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THE STATISTICAL ANALYSIS OF PRECIPITATION IN ANKARA, TURKEY

Ankara'da Yağışın İstatistiksel Analizi

İhsan ÇİÇEK

Ankara Üniversitesi, Dil ve Tarih-Coğrafya Fakültesi, Coğrafya Bölümü
cicek@humanity.ankara.edu.tr

ABSTRACT

Monthly and annual precipitation data of Ankara Station in Turkey for a 75 year period between years 1926-2000 are statistically analyzed. It was observed that the precipitation distribution is not normal with large year to year differences. The right –skewed distribution is more pronounced in summer. A trend analysis reveals an insignificant decrease in March, September and December but a significant increase in April, August and October. The monthly precipitation is distributed randomly except August. Annual precipitation has increased, significant at the 1 percent level.

Key Words: Ankara, Precipitation, Mann – Kendall rank correlation, Kruskal – Wallis test, Wald – Wolfowitz serial correlation

ÖZET

Ankara Meteoroloji İstasyonu'nun 1926-2000 yılları arasında 75 yıllık, aylık ve yıllık yağış verilerinin kullanıldığı bu çalışmada yağışların normal dağılım göstermediği saptanmıştır. Yıllar arasında büyük yağış farklılıkları vardır ve yağışlarda pozitif çarpıklıklar bulunmaktadır. Pozitif çarpıklıklar yaz aylarında daha da artmaktadır. Mart, eylül, aralık dışındaki ayların yağışlarında bir artma eğilimi vardır. Nisan, ağustos, ekim aylarındaki artış istatistiksel olarak anlamlıdır. Aylık yağışlar ağustos ayı hariç rasgele dağılmaktadır. Yıllık yağışlarda ise %1 anlamlılık düzeyinde bir artma eğilimi vardır.

Anahtar kelimeler: Ankara, Yağış, Mann – Kendall korelasyonu, Kruskal – Wallis testi, Wald – Wolfowitz seri korelasyonu

1. INTRODUCTION

Ankara, which is located in Central Anatolia Region, has a transition precipitation regime between continental and Mediterranean precipitation regimes. The Central Anatolia Region generally receives precipitation of less than 600 mm. It falls below 400 mm at planes and plateaus of the region. In Ankara precipitation is also low, and in average it is 382.5 mm. As in whole Turkey, there is a considerable difference between amounts of annual precipitation in Ankara. Data collected by Ankara Meteorology Station indicates that in the period from 1926 to 2000 year to year, annual precipitation varied between 218.1 mm and 612.6 mm.

In this study, precipitation data collected by Ankara Meteorology Station on monthly and annual basis from year 1926 to 2000 was analyzed. To describe precipitation characteristics of Ankara, the above mentioned data was analyzed using different statistical methods. Generally in the climatologic studies, the average monthly and annual precipitation data is used. In this approach, a normal distribution of amount of precipitation is assumed. However, the precipitation does not display a normal distribution over a long time period. Therefore, analysis performed assuming normal precipitation distribution can not predict precipitation variation between years. Therefore in this study, the moments are calculated to show the deviation from the normal distribution. In the mean time, the rank correlation tests were applied to identify the variation of precipitation from year to year using a long term annual meteorological data. The application of the rank correlation tests also helps to check if such variations are statistically significant. Application of different statistical methods to the long term precipitation data of Ankara reveals the detailed precipitation characteristics of Ankara. The results of the study would form a basis for various studies as administrating fresh water sources, projecting the investments to prevent the urban areas from the flood, and planning the agricultural activities.

2. DATA AND METHODOLOGY

The study is based on the monthly and annual precipitation data of Ankara Station in Turkey for a 75 year period between years 1926-2000. The homogeneity of data was tested using the non-parametric Kruskal-Wallis test. The parametric methods are not used for the analysis of data that do not show normal distribution as precipitation with considerable changes for the analysis of such data; the non-parametric methods are suggested (Sneyers, 1990). The principle feature of these methods is that they can be used for the analysis of data sets which do not show a normal distribution. In the non-

parametric methods, different from the parametric methods, the real values of variables are not used; instead the order of variable in the data series is used.

Under the null hypothesis of homogeneity of means, sample H is distributed as approximately χ^2 with degrees of freedom of (C-1). In this study, the sample size of sub-period is $n_j = 15$ and critical significance level of the test is of at least $\alpha = 0.05$. the results of application of Kruskal-Wallis test to the data of Ankara Station for the period between years 1926-2000 have homogeneous at 95% significance level. This indicates that, data collected by Ankara Station is not affected by external factors.

After determining the fact that the data is homogeneous, the data were normalized to examine the precipitation distribution between years. The calculated z values show the difference between the average and the given data point. The distance between average and the data point is z times the standard deviation of the data set. The normalized anomaly values are calculated by the expression

$$z = \frac{x - \bar{x}}{\delta}$$

In this equation, (x) is the data collected by a meteorology station for specified month or year, (\bar{x}) is the average of data set and (δ) is standard deviation of the data set. The graphs of the normalized values were compared with the precipitation graphs. To determine the variation of the precipitation from year to year and to identify the sub-periods, the 5 month moving average curve and the average precipitation line were superimposed on the precipitation graphics.

In order to show the deviation of the monthly and annual data from the average value, the statistical indicators as standard deviation, coefficient of variation, skewness, kurtosis, mode and median were calculated (Özgürel and Koçman., 1994). To determine the trends of the precipitation data, the method of Mann-Kendall serial correlation is applied to the average precipitation values of each month and year. In a time series, for each element y_i , the number n_i of elements y_j preceding it ($i > j$) is calculated such that $y_i > y_j$.

The test statistic t is then calculated by;

$$t = \sum_{i=1}^n n_i$$

t is distributed very nearly as a Gaussian normal distribution with an expected value of

$$E(t) = \frac{n(n-1)}{4} \text{ and a variance, } \text{var}(t) = \frac{n(n-1)(2n+5)}{72}.$$

A trend can be seen for high values of $|u(t)|$ with

$$u(t) = [t - E(t)] / \sqrt{\text{var}(t)} .$$

This principle can be usefully extended to the backward series and $u'_i = -u(t'_i)$ can be obtained. The intersection of $u(t)$ and $u'(t)$ curves denoted approximately the beginning of the trend. This is called the sequential version of the Mann-Kendall test (Sneyers, 1990; Toros et al., 1994; Türkeş, 1995).

After the determination of the trends at the precipitation data, in order to determine the randomness of data series, Wald-Wolfowitz correlation is applied. The coefficients calculated by application of Wald-Wolfowitz test show whether data series exhibit positive correlation or instant changes (Sneyers, 1990). In general, the tendency of increase and decrease in the average of climatologic data are non-linear. The changes in the data series do not show an explicit increase or decrease. A small change about the average value or instant change is observed. Because of this, the application of trend tests and randomness tests like Wald-Wolfowitz serial correlation is suggested for analysis of climatologic data (WMO, 1966; Sneyers, 1990; Gangam, 1988).

In using this test, the time series data are put in an order from the smallest to the largest. Then by using the series:

$$R = S_2 - \left[\sum_{i=1}^n \frac{(y'_i - y'_{i+1})^2}{2} \right]$$

The randomness of serial data. In this expression,

$$S_2 = \sum_{i=1}^n y_i^2 \text{ and } y'_i = y_i - \bar{y}$$

In the formula above, y_i is the order number of the i^{th} term in the order and \bar{y} is the average of order numbers.

The sampling values for Wald-Wolfowitz test is defined by,

$$u(r) = \frac{[(n-1)r + 1]}{\sqrt{(n-1)}} .$$

In this formula, the sampling value r is calculated as,

$$r = R / S_2 .$$

In this test, the biggest values of $u(r)$ are rejected according to null hypothesis distribution. This test is used to determine the randomness against the serial correlation or the abrupt change in the series.

3. THE PRECIPITATION PROPERTIES OF ANKARA

In Ankara, monthly precipitation is similar to each other in all seasons. Therefore, to avoid repetitions, the analysis are made on the seasonal base was analyzed instead of monthly base. The descriptive statistical analysis results were interpreted from the climatologic point of view and from the test statistic point of view. These results are presented in Tables 1 through 3 and in Figures 1 and 2.

3.1. The Precipitation Properties in Winter

As seen in Table 1, the average precipitation in winter months December, January and February are 45.6 mm, 38.8 mm and 34.9 mm, respectively in Ankara. These values are calculated from the precipitation data from 1926 to 2000. These precipitation values may look low, however years with very low and years with very high precipitation were observed in the time period considered. The highest precipitation of 120.0 mm was seen in December 1947, and the lowest precipitation of 4.2 mm was seen in December 1984. The January with the highest precipitation was January of 1979 with 101.7 mm precipitation. The January with the lowest precipitation was 1964 and 1992 January with 4.9 mm precipitation. The highest and the lowest February precipitations are lower than the highest and the lowest precipitations of December and January. The highest February precipitation was seen in 1963 and it is 86.2 mm, the lowest February precipitation was seen in 1966 and it is 2.3 mm. This indicates that in winter months the average precipitation varies considerable. As seen in Table 1, December, January and February show 165.2 %, 162.3 % and 146.9 % positive deviation from the average values, respectively. The negative deviations from the averages are 90.8%, 87.4% and 93.4%, respectively in December, January and February. This means in winter seasons which can be considered as an insatiable season on the basis of precipitation, there are considerable changes in the precipitation distribution from year to year. When the standard deviation values in Table 1 are examined and compared with the average precipitation, the same conclusion can also be derived. The standard variation for December is 23.1 mm, for January is 23.9 mm and for February are 20.1 mm as given in Table 2. These high values of standard deviation also show the great changes in the precipitation from year to year. Comparison of average standard deviation values show that the averages are approximately 2 times of the standard deviation. Therefore, the data sets can not be considered as a normally distributed data set. Hence, the possibility that the data is distributed around the average is very low (Hann, 1977).

Table 1: The statistical values of the monthly and annual precipitation in Ankara.

Months	Mean (mm)	Max. Precipitation		Min. Precipitation		Positive Deviation (mm)	Positive Deviation Ratio (%)	Negative Deviation (mm)	Negative Deviation Ratio (%)	Range (mm)
		mm	Year	mm	Year					
January	38.8	101.7	1979	4.9	1964,1992	62.9	162.3	33.9	87.4	96.8
February	34.9	86.2	1999	2.3	1966	51.3	146.9	32.6	93.4	83.9
March	36.7	92.6	1995	8.1	1959	55.9	152.5	28.6	77.9	84.5
April	41.8	110.8	1990	5.4	1929	69.0	165.0	36.4	87.1	105.4
May	51.1	121.5	1963	1.6	1992	70.4	137.8	49.5	96.9	119.9
June	33.8	122.4	1997	2.5	1935	88.6	262.6	31.3	92.6	119.9
July	14.8	107.2	1995	0	1928,1929,1948,1953	92.4	624.8	14.8	100	107.2
August	11.0	80.9	1982	0	1926,1927,1928,1931,1948,1949,1956,1961,1963,1969,1970,1988	69.9	634.5	11.0	100	80.9
September	16.9	95.6	1957	0	1937,1965,1984,1985	78.7	467.2	16.9	100	95.6
October	25.7	77.1	1942	0	1964	51.4	199.8	25.7	100	77.1
November	31.5	113.4	1983	0	1926	81.9	259.6	31.5	100	113.4
December	45.6	120.9	1947	4.2	1984	75.3	165.2	41.4	90.8	116.7
Annual	382.5	612.6	1963	218.1	1928	230.1	60.1	164.4	43.0	394.5

An other criterion for the relative distribution is the coefficient of variation. The comparison of standard deviations of data sets with different averages may yield incorrect results. Therefore, to eliminate such a possibility, the coefficient of variation should be used in comparing the samples. The coefficient of variation is calculated by dividing the standard deviation with the average and given in Table 2. The coefficient of variation for December, January and February are obtained as 0.5, 0.6 and 0.6, respectively. According to the coefficient of variation, December shows the minimum variation from year to year, compared to January and February. However, since the coefficients of variation of each of these three months are equal or greater than 0.5, the changes of precipitation from year to year in these months are high.

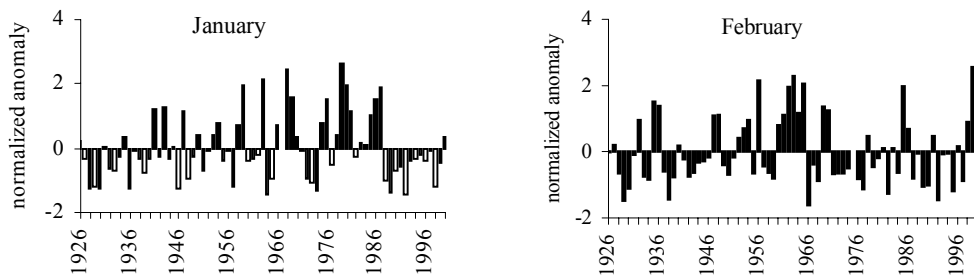


Figure 1: The normalized monthly and annual precipitation graphs of Ankara Meteorology Station.

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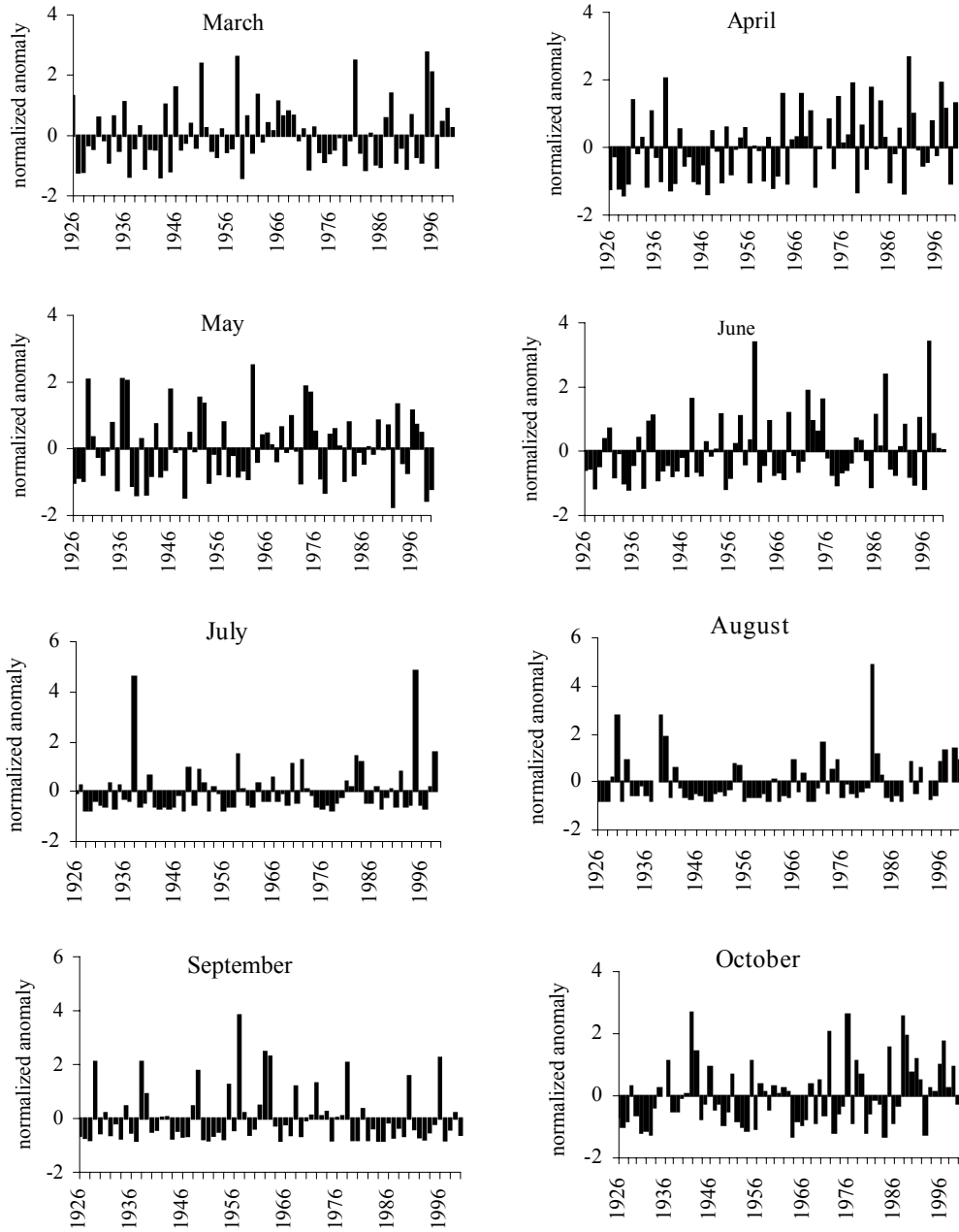


Figure 1 (Continued)

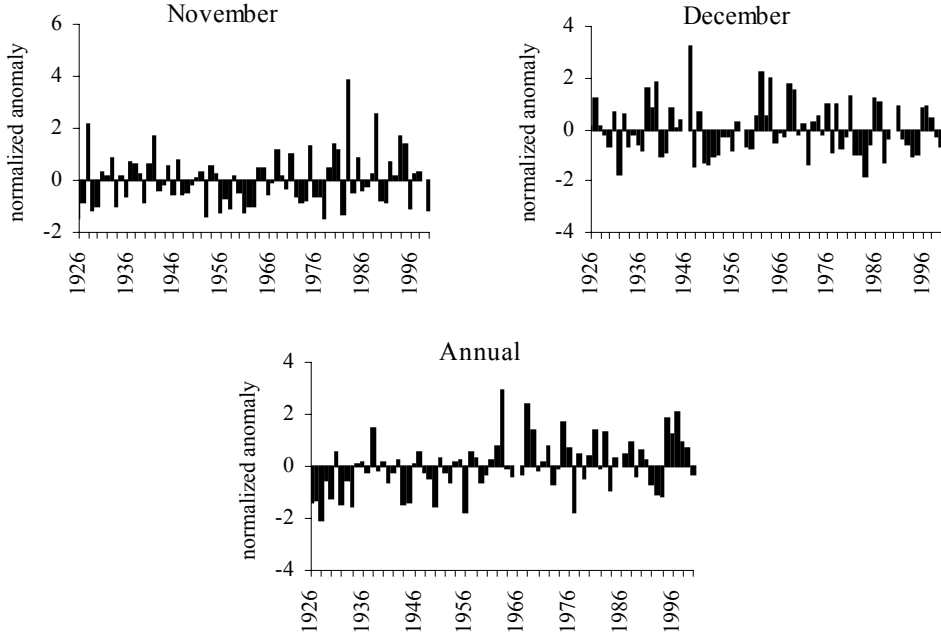


Figure 1 (Continued)

The skewness coefficient is a third-order centered moment and is the measure of the deviation of the data from the symmetry of the distribution. The skewness coefficient is found by summing the cube of ratio of difference between the data points and average to the standard deviation (Göçmençelebi, 1976; Kadioğlu and Erdun, 1994). If the positive and negative differences are symmetric, this sum leads to zero. The zero value of the skewness coefficient indicates that data series shows a normal distribution. Positive value of skewness coefficient indicates that data set is right skewed. Negative value of skewness coefficient indicates that data series is left skewed. As seen in Table 2, the skewness coefficients for all winter months are positive in Ankara. Therefore, the average precipitation is higher than median and mode. These positive values of skewness indicate that high extreme values of precipitation are rarely seen and winter precipitation values in general less than averages. Therefore, the frequency of low precipitation is high in Ankara in winter and the frequency of extreme values above the average is low.

The kurtosis is used to determine the peak points or shape of the peak of a frequency curve. The kurtosis is calculated from the forth-order moment. For a series of normally distributed data, the kurtosis coefficient is 3. If the central portion of the distribution is large, in other words, flatter than the normal distribution with the same variance and average, the kurtosis coefficient of such a distribution is less than 3. If the

data in the central portion of the curve fall in a narrow region, the value of kurtosis coefficient is greater than 3. The extreme deviation from the average value results in high kurtosis coefficient. The kurtosis coefficient higher than 3 indicates that frequencies increases in the center and the kurtosis coefficient less than 3 indicates that frequencies decreases in the center (Kadioğlu and Erdun 1994). The kurtosis coefficients of Ankara for winter are very close to zero, as seen in Table 2.

When the graphs representing the precipitation variations from year to year are plotted, the same conclusions can be reached. These graphs are given in Figure 1. As seen in these figures, in winter months, the precipitation generally below the average. In some years, it is above the average. When the deviation from the average is examined, it is seen that the precipitations below the average is within one standard deviation from the normal, however the precipitation above the average is within two standard deviation from the normal. As values of skewness and kurtosis coefficients also indicate, low precipitation values are more frequently see in winter months in Ankara.

3.2. The Precipitation Properties of Spring

Spring is the most precipitant season in Ankara. As seen in Table 1, the average precipitation of period from year 1926 to 2000 for March, April and May are 36.7 mm, 41.8 mm and 51.1 mm, respectively. The year to year irregularities seen in winter are also observed in spring. The amplitude of the precipitation data for spring months is more than twice of the average precipitation (See Table 1). The high standard deviation values also show the considerable precipitation changes from year to year. The standard deviation for March is 20.4 mm, for April is 25.9 mm and for May is 28.3 mm. The coefficient of variations are higher than 0.5. These values of coefficients of variation also indicate that there are considerable changes in the precipitation from year to year (See Table 2).

The skewness coefficients for spring months are all positive. This indicates the fact that low value precipitation happens frequently whereas the high value precipitation happens rarely. In this season, March has the skewness value of 0.9 which is much different than the other months. This property of March can be due to the fact that March in some years is affected by high pressure caused by thermal effects and in some years March is affected by low pressure. As a result of the low precipitation rates due to the effect of high pressure conditions and the high precipitation rates due to maritime polar air masses, the skewness coefficient of March is higher than those for the other months. The kurtosis value of the spring is very close to zero. As seen in Figure 1, the precipitation data do not accumulate around the average; it is distributed between extreme values. Based on positive and negative deviations, standard deviation and coefficient of

variation values, it can be said that, March precipitation characteristics are similar to winter months.

When the precipitation anomaly of the spring is examined, a distribution similar to the winter is observed. In spring negative anomalies are also dominant and they are within one standard deviation from the averages. On the other hand, positive anomalies are within two or three standard deviation from the average (See Figure 1). These confirm the considerable changes in distribution and the deviation from the normal distribution.

Table 2: The various descriptive statistical values of monthly precipitation amounts in Ankara.

Seasons	Months	St.Dev.	Coif. of var.	Skewness	Kurtosis	Median	Mode	First quartile	Third quartile
Winter	December	23,1	0,5	0,7	0,4	41,1	38,9	28,5	60,9
	January	23,9	0,6	0,8	0,0	33,1	30,9	21,7	49,1
	February	20,1	0,6	0,7	-0,2	31,1	21,7	20,5	48,8
Spring	March	20,4	0,6	0,9	0,5	32,1	49,4	22,4	49,2
	April	25,9	0,6	0,5	-0,5	40,2	14,4	16,1	56,8
	May	28,3	0,6	0,5	-0,4	48,9	47,0	27,7	70,0
Summer	June	26,1	0,8	1,4	2,1	26,3	19,8	14,8	46,1
	July	19,0	1,3	3,1	12,2	7,3	0,0	3,6	18,9
	August	14,4	1,3	2,3	7,3	4,5	0,0	1,8	17,1
Autumn	September	20,6	1,2	1,7	2,6	8,4	0,0	2,9	20,8
	October	19,3	0,7	0,9	0,3	20,6	30,3	10,3	35,1
	November	21,5	0,7	1,1	1,9	30,6	19,2	15,3	42,7
Annual		78,9	0,2	0,4	0,4	379,8	361,0	335,9	422,6

3.3. Precipitation Properties of Summer

In Ankara, summer precipitation distribution is quite distinct from those of other seasons. Following the most precipitant season spring, the average monthly precipitation decreases rapidly and reduces to 33.8 mm in June, 14.8 mm in July and 11.0 mm in August. As the precipitation decreases compared to the other seasons, the changes from year to year increase. For example, as precipitation of a 122.4 mm was observed in June 1997, only 2.5 mm precipitation was observed in June 1935. Following June, as summer conditions settle truly, the deviations increase further. In July 1995 the precipitation was 107.2 mm, and in August 1988 precipitation was observed. According to the data analyzed in recent years the maximum summer precipitations has increased. The climatologic studies on urban climate have shown that the heat islands increase the showers in cities (Changnon et al., 1976; Sanderson et al., 1973; Sanderson and Gorski, 1978). The fact that in Ankara the high precipitation values were observed in recent years are consistent with this statement. In some July and August months, no precipitation was observed at all (See Table 1). In the time period considered in this study, 4 July months and 12 August months did not received any precipitation. The frequency of minimum summer precipitation has decreased in recent years, and it could be due to the growth of

Ankara. This change also becomes evident with the positive and negative deviation values seen in Table 2. The average positive deviation ratios for June, July and August are 262.6%, 624.8% and 634.5%, respectively.

The precipitation changes from year to year are considerable in summer months. When the standard deviation values are examined, it is observed that the standard deviation values of July and August are higher than the averages of these months (See Table 2). This relation between the standard deviation and the average values indicates that the deviation from the normal distribution can not be ignored. This fact is especially supported by the coefficients of variation of July and August, which are over one. These show that in Ankara, the summer precipitation values are much different from the average values. In some years high precipitations, in some year low precipitations are observed.

The skewness values are high in summer months and they are over one. For July, it exceeds three (See Table 2). This high right-skewed distribution seen in summer months shows that that the precipitation is generally below average; however in some years it is high above the average. Except June, the kurtosis values exceeding three indicates that in summer months low precipitation values are observed more often than the high precipitation values.

It should be pointed out that June precipitation properties (deviation from average, standard deviation, skewness coefficient, kurtosis coefficient and coefficient of variation values) are close to that of spring months rather than that of July and August.

The summer precipitation values are distinct from the precipitation values of all other seasons when the distribution anomalies among years are considered. In this season the ratio of the negative anomalies at normalized data increases extensively. In August, it reaches 65%. This indicates that $\frac{2}{3}$ of the precipitation occur below the average. On the other and, the ratio of positive anomalies decreases as their value increases (Figure1 June, July and August). The anomalies of 1938 and 1995 in July and the anomalies of 1982 in August are distinct from the others. Anomalies for these periods are as much as 4 to 5 times of the standard deviation. This distribution shows that generally summer months are characterized with low precipitation, but in some years the summer precipitation is above the average. This characteristic causes a right skewed distribution and high kurtosis values.

3.4. Precipitation Properties of Autumn

In autumn, the precipitation begins to increase compared to the summer. The most important characteristic of this season is that in some years no precipitation occurs in any

of three months of the season. For example, no precipitation occurred in September for 4 years, and in October and November for 1 year. This indicates that the summer like conditions continue to be in effect in autumn in some years. The positive and negative deviations from the average in this season are much higher than the values of spring and winter. This indicates that the precipitation characteristics of autumn are similar to those of summer on the basis of variations (See Table 1). The standard deviation for September is 20.6. This high value of standard deviation is the indication of considerable from year to year in this month. The coefficient of variation for September is 1.2 and it is 0.7 for the other two months. These values indicate the magnitude of the precipitation instabilities.

As seen in Table 1, skewness coefficients for September, October and November are above 1. These values indicate that the precipitation occur at a low value as in the other seasons. The kurtosis value of 3 for September indicates that this month has the characteristics of summer season. The kurtosis values of the other two months are less than 3. This means that the frequency of low value precipitation is less than the frequency of the high value precipitation.

When the autumn season precipitation anomalies are examined, it is observed that the negative anomalies are dominant. According to the values of the anomalies, October and November have similarities with winter and spring seasons, and September has similarities with summer season.

3.5. Annual Precipitation Properties

The annual average precipitation distribution is smoother than the monthly distribution. The annual average precipitation of 382.5 mm was observed. In 1963 a maximum precipitation of 612.6 mm and in 1928 a minimum precipitation of 218.1 mm were received. These precipitation values are 60.1% higher and 43.0% lower than the average precipitation, respectively. The annual standard deviation is 78.9 mm. This is approximately $\frac{1}{5}$ of the annual precipitation and this ratio could be ignored for the precipitation variation. The same fact is also confirmed by the coefficient of variation of 0.2. It is an interesting fact that the high changes in the monthly precipitation do not affect the amount of annual precipitation. This could be explained as that the low value precipitation occur in some months of the year are balanced by the high value precipitations occur in other months of the same year.

When the anomalies of the annual precipitation are examined, it is seen that the ratio of the positive and negative anomalies in normalized data are equal. However, the fact that values of the positive anomaly values of 3 to 4 times the standard deviation from

the average indicates that the precipitation distribution is not normal. The weak right-skewed distribution of the annual precipitation values also shows the same result. This skewness value is small compared to that of the seasons. The possibility of receiving the low value precipitation at annual basis is high, although this possibility is not as high as at the seasonal basis.

4. THE MONTHLY AND ANNUAL PRECIPITATION TRENDS IN ANKARA

The variation and trend of precipitation among years are examined using the Mann– Kendall and Wald-Wolfowitz tests. The results of these tests are given in Table 3. Also the results of the statistical tests are plotted in Figure 2. As seen in Table 3, an increase in precipitation is observed in all months except March, September and December. A significant trend in the precipitation increase in April, August, October and annual precipitation exists. However, no significant trend in the precipitation increase and decrease in the other months are observed. This result is driven from the fact that the Mann - Kendall tests results of $u(t)$ is less than the critical value of 1.96. According to the Mann – Kendall test, the value of $u(t)$ should exceed the critical value 1.96 for a trend of 95% significance level. Despite this fact, in January from 1936 to 1988 in February from 1931 to 1977 February, in April from 1956 to 2000, in May from 1962 to 1999, in June from 1950 to 2000, in August from 1940 to 1983. There is a tendency for increase in precipitation (See Figure 2). But as stated above, this increase is not significant except in April, August and October. There is a tendency for decrease in March, September and December, but this decrease is not significant, neither.

Table 3: Mann - Kendall and Wald - Wolfowitz test results.

Months	Mann-Kendall	Wald-Wolfowitz
January	0,837	-0,929
February	0,379	-0,929
March	-0,027	-1,301
April	2,936*	-0,186
May	0,494	0,929
June	1,596	-0,557
July	1,500	0,557
August	2,140**	-2,044**
September	-0,173	0,557
October	2,181**	0,929
November	0,818	-0,929
December	-0,356	-0,557
Annual	3,320*	-0,186

(*) Significant at the 99 percent level

(**) Significant at the 95 percent level

To check the randomness of the monthly precipitation data series, the Wald - Wolfowitz test is applied. From the results of this test, a serial correlation with 95% significance level is observed for August only. This means that the precipitation do not have a serial interaction and is randomly distributed in the months except August (See Table 3). There is a negative correlation in August according to the results of Wald - Wolfowitz test at the significance level of 95 percent. Therefore, as seen in Figure 2, there are high frequency oscillations in the precipitation in August in Ankara.

There is a tendency of increase in the annual precipitation between 1950 – 2000 with a significance level of 99 percent. This tendency becomes more pronounced in 1970s, but there is no significant serial correlation in this precipitation series.

5. CONCLUSIONS AND SUGGESTIONS

The followings are observed from the analysis of monthly and annual precipitation data of Ankara Meteorology Station for a 75 year period between years 1926-2000.

- The standard deviation, coefficient of variation and period of variation values of the monthly precipitation data in Ankara are high. These high values show the irregular distribution of precipitation among years. July, August and September are the months in which the precipitation variations among years are clearly observed.
- The precipitation data for all months have right-skewed distributions. This indicates that the precipitation occurs mostly at low values and the high value precipitation frequencies are low. The skewness in summer and autumn is due to the thunderstorm precipitation and the skewness in March is due to the dominant pressure conditions.
- The high kurtosis values seen in summer months and in September show that the precipitation characteristics of these months are determined with the low value precipitation. The high maximum precipitation encountered in the summer months in recent years in Ankara can be due to the heat island resulted as a consequence of the urbanization. This issue of effect of urbanization on precipitation should be studied extensively.
- September has the precipitation characteristics of summer, and June has the precipitation characteristics of spring. The spring precipitation characteristics shown by June could be related to the continuation of conventional spring precipitation in June and the summer precipitation characteristics shown by September can be related to the continuation of the pressure conditions causing low value precipitations.

- Annual and monthly precipitation distributions show different characteristics. The high instabilities in the monthly precipitation are not reflected in the annual precipitation. This is due to the fact that low value precipitations are compensated by high value precipitations on the annual basis. The low value of standard deviation, coefficient of variation and skewness coefficient compared to the average indicates that the annual precipitation is more stable than monthly precipitation.
- There is a statistically significant precipitation increase in April, August and October. There is an increase with 5% significance level in the August precipitation. Also, the negative correlation coefficient with the significance level of 5% shows that there are oscillations with short periods in August precipitations.
- The considerable differences in the distribution of the precipitation in Ankara influence the human activities. The flood due to the high value precipitation in unknown periods should be taken into consideration in choosing new settlement locations and in the improvement of old neighborhoods. Because of this the settlement to the valleys nearby rivers should be done carefully.
- The high variation precipitation may cause a considerable difference in the level of reservoirs providing water to the cities. Therefore, to provide enough water to the cities in the years receiving low precipitation, the minimum reservoir levels are need to determined instead of average reservoir level in the planning of the water supply for future. This planning should be done urgently.
- In Ankara where the low value precipitation is frequently encountered and the frequency of the high value precipitation is low, in order to secure agricultural activities, irrigation systems (regulator, dam, irrigation canals, etc.) should be constructed. Since the dry agriculture is common in Ankara, for safety of agriculture activities, the measures are necessary for the damage of floods more than for the drought period of summer. Therefore, the agricultural systems to decrease the erosion and flow of surface water are necessary.

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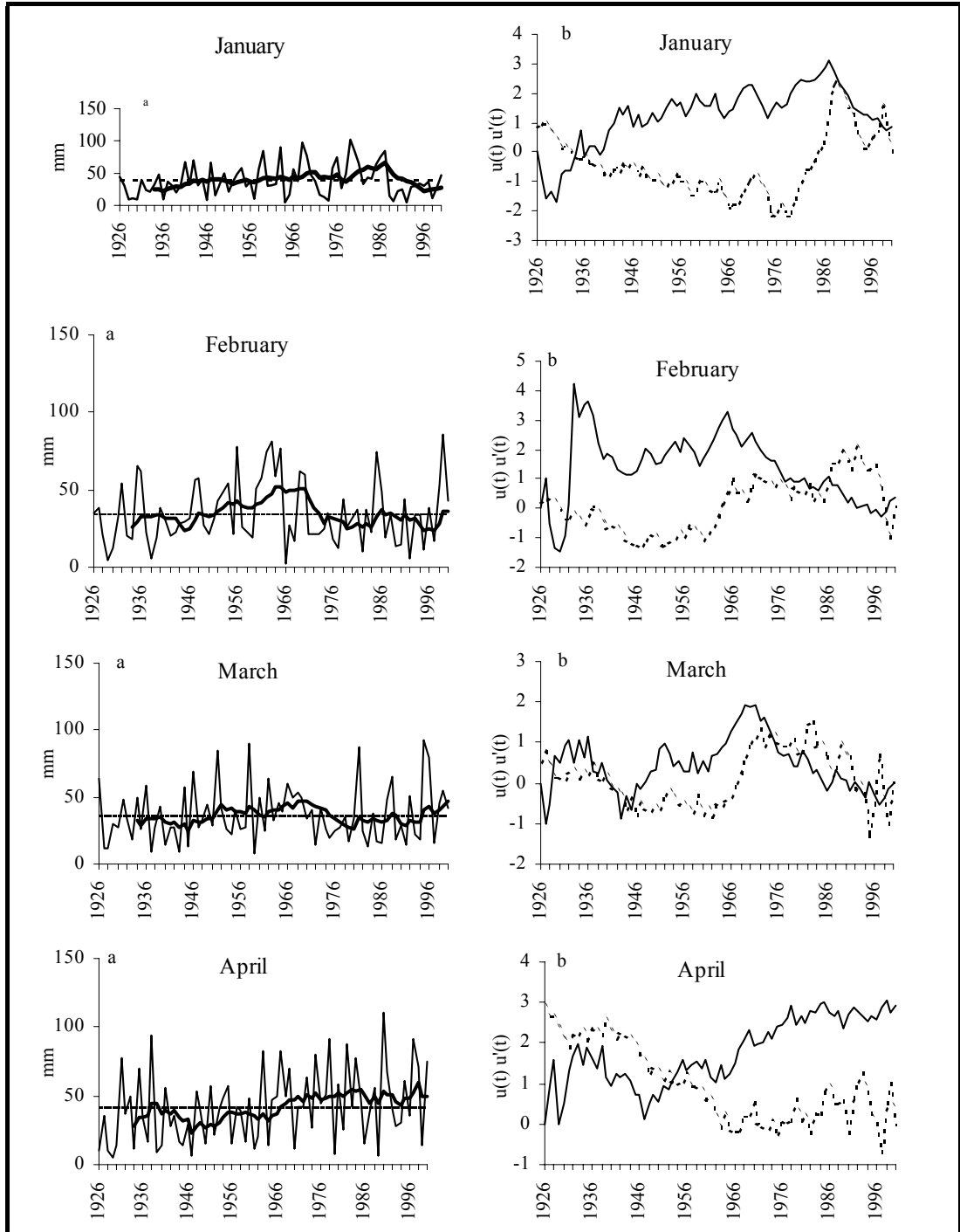


Figure 2: Trend graphs of (a) monthly and annual precipitation, (b) monthly and annual precipitation according to Mann - Kendall test of Ankara Meteorology Station.

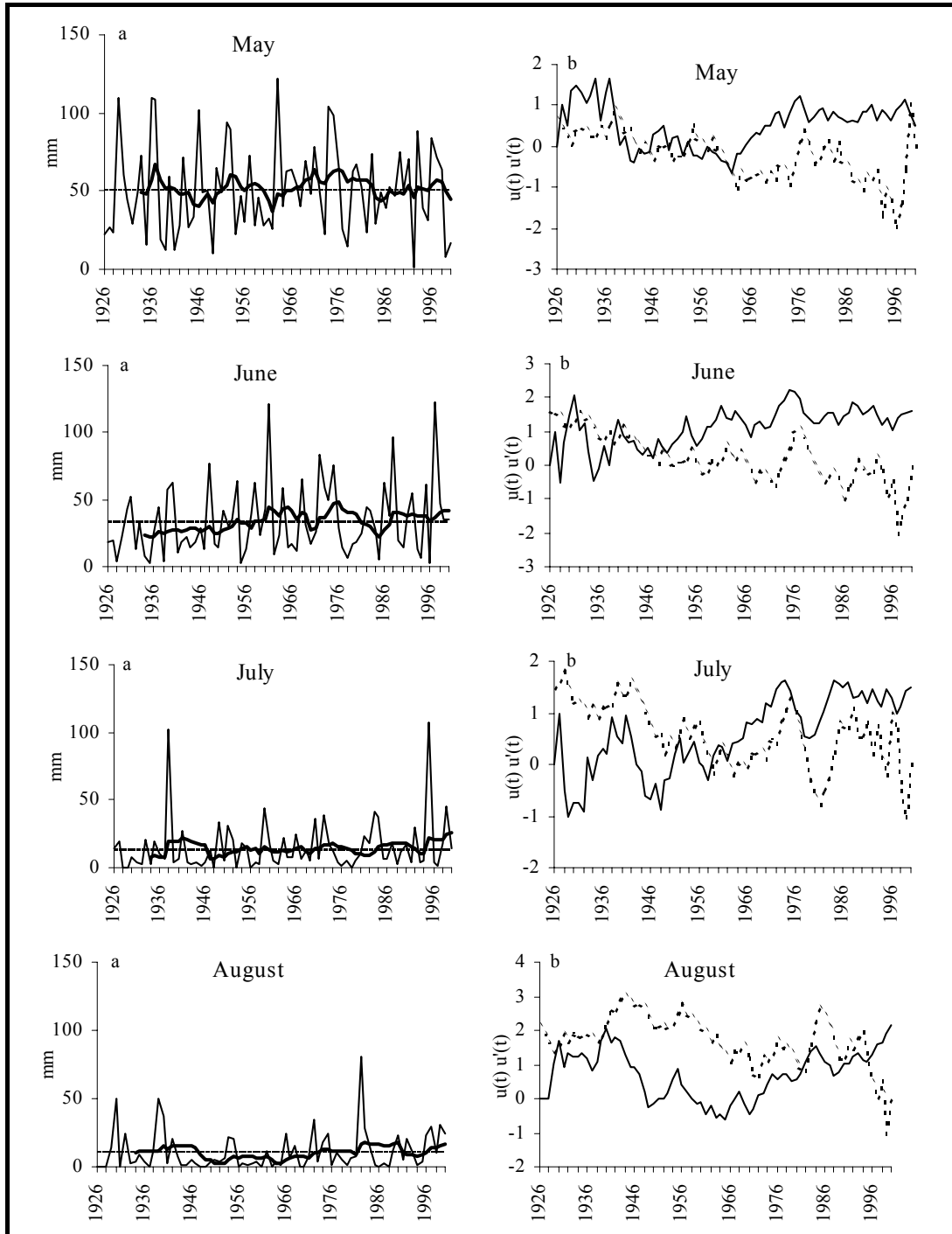


Figure 2 (Continued)

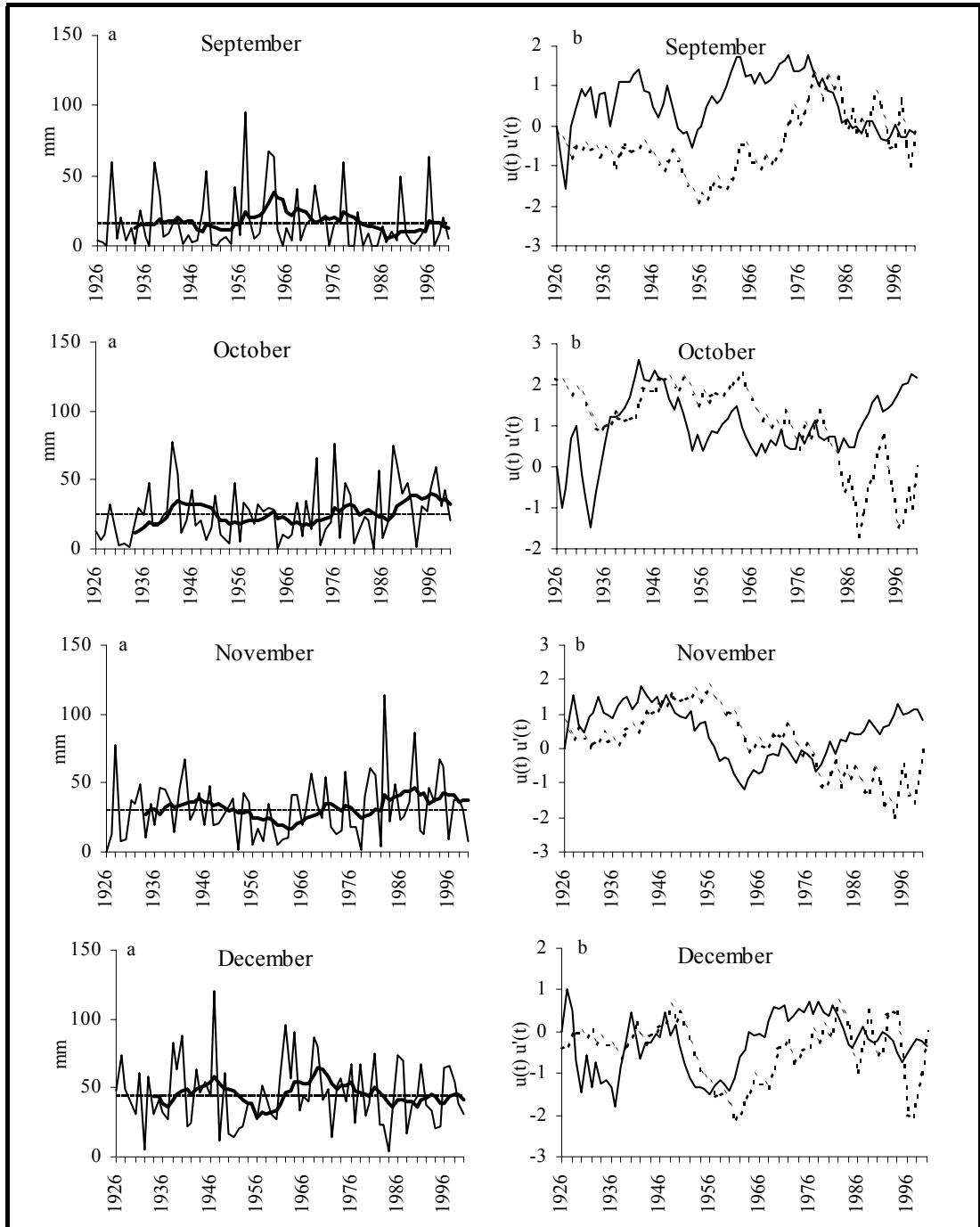


Figure 2 (Continued)

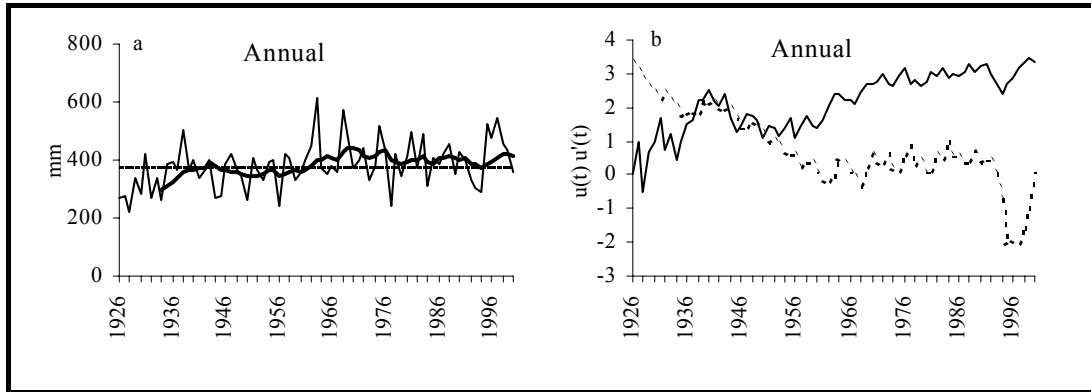


Figure 2 (Continued)

Explanation about Figure

- a : Straight line precipitation, horizontal dashed line long-term annual average, thick line 5-month moving average monthly average precipitation
- b: Straight line $u(t)$ dashed line $u'(t)$ test sample values are shown.