Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 120 (2014) 586 – 599

Procedia
Social and Behavioral Sciences

The 3rd International Geography Symposium - GEOMED2013

Changes and trends in total yearly precipitation of the Antalya district, Turkey

Türkan Bayer Altın[a]*, Belma Barak[b]

[a]Niğde University, Faculty of Science and Letters, 51100 - Niğde, Turkey
[b]Bartın University, Faculty of Education, 74100 - Bartın, Turkey

Abstract

In this study, long term changes and trends in the annual rainfall of the Antalya Part, which is the region located in the western Mediterranean coast of Turkey containing many agricultural areas in its surrounding, were analysed. The aim of this study was to analyse the long term changes and trends in rainfall totals and present spatial distributions of annual and seasonal rainfall variability over the part. Rainfall data from 7 meteorological stations (Antalya, Alanya, Manavgat, Gazipaşa, Finike, Korkuteli and Elmalı) covering the years 1970-2011 were used in this study. Prepared rainfall variation maps clearly show that the highest annual variation is Antalya, while the lowest variation is Manavgat. According to the results obtained in trend analysis, in general, while a decreasing trend in winter rainfall is apparent, there is an apparent increasing trend in autumn rainfall. These results show a shift in seasons causing long-term droughts and potential infertile land to emerge. At some stations in the vicinity, there has been a prominent change from humid conditions to semi-arid conditions from beginning of 2000s. This study is expected to contribute to better understanding the effects of global climate change over precipitation in Antalya vicinity.

Keywords: Antalya; Climate change; Trend; West Mediterranean; Mann-Kendall Test.

* Corresponding author. Tel.: +905387364916; fax: +903882112100.
E-mail address: turkanaltin@yahoo.com

doi:10.1016/j.sbspro.2014.02.139

1. Introduction

Show that there have been marked increases in precipitation in the latter part of the 20th century over northern Europe, with a general decrease southward to the Mediterranean. According to Piervitali, Colacino and Conte. (1998) and Romero, Guijarro, Ramis and Alonso (1998), dry wintertime conditions over southern Europe and the Mediterranean. Generally, important decreasing trends were observed in the winter rainfall, annual rainfall of Turkey and rainfall of the East Mediterranean Basin are associated with very high frequency in the Mediterranean low pressures and frontal middle latitude pressures dominating in this region (TÜBA, 2010). Some studies (Türkeş and Erlat, 2003; 2005; 2006) determined that changes and variability in the North Atlantic Oscillation (NAO) winter indices are one of the major atmospheric sources for controlling spatial and temporal variability of winter precipitation in Turkey, as much as in the Atlantic, the Europe and the Mediterranean Basin. As a result of climate change, many studies on changes related to atmospheric circulation types and anomaly affecting in Mediterranean Basin and long term surface air temperature changes and trends are formed for countries situated within Mediterranean Basin and its surrounding (Metaxas et al., 1991; Arseni-Papadimitriou and Maheras, 1991; Kutiel et al., 2002; Kutiel and Maheras, 1998; Price et al., 1999; Gönençgil and İçel, 2010; Bahadır, 2011). In these studies, decreasing trends in the amount of rainfall are determined, especially in the East Mediterranean. As temporal and spatial, rainfall is the most variable element of climate and this variability is the most prominent feature of the arid, semi-arid and continental climates (Türkeş, 1990). There are many studies on year by year changes in annual and monthly rainfall in Turkey (Kadıoğlu, 2000; Türkeş and Erlat, 2003, 2005; Tatlı, 2007; Ölgen, 2010). The results of these studies indicate that the vulnerability in annual rainfall and longer term rainfall changes are associated with NAO, Arctic Oscillation, Mediterranean Oscillation and El-Nino-Southern Oscillation (ENSO).

In this study, trends and changes in the annual and seasonal rainfall of Antalya Part using the rainfall data sets were examined in detail. The data sets include monthly and annual rainfall totals (mm) recorded at the stations of the Turkish State Meteorological Service (TSMS), most of which are principal climatological stations. The maps showing the spatial distribution of these trends and changes were formed using GIS. The purpose of this study was to determine changes in the spatial dispersion and inter-annual variations of rainfall. The results of this study are important for Antalya Province with its many agricultural areas.

2. Study area

The study area is situated within the Antalya section of the Mediterranean Region, with Antalya city at the centre. Antalya Province (including districts) has an area of 20723km², while Antalya coast is 630km long. The province is surrounded by the Burdur, Isparta and Konya Provinces to the north; Karaman, Mersin provinces to the east and Muğla to the west and the Mediterranean Sea to the south. The Antalya Part overlooks the Mediterranean Sea of Taurus Mountains situated between Antalya Gulf to the west and Manavgat district to the east (Fig. 1). The Antalya Part contains the productive agricultural areas of the Serik district. For this reason, changes in climate are very important for this part. Agriculture is performed all year round and yield is obtained twice yearly (Atalay and Mortan, 2007).

The northeast-southwest trending mountain chains extend in the west of the Antalya Part. Many valleys are found among these mountain chains. These mountains are Akdağ (2375m), Beydağları (3069m), Mount Elmalı (2490m), Bozdağ (2421m), Mount Çiçekbaba (2294m), Mount Geyik (2529m) and Mount Dedegöl (2980m) is found in the east of the Antalya Part. These mountains consist of limestone. The lakes and valleys are found in the tectonic and subsidence areas among these mountains (Yücel, 1987). The rainfall of Antalya Part is determined by topography and frontal activities. According to Atalay and Efe (2007), the rainy area of the region is the southwest slopes of the Taurus Mountains due to the fact that the fronts coming from the Mediterranean Sea are mostly shielded by the mountains. The mean annual precipitation of Antalya and Manavgat is above 1000mm because the fronts coming from the Mediterranean Sea are prevented by the mountains as well as Antalya. Orographic rainfall also causes an increase in precipitation, especially on the southern high slopes of the Taurus Mountains (Atalay and Efe, 2007). The frontal system depending on air mass penetrating into the Mediterranean Basin and formation of low-pressure manage air conditions of the Mediterranean coast from the end of October to May (Koçman, 1993; Kafalı Yılmaz, 2008). During the summer the fronts form between the maritime tropical air mass (mT) coming from the Atlantic

Ocean and the maritime polar air mass originating from Western Europe lead to heavy rainfall (Atalay and Efe, 2007). Therefore, approximately half of the total yearly rainfall occurs during the winter. The fronts coming from the southeast move northeast and high throughout the slopes of Mount Taurus. This situation leads to an increase in rainfall duration and intensity and is clarified on the southwest slopes of Mount Geyik (Atalay and Efe, 2007; Kafalı Yılmaz, 2008). 54.2% of the total annual precipitation falls in the winter.

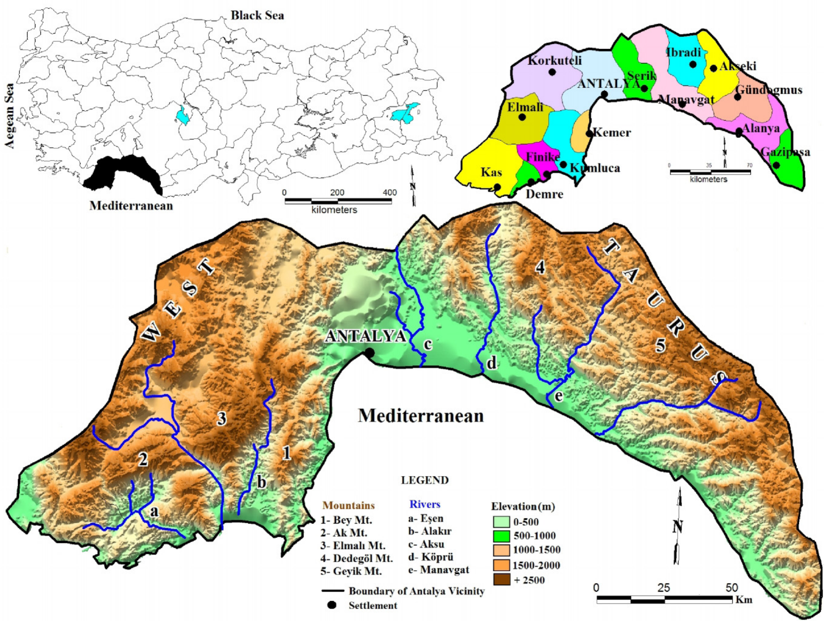

Fig. 1. Location and simplified geomorphology map of the study area. This map was derived from Turkey DEM.

The second rainiest season is the autumn (24.4%). 20% of the total annual precipitation falls in the spring in Alanya, Finike, Gazipaşa, Manavgat and Demre as well as Antalya. However, the second rainiest season is the spring in Elmalı and Korkuteli which is located in tectono-karstic depression where frontal movements affecting the Mediterranean region do not penetrate and continental effects are dominant. The amount of rainfall decreases in the summer (0.8%) because effects of frontal activities disappear and tropical air masses affect the region. According to Atalay and Efe (2007), these depressions have a low amount of the precipitation because these areas are situated within the rain shadow, for example, the yearly rainfall is less than 500mm in the Korkuteli and Elmalı poljes. The amount of daily rainfall sometimes exceeds 200mm. Above 200mm rainfall and storms cause severe floods, resulting in heavy damage to the agriculture and greenhouses (Kafalı Yılmaz, 2008; Atalay and Efe, 2007) The summer experiences drought due to lack of rain. According to this distribution of the precipitation in the year, the Antalya Part is under the influence of the Mediterranean Rainfall Regime.

3. Data and methods

In this study, the annual of monthly rainfall data from 7 meteorological stations on the western Mediterranean Part of Turkey covering the years 1970-2011 was used. These stations are Antalya, Alanya, Manavgat, Gazipaşa, Finike, Korkuteli and Elmalı (Table 1). Annual and seasonal rainfall totals were calculated from monthly values recorded at stations of the Turkish State Meteorological Service (TSMS). Spatial distribution of annual and seasonal rainfall variability of Antalya Part was examined. Therefore, for every station in the study area, coefficient of variation (CV) was calculated by the below formula:

$$CV = \frac{\sigma s}{Ps} 100$$

Ps: Long term mean rainfall, σ s: standard deviation.

Areas with a coefficient over 25% are evaluated as severe droughts areas. However, areas with a value lower than 25% have a uniform rainy pattern such as the Black Sea Region (Türkeş, 2010).

The following time series analyses and tests, majority of which are non-parametric, have been applied on the time series in order to determine the long-term changes and trends in the annual and seasonal series (Türkeş, Sümer and Yıldırım, 2005; WMO, 1966; Sneyers, 1990): 1-Homogeneity analysis and randomness tests were used to test whether the time series were statistically homogeneous. The methods of analysis that we used are Homogeneity of Means and Variances in the Kruskal - Wallis Homogeneity Test, Runs test in the tests of Randomness, and Wald-Wolfowitz Serial correlation test.

Table 1. Meteorological stations in the study area

Station	Period	Elevation (m)	Latitude	Longitude
			North	East
Antalya	1970-2011	64	36º88′	30º68′
Alanya	1970-2011	6	36º55′	31º98′
Manavgat	1970-2011	38	36º79′	31º44′
Gazipaşa	1970-2011	21	36º27′	32º30′
Finike	1970-2011	2	36º30′	30º15′
Korkuteli	1970-2011	1017	37º06′	30º19′
Elmalı	1970-2011	1095	36º74′	29º91′

2- In order to determine long-term trends, points of change and significant hot or cold, wet or dry etc. periods, *Mann-Kendall* (M-K) *rank correlation coefficient test* and M-K *sequential analysis of rank correlation coefficient* were performed. 3- In order to decide whether there is any trend in the series of observations examined, *Spearman Rank Correlation Coefficient* analysis was conducted. 4-In order to determine linear trends Student's t test for the significance of the regression coefficient (β) obtained from the *least-squares linear regression (LSLR) calculations;* LSLR equation to estimate 10-year-long trend rates. *Kruskal – Wallis Homogeneity Test:* "Kruskal - Wallis Test of Homogeneity" is an effective non-parametric test of homogeneity used to verify the homogeneity of means and variances. Here, instead of (X_i s), the series is sorted in descending order and then the observations' rank orders (m) in the total ordered series are used (Türkeş, 2008). a) Homogeneity of Means: If k is the number of independent series, nj is the sample size (number of observations) of independent sub-series (or periods) from j=1………k and r_{ij} are the rank orders in the total ordered series composed of i observations in j sub-series, then the sum of all rank orders in each independent series is

Rj,

$$R_j = \sum_{i=1}^{nj} r_{ij}$$

and the number of observations in the total rank ordered series is

$$n = \sum_{j=1}^{k} n_j$$

the sample test statistic X_K is calculated using

$$X_K = [\frac{12}{n(n+1)} \sum_{j=1}^{k} \frac{R_j^2}{n_j}] - 3(n+1)$$

equation (Sneyers, 1990 cited in Türkeş, 2008). Before calculating the sample test statistic, it should be checked whether R_j values are correct or not using the

$$\sum_{j=1}^{k} R_j = \frac{n(n+1)}{2}$$

In order to test the homogeneity of means, the null and the alternative hypotheses are set as follows; H_0: Means of the series of observations are homogeneous. H_a: Means of the series of observations are not homogeneous. Under the null hypothesis of means are homogeneous, X_K the sample statistic approximately follows (X^2) distribution with (k-1) degrees of freedom. Non-rejection or rejection of the null hypothesis depends on the required significance level (à=0.05 or à=0.01) and f= (k-1) degrees of freedom, the size of the X^2 critical value that is to be found in the X^2 table and the test statistic X_K that is to be compared with the critical value. The null hypothesis is rejected for values of X_K where ($X_K \geq X^2$) (Türkeş, 2008). If some of the actual values in the total ordered series are equal, then X_K sample test statistic should be corrected by dividing it by the correction coefficient given in the

$$C_c = 1 - \frac{\sum T}{n^3 - n}$$ *equation.*

Here

$\sum T$, $T = [(t^3 - t).$

(number of repetitions)] and t, which is the equal values in a group of equal values, gives the sum of all groups of equal values (Türkeş, 2008). b) Homogeneity of Variances: The sample test statistic (X_K) used in the homogeneity of means is also used in the homogeneity of variances. In the homogeneity of variances, the series obtained by using the differences of original observations from the general mean are used as the basis for the analysis (Sneyers, 1990 cited in Türkeş, 2008). In the homogeneity of variances, rank orders r_{ij} represent the rank orders obtained from the total ordered series which is constructed by sorting the absolute differences

$$(d = \left| X_i - \bar{X} \right|)$$

in ascending order (Türkeş, 2008). *Runs Test:* This is a non-parametric test. In this test, the difference of the values (Xi) in the time series from the median are calculated and the obtained (-) and (+) values are regarded as runs. The following formula is applied on the number of runs which is obtained as a result of the operation performed on the number of runs. The mean (E(R)) and the variance (var(R)) of the distribution function are represented by;

$$E(R) \cong \frac{n}{2} + 1 \quad Var(R) = \frac{n(n-2)}{4(n-1)} \cong \frac{(n-1)}{4}$$

equations respectively. (Türkeş, 2008). When the normal distribution approach is used, the standardized sample test statistic is calculated by

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

The null hypothesis is rejected for large Z values according to the shape of the one-sided distribution. Two alternative hypotheses are taken into account for this test; H_0 =Observations are random. H_1 =Observations are not random. Depending on the probability of the sample test statistic, the hypothesis is not rejected if a1>a0 (do not reject) or rejected if a1>a0 (reject). When the Ho is true, the runs of the observations are frequently below and above the median. If the null hypothesis is false, the route of the observations is less frequently below and above the median. *Wald – Wolfowitz Serial Correlation Coefficient:* Serial correlation tests are generally used to check whether there is a serial correlation or dependence among sequential observations in a time series. Wald-Wolfowitz serial correlation test is based on the assumption that the lack of randomness in the series of observations might be related to the relatively low frequency changes (long-term fluctuations). When it is used to search for a serial relationship in climatic observation sequences, the alternative hypothesis is only a positive serial correlation or persistence (Türkeş, 2008). The sample test statistic is tested according to the shape of the one-sided distribution. Instead of the series of observations with actual values, when the rank ordered series obtained by sorting the values of observation in ascending order is used, the Wald-Wolfowitz test, R, is calculated by

$$R = S_2 - \sum_{i=1}^{n} (y'_i - y_{i+1})^2 / 2$$

formula (Türkeş, 2008). S2 and yi are defined by

$$S_2 = \sum_{i=1}^{n} y_i'^2$$

.

Instead of R sample statistic, r=R/ S_2

function is used and the approximate distribution of this statistic is asymptotically normal. The r sample statistic given above is transformed into a new sample test statistic (U(r)) with the

$$u(r) = (n-1)r + 1/\sqrt{n-1}$$

The null hypothesis (Ho) is rejected for large values of u(r) (Türkeş, 2008). The hypotheses identified in this test are: Ho= Observations are random. Ha1= Observations are not random. Ha2= Observations show a positive correlation. Arrangements for equal values: Sometimes there may be equal values in the new series formed by sorting the observations in ascending order for Kruskal - Wallis homogeneity test and Wald-Wolfowitz serial correlation tests. These equal values must be given equal rank orders. Therefore, the average rank order of equal values is found and then this average rank order is used as the rank order of all equal values. In case there are more than one equal values in these tests, T values should be calculated for each equal value separately and $\sum T$ value should be obtained as a sum of all Ts. In the calculation of Wald-Wolfowitz serial correlation coefficient, the average of the rank orders of the consecutive equal values is used in order to determine the yi rank orders of the equal values. This average is used as the rank order of equal values in the yi series formed by using rank orders of the original values in the new ordered series. *Mann –Kendall Rank Correlation Coefficient Test:* M-K u(t) sample statistic gives the direction and statistical size of any long-term trend in a series and calculated by the following equations 1-4 (WMO, 1966):

$$t = \sum_{i=1}^{n} n_i \quad E(t) = \frac{n(n-1)}{4} \quad \mathrm{var}(t) = \frac{n(n-1).(2n+5)}{72} \qquad u(t) = [t - E(t)] / \sqrt{\mathrm{var}(t)}$$

The null hypothesis 'There is no trend in the average of the series of observations' (H_0) is rejected for large values of $|u(t)|$. In case the calculated $u(t)$ value is significant, an increasing trend can be assumed to be present in the series if $u(t) > 0$, and a decreasing trend can be assumed to be present in the series if $u(t) < 0$. As a basic rule in interpretations of time series plots of $u(t)$ and $u'(t)$ values obtained from the sequential analysis of the M-K test, where the $u(t)$ curve shows the direction of the trend, superposition of $u(t)$ and $u'(t)$ curves for a number of times suggests that there is no trend in the series whereas the point where $u(t)$ and $u'(t)$ curves intersect is regarded as the point where a strong trend begins or where a change occurs in the series (Sneyers, 1990; Türkeş, 1996, 1999; Türkeş, Sümer and Demir, 2002). Following such a point of change, the areas outside the 95% confidence limits of the $u(t)$ curve depending on the two-sided shape of the normal distribution (here, the critical values of ± 1.96) are considered periods of significant increase (decrease). In this evaluation, when temperature series are used, a significant wet period (low precipitation or dry) is defined as a low humidity (high humidity) period where relative humidity is less than the mean when humidity series are used. *Spearman Rank Correlation Coefficient:* In the Spearman rank correlation coefficient, instead of original x_i values where $i=1,...,n$, the y_i values corresponding to the rank orders in the series formed by sorting the original series in ascending order. The sample test statistic is the correlation coefficient between i and y_i series, represented as r_s. This coefficient is calculated by

$$r_s = 1 - \frac{6}{n(n^2-1)} \sum (y_i - i)^2$$

equation (Bernard, 2000). Its expected value *(E(r_s))* and variance *(var(r_s))* are given as $E(r_s)=0$,

$$\mathrm{var}(r_s) = \frac{1}{n-1} \text{ equations}$$

and the distribution of this sample test statistic is asymptotically normal. Sample test statistic, $u(r_s)$ is represented by

$$u(r_s) = r_s\sqrt{n-1} \text{ equation}$$

and the null hypothesis is rejected for large values of $|u(r_s)|$. As is the case in *Mann – Kendall* trend test, in order to decide whether there is a trend in the analyzed series of observations, initially the sample test statistic should be statistically significant. Whether the trend is decreasing or increasing depends on $r_s > 0$ or $r_s < 0$, respectively. *Student t Test:*The Student's t test for the significance of LSLR coefficient β is calculated as follows: For $i = 1, ..., n$, X_i and Y_i are the series of two variables: the means of X and Y series are respectively:

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \ , \ \overline{Y} = \frac{\sum_{i=1}^{n} Y_i}{n}$$

a coefficient in the least squares linear regression equation: $a = \overline{Y}$ b coefficient in the least squares linear regression equation:

$$\text{where } x_i = X_i - \overline{X} \ , \ b = \frac{\sum_{i=1}^{n} x_i . Y_i}{\sum_{i=1}^{n} x_1^2}$$

The general and the estimation equations in the least squares linear regression:

$$\hat{Y}_i = a + b \cdot x_i \ , \ Y = a + bx$$

For the hypothesis test for the significance (*Student t* test) of $\hat{\beta}$ (*regression* or coefficient of X) initially the variance of Y, s^2 is estimated as follows:

$$s^2 = \frac{1}{n-2} \sum_{i=1}^{n} (Y_i - \hat{Y})^2 \text{ Here, } \hat{Y}_1, \hat{Y}_i = a + \hat{\beta} x_i$$

is the estimated value of Y on the regression line. s^2 is also called the '*residual variance*'; s is the standard error of Y. Then, *Student's t* test is performed for the significance of β (the slope):

$$t = \frac{\hat{\beta} - \beta}{\sqrt{s^2 / \sum_{i=1}^{n} x_i^2}}$$

t follows *Student's t* distribution with *(n-2)* degrees of freedom. The above equation could be written more simply:

$$t = \frac{\hat{\beta} - \beta}{S_{\hat{\beta}}}$$

here; $S_{\hat{\beta}} = s / \sum_{i=1}^{n} x_i^2$

is referred to as the *standard error* of β or estimated *standard deviation*. Sample test statistic *t* follows *Student's t* distribution with (n-2) degrees of freedom. The null hypothesis of "observations do not show a trend" (or there is no trend in the observations) is rejected according to the two-sided shape of the distribution for the values that are greater than $|t|$ ($|t| \geq t_{a/2}$).

4. Results

4.1. Annual and seasonal rainfall variability

Variability of seasonal rainfall ranges between 147.9 and 34.7 over the part (Table 2). The highest rainfall variability is determined for Manavgat during the summer. Variability of summer rainfall is above 55% for other stations. Variability of winter rainfall is 44% for Antalya. This station is followed by Korkuteli, Elmalı, Finike, Alanya, Manavgat and Gazipaşa, respectively. Variability of autumn rainfall is above 50% for all stations. The highest value is 81.5% for Antalya, and the lowest value is 50.6% for Manavgat. Variability of spring rainfall ranges between 59 and 38. This value decreases in the northern part of the part (Fig. 2a, b, c, d). Variability of annual rainfall is above 25% for Antalya, Finike, and Alanya, respectively, and decreases from the northern part of the Antalya Part (Fig. 2e), which is generally characterized by upland and below 25% for Manavgat.

Table 2. Variability of annual and seasonal rainfall

Time	Rainfall Variability (%)						
	Antalya	Finike	Gazipaşa	Manavgat	Alanya	Elmalı	Korkuteli
Winter	44.4	37.3	34.7	35.1	36.7	40.6	43.5
Spring	59.1	54.8	51.4	43.2	52.4	38.8	39.7
Summer	119	138.9	144.1	147.9	130	74.1	59.6
Autumn	81.5	59.9	57	50.6	53.3	55.6	62.9
Annual	34.8	30.2	25.8	23.8	27.6	24.7	25.9

4.2. Homogeneity and randomized test

Homogeneity of data was tested according to the Kruskal-Wallis homogeneity test, means and variances homogeneous. Randomized data was analyzed by the Wald-Wolfowitz test (Table 3). According to analyses, the long-term annual and seasonal rainfall series of Antalya, Manavgat and Gazipaşa stations are homogeneous. According to homogeneity of the variances, spring rainfall data of Finike is in-homogeneous. According to homogeneity of means, total annual rainfall and autumn data of Korkuteli is in-homogenous. According to the run test, seasonal and long-term mean annual rainfall series of Antalya, Alanya, Finike, Korkuteli, Elmalı are random, although the spring rainfall series of Manavgat and Gazipaşa are non-random. According to the results of the Wald-Wolfowitz test, observation in seasonal and long-term mean annual rainfall series of Antalya and Manavgat are random. Observation in winter long-term rainfall total series of Finike, Elmalı and Gazipaşa, observation in summer long-term rainfall total series of Antalya and observation in autumn long-term rainfall total series of Korkuteli are non-random.

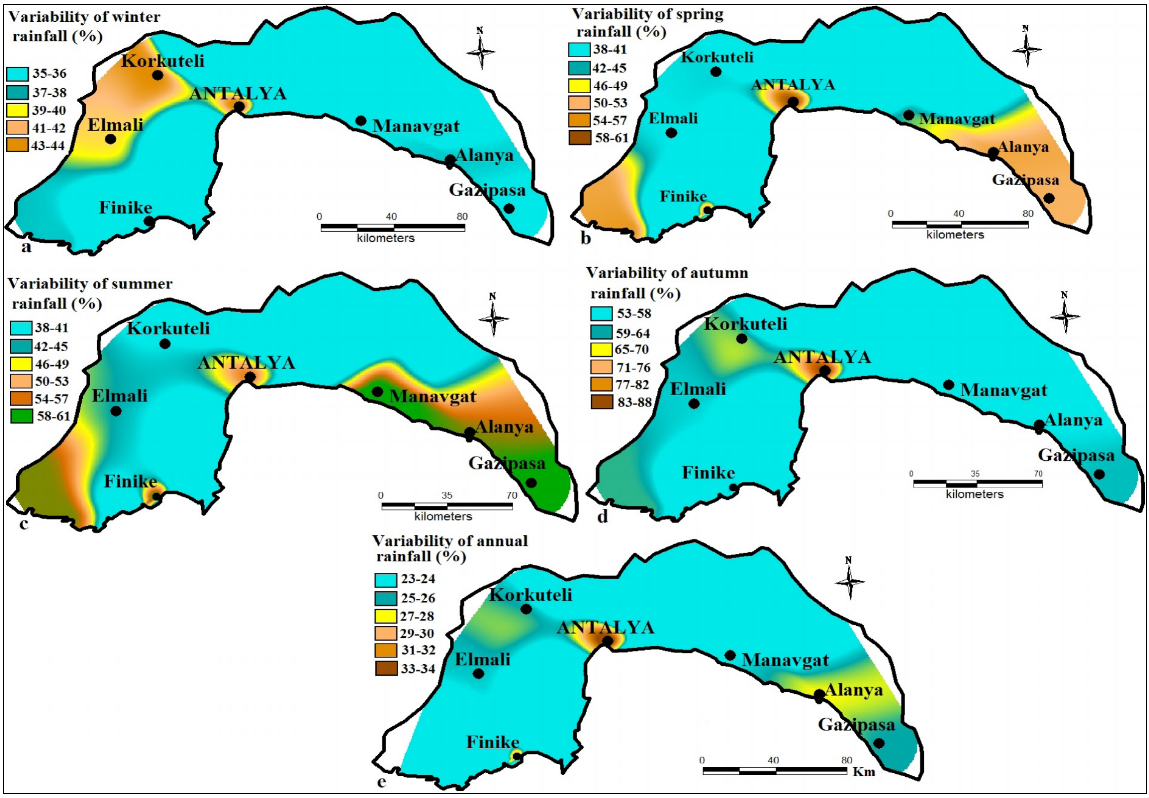

Fig. 2. Annual and seasonal rainfall variability of the stations

4.3. Trend in annual and seasonal rainfall totals

According to the Mann-Kendall test, a decreasing trend in long-term annual rainfall totals is determined for Antalya and Alanya. There is a statically non-significant decreasing trend in annual rainfall of Alanya and Gazipaşa from 2001 to the present and annual rainfall of Antalya from 2005 to the present and non-significant increasing trend in annual rainfall of Finike, Elmalı and Korkuteli. A heavy rainfall period is determined statistically for Manavgat during the period 1975-1990. A lighter rainfall period is determined for Manavgat during the period 1991-2011. The results of the Spearman test are consistent with the results of the Mann-Kendall test. According to this test, a decreasing trend in annual rainfall totals is determined for Antalya and Alanya.

According to the student t test, there is also a decreasing trend in annual rainfall of Antalya, and a statistically significant increasing trend in annual rainfall for Korkuteli (Table 4). Antalya and Elmalı have a non-significant downward trend in the winter. Antalya also has a downward trend in the autumn.

The spring rainfall series shows a general downward trend in Alanya, Finike and Korkuteli. The summer rainfall series indicate a downward trend in Alanya, Elmalı, Finike, Korkuteli and Manavgat. Antalya has a statistically a non-significant decreasing trend in all seasons from the beginning of 2000s to the present. A significant decreasing trend in seasonal rainfall is observed specifically from 2005. The spring and summer rainfall series generally show a fluctuation about a non-significant decreasing mean in the last decade for Alanya. The autumn rainfall series shows an increasing mean from 2006 to recent in Elmalı. These series reach a statistically significant level (+1.96) from

2009. While there were more rainy periods in Finike during the winter from 1975 to 1990, there were fewer rainy period from 1990 to the present. A non-significant decreasing trend is observed in the autumn from 1997, which is the important change point.

Table 3. Results of homogeneity and randomised tests of meteorological stations.
HM: Homogeneity Method. CV: Critical value. Rs: Result. Hmg: Homogen. In-HMG: in-homogen. R: Random. Non-R: non-Random.

A		Kruskal-Wallis Test				Run Test			Wald-Wolfowitz Test			AL		Kruskal-Wallis Test				Run Test			Wald-Wolfowitz Test		
	T	HM	xk	C.V	Rs	Z	a1	Rs	U(r)	a1	Rs		T	HM	xk	C.V	Rs	Z	a1	Rs	U(r)	a1	Rs
	W	mean	2.17		Hmg								W	mean	3.17		Hmg						
		variance	2.91		Hmg	-0.62	0.27	R	1.03	0.15	R			variance	1.38		Hmg	-0.62	0.27	R	1.52	0.06	R
	Sp	mean	2.13		Hmg								Sp	mean	0.85		Hmg						
		variance	0.98		Hmg	0.6	0.27	R	0.26	0.4	R			variance	3.33		Hmg	0.94	0.17	R	0.26	0.28	R
Rainfall Total	S	mean	0.68		Hmg								S	mean	6.88		Hmg						
		variance	1	7.81	Hmg	-0.6	0.27	R	-1.74	0.04	non-R			variance	1.01	7.81	Hmg	0.94	0.17	R	-1.74	0.18	R
	Au	mean	1.27		Hmg								Au	mean	1.21		Hmg						
		variance	1.48		Hmg	-0.93	0.14	R	1.49	0.07	R			variance	0.89		Hmg	0.94	0.17	R	1.49	0.06	R
	An	mean	0.73		Hmg								An	mean	2.52		Hmg						
		variance	2.32		Hmg	0.31	0.38	R	1.17	0.12	R			variance	2.32		Hmg	0.31	0.17	R	0.11	0.46	R
F	T	HM	xk	C.V	Rs	Z	a1	Rs	U(r)	a1	Rs	M		HM	xk	C.V	Rs	Z	a1	Rs	U(r)	a1	Rs
	W	mean	1.38		Hmg								W	mean	0.7		Hmg						
		variance	1.72		Hmg	-0.62	0.38	R	1.72	0.04	non-R			variance	4.2		Hmg	-0.94	0.38	R	1.37	0.09	non-R
	Sp	mean	0.9		Hmg								Sp	mean	1.3		Hmg						
		variance	8.5		Hmg	0.00	0.50	R	0.26	0.49	R			variance	5.4		Hmg	-1.87	0.03	non-R	1.23	0.11	R
Rainfall Total	S	mean	0.03		Hmg								S	mean	0.3		Hmg						
		variance	0.26	7.81	Hmg	0.31	0.38	R	-0.81	0.18	R			variance	2.5	7.81	Hmg	0.94	0.17	R	0.01	0.50	R
	Au	mean	7.16		Hmg								Au	mean	2.8		Hmg						
		variance	4.52		Hmg	0.00	0.50	R	0.38	0.35	R			variance	4.0		Hmg	-0.31	0.38	R	-0.31	0.38	R
	An	mean	3.78		Hmg								An	mean	1.2		Hmg						
		variance	0.41		Hmg	0.31	0.38	R	0.11	0.36	R			variance	0.5		Hmg	1.56	0.06	R	-0.57	0.28	R
G	T	HM	xk	C.V	Rs	Z	a1	Rs	U(r)	a1	Rs	K		HM	xk	C.V	Rs	Z	a1	Rs	U(r)	a1	Rs
	W	mean	2.0		Hmg								W	mean	1.24		Hmg						
		variance	1.2		Hmg	-1.2	0.11	R	1.75	0.04	non-R			variance	7.20		Hmg	-0.62	0.27	R	1.03	0.15	R
	Sp	mean	0.7		Hmg								Sp	mean	1.11		Hmg						
		variance	1.2		Hmg	0.94	0.17	non-R	-0.05	0.48	R			variance	0.6		Hmg	0.62	0.27	R	-1.64	0.49	R
Rainfall Total	S	mean	3.2		Hmg								S	mean	1.25		Hmg						
		variance	1.2	7.81	Hmg	0.00	0.50	R	-0.72	0.24	R			variance	3.45	7.81	Hmg	0.62	0.27	R	-0.81	0.18	R
	Au	mean	0.6		Hmg								Au	mean	12.43		Hmg						
		variance	1.2		Hmg	1.25	0.11	R	-0.88	0.19	R			variance	4.08		Hmg	0.00	0.06	R	2.00	0.02	non-R
	An	mean	0.4		Hmg								An	mean	8.1		Hmg						
		variance	1.2		Hmg	0.94	0.17	R	-0.57	0.33	R			variance	1.3		Hmg	0.62	0.27	R	0.13	0.45	R
E	T	HM	xk	C.V	Rs	Z	a1	Rs	U(r)	a1	Rs												
	W	mean	2.1		Hmg																		
		variance	3.8		Hmg	-0.31	0.38	R	1.98	0.02	non-R												
	Sp	mean	2.3		Hmg																		
		variance	2.9		Hmg	0.62	0.27	R	-0.95	0.17	R												
Rainfall Total	S	mean	1.8		Hmg																		
		variance	2.7	7.81	Hmg	-0.31	0.38	R	0.11	0.46	R												
	Au	mean	7.5		Hmg																		
		variance	3.08		Hmg	0.00	0.11	R	1.43	0.08	R												
	An	mean	2.6		Hmg																		
		variance	0.3		Hmg	0.62	0.27	R	-0.27	0.45	R												

There is a randomised trend in spring rainfall from 1990 and a rainier period of 1990-2000 for Gazipaşa, statistically non-significant fewer rainy periods of 2001 and 2011. An increasing trend is observed in Korkuteli from

2000 to the present. This trend is at a statistically significant level specifically from 2007. There is a statistically significant increasing trend in autumn rainfall. A non-significant decreasing trend in summer rainfall is observed in Manavgat. The results of the Spearman test are consistent with the results of the Mann-Kendall test.

A decreasing trend in winter and autumn rainfall is determined in Antalya in respect to u(rs) values.

There is a decreasing trend in spring and summer rainfall in Alanya, Finike and Gazipaşa, and this trend occurs in winter and summer rainfall in Elmalı (Fig. 3).

There is a significant increasing trend in autumn rainfalls in Korkuteli and Elmalı. According to the analysis of the student t test for significance of the EKKDR approach and β, there is a decreasing trend in winter rainfall in Antalya, spring, summer rainfall in Alanya and Gazipaşa, spring rainfall in Finike and winter and summer rainfall in Elmalı. A significant increasing trend in autumn rainfall is determined in Finike, Elmalı and Korkuteli.

Table 4. Results of trend tests of stations

A		Mann-Kendall		Spearman		Student t test				
P	Time	u(t)	a1	u(rs)	a1	b	t	n-2	0.05	0.01
Rainfall	Winter	-0.96	0.3	-1.08	0.2	-3.48	-1.32			
	Spring	0.9	0.3	0.79	0.4	1.42	1.32			
	Summer	0.7	0.4	0.69	0.4	0.17	1.04	40	2.021	2.704
	Autumn	-0.7	0.4	-0.89	0.3	0.13	0.07			
	Annual	-0.2	0.7	-0.37	0.7	-2.4	-0.68			
AL		Mann-Kendall		Spearman		Student t Test				
P	Time	u(t)	a1	u(rs)	a1	b	t	n-2	0.05	0.01
Rainfall	Winter	0.40	0.69	0.4	0.6	0.04	0.01			
	Spring	-0.82	0.41	-0.8	0.4	-0.6	-0.5			
	Summer	-1.5	0.11	-1.6	0.08	-0.1	-0.7	40	2.021	2.704
	Autumn	0.5	0.5	0.6	0.5	1.1	0.7			
	Annual	-0.04	0.96	-0.1	0.9	0.09	0.03			
M	Time	u(t)	a1	u(rs)	a1	b	t	n-2	0.05	0.01
P	Winter	0.3	0.7	0.4	0.66	0.5	0.2			
Rainfall	Spring	0.2	0.8	0.2	0.81	0.1	0.2			
	Summer	-0.4	0.6	-0.3	0.68	-0.3	-1.78	40	2.021	2.704
	Autumn	0.7	0.4	0.6	0.9	1.4	1.04			
	Annual	0.7	0.4	0.7	0.4	1.7	0.67			
G	Time	u(t)	a1	u(rs)	a1	b	t	n-2	0.05	0.01
P	Winter	1.2	0.2	1.1	0.8	1.0	0.7			
Rainfall	Spring	-0.3	0.7	-0.3	0.7	-0.5	-0.7			
	Summer	-0.9	0.3	-0.6	0.5	-0.05	-0.8	40	2.021	2.704
	Autumn	0.6	0.5	0.6	0.5	1.5	1.21			
	Annual	0.6	0.4	0.7	0.4	1.7	0.8			
K	Time	u(t)	a1	u(rs)	a1	b	t	n-2	0.05	0.01
P	Winter	0.2	0.83	0.2	0.78	0.43	0.69			
Rainfall	Spring	0.4	0.66	0.5	0.62	0.52	1.15			
	Summer	0.8	0.39	0.9	0.33	0.22	0.94	40	2.021	2.704
	Autumn	2.2	0.02	2.2	0.02	1.24	2.38			
	Annual	1.6	0.1	1.5	0.11	2.34	2.26			
F	Time	u(t)	a1	u(rs)	a1	b	t	n-2	0.05	0.01
P	Winter	0.09	0.9	0.1	0.8	1.06	0.5			
Rainfall	Spring	-0.2	0.7	-0.2	0.7	-0.1	-0.1			
	Summer	-0.05	0.9	-0.1	0.8	0.07	0.4	40	2.021	2.704
	Autumn	1.7	0.07	1.5	0.1	2.9	2.2			
	Annual	0.6	0.5	0.6	0.5	3.6	1.3			
E	Time	u(t)	a1	u(rs)	a1	b	t	n-2	0.05	0.01
P	Winter	-0.3	0.7	-0.2	0.8	-0.3	-0.3			
Rainfall	Spring	0.8	0.4	0.9	0.3	0.62	1.39			
	Summer	-0.1	0.8	-0.3	0.05	-0.2	-0.7	40	2.021	2.704
	Autumn	2.1	0.03	2.2	0.02	1.2	2.2			
	Annual	1.2	0.2	1.2	0.2	1.4	1.2			

5. Discussion

The results in this study are consistent with the study of Ölgen (2010). He pointed out that highest annual and seasonal variations are over southern regions and Mediterranean region with a coefficient over 25% has more frequent and severe droughts because of the low reliability of normal rainfall.

Annual variations are higher along the coast than the inner part of the study area. According to Türkeş (1996), the area averaged annual rainfall series have decreased apparently in Mediterranean rainfall regions. Gönençgil and İçel (2010) studied variations of total yearly rainfall in the Eastern Mediterranean coasts of Turkey (1975-2006). Bayer Altın and Barak (2012) examined seasonal and annual rainfall data of the Seyhan basin using 29 stations for the period 1970-2009. When the results of these studies are compared with the results of our study, it appears that a decreasing trend in annual and seasonal rainfall is more evident in the Eastern Mediterranean region. Bahadır (2011) assessed the future trends and possible consequence of temperature and precipitation in the Mediterranean Region. In this study, according to the trend analysis trend, a decrease in rainfall totals was determined for Antalya for the period 2010-2015. In our study, although Antalya has a slightly decreasing trend in long term annual rainfall totals, the results of our study favour the results of this study for future trends. Türkeş (1996) also showed that a low frequency fluctuation about a slightly decreasing long term mean existed in the coastal belt of the Mediterranean Region. Türkeş (1995a, b) analysed the annual and seasonal rainfall data of 91 stations for the period 1930-1993 and reported a decreasing trend over Turkey and Mediterranean rainfall regions. Türkeş (1999) analysed the rainfall data of Turkey to desertification and showed that the coefficient of variation are greater than 25% over a great part of the Aegean and Mediterranean regions. The results of this study are consistent with the results of our study. In our study, coefficient of variation of annual rainfall vulnerability is above 25% for all stations expect Elmalı and Manavgat. Türkeş (1999) concluded that the higher the inner-annual variability the higher the probability of drought occurrence.

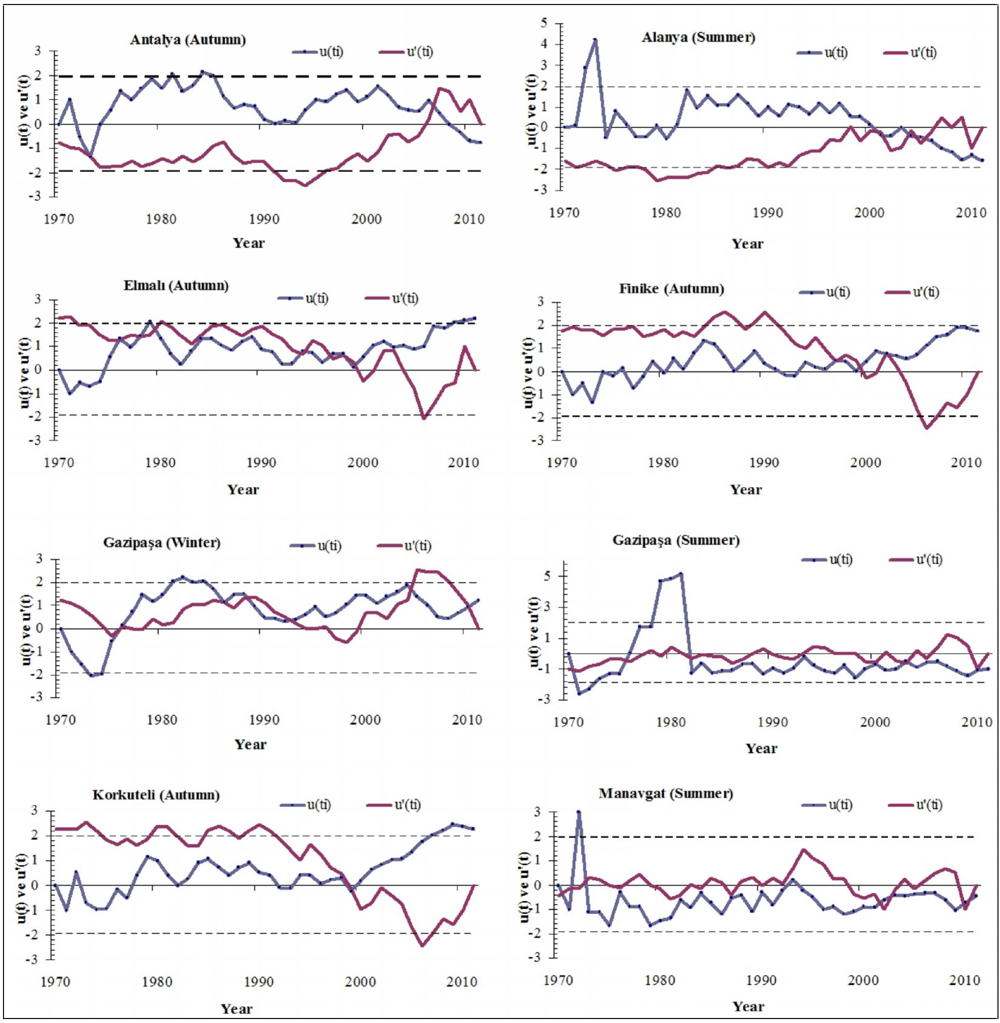

Fig. 3. Trends in seasonal rainfall series of selected stations from values of the statistic u(t) (—) and u´ (t) (—•—) of the Mann-Kendall test, with the critical significance vale of ±1.96 at the 0.05 level (---).

6. Conclusions

The results of the Mann-Kendall test, Spearman test and student t test are consistent with each other. According to the results of these analyses, an annual series of 7 stations showed statically that a non-significant trend in the mean and majority of these trends are downward, and the increasing trend in annual rainfall totals is determined in Korkuteli and Elmalı due to the elevation factor. A trend towards more arid conditions in annual rainfall totals is shown in Antalya, Alanya, Finike, Gazipaşa and Manavgat from the beginning of the 21st century. When distributions of rainfall and trend analysis are examined, it appears that there are important differences inter-annually. A decrease in annual rainfall in the part appears from the coast to the northwest. Heavy rainfall part of the Antalya Part is Alanya and its surrounding due to orographic rise. In general, when a decreasing trend in winter rainfall is apparent, an increasing trend in autumn rainfall is apparent. It is notable that Elmalı and Korkuteli have less rain than other stations in the winter, spring and summer while more rain than other stations in the autumn. According to the ratio of seasonal variability, ratios exceed 25% critical limiting values in all stations for all seasons. Considering the 25% change coefficient limit, all stations should be considered semi-arid areas. In general, coefficients of variations for the stations are lower in the rainy period, although they are higher in the arid period.

References

Arseni-Papadimitriou, A. and Maheras, P. (1991). Some statistical characteristics of air temperature variations at four Mediterranean stations. *Theoretical and Applied Climatology* 43, 105-112.

Atalay, İ.; Mortan K. (2007). Türkiye Bölgesel Coğrafyası (3rd ed). İnkılap Yayınları, İstanbul.

Atalay, İ. and Efe, R. (2007). Ecoregions of The Medıterranean Area and The Lakes Region of Turkey. In R. Efe, G. Carvins, I. Atalay, & M. Öztürk (Eds.), *Environment and Culture in the Mediterranean Region* (pp. 1–14). Cambridge University Pres, Newcastle.

Bahadır, M. (2011). Akdeniz Bölgesinde Sıcaklık ve Yağışın Gelecekteki Eğilimleri ve Olası Sonuçları. *Uluslararası Sosyal Araştırmalar Dergisi*, 19 (**4**), 364-378.

Bayer Altın, T. and Barak, B. (2012). Seyhan Havzasında 1970-2009 Yılları Arasında Yağış ve Hava Sıcaklığı Değerlerindeki Değişimler ve Eğilimler. *Türk Coğrafya Dergisi*, 58, 21-34.

Bernard, H.R. (2000). *Social Research Methods: Qualitative and Quantitative Approaches* (1st ed.). Thousand Oaks, CA, SAGE.

Folland, C.K., Rayner, N.A., Brown, S.J., Smith, T.M., Shen, S.S., Parker, D.E., Macadam, I., Jones, P.D., Jones, R.N., Nicholls N.,. Sexton, D.M.H. (2001). Global temperature change and it uncertainties since 1861. *Geophys. Res. Lett.,* 28 (**13**), 2621-2624.

Gönençgil, B. and İçel G. (2010). Türkiye'nin Doğu Akdeniz Kıyılarında Yıllık Toplam Yağışlarda Görülen Değişimler (1975-2006). *Türk Coğrafya Dergisi*, 55, 1-12.

IPCC. (2007). Climate Change (2007). The Physical Science Basis. In S.Solomon, D.Qin, M.Manning, Z. Chen, M.Marquis, K.B. Averyt, M.Tignor and H.L. Miller (Eds.), *Climate Change,* Cambridge University Pres, Newcastle.

Kadıoğlu, M. (2000). Regional variability of seasonal precipitation over Turkey. *International Journal of Climatology*, 20, 1743–1760.

Kafalı Yılmaz, F. (2008). Antalya'nın Günlük Yağış Özellikleri ve Şiddetli Yağışların Doğal Afetler Üzerine Etkisi. *Uşak Üniversitesi, Sosyal Bilimler Dergisi*, 1 (10), 19-65.

Koçman, A. (1993). *Türkiye İklimi* (3rd ed.). Ege Üni. Edebiyat Fakültesi Yayınları.72, İzmir.

Kutiel H., Maheras P., Türkes M. and Paz S. (2002). North Sea–Caspian Pattern (NCP) – an upper level atmospheric teleconnection affecting the Eastern Mediterranean – Implications on the regional climate. *Theoretical and Applied Climatology*, 72, 173-192.

Kutiel H. and Maheras, P. (1998). Variations in the temperature regime across the Mediterranean during the last century and their relationship with circulation indices. *Theoretical and Applied Climatology*, 61, 39-53.

Metaxas, DA.; Bartzokas, A. and Vitsas, A. (1991). Temperature fluctuations in the Mediterranean area during the last 120 years. *International Journal of Climatology*, 11, 897-908.

Ölgen, K. (2010). Türkiye'de Yıllık ve Mevsimsel Yağış Değişkenliğinin Alansal Dağılımı. *Ege Coğrafya Dergisi*, 19 (**1**), 85-95.

Piervitali, E., M. Colacino and M. Conte (1998) Rainfall over the Central-Western Mediterranean basin in the period 1951-1995. Part I: Precipitation trends. *Geophysics and Space Physics*, 21C(**3**), 331-344.

Price, C.; Michaelides, S.; Pashiardis, S. and Alpert, P. (1999). Long term changes in diurnal temperature range in Cyprus. *Atmospheric Research*, 51, 85-98.

Romero, R.; Guijarro, J.A.; Ramis, C. and Alonso, S. (1998). A 30-year (1964-1993) daily rainfall data base for the Spanish Mediterranean regions: First exploratory study. *International Journal of Climatology*, 18, 541-560.

Schönwiese, C.D. and Rapp, J. (1997). *Climate Trend Atlas of Europe Based on Observations 1891-1990* (1st ed.). Kluwer Academic Publishers, Dordrecht.

Sneyers, R. (1990). *On the statistical analysis of series of observations*. WMO Publication No. 415, (Technical Note no. 143**)**, WMO, Geneva.

Tatlı, H. (2007). Synchronization between the North Sea–Caspian pattern (NCP) and surface air temperatures in NCEP. *International Journal of Climatology*, 27, 1171-1187.

TÜBA. (2010). *Türkiye Açısından Dünyada İklim Değişikliği* (1st ed.). Türkiye Bilimler Akademisi Raporlar, Ankara.
Türkeş, M. (1990). Türkiye'de Kurak Bölgeler ve Önemli Kurak Yıllar, Doktora Tezi, İstanbul Üniversitesi Deniz Bilimleri ve Coğrafya Enstitüsü, 195 pp.
Türkeş, M. (1995a). *Türkiye'de Yıllık ve Mevsimlik Yağış Verilerindeki Eğilimler ve Dalgalanmalar*, Türkiye Ulusal Jeodezi ve Jeofizik Birligi (TUJJB) Bilimsel Kongresi
Türkeş, M. (1995b). Trends and fluctuations in annual and seasonal rainfall data in Turkey, in Draft Papers of the Regional Workshop on *Climate Variability and Climate Change Vulnerability and Adaptation*, Temperature and Precipitation Variability, Praha.
Türkeş, M. (1996). Spatial and temporal patterns analyses of annual rainfall variations in Turkey. *Journal of Climatology*, 16: 1057-1076.
Türkeş, M. (1999). Vulnerability of Turkey to desertification with respect to precipitation and aridity conditions. *Turkish Journal of Engineering and Environmental Sciences,* 23, 363-380.
Türkeş, M. (2008). Coğ 525 *Klimatolojik ve Hidrolojik Verilerin Türdeşlik Analizi* , ders notları, Çanakkale Onsekiz Mart Üniversitesi, Fen-Edebiyat Fakültesi,Coğrafya Bölümü, Çanakkale.
Türkeş, M. (2010). *Klimatoloji ve Meteoroloji* (1st ed). Kriter Yayınları, İstanbul.
Türkeş, M.; Sümer, U.M.; Demir, İ. (2002). *Türkiye'nin günlük ortalama, maksimum ve minimum hava sıcakları ile sıcaklık genişliğindeki eğilimler ve değişiklikler.* Prof. Dr. Sırrı Erinç Anısına Klimatoloji Çalıştayı 2002 Bildiriler Kitabı, s. 89-106.
Türkeş, M. and Erlat, E. (2003). Precipitation changes and variability in Turkey linked to the North Atlantic Oscillation during the period 1930–2000. *International Journal of Climatolology*, 23, 1771–1796.
Türkeş, M. and Erlat, E. (2005). Climatological responses of winter precipitation in Turkey to variability of the North Atlantic Oscillation during the period 1930–2001. *Theoritical Applied Climatolology*, 81, 45–69.
Türkeş, M.; Sümer, U.M. and Yıldırım, Y. E. (2005). *GAP Bölgesi'nde Gözlenen Uzun Süreli İklimsel Değişimlerin ve Eğilimlerin Zaman Dizisi Çözümlemeleri*. Ulusal Coğrafya Kongresi Bildiri Kitabı, s. 373-384.
Türkeş, M. and Erlat, E. (2006). Influences of the North Atlantic Oscillation on Precipitation Variability and Changes in Turkey. Nuovo Cimento Della Societa Italiana Di Fisica C-*Geophysics and Space Physics*, 29, 117-135.
WMO. (1966). *Climatic Change*. World Meteorological Organization (WMO), Technical Note No. 79, Geneva.
Yücel, T. (1987). *Türkiye Coğrafyası*. Türk Kültürü Arş. Ens. Yay., Ankara.