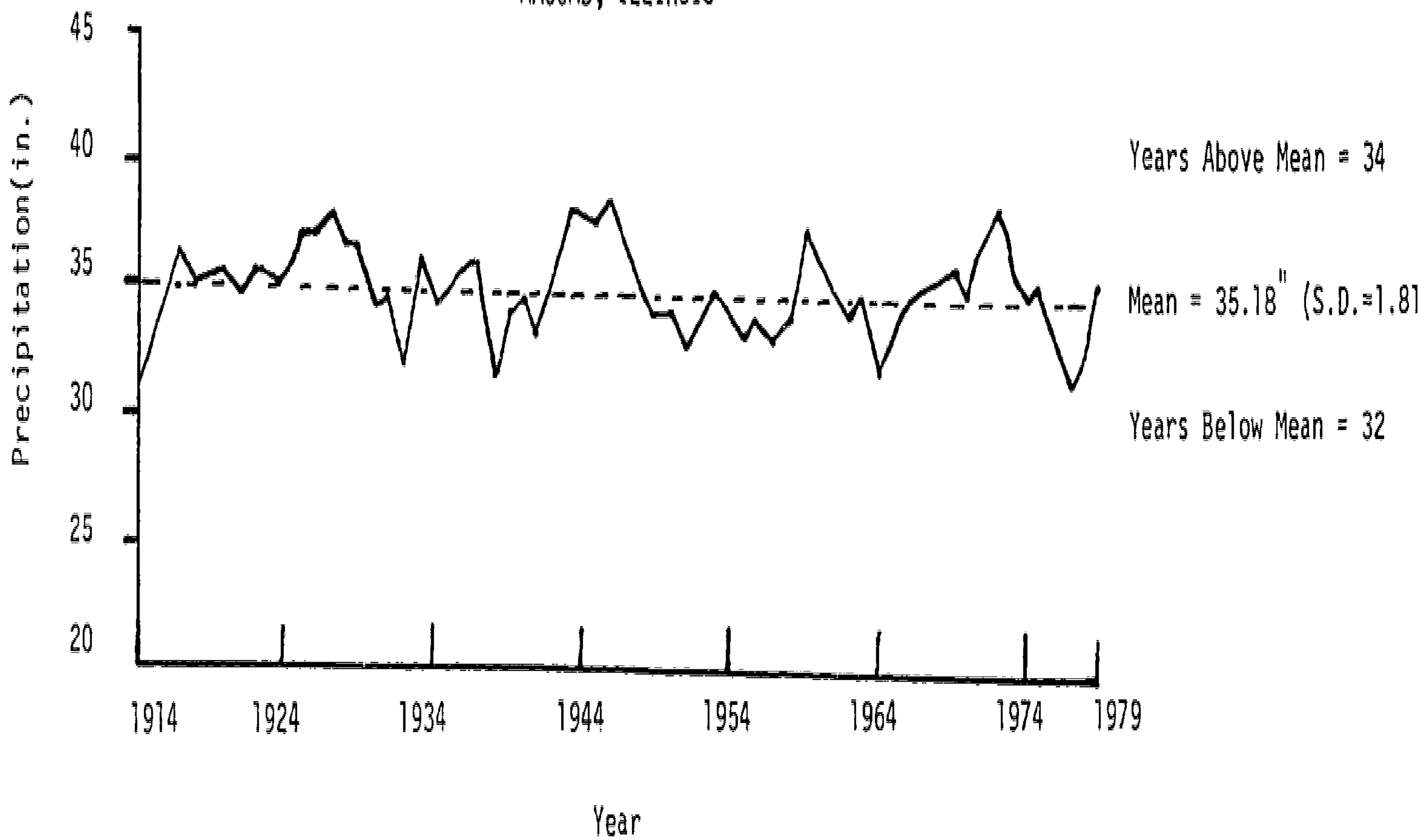

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FIGURE 3

COMPARISON OF YEARLY PRECIPITATION VALUES

MACOMB, ILLINOIS

Year	Mean(in.)	Standard Deviation(in.)
1912-1981	35.00	6.06
1912-1946	34.98	6.47
1947-1981	35.02	5.62

FIGURE 4

COMPARISON OF YEARLY PRECIPITATION VALUES

TEN YEAR INTERVALS FOR MACOMB, ILLINOIS

Year	Mean(in.)	Standard Deviation(in.)
1912-1921	33.02	6.20
1922-1931	36.00	6.84
1932-1941	34.28	6.58
1942-1951	36.28	3.64
1952-1961	35.96	6.16
1962-1971	33.89	6.25
1972-1981.	35.58	5.32

balance one another over several decades. The precipitation characteristics of the Koppen type associated with this area could be examined as part of a class exercise. The standard deviation of 3.64 inches for 1942-1951 was very prominent because it was so low compared to the others. Interestingly, it is very difficult to detect the period associated with the relatively low standard deviation on Figure 1. A combination of tables and graphs for the same data may reveal different characteristics about precipitation patterns. Students could be asked to comment on which type of data presentation they find easiest to understand and use.

Figures 5, 6 and 7 displayed in several different ways the normal probability distribution of yearly precipitation for Macomb. The procedure for completing a table like that in Figure 5 is discussed in the book by Hammond and McCullagh.[2] The precipitation intervals were chosen somewhat arbitrarily but it is recommended that at least seven classes and no more than twelve be used in this type of exercise. The percentage cumulative frequency was obtained by dividing the corresponding cumulative frequency of 70, the number of years of record. Thus, for the interval 33-36 the number 41 divided by 70 and then multiplied by 100 equals 59%.

The main value of Figure 5 is that it allows the data to be plotted on probability graph paper similar to that displayed in Figure 6 but without the detailed lines. A trend line has been fitted by sight to the points. Notice that the points are all very close to the trend line indicating that the data are nearly normally distributed. It is now possible to determine the probability of a given amount of precipitation during the period of record using either the right or left axis. For example, the probability of receiving 33 inches of precipitation in any given year can be found by moving vertically from 33 to the trend line and then horizontally to the right axis. The answer

FIGURE 5

YEARLY PRECIPITATION VALUES 1912-1981

NORMAL PROBABILITY DISTRIBUTION FOR MACOMB, ILLINOIS

	Precipitation Interval (in.)								
	21-24	24-27	27-30	30-33	33-36	36-39	39-42	42-45	45-48
Frequency	4	4	4	14	15	11	9	4	5
Cumulative Frequency	4	8	12	25	41	52	61	65	70
% Cumulative Frequency	6	11	17	37	59	74	87	93	100

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FIGURE 6

YEARLY PRECIPITATION VALUES 1912-1981

NORMAL PROBABILITY DISTRIBUTION FOR MACOMB, ILLINOIS

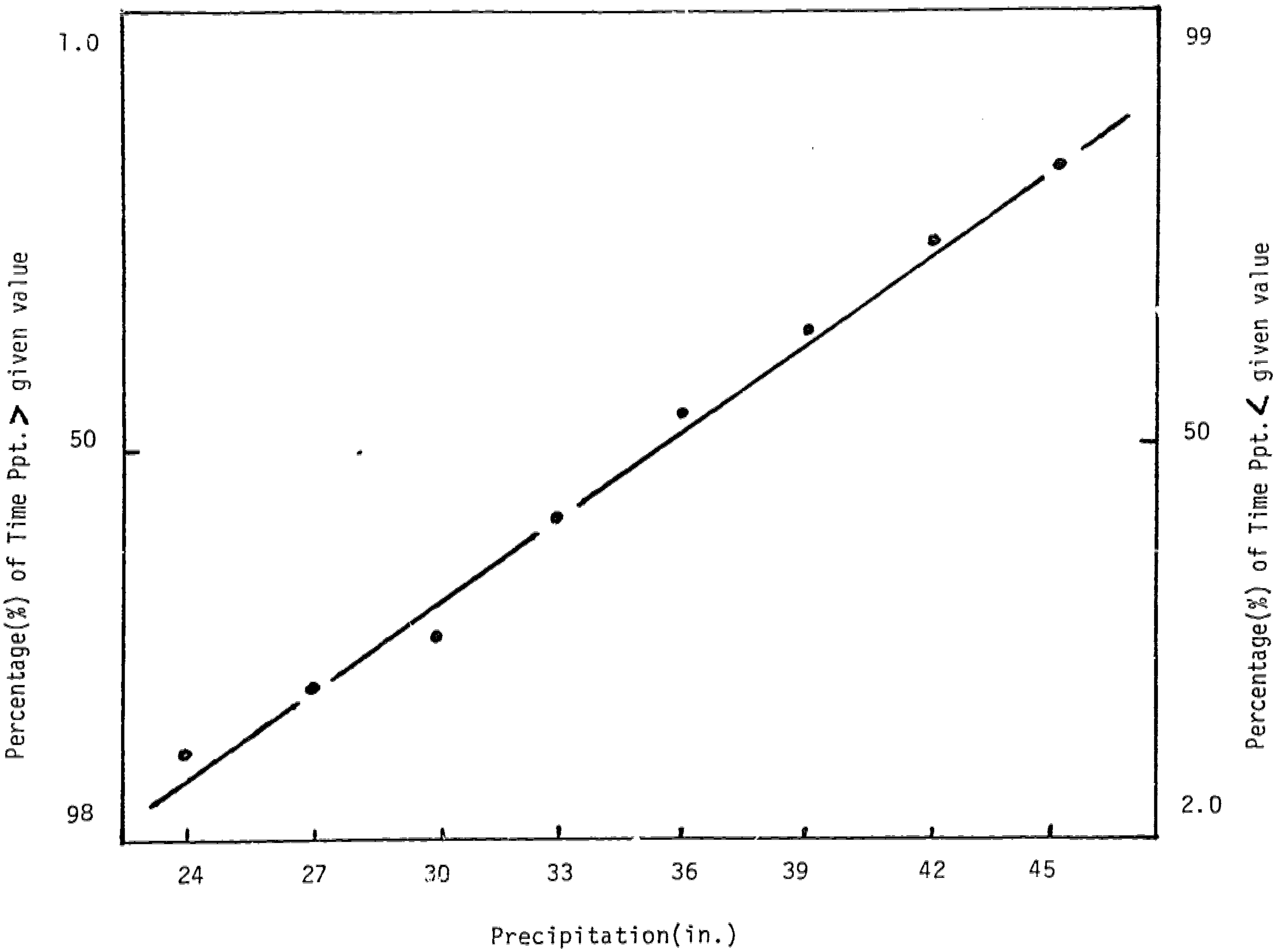

FIGURE 7

COMPARISON OF EXPECTED AND ACTUAL PRECIPITATION

FOR MACOMB, ILLINOIS 1912-1981

Category	Expected	Actual
Ppt. less than 35.00"	35	36
Ppt. greater than 35.00"	35	34
Years within one standard deviation	48	49
Years within two standard deviations	67	68
Years within three standard deviations	70	70

is a 37% probability that in any given year the total precipitation will be equal to or less than 33 inches. Conversely, if you moved vertically from the value 33, intersected the trend line and then moved horizontally to the left you would obtain an answer of 63%. This figure means that there is a 63% probability that the yearly precipitation total for Macomb will be equal to or greater than 33 inches. Notice that when you move to the right and to the left of a point on the trend line the values intersected on the two vertical axes always equal 100%. It is also possible to use a probability to find a corresponding precipitation value. For example, the 50% value on either vertical axis corresponds to a precipitation value of 35 inches which is the long-term yearly mean for Macomb. Thus, there is a 50% probability that in any given year precipitation will be equal to or greater than 35 inches and a 50% probability that precipitation will be equal to or less than 35 inches.

Figure 7 compared the expected precipitation probabilities with the actual values obtained from the ranking of the original data. In each case the expected and actual values were almost identical confirming the normal distribution and validity of the trend line used for interpreting Figure 6.

Figures 8 and 9 revealed characteristics of the seasonal precipitation pattern at Macomb. The mean seasonal precipitation for the entire 70 years was compared to the mean seasonal precipitation for the first 35 years and for the second 35 years of the record. Patterns were similar in all three time periods with winter being the driest season, fall the next driest while summer was just slightly wetter than spring on the average. When the two halves of the 70 year record are compared by season in Figure 8 wet and dry seasons alternated with one another compared to the overall 70 year seasonal means. Students could comment on the climate type and the climatic controls responsible for the seasonal patterns. The second half of the 70 year record revealed a

FIGURE 8

COMPARISON OF MEAN SEASONAL PRECIPITATION

MACOMB, ILLINOIS

Season	Mean(in.)		
	1911/12 to 1981/82	1911/12 to 1946	1947 to 1981/82
Winter	4.61	4.66	4.55
Spring	10.24	9.99	10.48
Summer	11.64	11.08	12.19
Fall	8.64	9.28	7.99

FIGURE 9

COMPARISON OF THE RANGE OF SEASONAL PRECIPITATION

MACOMB, ILLINOIS

Season	1911/12 to 1981/82	
	Months Above Mean	Months Below Mean
Winter	37	34
Spring	35	36
Summer	30	41
Fall	29	41

spring and summer which were wetter, and a winter and fall which were drier than the first half of the record. Does this indicate a trend in seasonal precipitation? What arguments can be offered by students to support or reject the idea that a trend in seasonal precipitation is taking place?

The months above and below the mean for each season were compared in Figure 9. The winter and spring seasons exhibited distributions that were almost equally divided above and below the mean. The summer and fall seasons, in contrast, were skewed significantly toward the months below the mean. This data could be compared to Figure 8 and the students could consider the climatic controls that might cause this situation. It is also possible that some of the monthly distributions are not normal and students might test for this condition using the same procedure followed in completing Figure 6.

The mean monthly precipitation for the 70 year period and the number of months above and below the monthly means were listed in Figure 10. More than 60% of the yearly mean precipitation was concentrated in the spring (March-May) and summer(June-August) months. The four months of February, March, April and December were the only ones which were almost evenly divided between months above and below the mean. The eight remaining months had a substantially greater number below the mean than above. Perhaps, the months that most closely approximate a normal distribution are also the four which are divided most evenly around the mean?

Figure 11 lists the highest and lowest monthly precipitation totals for each month during the study period. Several questions could be examined by students regarding the highest precipitation values for Macomb. First, what accounts for September having the highest monthly precipitation total when normally spring and summer are the wettest seasons? Second, was this particular September associated with an especially wet fall or wet year? Could

FIGURE 10

MONTHLY MEAN PRECIPITATION VALUES

MACOMB, ILLINOIS 1911/12-1981/82

Month	Mean(in.)	Months Equal to or Above Mean	Months Below Mean
January	1.65	26	45
February	1.32	32	39
March	2.76	35	36
April	3.50	34	37
May	3.97	31	40
June	4.56	30	41
July	3.81	29	42
August	3.27	26	45
September	3.82	28	42
October	2.76	30	41
November	2.07	30	42
December	1.64	36	35

FIGURE 11

MONTHLY HIGH AND LOW PRECIPITATION VALUES

MACOMB, ILLINOIS 1911/12-1981/82

Month	Highest(in.)	Lowest(in.)
January	8.13	T
February	3.72	.18
March	5.86	.39
April	7.97	.64
May	9.81	.47
June	10.72	.20
July	11.31	.16
August	8.87	.46
September	13.29	.03
October	10.04	.05
November	6.68	.01
December	3.76	.15

this anomaly be explained by considering mesoscale atmospheric disturbances like tornadoes and hurricanes? Third, why is the highest value for August so much less than either July or September? Could some special weather factor such as a blocking high help explain this situation? Finally, what weather situation might be associated with the highest value in January. It is substantially higher than either December or February. Similar questions could be posed to students about the lowest monthly precipitation values in Figure 11. Notice that the ratio between the highest and lowest values in the lowest category is much greater than the ratio in the highest category. The class could investigate which causes more difficulties with the local economy--an excess of precipitation or a lack of precipitation?

The number of days on which precipitation equaled or exceeded .01 inch was portrayed seasonally and monthly in Figures 12 and 13. Spring experienced more precipitation days than summer in Figure 12, yet summer had a greater percentage(33%) than spring(29%) when average annual precipitation was considered. The explanation for this situation will require students to consider frequency of precipitation versus intensity of precipitation. The summer is usually characterized by more intense precipitation than spring. The same sort of reasoning should also be employed during the winter when the percentage of precipitation days(20.6%) was considerably more than the percentage of average annual precipitation(13%). The constrasts between winter and summer types of precipitation and the weather systems that cause them should be examined by students for a more complete understanding of seasonal precipitation.

Another class project might involve calculating the climatic frequency. This value represents the number of days or percentage of the time that precipitation occurs in a given locale. The climatic frequency for Macomb is 102 days which means that during an average year precipitation occurred on

FIGURE 12

AVERAGE SEASONAL PRECIPITATION DAYS(.01" or >)

MACOMB, ILLINOIS 1912-1982

Season	Percentage of Precipitation Days*	Percentage of Average Annual Precipitation
Winter	20.6	13
Spring	30.5	29
Summer	25.9	33
Fall	23.0	25

*During an average year precipitation occurred on 28% of the days.

FIGURE 13

AVERAGE MONTHLY PRECIPITATION DAYS(.01" or >)

MACOMB, ILLINOIS 1912-1982

Month	Percentage of Precipitation Days*	Percentage of Average Annual Precipitation
January	7.0	5
February	6.4	4
March	9.2	8
April	10.3	10
May	11.0	11
June	10.1	13
July	7.9	11
August	7.9	9
September	8.4	11
October	7.2	8
November	7.4	6
December	7.2	4

* Average per month is 8.3%.

28% of the days.

Finally, Figure 13 compared the percentage of precipitation days to the percentage of average annual precipitation on a monthly basis. Questions similar to those posed for Figure 12 can be applied to the data in Figure 13. Again, the summer months of June, July and August experienced fewer precipitation days on a percentage basis compared to the percentage of average annual precipitation. Very likely precipitation that does fall is convectional in nature and more intense than at other times of the year. Contrast this with the situation during the spring when the precipitation days and the percentage of average annual precipitation are nearly equal.

Summary

The original 70 years of precipitation data for Macomb were the bases for developing classroom exercises that offered students experience in collecting precipitation data, reducing it to manageable proportions and then examining average long-term relations which may have emerged among yearly, monthly and daily values. Presenting the data in a variety of tables should assist students in reflecting on how the climate and weather conditions influenced the precipitation patterns. This approach is in contrast to the usual situation which first considers climate and weather conditions and then examines individual stations. The approach presented in this paper may assist in making the study of weather and climate more relevant by utilizing local sources of data that students may find more appealing and informative.

FOOTNOTES

1. Theakstone, W. H. and C. Harrison. The Analysis of Geographic Data. London: Heinemann Educational Books, 1975.

2. Hammond, Robert and Patrick McCullagh. Quantitative Techniques in Geography: An Introduction. Oxford: Clarendon Press, Second Edition, 1978.