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Precipitation and Temperature Trend Analyses in Samsun[#]

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Abstract: Turkey is one of the sensitive regions to climate variation particularly to precipitation changes in the World. In this study, trends in precipitation and temperature at annual, seasonal and monthly time scales for the periods of 1931-2006 and 1974-2006 were examined for the Samsun which is located in the Black sea region of Turkey. Non-parametric tests (such as Mann-Kendall and Sen's Slope), linear regression, cumulative deviation curve techniques were used to determine climatic trends. The results showed that there is no negative or positive statistically significant trend in the study area, despite of slight precipitation decrease in winter for the period of 1931-2006. In contrast, 1974-2006 seasons represent slight precipitation increase (which are not statistically significant) annually and seasonally. Temperature data showed slight increase annually even though results are not statistically significant during the period of 1931-2006. On the other hand, results of temperature trend analyses represent statistically significant trend for the period of 1974-2006. The temperature data for summer months represent statistically significant trends during the last 32 years.

Key words: *Climate Variation, Precipitation, Mann-Kendall, Trend, Samsun*

Introduction

Climate of the Earth varies across temporal and spatial scales throughout the planet. Large areas of the earth represent variability as a part of their normal climate over both short and long time periods (Houghton et al., 1994; Gardner et al., 1996). Climatic variability can be described as the annual difference in values of specific climatic variables within averaging periods such as a 30-year period (Melillo et al., 1990). These climatic variations will have unexpected consequences with respect to frequency and intensity of precipitation and temperature variability for many regions of the Earth.

Air temperature and precipitation are principle element of weather systems, so that examination of their behavior is important for understanding of climate variability because both are highly variable spatially and temporarily at different local, regional and global scales. For the prediction of future climate conditions, level of variability of these two weather elements must be examined and understood. Therefore, recently, the focus on climate variability bases mostly on the detection of trends in instrumental records of precipitation and temperature. Several researches of climatic trends have recently been conducted on rainfall and temperature data at different periods of records throughout the world and Turkey (Turkeş, 1996a; Tanyaç et al., 1997; Kadıoğlu, 1997; Lazaro et al., 2001; Turkeş et al., 2002; Turkeş, 2003; Tosiç & Ukaseviç, 2005).

Turkey is among those areas in the world most likely to experience climatic variations for short and long time periods. Mediterranean macro climate type is prevalent in Turkey. This climate type "results from the seasonal alteration of frontal depressions with polar air masses and sub tropical high pressures with subsiding maritime tropical a continental tropical air masses" (Turkeş, 1996b). Inter-annual variability of precipitation and temperature in Turkey is relatively large from the annual mean. As a result of climatic variations, natural resources of the country, such as vegetation, and the existing resources are easily damaged by changes in

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[#] *This study has been presented at BIES'08, Giresun-Turkey* precipitation patterns. Many recent studies show that there is an increasing trend in climate variability (Kadıoğlu, 2000; Turkeş, 2001; Turkeş et al., 2002).

In this study, we examined precipitation and air temperature trends in Samsun (Turkey) for the 1931- 2006 time scale. The study area, which is located in the Black sea region (Figure 1), depends heavily on precipitation for its water supply. Precipitation is characterized by a typical annual pattern with low rainfall totals during summer months and high during autumn and winter months. Annual mean precipitation is around 710 mm. Temperature is low during winter and high during summer with 14 ^{o}C annual mean.

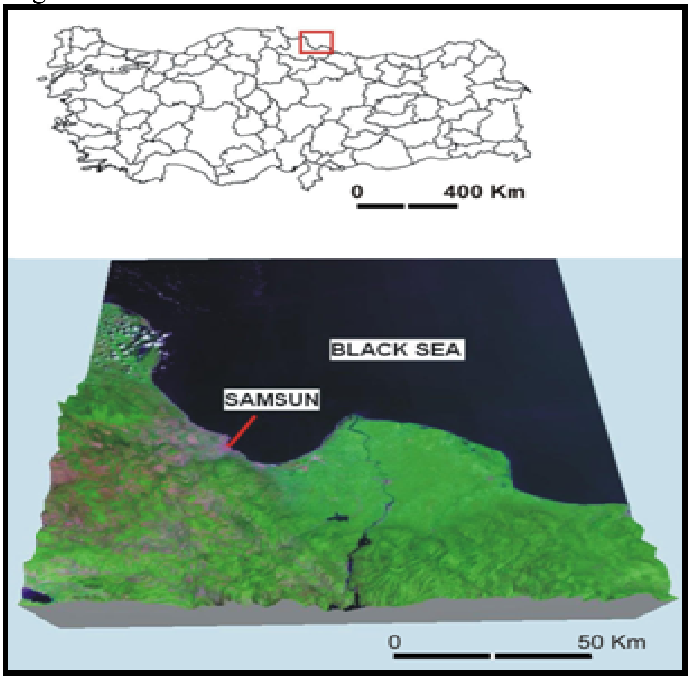

Figure 1. Location map of the study area.

The aim of this study is to evaluate precipitation and temperature trends in Samsun. To be able achieve our goals we conduct a through examination of climatic data from 1931 to 2006 in order to identify seasonality, variability, trends and other characteristics of precipitation and temperature at different time scales. The main purpose of this study is the detection of significant trends or fluctuations in the annual and seasonal climatic conditions.

Methods

In this study, the annual, seasonal and monthly precipitation totals and temperature measured at the Samsun meteorological observation station (latitude: 41° 17' 12 N and longitude: 36° 19' 48 E) were used for the period of 1931-2006. Daily precipitation and temperature data were first calculated as monthly and annually. For the precipitation data set, seasonal amount was calculated by summing precipitation quantity during quarks starting from winter. Then the average precipitation amount was computed over the 76-year period to be able to examine precipitation anomalies which is commonly or generally defined as distance from the average. The trend detection methods were applied to annual, seasonal and monthly precipitation and temperature data.

Even though the location of this station has not been changed during the period of observation, in order verify the suitability of the data set the none-parametric Thom's homogeneity test (Eq. 1 and 2) was applied to annual precipitation and temperature (Lazaro et al., 2001). In this test, for N is equal or larger than 25, if the series is homogeneous, the distribution of the number of runs (*R*) approximates a normal distribution with the following average (*E*) and variance (*Var*):

$$E(R) = \frac{N+2}{2} \qquad Var\ (R) = \frac{N(N-2)}{4(N-1)}$$

Eq. (1)

The Z statistic is defined as:

$$Z = \frac{R - E(R)}{\sqrt{Var(R)}}$$

Eq. (2)

The Thom test resulted homogenous and statistically significant at 95% confidence limit for precipitation and temperature. Thus, time series can be taken as homogeneous during the study period.

Firstly, regression models were created in order to detect linear trends of precipitation and temperature data. Secondly, statistical trend detection methods are applied to detect inconsistencies and non-homogeneities (both gradual trends and abrupt changes/shifts) in the data series of climatic variables. Therefore, the determination of abrupt changes or shifts (based on the mean values) in the data series is emphasized in the statistical trend analyses.

In this paper, standard monthly, seasonal and annual precipitation and temperature data were analyzed for trends using Mann Kendall (MK) and Sen's slope (SS) estimator none parametric tests. This technique is based on the detection of trends and change point(s) and attaching to it a probability significance level in a time series. This test has been widely used climatologic data analysis (Libiseller and Grimvall, 2002; Lazaro et al., 2001; Mirza et al., 1998). The test examines whether a random response variable monotonically increases or decreases with time. It is a rank based procedure, resistant to the influence of extremes, and useful for skewed data and has a higher power than many other commonly used linear tests (Önöz and Bayazıt, 2003; Lazaro et al., 2001; Kahya and Kalaycı, 2004). There is no need for normally distributed data. These powerful aspects of test make it particularly appropriate for use with precipitation sampled up to consecutive time.

In this test, the null hypothesis of randomness H_0 states that the data ($x_1, \ldots x_n$) are a sample of n independent and identically distributed random variables. The alternative hypothesis H_A is that the distributions of x_k and x_j are not identical for all $k, j \leq n$ with $k \neq j$. Under H_0 , the Mann-Kendall test statistic can be calculated by using following equations (Lazaro et al., 2001; Önöz and Bayazıt, 2003; Kahya and Kalaycı, 2004).

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k)$$

Eq. (3)

Wehre

$$sgn(x) = \begin{cases} +1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases}$$

Eq. (4)

It represents that S is asymptotically distributed and gave the mean and variance of S, for the situation where there may be ties in the x values, as

$$E[S] = 0$$

$$Var[S] = \left\{ n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_j-1)(2t_j+5) \right\} / 18$$

Eq. (5)

Where p is the number of tied groups in the data set and tj is the number of data points in the j*th* tied group. For the cases that n is larger than 10, the normality approximation is good provided one employs the standard normal variate Z given by

$$Z = \begin{cases} \dfrac{S-1}{[Var(S)]^{1/2}} & \text{, if } S > 0 \\ 0 & \text{, if } S = 0 \\ \dfrac{S+1}{[Var(S)]^{1/2}} & \text{, if } S < 0 \end{cases}$$

Eq. (6)

Thus, the null hypothesis is rejected at a significant level α if $|Z_s|> Z_{scrit}$, where Z_{crit} is the value of the standard normal distribution with an exceedance probability of /2α. A positive value of Z indicates an upward trend, whereas a negative value indicates a downward trend in the tested time series (Lazaro et al., 2001; Önöz & Bayazıt, 2003; Kahya & Kalaycı, 2004). Statistically significant trends are generally reported at the 95% confidence level (α = 0.05, two-tailed test) in this study.

Departures from the mean, which is called individual deviations, were calculated because they can give us clues about climatic variability than absolute values and permit comparison among data from different time series (Lazaro et al. 2001, Tosic & Ukasevic 2005). Afterwards the cumulative deviation curve, which is a statistical procedure for examination of the possible existence of climatic fluctuations, was used to examine precipitation and air temperature trends. It is useful for determination of non-abrupt changes in the series. It can also provide information about differentiation of wet and dry periods.

To be able to determine distribution of extreme rainfall events, high and low extremes were computed using percentile for each month, season and year as threshold (Lazaro et al., 2001). The data converted to percentile ranks from annual low extremes (Q10) to the annual high extremes (Q90). The 90^{th}, 75^{th}, 50^{th}, 25^{th}, and 10^{th} percentiles of monthly, seasonal annual data were calculated in order to determine probabilities of monthly, seasonal annual data series. It was used Q75 for the upper abnormal and Q25 for the lower abnormal year.

Results and Discussions

Precipitation Trends

In general, the climate of the study area is under dominant macro Mediterranean climate with a relatively cool winter and hot summer (Türkeş, 1996b). The precipitation is not evenly distributed throughout the year, predominantly frontal in winter and often convective in summer. The average annual precipitation is influenced by the planetary wind pattern and topography, the evaporation shows peak values during the summer months and low values during the winter months. The maximum monthly precipitation occurs in January and minimum in July and August. On the other hand, maximum monthly temperature occurs in August and minimum in January.

Statistical properties of the annual, seasonal, and monthly rainfall series were tested and presented in Table 1. The results showed that the data were normally distributed despite of slight positive skewness. According to the results, late winter and early spring months have represented smaller CV (coefficient of variation) which means that January, February, March and April are the homogenous months in terms of rainfall variations. On the other hand July and August showed the largest CV with 112 and 97 percents, respectively. The rest of the months depicted similar rainfall pattern representing similar variation during the study period.

Seasonal distribution of mean precipitation in the study area is shown Figure 2. On the average, most precipitation occurs during the Autumn months with 219,45 (30,83%) mm total, and October, November and December are commonly the months with the highest observed precipitation. There is considerable amount of precipitation in the summer moths of July and August with summer precipitation being around 111,21 (15,62 %) mm of annual total in the area. Figure 2 also represents the total annual and seasonal precipitation and its trend in the period of under examination. Using a linear regression model, the rate of change is defined by the slope of regression line which in this case is about -0.799 mm/year. On the other hand, while winter, spring and summer seasons have represented with decreasing trend, autumn have depicted with slight increasing trend in the study area (Figure 2).

Table 1. Statistical summary of monthly precipitation series for Samsun

		Annual	J	F	M	A	M	J	JL	A	S	O	N	D
N		76	76	76	76	76	76	76	76	76	76	76	76	76
Mean		711,65	70	59,8	65,7	58,6	47,1	44,1	33,7	34,3	55,2	79,9	84,3	79,9
Std. Error of Mean		13,27	4	3,42	3,58	3,2	3,12	3,24	4,33	3,88	3,95	5,8	5,75	5,14
Median		697,15	63	51,2	62,7	53,1	41,2	37,5	24,2	25,8	49,2	69,2	80,8	70,4
Mode		503,3	28,1	35,2	19,7	44,1	8,1	16,4	0	3,4	82,4	61,6	66,3	40,4
Std. Deviation		115,7	34,9	29,9	31,3	28	27,2	28,3	37,8	33,4	34,5	50,6	50,2	44,8
CV (%)		16,25	49,9	50	47,6	47,7	57,8	64,1	112	97,3	62,5	63,3	59,5	56,1
Variance		13387,79	1221	893	979	782	740	799	1427	1114	1191	2558	2521	2010
Skewness		0,39	0,66	1	0,75	0,79	0,83	1	2,27	1,64	0,47	1,01	2,08	1,31
Std. Error of Skewness		0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,27
Kurtosis		-0,42	0,19	0,97	1,01	0,28	0,67	1,64	6,69	2,73	-0,7	1,28	9,53	2,24
Std. Error of Kurtosis		0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,54	0,55	0,54	0,5	0,54	0,54
Range		508,9	154	138	159	134	126	150	205	154	129	255	346	234
Minimum		503,3	8,9	10,9	4,8	11,8	7	0,7	0	0	3,9	2,4	4,8	4,6
Maximum		1012,2	163	149	164	146	133	151	205	154	133	257	350	239
Sum		54086	5316	4542	4996	4451	3578	3353	2561	2538	4197	6072	6409	6073
Percentiles	**10**	572,79	30,2	28,9	28,8	27,6	15,4	13,2	2,66	3,4	13,1	18,4	26,5	38,6
	25	625,42	45,9	39,7	45,8	37,4	23,8	22,6	7,73	10,7	28,1	47,9	55,7	46,4
	50	697,15	63	51,2	62,7	53,1	41,2	37,5	24,2	25,8	49,2	69,2	80,8	70,4
	75	787,42	91,4	75,3	83,4	76,3	64,8	60,2	42,9	45,6	80,7	109	104	105
	90	891,03	120	99,2	106	100	79,6	81,8	78,7	90,3	108	152	139	139

A description of the applied statistical test procedure is given in Table 2. Statistically, significant trends are not found for precipitation on annual, seasonal and monthly basis, even though there are negative and positive trends for any of period of record (1931-2006 and 1974-2006) considered. Overall, precipitation trend is negative but this result is not statistically significant at 95 % confidence limit (MK= -1.03) during the period of 1931-2006. The decrease in annual precipitation observed in the study area is caused by decrease in winter precipitation totals, which compensate the slight increase in the other seasons especially summer months (Table 2). On the other hand, annual precipitation trend is positive but the result is not statistically significant at 95 % confidence limit (MK= 1,94) during the period of 1974-2006. In the study area, the increase in annual precipitation observed during last three decades is caused by increase in winter, spring and summer precipitation totals.

Table 2. Monthly and seasonal Mann-Kendall results of precipitation for the study area.

Months	**1931-2006**			**1974-2006**		
	Mann-Kendall	**P-value**	**Sen's-Slope**	**Mann-Kendall**	**P-value**	**Sen's-Slope**
January	-1,35	0,177	-0,279	1,44	0,145	0,649
February	-1,89	0,057	-0,275	1,49	0,132	0,471
March	-1,55	0,120	-0,240	1,86	0,060	1,095
April	-0,27	0,780	-0,037	-0,31	0,744	-0,227
May	0,73	0,464	0,096	0,56	0,566	0,218
June	0,93	0,350	0,140	-0,19	0,840	-0,091
July	-0,48	0,631	-0,050	0,15	0,864	0,086
August	0,18	0,851	0,020	-0,46	0,630	-0,194
September	-0,44	0,657	-0,098	0,73	0,457	0,533
October	0,60	0,544	0,148	0,00	0,989	-0,005
November	-1,09	0,273	-0,224	-0,05	0,950	-0,045
December	-0,52	0,602	-0,101	0,39	0,687	0,181
Annual	-1,03	0,302	-0,653	1,94	0,0503	3,578
Winter	-2,06	0,039*	-0,717	1,38	0,163	1,597
Spring	-0,12	0,903	-0,035	1,16	0,238	1,336
Summer	0,78	0,435	0,292	1,04	0,292	1,093
Autumn	0,08	0,935	0,033	0,51	0,598	0,617

Trend analyses were also conducted on monthly and seasonal precipitation data (Table 2). Precipitation patterns for seasons do not represent significant positive or negative trends at 95 % confidence level. However there is considerable amount of precipitation decrease for winter which is statistically significant at 90 % confidence limit during the period of 1931-2006. On the other hand, all four seasons has showed slight increase during the period of 1974-2006 but all are not statistically significant (Figure 2). From the above explanations seasons have showed almost no significant change during last three decades, even though overall these seasons represent slight precipitation increase.

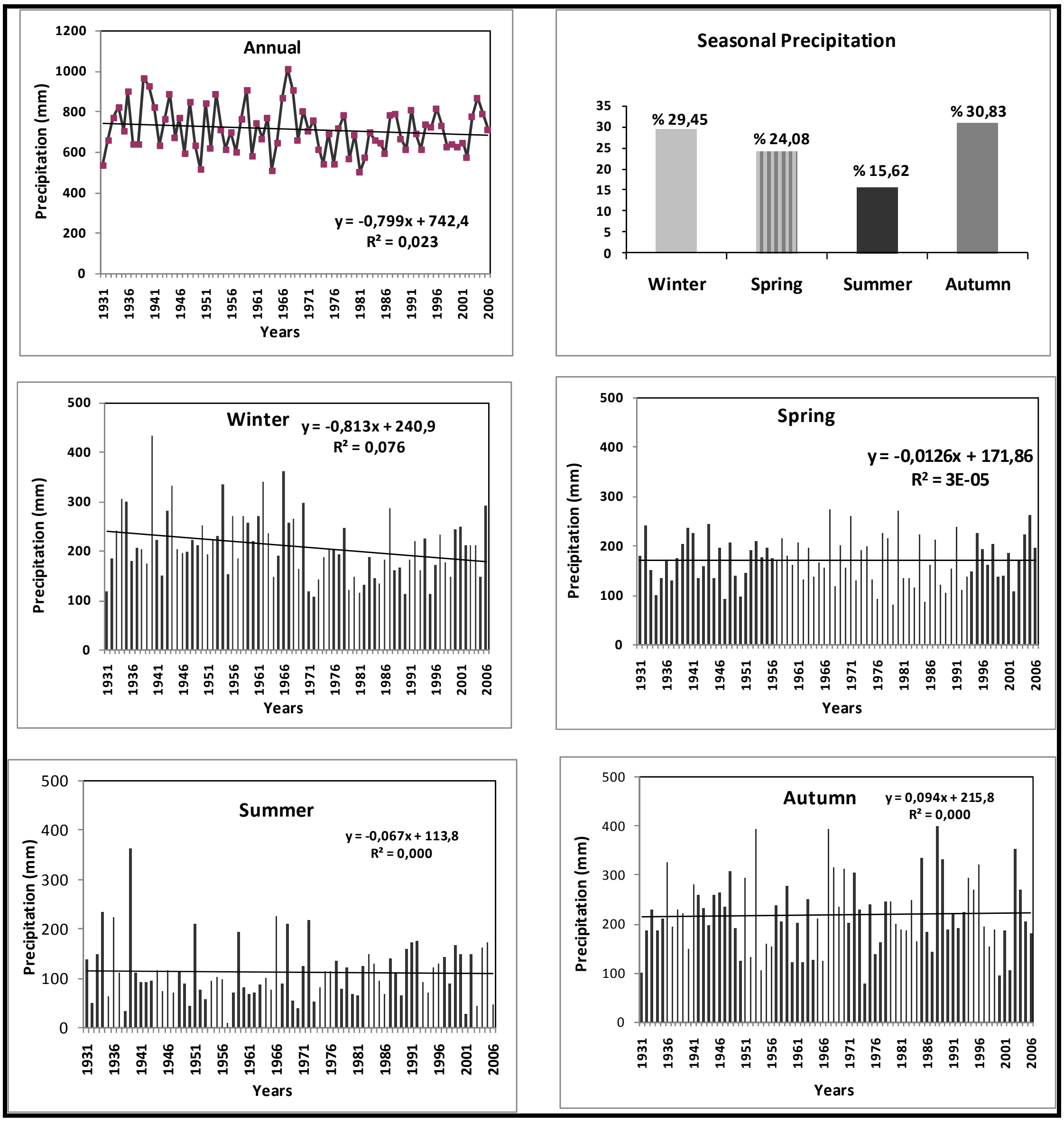

Figure 2. Annual and seasonal rainfall series for the period of 1931-2006

Figure 3 shows the cumulative deviations of rainfall pattern in the study area for the periods of 1931-2006. Results reveal that a cyclic pattern of variations with alternating drier and wetter years is suggested. An increase of annual precipitation up to the early 1972s was followed by decrease until 1986s. The last thirty years were characterized by decrease of precipitation in general until 2002. However last four years have showed slight precipitation increase. Dry periods can be determined in 1973-1986 (with 630,3 mm mean precipitation), and 1998/2002 (622,4 mm). According to 25th percentile measurements, it can be seen that 1973-1986 time scale was driest period.

Wetter periods, on the other hand, can be identified in 1933-1948 (774,16 mm), 1966-1972 (816,5 mm) and 2003-2006 (787,37 mm). 75th percentile measurements show 1966-1972 period as wettest period.

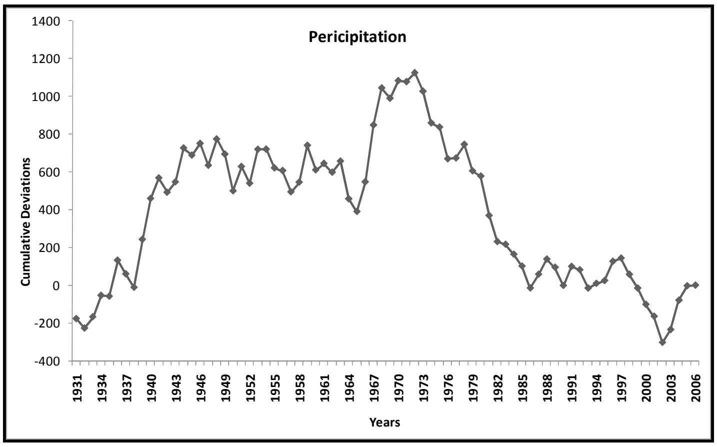

Figure 3. Cumulative deviations from average rainfall

To be able to determine normal, wet and dry years, seasons and moths, percentiles were computed. Rainfall amount was considered normal between P25 and P75, on the other hand, P25 was considered as drier than normal and called low abnormal year, season or moth. Similarly over P75 was accepted as wet year, season or month for the study area. The dry months frequency results were represented in the Figure 4. It can be seen that low number of abnormal months were distributed almost evenly throughout the study period.

While for the summer season absolute frequency of low abnormal moths were the highest, winter showed low frequency in terms of absolute frequency of dry months. According to Figure 5 absolute frequency of high abnormal (wet) months were decreased during the period of 1931-2006. On the other hand, frequencies of dry months were increased during the study period. Last five year showed lower frequency of dry months.

Temperature Trends

Air temperature has crucial impact on the water cycle in the study area. So that analysis of trends in annual, seasonal and monthly temperature data conducted for the periods of record 1931-2006 and 1974-2006. Figure 6 represents the mean annual temperature and its trend in the period of under examination. Using a linear regression model, the rate of change is defined by the slope of regression line which in this case is about 0.00 ^{o}C/76 yr during the period of 1931-2006. This finding is not similar to global warming rate which is estimated a 0.6 C for the past century. However, the rate of change (during the period of 1974-2006) is around 0,86 ^{o}C/yr which was consistent with that of global mean of 0.6 ^{o}C. This result shows that global warming has important impact on the regional climate in the study area for the last three decades.

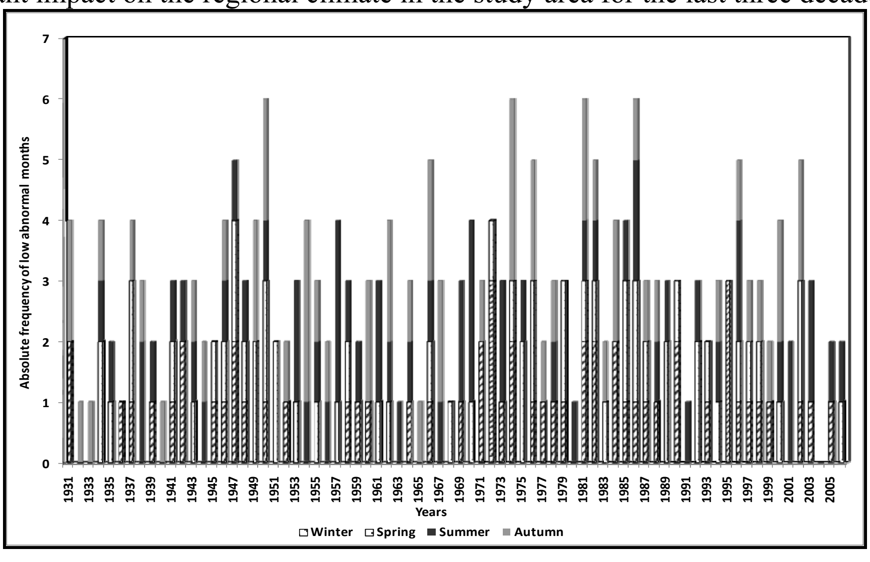

Figure 4. Absolute frequency of dry months

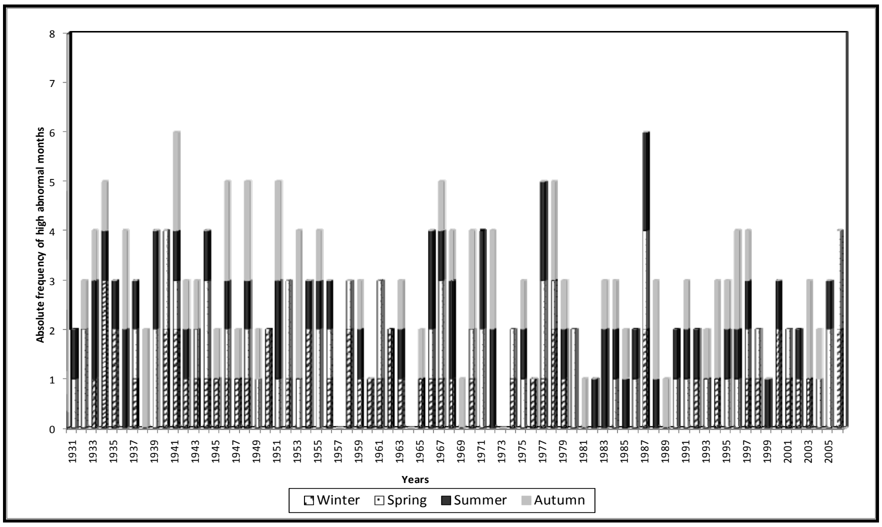

Figure 5. Absolute frequency of wet months.

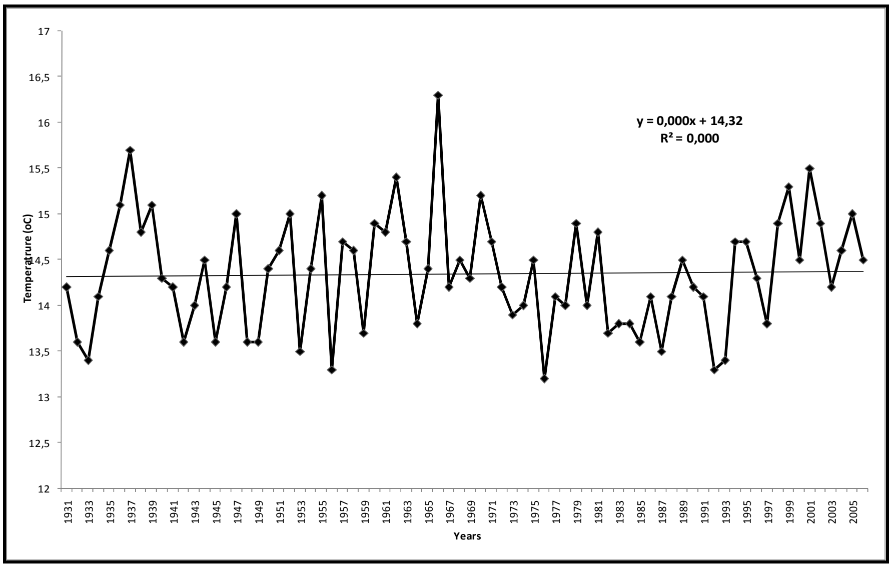

Figure 6. Annual temperature trend for the period of 1931-2006.

Statistically, significant trends are not found for temperature data on annual, seasonal and monthly basis, even though there are negative and positive trends for period of record (1931-2006) considered. Overall, annual temperature trend is positive but this result is not statistically significant at 95 % confidence limit (MK= 0.770) during the period of 1931-2006. The increase in annual temperature observed in the study area is caused by increase in summer months, which compensate the slight decrease in the other seasons especially autumn months (Table 3). On contrast, annual temperature trend is positive and the result is statistically significant at 95 % confidence limit (MK= 2,61) during the period of 1974-2006. In the study area, the increase in annual temperature observed during last three decades is caused by increase in summer months temperatures especially increase in July and August.

Long term changes in temperature of four seasons showed different patterns (Table 3). Winter and spring seasons represent similar slight increasing trend. On the other hand, summer and autumn season's temperature showed increasing trend which is statically significant for three decades. Trends in monthly temperature data are consistently positive most of the moths excluding moths of December and statistically significant in June, July, August, September and October at 95 % confidence level during the period of 1974-2006.

Table 3. Monthly and seasonal Mann-Kendall results of temperature for the study area.

Months	1931-2006			1974-2006		
	Mann-Kendall	**P-value**	**Sen's-Slope**	**Mann-Kendall**	**P-value**	**Sen's-Slope**
January	0,24	0,805	0,004	0,65	0,504	0,016
February	-0,61	0,538	-0,007	0,05	0,950	0,000
March	0,57	0,565	0,005	0,36	0,709	0,010
April	0,68	0,492	0,005	0,17	0,852	0,005
May	-0,49	0,618	-0,002	0,42	0,663	0,008
June	1,07	0,282	0,005	2,68	0,007**	0,033
July	1,40	0,161	0,009	3,34	0,000***	0,067
August	1,70	0,087	0,008	4,25	0,000***	0,093
September	0,90	0,364	0,005	2,42	0,014*	0,042
October	-0,57	0,562	-0,006	1,99	0,045*	0,040
November	-1,83	0,066	-0,017	0,22	0,815	0,006
December	-0,60	0,547	-0,006	-0,11	0,901	0,000
Annual	0,29	0,770	0,000	2,61	0,008**	0,029
Winter	-0,39	0,696	-0,002	0,28	0,768	0,006
Spring	0,69	0,486	0,003	0,81	0,410	0,019
Summer	1,62	0,104	0,008	3,98	0,000***	0,070
Autumn	-1,08	0,277	-0,006	2,29	0,020*	0,033

Figure 7 shows the cumulative deviations of temperature pattern in the study area for the periods of 1931-2006. Results reveal that a cyclic pattern of variations with alternating warming and cooling years is suggested. The last thirty five years were characterized decrease of temperature up to the early 1993s and was followed by increase until 2006s. Cooling periods can be determined in 1931-1934 (with 13,82°C, mean temperature), 1940-1949 (13,88°C, except years of 1944 and 1947), and 1972-1993 (13,90°C, except years of 1979 and 1981). Warming periods, on the other hand, can be identified in 1935-1939 (with 15,06°C, mean temperature), 1960-1971 (14,85°C except year of 1964), and 1994-2006 (14,86°C, except years of 1996, 1997 and 2003).

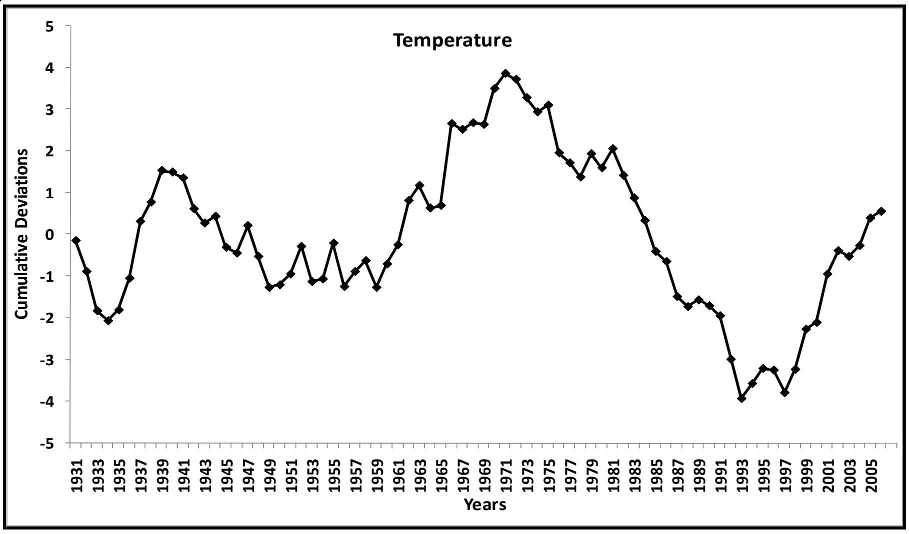

Figure 7. Cumulative deviations from average temperature.

Conclusion

In this study precipitation and temperature data from 1931 to 2006 were used to identify seasonality, variability, trends in Samsun (Turkey). From analysis of annual, seasonal and monthly rainfall data series it can be concluded that precipitation characteristics of the area is changing, even though results of trend analysis on annual precipitation data show no statistically significant trend for period of record considered. This result is consistent with the analysis of precipitation trend in Turkey (Turkeş 1996a, Kadığlu 1997).

This study have also represented that a slight decrease of precipitation in the study period is determined in annual, winter and spring seasons. Winter precipitation decrease is more apparent than spring. A slight increase in the study period is found in summer and autumn data series. While June, August and October are representing little increase in precipitation, November depicts more abundant precipitation decrease. However, according to Mann-Kendall test results, any season or months shows statistically significant trends. According to cumulative deviation curve the study area has experienced couple of dry and wet periods during the period of 1931-2005. According to this curve last five year precipitation increase has become apparent.

From analysis of temperature data series it can be concluded that temperature characteristics of the area is changing, especially results of temperature trend analyses represent statistically significant trend for the period of 1974-2006. This result is consistent with the analysis of temperature trend in Turkey (Kadığlu 1997, Türkeş 1995, Turkeş et al 2002). Summer temperature increase is more apparent than other seasons during the last three decades. A slight decrease in this period is found in December data series. June, July, August and September are representing significant temperature increase.

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