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DETERMINATION OF CHANGE POINTS AND TREND ANALYSIS OF ANNUAL TEMPERATURE DATA IN KONYA CLOSED BASIN (TURKEY)

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ABSTRACT

Climate change is expressed as major changes in the average climate which exist for many years. Although climate change occurs on a global scale, the impact of climate change varies from region to region. Therefore, the analysis of the variations in meteorological variables is a very vital issue in monitoring of climate change. In this study, assignment of the change points and trends of annual temperature (Tmean, Tmin and Tmax) data of the Konya Closed Basin in Turkey is examined. For this aim, air temperature data of 11 meteorology station were used. The change point of temperature data was examined using the Pettitt test, Standard Normal Homogeneity test and Buishand Range test. The Mann-Kendall, Spearman Rho and Innovative Şen Trend methods were used to determine trends of air temperature. Most of the change points in annual temperature data were determined as 1993-1994. The trend results show that annual temperature at most stations have increased, more than 80% of which are statistically significant.

Keywords: Climate change, Konya Closed Basin, Temperature, Trend analysis

KONYA KAPALI HAVZASI (TÜRKİYE) YILLIK SICAKLIK VERİLERİNİN TREND ANALİZİ VE DEĞİŞİM NOKTALARININ BELİRLENMESİ

ÖZET

İklim değişikliği, uzun yıllar için var olan iklim ortalamalarındaki büyük değişimler olarak ifade edilmektedir. İklim değişikliği küresel ölçekte gerçekleşse de, etkileri bölgeden bölgeye değişmektedir. Bu nedenle, meteorolojik değişkenlerdeki değişikliklerin analizi iklim değişikliğinin izlenmesinde çok önemli bir konudur. Bu çalışmada, Türkiye'deki Konya Kapalı Havzası'nın yıllık ortalama sıcaklık, maksimum sıcaklık ve minimum sıcaklık verilerinin trendlerinin ve değişim noktalarının belirlenmesi incelenmiştir. Bu amaçla 11 meteoroloji istasyonunun hava sıcaklığı verileri kullanılmıştır. Sıcaklık zaman serisi verilerinin değişim noktası Pettitt testi, Standart Normal Homojenlik testi ve Buishand Range testi kullanılarak incelenmiştir. Hava sıcaklığı trendlerini belirlemek için Mann-Kendall, Spearman Rho ve Yenilikçi Şen Trend yöntemleri kullanıldı. Yıllık sıcaklık verilerindeki değişim noktalarının çoğu 1993-1994 olarak belirlenmiştir. Trend sonuçları çoğu istasyonda yıllık sıcaklığın arttığını, bunun% 80'inden fazlasının istatistiksel olarak anlamlı olduğunu göstermektedir.

Anahtar kelimeler: İklim değişikliği, Konya Kapalı Havzası, Sıcaklık, Trend analizi

1. INTRODUCTION

In many countries around the world, global climate change causes significant effects on different meteorological and hydrological variables and changes in their pattern can affect water resources, ecosystem, human health, plants and animals. For this reason, it is very important to analyze and observe changes in hydro-meteorological parameters. Climate change is not only the result of differences in average values, but also in the case of changes in extreme values. Climate change and global warming can be detected as a result of studies on meteorological parameters.

Changes in air temperature and precipitation are more important than other parameters on climate change. Accurate information on these parameters are an important starting point for flood and drought control, optimum use of water resources, effective water management and assessment of climate change [1]. In recent years, the trends in climate variables have been

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studied extensively using different methods at the global and regional scales by many researchers [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13].

Eris and Agiralioglu [14] studied homogeneity and trend analysis of long-term annual precipitation and streamflow series of the Eastern Black Sea Region in Turkey. Ros et al. [15] studied the trend and homogeneity analysis of rainfall data in 50 stations on the Kelantan River Basin in the northeastern Malaysian Peninsula. Taxak et al. [16] studied trends of rainfall data on annual and seasonal scales during the period 1901–2012 of the Wainganga basin in Central India. Kumar and Jain [17] investigated trend of the annual rainfall and rainy days in 22 river basins for the period 1951-2004 in India. Safari [18] examined the variations and trends of the annual mean temperature time series for the period 1958-2010 in Rwanda using Regression Analysis and Mann-Kendall Rank Statistic tests. Shi et al. [19] examined linear trend of daily total precipitation, daily maximum and minimum air temperature during the 1961-2015 at 2474 meteorological stations in China using Mann-Kendall test. Abatan et al. [20] studied trends of extreme temperature absolute indices using the newly homogenized daily maximum and minimum temperature series from 21 stations in Nigeria for the period 1971-2012. Siddik and Rahman [21] analyzed trends of mean maximum, mean minimum temperature data on annual, seasonal and monthly timescales for the period 1961-2008 of the 15 meteorological stations in Bangladesh.

In this study, the change point and trend analysis were performed using annual maximum temperature (T_{max}), minimum temperature (T_{min}) and mean temperature (T_{mean}) of 11 meteorology observation station in Konya Closed Basin, Turkey**.**

2. STUDY AREA AND DATA

Konya Closed Basin is located in the Central Anatolia Region of Turkey, between 36°51'- 39°29' north latitudes and 31°36' -34°52' east longitudes. Its area is almost 50 000 km^2, covers about 7% of Turkey. It is the biggest closed basin in Turkey (Figure 1).

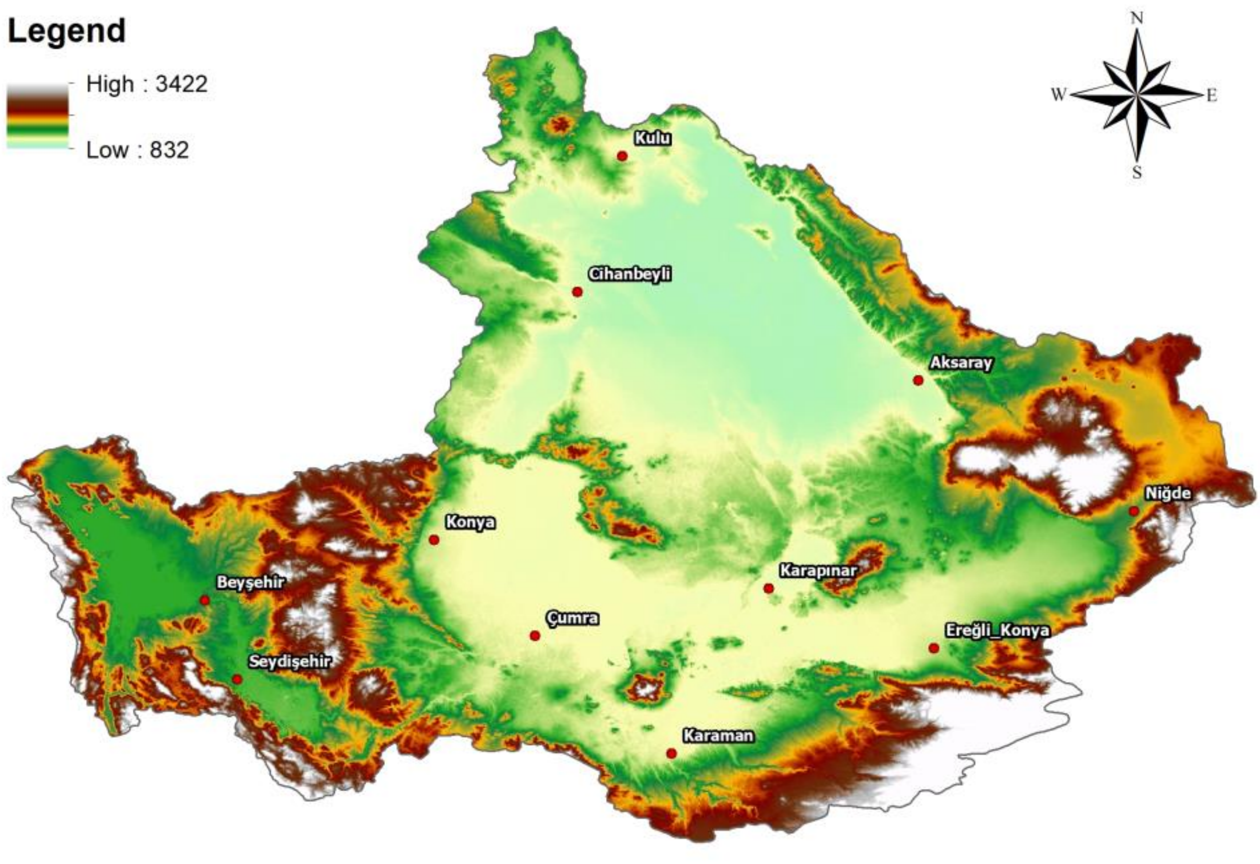


Figure 1. The location of meteorology observation stations in the Konya Closed Basin

The basin is sided by Kızılırmak and Sakarya in the north, Seyhan and Kızılırmak in the east, Eastern Mediterranean in the south, Akarçay and Antalya basins in the west. The central part of the Konya Closed Basin is characterized by the presence of plains at an elevation of 900 – 1050 m. Due to the large area it covers; various climates can be seen in Konya Closed Basin. The central and northern areas have semi-arid and sub-humid continental climate; southern areas have Mediterranean climate; Konya and particularly Karapınar district have continental and exact semi-arid climate [22].

In this study, annual T_{max}, T_{min} and T_{mean} data were used. Annual air temperature data were obtained from 11 meteorology stations on Konya Closed Basin operated from the Turkish State Meteorological Service for the period ranging from 1960 to 2012. The locations of 11 stations on Konya Closed Basin are given in Figure 1. The observation periods and the characteristics of the meteorology stations used in the study are shown in Table 1.

Table 1. Observation period and characteristics of 11 meteorology stations

Station Name	Station Number	Data years	Latitude	Longitude	Elevation (m)
Beyşehir	17896	1960-2012	37.41	31.43	1129
Karaman	17246	1960-2012	37.11	33.13	1025
Konya	17244	1960 2012	37.52	32.29	1031
Niğde	17250	1960-2012	37.58	34.41	1211
Cihanbeyli	17191	1964-2012	38.39	32.56	969
Seydişehir	17898	1964-2012	37.25	31.50	1131
Aksaray	17192	1964-2012	38.23	34.05	965
Karapınar	17902	1963-2012	37.43	33.33	1004
Konya-Eregli	17248	1965-2012	37.30	34.03	1044
Çumra	17900	1972-2012	37.35	32.47	1013
Kulu	17754	1969-2012	39.06	33.00	1010

3. METHODOLOGY

3.1. Tests of Change Point Detection

In this study, the change points of annual air temperature (max, min and mean) were performed using the Pettitt Test (PT), Standard Normal Homogeneity Test (SNHT) and Buishand Range Test (BRT). These three tests can determine the year in which the data set used was broken. While the SNHT test reveals breaks at the beginning and end of the time series, the other two tests are more sensitive to detecting breaks in the middle of the time series [23, 24, 25]. The SNHT and BR tests assume that the data have normal distribution. The PT does not require this assumption because it is a nonparametric rank test, and is less affected than the outliers [26].

Computational procedures of the PT, SNHT and BRT are not described here because they can be found in the literature [15, 27, 28, 29]. The critical values for a significance level of 95% of SNHT, BRT and PT for different time series lengths are shown in Table 2. If the test statistics found in these methods do not exceed the critical values given, the Ho hypothesis is accepted, and the time series is homogenous.

3.2 Trend Methods

In this study, three different trend methods were used to detect whether there is a monotonic trend in annual T_{max}, T_{min} and T_{mean} data of 11 stations on Konya Closed Basin.

Mann-Kendall (MK): MK test that is widely used for the trend analysis of hydrological, meteorological and environmental time series is a rank-based distribution-free non-parametric statistical test [30, 31].

Spearman's Rho (SR):SR test, a quick, simple and a distribution-free statistic test, is another rank-based nonparametric trend method and provides a measure of the linear association between two variables [32, 33].

Innovative Şen Trend (IŞT) Test: The Innovative Trend test is proposed by Şen[34]. It is successfully used in environmental, hydrological and meteorological time series. This method, which does not require any assumption, can be applied to all time series. One of the most important features of this method is that trends in the time series can be shown in non-monotonic or monotonic form [35].

Computational procedures of the MK, SR and IŞT are not described here because they can be found in the literature [7, 15, 16, 30, 31, 32, 33, 34, 36].

The results of MK and SR tests for the annual Tmean, Tmin and Tmax data of 11 stations were evaluated according to 95% confidence level. Critical value for 95% confidence level is ± 1.96

Table 2.The critical values (0.05%) of SNHT, BRT and PT for different time series lengths

Station Name	Number of data	SNHT (T_o)	PT (X_k)	BRT ($R/\sqrt{n}$)
Beysehir **Karaman** **Konya** **Nigde**	53	8.503	258.70	1.556
Cihanbeyli **Seydisehir** **Aksaray**	49	8.415	228.20	1.548
Karapinar	50	8.450	235.00	1.550
Konya-Eregli	48	8.380	221.40	1.546
Cumra	41	8.135	173.80	1.532
Kulu	44	8.240	194.20	1.538

4. RESULTS

4.1.Results of Homogeneity and Change Point

In this study, the homogeneity/inhomogeneities of the annual T_{max}, T_{min} and T_{mean} time series at the 11 stations in the Konya Closed Basin were tested by using BRT, SNHT and PT methods. The results of each method were interpreted for a significance level of 95% and the change points were obtained. Table 3 shows the results of test statistics calculated by the three methods. The results given in Table 3 for the three methods are compared with the critical values given in Table 2 for each method, and homogeneous and non-homogeneous stations are determined for the annual temperature parameters. If at least two of the SNHT, PT and BRT methods exceed the critical value of the relevant method, it is decided that the data are not homogenous, otherwise data are homogeneous. As a result of the evaluations, the minimum and mean temperature data at Beysehir station, and the minimum temperature data at Seydisehir and Cumra stations are homogeneous. All other data are not homogeneous (Table 3).

Figure 2 shows the change point years according the SNHT, PT and BRT methods applied to the annual T_{max}, T_{min} and T_{mean} series of 11 stations in Konya Closed Basin.

The analyses of the abrupt changes in annual mean temperature series show that most of the change points in Konya Closed Basin are detected during the 1994. Only the change points of Konya and Beysehir stations are different from 1994. It is also seen in the Figure 2a that both the BRT and PT detected change point in the 1998 year for Konya station. However, according to SNHT method, the change point was obtained as 2007 year. Three homogeneity tests at Beyşehir station for annual mean temperature also show change points at different years.

Table 3. Results of homogeneity tests

Station Name	Parameter	SNHT		PT		BRT		RESULT
		$T_o$value	Result	K value	Result	Q value	Result	
Beysehir	Mean T	**4.13**	**Ho**	**197**	**Ho**	1.71	H1	**Ho**
	Min T	**6.46**	**Ho**	305	H1	**1.42**	**Ho**	**Ho**
	Max T	10.09	H1	364	H1	2.53	H1	H1
Karaman	Mean T	9.79	H1	327	H1	1.81	H1	H1
	Min T	10.76	H1	292	H1	1.70	H1	H1
	Max T	10.26	H1	314	H1	2.30	H1	H1
Konya	Mean T	17.91	H1	333	H1	1.69	H1	H1
	Min T	29.92	H1	282	H1	1.75	H1	H1
	Max T	15.38	H1	417	H1	2.11	H1	H1
Nigde	Mean T	16.54	H1	443	H1	2.18	H1	H1
	Min T	13.56	H1	387	H1	1.78	H1	H1
	Max T	16.74	H1	482	H1	2.65	H1	H1
Cihanbeyli	Mean T	21.46	H1	437	H1	2.28	H1	H1
	Min T	14.47	H1	361	H1	1.83	H1	H1
	Max T	20.70	H1	520	H1	2.68	H1	H1
Seydisehir	Mean T	13.83	H1	356	H1	1.83	H1	H1
	Min T	**6.72**	**Ho**	**180**	**Ho**	**0.97**	**Ho**	**Ho**
	Max T	19.37	H1	475	H1	2.54	H1	H1
Aksaray	Mean T	19.47	H1	434	H1	2.26	H1	H1
	Min T	13.74	H1	362	H1	1.87	H1	H1
	Max T	12.23	H1	370	H1	2.02	H1	H1
Karapinar	Mean T	9.55	H1	313	H1	1.67	H1	H1
	Min T	9.84	H1	341	H1	1.54	H1	H1
	Max T	16.14	H1	405	H1	2.11	H1	H1
Eregli-Konya	Mean T	23.97	H1	490	H1	2.42	H1	H1
	Min T	18.12	H1	425	H1	2.10	H1	H1
	Max T	22.04	H1	482	H1	2.43	H1	H1
Çumra	Mean T	14.28	H1	309	H1	1.91	H1	H1
	Min T	**4.86**	**Ho**	**171**	**Ho**	**1.11**	**Ho**	**Ho**
	Max T	19.29	H1	347	H1	2.30	H1	H1
Kulu	Mean T	15.13	H1	329	H1	2.16	H1	H1
	Min T	11.64	H1	291	H1	2.03	H1	H1
	Max T	12.77	H1	306	H1	2.02	H1	H1

According to the results given in Fig. 2b-2c, while there are generally similar results in change point the annual T_{min} and T_{max} data for PT and BRT, there are some minor differences in SNHT method. Figure 2b shows that the change points were detected as 1994 for seven stations. In the other four stations, the change points vary between 1978 and 2007. 1993 is the dominant change point for annual maximum temperatures according to Fig. 2c. The results shown in Figure 2c indicated that change points were most often detected in 1993 (nine stations). The remaining change points were identified in 1994 and 1996. As a result, most of the change points denoted by three tests in T_{max}, T_{min} and T_{mean} data were determined at the middle of the 1990s, with these most frequently observed in the years 1993–1994.

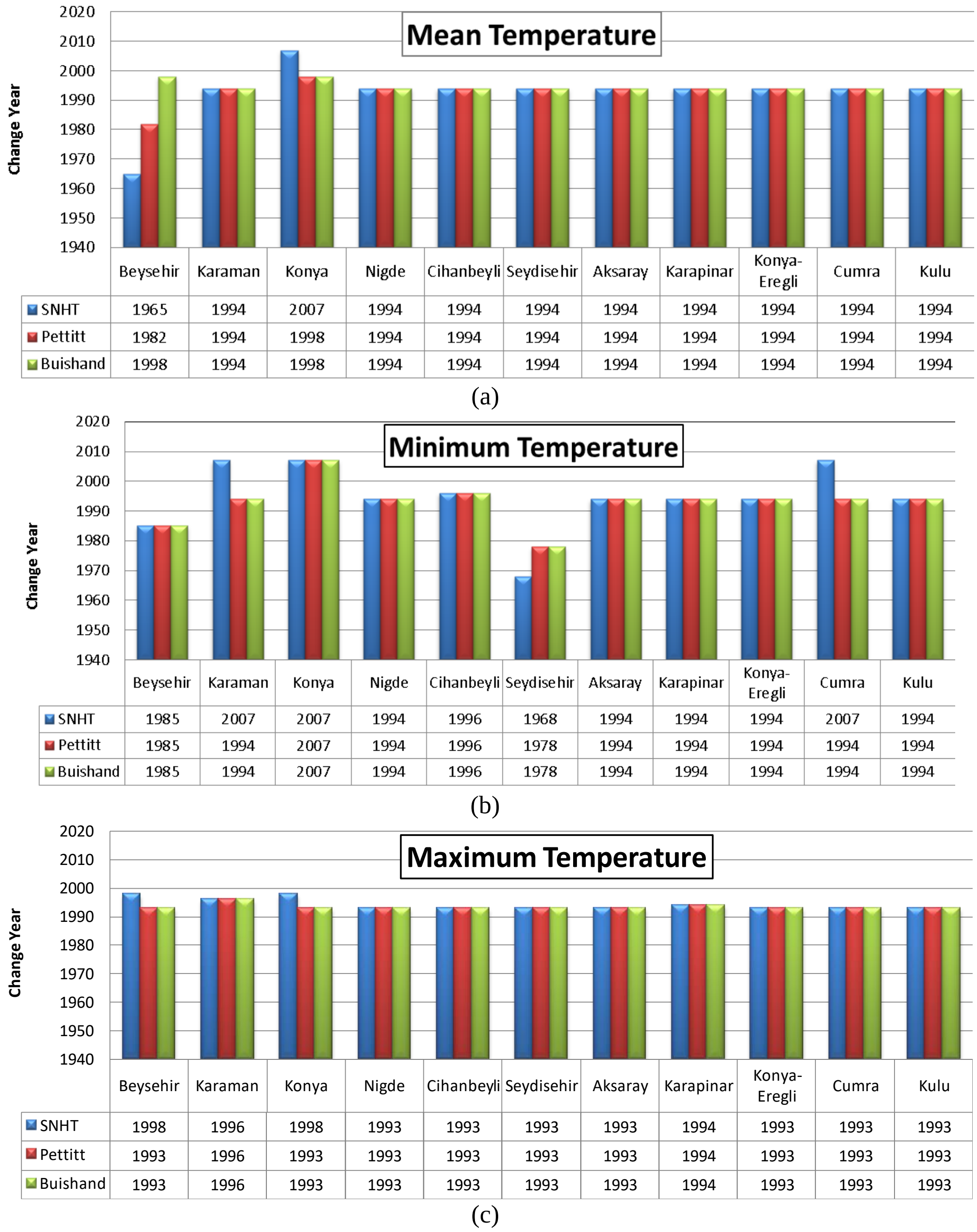


Figure2. Change point years according the SNHT, PT and BRT methods **a)**T_{mean}, **b)** T_{min}, **c)**T_{max}

4.2.Results of Trend Analysis

Figure 3 illustrates the MK and SR test results of the 11 stations for annual T_{mean}, T_{min} and T_{max} data according to the confidence level of 95%. The critical value for a 95% confidence level is ±1.96. If the obtained MK and SR values are outside the ± 1.96, there are significant trends at 95% confidence level, otherwise there is no significant trend. As shown in Figure 3, the annual temperature trends show generally an increasing trend.As seen in Figure3, the results revealed that all stations except Beysehir, Karaman, Karapinar and Konya denoted statistically significant increasing trends in annual T_{mean} data according to MK and SR. Konya, Karapınar and Karaman stations also have an increasing trend for T_{mean}. However, it is not statistically significant. While the MK and SR methods for Beyşehir Station show a negative trend for T_{mean} data, this decreasing trend is not significant according to the 95% significance level.

According to the results of MK and SR methods, for annual T_{min} (Figure 3), significant increasing trends were determined in Aksaray, Nigde, Kulu, Karapinar, Konya-Eregli and Cihanbeyli Stations. However, Seydisehir, Konya, Karaman and Cumra stations have not significant increasing trend. Only Beysehir Station illustrated decreasing trend which is not significantly with respect to 95% confidence level at annual T_{min} data.

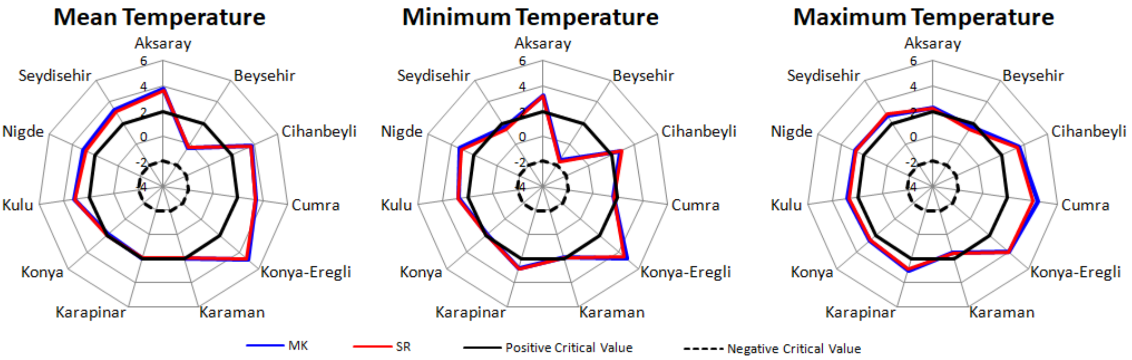


Figure 3. The results of MK and SR trend tests

Generally, it seems that no decreasing trends were detected for annual T_{max} data. Annual T_{max} data show statistically significant increasing trends for all stations except Karaman and Beysehir stations according to MK and SR results (Figure 3).The results of the IŞT test for annual T_{mean}, T_{min} and T_{max} parameters are illustrated in Figure 4-6 for eleven stations on Konya Closed Basin. From Figure 4-6, it is clear that the IŞT method give similar trend results to MK and SR for all stations.

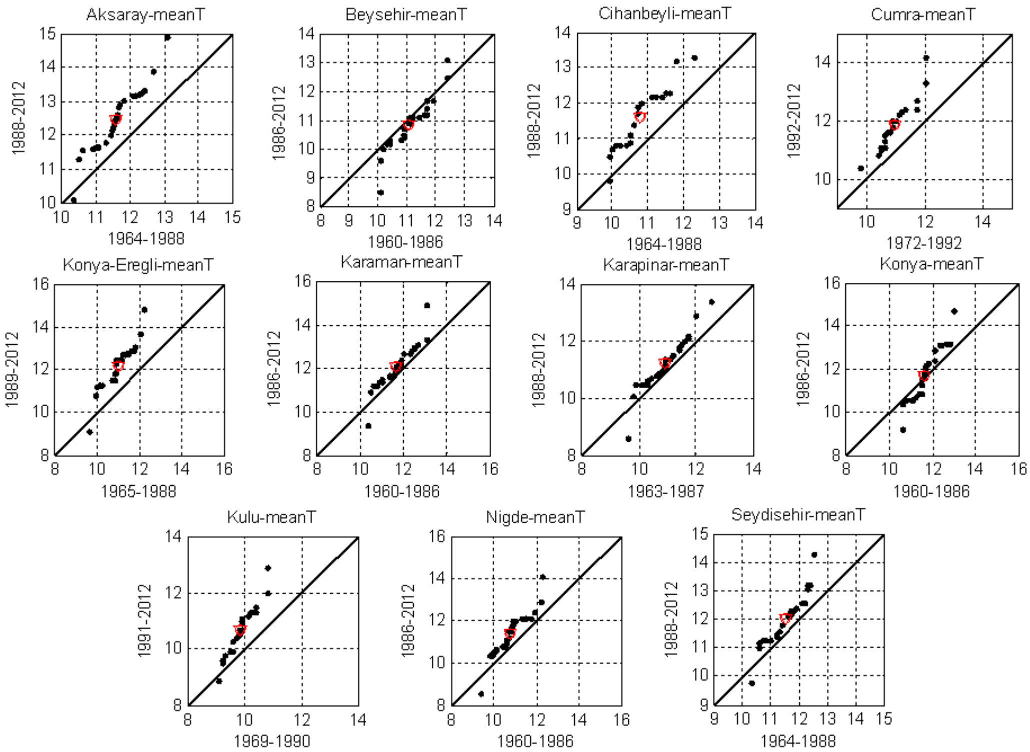


Figure 4. The results of IŞT method for annual T_{mean} data

According to the IŞT graphs (Figure 4) drawn for annual T_{mean} data, monotonic increasing trends are shown in the Aksaray, Cihanbeyli, Cumra, Konya-Eregli, Karaman, Karapinar, Kulu, Nigde and Seydişehir stations. In Beysehir Station, the high values show increasing trend while the low and medium values generally indicate decreasing trend. In Konya Station, the low and medium values show decreasing trend while the high values generally indicate increasing trend. In other words, Beysehir and Konya Stations are illustrated non-monotonic increasing trend for annual T_{mean}.

In Aksaray, Cihanbeyli, Cumra, Konya-Eregli, Kulu and Nigde stations, the low, medium and high T_{min} values show highly increasing trend similar to the MK and SR trend tests (monotonic increasing trend). It is clear from the Figure 5 that there exists a decreasing trend for the low and medium values (<0°C) of the Beysehir Station while the high values show no trend. In Karaman Station, the low T_{min} data values (<-4°C)show decreasing trend while the medium and high values illustrates an increasing trend. There is a similar trend in the Karapınar station (non-monotonic increasing trend). As seen from the Figure 5, the low values show no trend while there is a decreasing trend in some values including low-medium T_{min} data (between -3°C and -1 °C). The medium-high values (>0°C) show increasing trend (non-monotonic increasing trend). In Seydisehir Station, the low (<-1°C) and high (>1°C) values show increasing trend while no significant trend is seen for the low-medium temperatures. As seen from the Figure 5, the medium-high values indicate slightly decreasing trend.

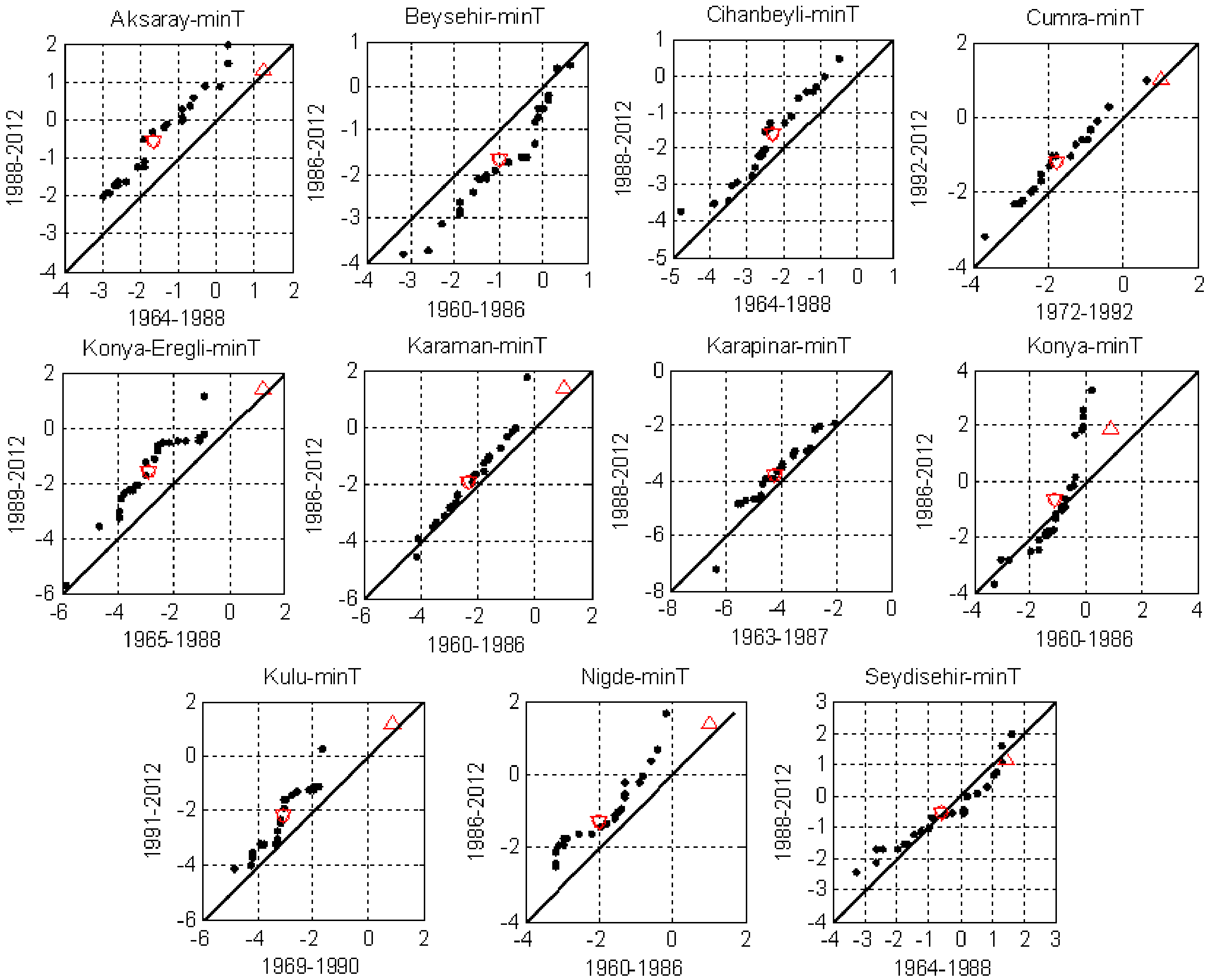


Figure 5. The results of IŞT method for annual T_{min} data

From the Figure 6, it is seen that increasing trend exists in all stations except Beysehir Station for T_{max} values. In Beysehir Station, the low and medium-high T_{max} values show no trend while the low-medium (between 22 ºC and 24 ºC) values illustrate an increasing trend.

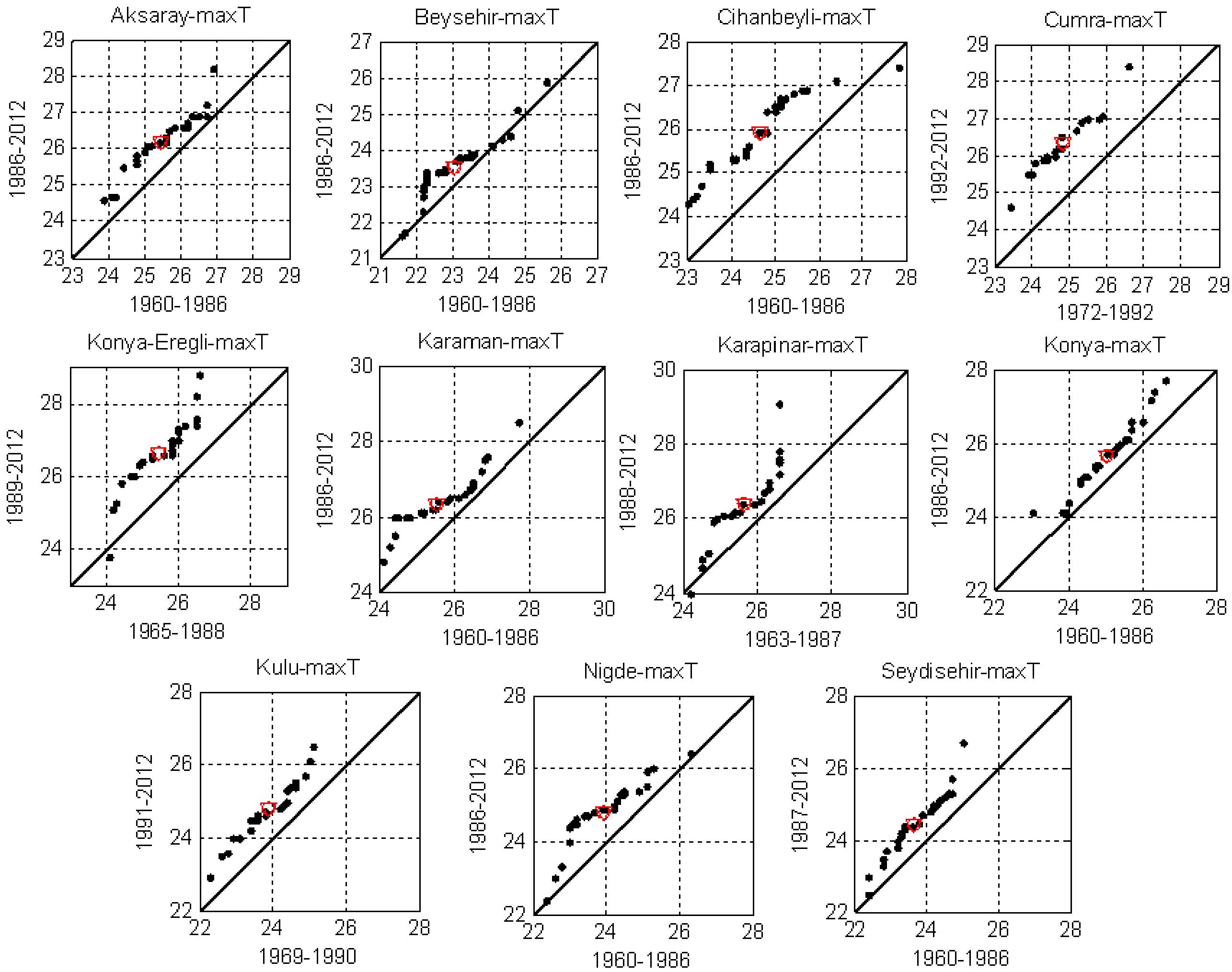
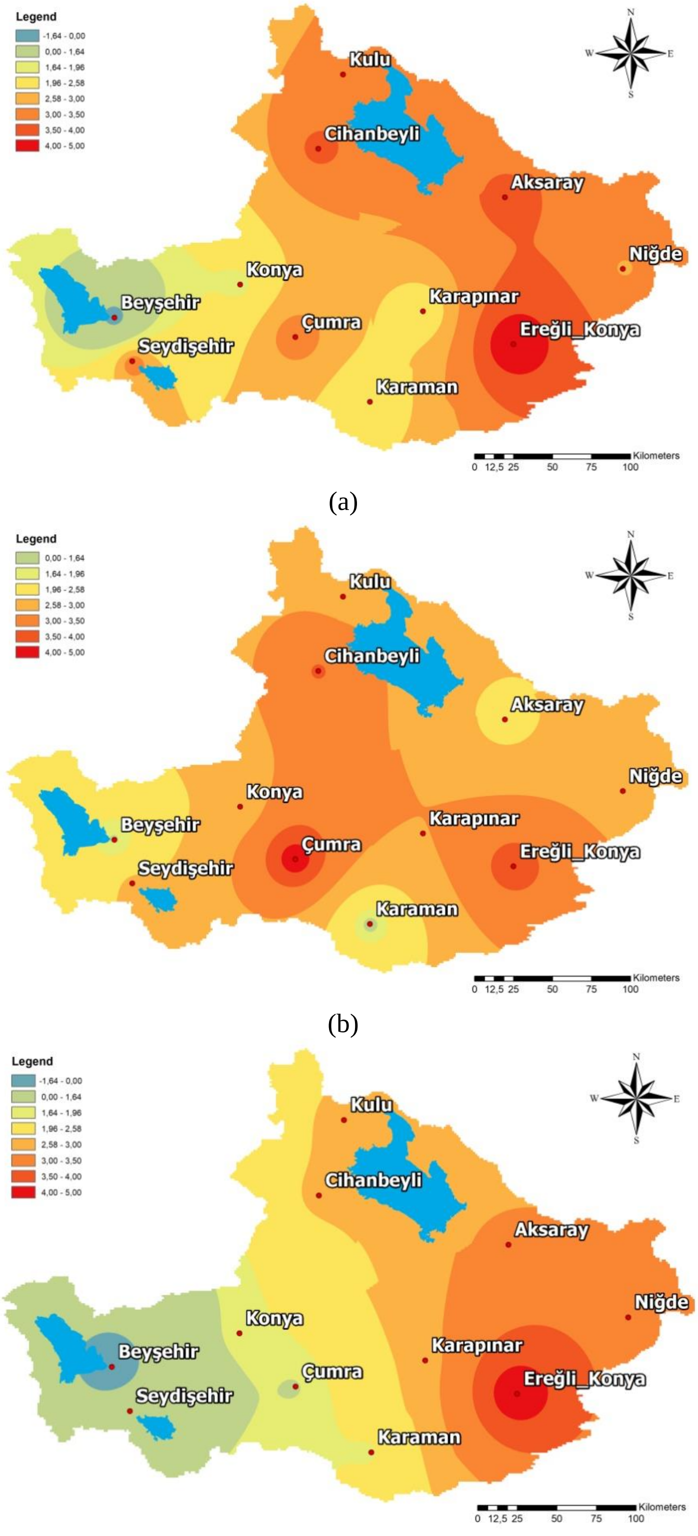


Figure 6 The results of IŞT method for annual T_{max} data

Figure 7 represents the spatial distribution of MK trend analyses calculated in annual T_{mean}, T_{max}, and T_{min} temperatures over the study area. For the annual T_{mean} time series, significant increase trends have been observed except for four stations in the study area (Figure 7a). The non-significant decreasing trend is shown in Beysehir Station while non-significant increasing trends are shown in Konya, Karaman and Karapinar Stations.

For annual T_{min} data, the sensitive region was located in the northeast, east and southeast parts of the basin (Figure 7b). The stations displaying non-significant increasing trends were mainly seen in the western parts. According to Fig. 7b, for the annual T_{min}, there is only a non-significant decreasing trend in the Beyşehir station west of the basin.

For the annual T_{max} time series, significant increase trends have been observed almost all over the study area (Figure 7c). According to Figure 7c, there is a non-significant increasing trend in the west (Beysehir Station) and south (Karaman Station) of the basin.



(a)

(b)

(c)

Figure 7. The spatial distribution of MK trend analyses calculated in annual a) T_{mean}, b) T_{max}, c)T_{min} over the study area

5. CONCLUSIONS

In this study, trend analyses and change points detection of annual T_{max}, T_{min} and T_{mean} data were studied out for eleven meteorological stations located on Konya Closed Basin in Turkey. The change points were determined using the SNHT, PT and BRT methods while the MK, SR and IŞT methods were used for trend analyses. According to these three tests, most of the change points for T_{max}, T_{min} and T_{mean} data were determined as 1993-1994 years.

The annual T_{mean} show a decreasing trend only at the Beysehir station, but not statistically significant. In annual T_{mean} data, 7 of the 11 stations in the Konya Closed Basin show a significant increase trend. The increase trends in 4 stations are not statistically significant. Generally, annual T_{max} data illustrate statistically significant increasing trends for all stations (except Karaman and Beysehir stations).

For the annual T_{min} data, only Beyşehir Station indicates a non-significant decrease trend. Six stations show statistically significant increasing trend. Non-significant increase trends are obtained in four stations. As a result, almost all the stations for annual temperature data in the Konya Closed Basin illustrate statistically significant increase trends.

Konya Closed Basin is a region with both arid and semi-arid climatic characteristics and an important agricultural area. The significant increase trends in temperature data in such regions will make an important contribution to the strategies that will be developed in the planning, project and operation phases of irrigation projects, along with water resources planning and sustainable management studies.

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