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Research Article

Homogeneity and Change Point Detection Analysis of Seasonal and Annual Precipitation and Temperature Series Van, Türkiye

Islam YASA*[1], Mehmet Ishak YUCE [2], Musa ESIT [3]

[1] Ondokuz Mayis University, Faculty of Engineering, Department of Civil Engineering, Samsun, Türkiye
[2] Adiyaman University, Faculty of Engineering, Department of Civil Engineering, Adiyaman, Türkiye
[3] Gaziantep University, Faculty of Engineering, Department of Civil Engineering, Gaziantep, Türkiye
Islam YASA, ORCID No: 0000-0002-4809-9471 Mehmet Ishak YUCE, ORCID No: 0000-0002-6267-9528
Musa ESIT, ORCID No: 0000-0003-4509-7283
*Sorumlu yazar e-posta: islam.yasa@omu.edu.tr

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Abstract: The quality and consistency of historical temperature and precipitation records are extremely important to researchers who study water resources, hydrological processes, and climate change. In this regard, Homogeneity tests are helpful tools for managing the accuracy and consistency of the data. In this study, the homogeneity of long-term annual and seasonal precipitation and temperature records obtained from five meteorological stations located in Van, Turkey, is examined using Standard Normal Homogeneity (SNHT), Pettitt (PT), Buishand Range (BR), and Cumulative Deviation (CD) tests at a significance level of 0.05. Finally, change-points were determined for each station where the homogeneity was disturbed. As a result of the study, there is mostly homogeneity in the precipitation data, and the homogeneity in the temperature data is deteriorated. The results of this study constitute a source of information in terms of the reliability of the meteorological data series. As a result, the reliability of the data should be questioned in the hydrological studies to be carried out in the Van region and the data should be made reliable in the projects to be carried out.

Mevsimsel ve Yıllık Yağış ve Sıcaklık Serilerinin Homojenlik ve Değişim Noktası Tespit Analizi Van, Türkiye

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Anahtar Kelimeler
Değişim noktası,
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Öz: Su kaynakları, hidrolojik süreçler ve iklim değişikliği alanlarını inceleyen araştırmacılar, tarihsel sıcaklık ve yağış serilerinin doğruluğuna ve tutarlılığına büyük önem vermektedir. Bu bağlamda, homojenlik testleri, verilerin doğruluğunu ve tutarlılığını yönetmek için yararlı araçlardır. Bu çalışmada, Türkiye'nin Van ilinde bulunan beş meteoroloji istasyonundan alınan uzun süreli yıllık ve mevsimsel yağış ve sıcaklık kayıtlarının homojenliği, Standart Normal Homojenlik (SNHT), Pettitt (PT), Buishand Range (BR) ve Kümülatif Sapma (CD) testleri kullanılarak 0.05 anlamlılık düzeyinde incelenmiştir. Son olarak homojenliğin bozulduğu her istasyon için kırılma noktaları tespit edilmiştir. Çalışmanın sonucunda yağış verilerinde çoğunlukla homojenliğin olduğu sıcaklık verilerinde ise homojenliğinin bozulduğu söylenebilir. Bu çalışmanın sonuçları, meteorolojik veri serilerinin güvenilirliği açısından bir bilgi kaynağı oluşturmaktadır. Sonuç olarak Van bölgesinde yapılacak olan hidrolojik çalışmalarda verilerin güvenilirliği sorgulanmalı ve yapılacak projelerde verilerin güvenilir hale getirilmesi gerekmektedir.

1. Introduction

Analysis of climate change has become necessary given the possibility that the impact of extreme events such as heavy rainfall or rising temperatures in recent times is attributable to climate change, which causes danger and anxiety to communities, the natural environment, and human life (Yozgatlıgil & Yazıcı 2016; Yüce et al.,2019; Yıldırım & Rahman 2022). Climate analysis requires accurate measurement of climate data. However, issues resulting from a variety of parameters, such as the environment around the station, the accuracy of the measurement tool, the relocation of stations, equipment changes, equipment losses, equipment shifts, and changes in the collection method, have an impact on the climate data (Karl & Williams 1987; Khaliq & Ouarda 2007; Dikbas et al., 2010; Şahin & Cığızoğlu 2010; Ho Ming & Yusof 2012; Yuce et al., 2022; Yuce & Esit 2021). These aspects need to be recognized and considered for scientific and meteorological analyses.

Hydrological time series, one of the climate data, are the outputs of certain natural conditions and may show irregular fluctuations. In addition, these series may show significant trends or jumps (Wong et al., 2006; Yüce et al., 2018; Elzeiny et al., 2019). The reliability and homogeneity of the data should be assessed before beginning a research study, climate analysis, water resources management, or project planning. The homogeneity analysis is a crucial component of this quality control. Once the series' homogeneity has been established, the non-homogeneous series should either be adjusted or excluded from the analysis (Ahmad & Deni 2013; Yozgatlıgil & Yazıcı 2016; Kazemzadeh & Malekian 2018). Consistency issues might arise when non-homogeneous climatological time series is used in the project and research study.

Ho Ming & Yusof (2012) examined the homogeneity of the daily rainfall series of 33 Damansara, Johor, and Kelantan stations in the Malaysian Peninsula using four methods: the SNHT, the BR test, the Pettitt test, and the VNR test. They observed that these 33 stations were homogeneous in their annual average and annual maximum rainfall, and there was no homogeneity in only 12.12% of their annual median. Agha et al. (2017) investigated the homogeneity of the recorded long-term precipitation data of 9 meteorological stations in northern Iraq, namely Mosul, Dohuk, Arbil, Suleimaniyah, Kirkuk, Telaffer, Sinjar, Dokan, and Derbandghan, with the Pettit, SNHT, BR, and VNR tests at a significance level of 0.05. the SHNT test results based on annual data indicate that there was no homogeneity among the four stations. Mosul and Derbandghan stations also showed inhomogeneous Pettit results. Elzeiny et al. (2019) obtained precipitation data from 30 meteorological stations along the Upper Blue Nile River Basin between 1901 and 2013. they determined the precipitation data homogeneity by using SNHT, BR, Pettitt, and VNR tests, frequently used in the literature. According to the SNHT and BR tests results, the annual series of all stations were homogeneous and classified as “useful” at the 95% significance level. However, in the Von Neumann ratio test, the homogeneous data of six stations were not homogeneous. It revealed that 14 stations were not homogeneous according to the Pettitt test, which confirmed that it was more sensitive in detecting inhomogeneity for time series. Şenocak & Emek (2019) examined the homogeneity of Monthly Precipitation data of 46 meteorological stations in the Eastern Anatolia Region with the Run and Pettitt tests. The results showed that the data of seven stations according to the Pettitt test and one station according to the Run test were not homogeneous. The results of the two tests determined the homogeneity of the precipitation data of 38 stations. In the study performed by Yılmaz (2021), homogeneity analysis was applied to the monthly average temperature (°C) and total precipitation (mm) data of 17 stations between 1961 and 2019 in the Black Sea Region. The analysis was conducted in annual, seasonal, and monthly time series.Von Neumann ratio test, Run, Pettit, BR, and SNHT were used among the homogeneity methods. Considering the results of the study, while the annual precipitation data was found non-homogeneous at three stations according to the Buishand, SNHT, and Von Neumann tests, four stations showed as non-homogeneous according to the Pettitt in one station according to the Run test. Apart from these stations, no deterioration in homogeneity was observed at other stations. In the annual temperature data, it was observed that homogeneity was impaired at all stations according to the Pettitt, Buishand, and SNHT and at all stations except one station according to the Von Neumann test. Compared to these tests, the Run test determined that all stations were homogeneous except for four stations.

In this study, we examined the homogeneity of the annual and seasonal precipitation and temperature series of five meteorological stations in the Van Region by applying Standard Normal

Homogeneity (SNHT), Pettitt (PT), Buishand Range (BR), and Cumulative Deviation (CD) homogeneity tests and detecting the years of change when not homogeneous.

2. Material and Methods

2.1. Study area and data

Eastern Anatolia, one of Turkey's seven regions, has the highest elevation, with an average height of approximately 2000 meters. It was formed as a result of compression due to the collision of the Eurasian and Arabian plates about 13 million years ago (Şaroğlu & Yılmaz 1986). The study site is located in the east of Turkey, covering an area of 19069 km^2 which lies between the latitudes of 37° 43′ and 39° 26′ N and the longitudes of 42° 40′ and 44° 30′ E as shown in Figure 1. Lake Van, located in the Van region, is the largest lake in Turkey, with a surface area of 3602 km² and a maximum depth of 451 meters. It is the largest lake in the world as a soda lake, with a salinity of 21.7%, a water volume of 614 km³, and a pH value of 9.7.

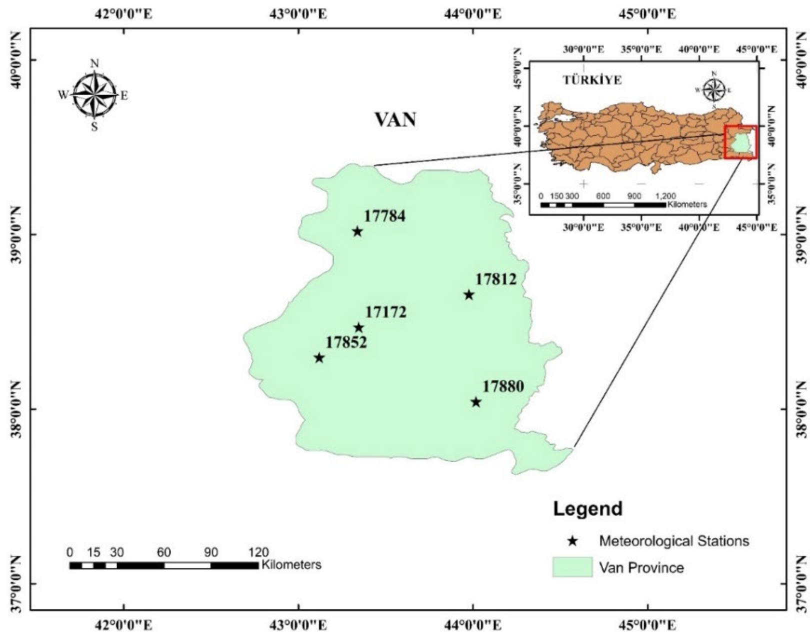

Figure 1. Location of meteorological stations in Van.

In this study, five meteorological stations including Van Bölge (17172), Erciş (17784), Özalp (17812), Gevaş (17852) and Başkale (17880) are performed. Figure 1 illustrates the province of Van's location in Turkey, along with the locations of its five meteorological stations, whose latitude and longitude values are listed in Table 1. Figure 1 also shows the location of the Van region in Turkey. While Van Bölge station is located in the centre of Van province, other stations are located around this station. Monthly average precipitation, and average temperature information of these five meteorological stations were obtained from the Turkish State Meteorological Service. The data ranges and descriptive statistics of precipitation and temperature records of stations are presented in Table 1.

Table 1. Descriptive statistics of precipitation and temperature data series. (St. Dev.: Standard Deviations, Cv: Coefficient of variation, Cs: Skewness, r1: kurtosis)

Station	Parameter	Earliest record year	Latest record year	Latitude	Longitude	Mean	St. Dev.	Cv	Cs	r1
17172	Precipitation (mm/yr)	1960	2021	38.4693	43.346	395.25	72.25	0.18	0.19	0.16
	Temperature (°C)					9.46	1.12	0.12	-0.18	0.57
17784	Precipitation (mm/yr)	1965	2021	39.0198	43.3386	433.74	113.78	0.26	0.46	0.36
	Temperature (°C)					8.16	1.07	0.13	0.08	0.39
17812	Precipitation (mm/yr)	1959	2021	38.6573	43.9767	455.32	174.38	0.38	1.77	0.61
	Temperature (°C)					5.84	1.30	0.22	-0.97	0.30
17852	Precipitation (mm/yr)	1982	2021	38.2963	43.1197	499.45	107.22	0.21	0.16	0.37
	Temperature (°C)					9.11	0.77	0.08	0.28	0.27
17880	Precipitation (mm/yr)	1959	2021	38.0435	44.0173	451.44	142.28	0.32	1.97	0.25
	Temperature (°C)					6.12	1.15	0.19	-0.63	0.36

2.2. Homogeneity tests

Four different homogeneity tests were selected to identify the inhomogeneity in the rainfall and temperature meteorological time series. These are SNHT (Alexandersson, 1986), the Pettitt test (Pettitt, 1979), BR (Buishand, 1982), and Cumulative Deviation tests (CD) (Buishand, 1982). These tests, which are homogeneity tests, can determine if a given set of time series data is homogeneous or not (Wijngaard et al., 2003; Ho Ming &Yusof 2012; Elzeiny et al., 2019; Yıldırım & Rahman2022). SNHT, Pettitt test, and BR test, the main advantage of which is the exact year of the breakout and which are commonly referred to as "location-specific tests" (Wijngaard et al., 2003), assumes that, under the alternative hypothesis, it contains a break in the mean and is classified as inhomogeneous (Elzeiny et al., 2019).

2.2.1. Standard normal homogeneity test (SHNT)

The SNHT, proposed by (Alexandersson, 1986), is more susceptible to time series breaks at the start and end. The null and alternative hypotheses are the same in both the Buishand range and Pettitt tests (Agha et al., 2017; Elzeiny et al., 2019). The statistic T_d is computed as:

$$T_d = D\bar{z}_1^{\,2} + (n-d)\bar{z}_2^{\,2}, \qquad d = 1,2, \dots \dots \dots n \tag{1}$$

$$\bar{z}_1 = \frac{1}{d}\sum_{i=1}^{d}(Y_{\mathrm{i}} - \bar{Y})/s \;\; and \;\; \bar{z}_2 = \frac{1}{n-d}\sum_{i=d+1}^{n}(Y_{\mathrm{i}} - \bar{Y})/s \tag{2}$$

where $\bar{\boldsymbol{z}}_{\boldsymbol{1}}$ and $\bar{\boldsymbol{z}}_{\boldsymbol{2}}$ are the parameters of $\boldsymbol{T_d}$ statistic: k is the years of record; $\bar{\boldsymbol{Y}}$ is the mean of time series; $\boldsymbol{Y}_{\mathrm{i}}$ is the annual series which will be tested, and s is the standard deviation.

When the records are broken at any year D, T(d) reaches its maximum near the year $D = \boldsymbol{d}$. As defined above, $\boldsymbol{T_0}$ is the test statistic:

$$\max_{1 \le d \le 0} T(d) \tag{3}$$

The critical values of $\boldsymbol{T_0}$ statistics are given in Table 2. The null hypothesis is rejected if $\boldsymbol{T_0}$ exceeds a critical value, which is based on the sample size.

Table 2. The 1% critical values (Jaruskova, 1996) and the 5% critical values of T_0 statistic in the standard normal homogeneity test (Alexandersson et al., 1997)

Critical value of T_0 statistic						
	$n = 20$	$n = 30$	$n = 40$	$n = 50$	$n = 70$	$n = 100$
99%	9.56	10.45	11.01	11.38	11.89	12.32
95%	6.95	7.65	8.10	8.45	8.80	9.15

2.2.2. Pettitt test

The Pettitt test is a nonparametric distribution predicated on the Mann-Whitney and Wilcoxon test used to assess categories of homogeneity in time series and can reveal the breakpoint (month or year) at a continuous data set (Pettitt, 1979). The ranks $r_1, \ldots, r_n$, of the ......, Y_n are used to calculate the statistics:

$$X_k = 2\sum_{i=1}^{k} r_i - k(n+1), \qquad k = 1,2,\ldots,n \tag{4}$$

If a break is detected in year K, the absolute value of X_k approaches to the maximum value,

$$X_K = \max_{0\le x\le 1} |X_k| \tag{5}$$

The critical values of X_k the statistic in the Pettitt test suggested by Pettitt (1979) is presented in Table 3.

Table 3. The 1% and 5% critical values of X_k statistic

The 1% and 5% critical values of X_k statistic						
	$n = 20$	$n = 30$	$n = 40$	$n = 50$	$n = 70$	$n = 100$
99%	71	133	208	293	488	841
95%	57	107	167	235	393	677

2.2.3. Buishand range test (BR)

A parametric test that is more susceptible to detecting breakpoints in the middle of a time series is the Buishand Range Test (Hawkins, 1977). Buishand (1982) introduced it to find breakpoints in time series assuming test values are independent and normally distributed (Wijngaard et al., 2003).

The following formula is used to determine the statistics-adjusted partial sums;

$$S_0^* = 0 \; and \; S_k^* = \sum_{i=1}^{k} (Y_\mathrm{i} - \bar{Y}) \qquad k = 1, 2, \ldots, n \tag{6}$$

When the series is homogeneous S_k^* of the given series will change around zero. When there is a break in the year K, the adjusted partial sums come to a maximum or minimum close to year $k = K$. The test statistic is defined as:

$$Range = [\max S_k^* - \min S_k^*]/s \tag{7}$$

where s is the sample standard deviation. Table 4 shows the crucial values for $R/\sqrt{n}$.

2.2.4. Cumulative deviation (CD) test

The adjusted partial sums or cumulative deviations (S*) from the mean can be utilized to test the homogeneity of the data series in the following formula.

$$S_k^* = \sum_{i=1}^{k}(Y_\text{i} - \bar{Y}) \qquad k = 1, 2, \dots, n \tag{8}$$

where Y_i is the climatic parameter's observed value i; $\bar{Y}$ is the sample mean; and the data series' number of records is n. Equation 9 indicates the scaled-adjusted partial sums S_k^* .

$$S_k^{**} = {S_k^*}/{D_x} \ (k = 1, 2, \dots, n) \tag{9}$$

where D_x is the sample standard deviation, which may be determined using the formula below;

$$D_x^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2 \tag{10}$$

$$Q = \max_{0 \le k \le 1} |S_k^{**}| \tag{11}$$

Higher Q statistic values signify non-homogeneity in the time series (Kazemzadeh & Malekian 2018). Based on the 19,999 artificial Gaussian random number sequences, Buishand (1982) provided the crucial Q values for a few specified values of n. Table 4 displays the Q statistic's critical values for the cumulative deviation test.

Table 4. The 1% and 5% critical values of $Q/\sqrt{n}$ statistic in the cumulative deviation test and $R/\sqrt{n}$ statistic in the Buishand range test as a function of n (Buishand, 1982)

n	$Q/\sqrt{n}$ statistic		$R/\sqrt{n}$ statistic	
	95%	99%	95%	99%
10	1.14	1.29	1.28	1.38
20	1.22	1.42	1.43	1.60
30	1.24	1.46	1.50	1.70
40	1.26	1.50	1.53	1.74
50	1.27	1.52	1.55	1.78
100	1.29	1.55	1.62	1.86
∞	1.36	1.63	1.76	2

3. Results

The Pettitt, Standard Normal Homogeneity Test (SNHT), Buishand range test (BR), and Cumulative Deviation tests (CD) were used to determine the homogeneity of the annual and seasonal precipitation and temperature data for each station in the Van region. Homogeneity test results were assessed at a 5% level of significance. When the p-values fell below the 5% level, the data series were found to be inhomogeneous. Table 5 presents the results of the Pettitt test and SNHT homogeneity tests of the annual total precipitation and average temperature series. Furthermore, the results of BR and CD homogeneity tests of these station precipitation and temperature series are given in Figures 2-6. Series are handled with homogeneity states H_a and H_0 in the tables. H_0 indicates that the series are homogeneous, while H_a indicates non-homogeneous.

With a few exceptions, the tests give similar results, as shown by Table 5 and Figures 2-6. The results indicate that the annual total precipitation and average temperature series for the 17172-Van Bölge (Figure 2) and 17852-Gevaş (Figure 5) stations only demonstrate homogeneity in terms of precipitation. In addition to this, it was found that other series' homogeneity was impaired.

Table 5. Annual SHNT and Pettitt tests results (H_0: Homogeneous, H_a: Nonhomogeneous)

Station Number	Meteorological Variables	SNHT			Pettitt Test		
		p-value	Tk	Decision	p-value	U	Decision
17172 Van Bölge	Annual total precipitation (mm/yr)	0.771	2.681436	H_0	0.545463	229	H_0
	Annual mean temperature (°C)	0	30.68493	H_a	8.75E-08	827	H_a
17784 Erciş	Annual total precipitation (mm/yr)	0.00025	17.50556	H_a	0.093792	310	H_a
	Annual mean temperature (°C)	0	21.18619	H_a	0.002303	461	H_a
17812 Özalp	Annual total precipitation (mm/yr)	0.05275	8.69628	H_a	0.057109	388	H_a
	Annual mean temperature (°C)	0.0005	16.61247	H_a	6.8E-05	660	H_a
17852 Gevaş	Annual total precipitation (mm/yr)	0.28635	5.017537	H_0	0.316282	142	H_0
	Annual mean temperature (°C)	0.0016	13.85905	H_a	0.009435	242	H_a
17880 Başkale	Annual total precipitation (mm)	0	21.81767	H_a	0.14802	332	H_0
	Annual mean temperature (°C)	0	21.88136	H_a	1.6E-06	771	H_a

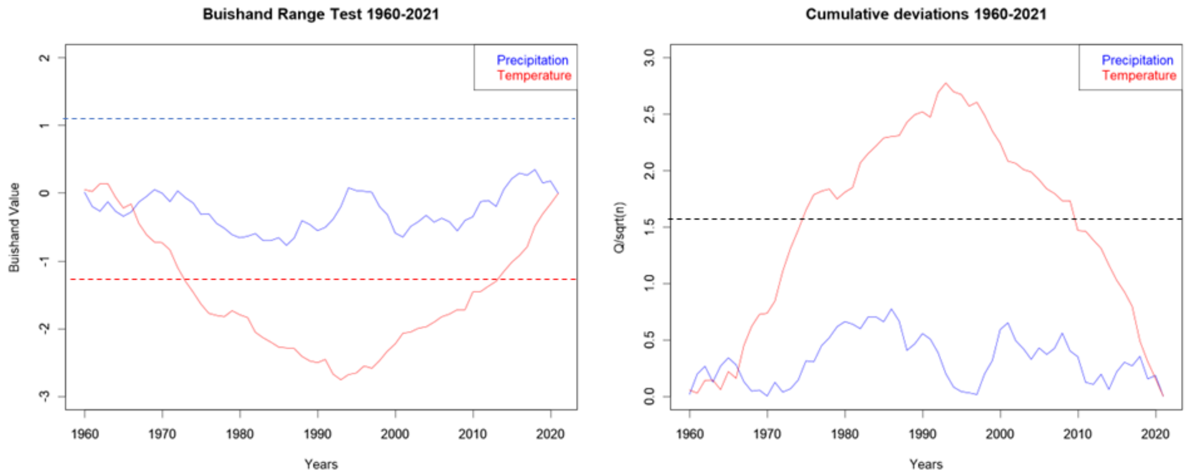

Figure 2. Annual buishand range and cumulative deviations test results of station 17172.

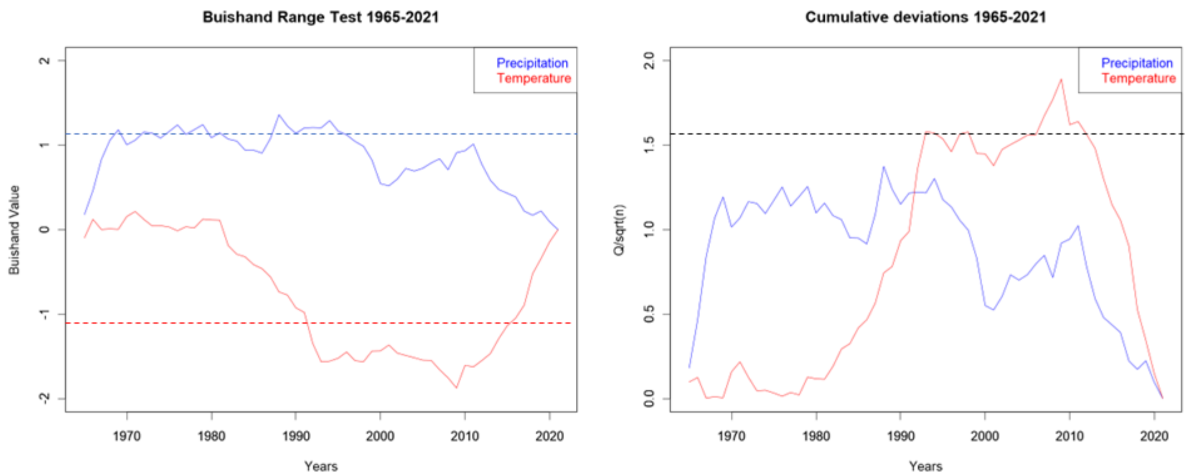

Figure 3. Annual buishand range and cumulative deviations test results of station 17784.

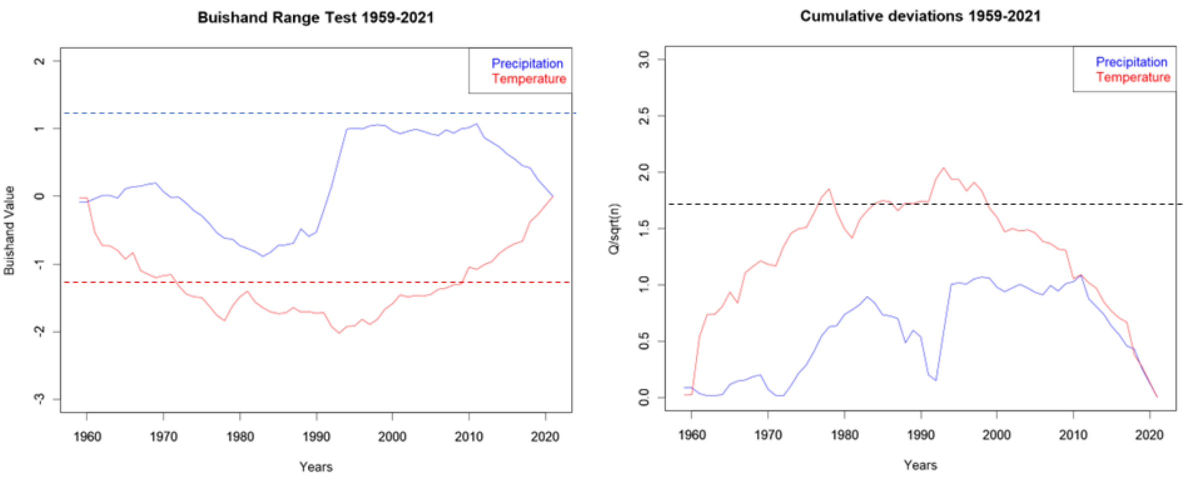

Figure 4. Annual buishand range and cumulative deviations test results of station 17812.

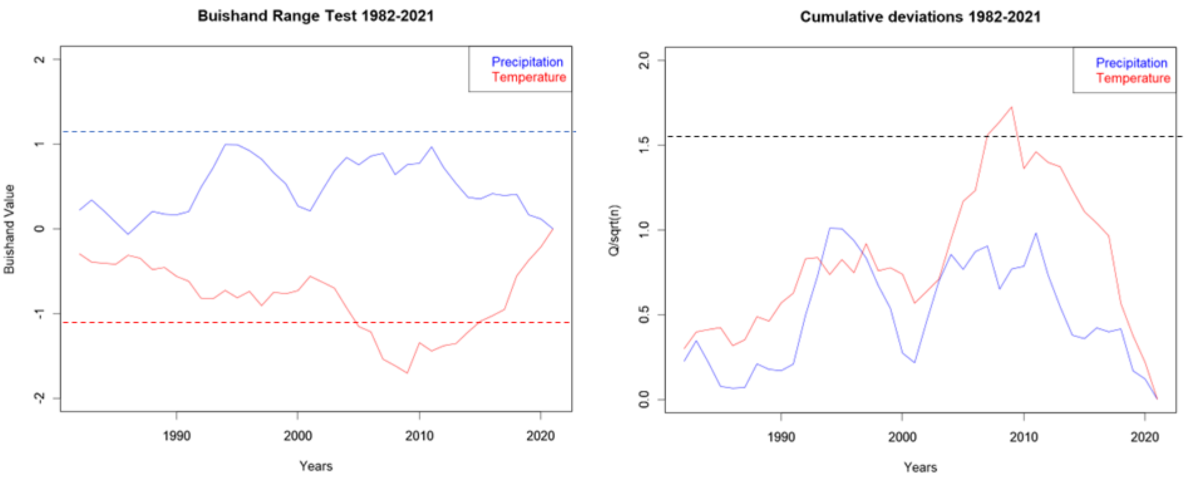

Figure 5. Annual buishand range and cumulative deviations test results of station 17852.

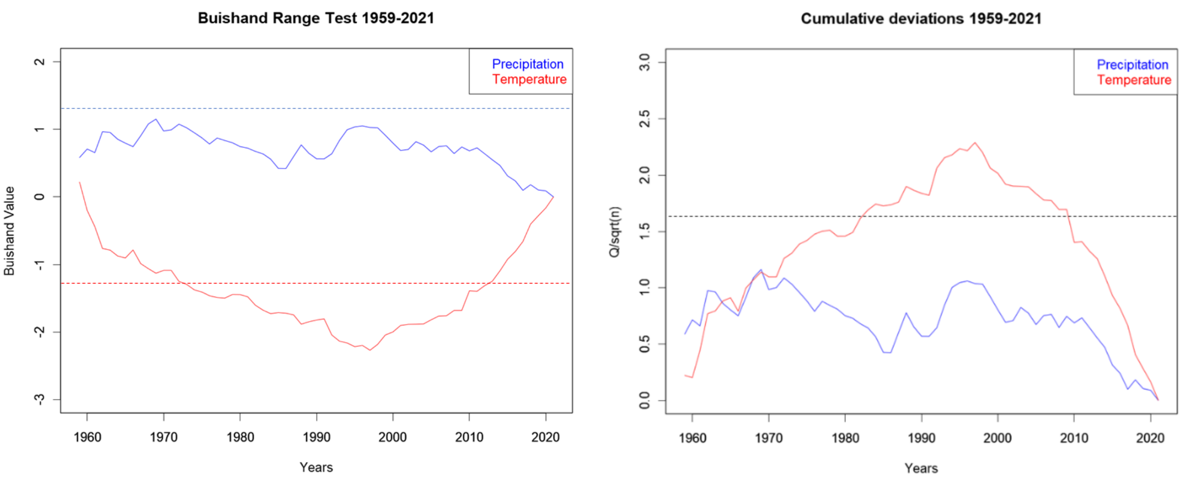

Figure 6. Annual buishand range and cumulative deviations test results of station 17880.

The Pettitt and SHN homogeneity tests results of seasonal time series of stations are given in Table 6. When Table 6 is examined, homogeneity is observed in the precipitation series in general in the fall, winter, spring, and summer seasons of the stations. In the temperature series, it was concluded that the homogeneity did not follow the precipitation series. Figures 7-10 show the seasonal results of 17172 station BR and CD homogeneity tests. The presence of the data set below the critical level in the figures showing the BR test results or above the critical level in the CD figures indicates that the homogeneity has deteriorated in that series. When Figures 7-10 are examined the temperature series at station 17172 is not homogeneous across four seasons.

Table 6. Seasonal SHNT and Pettitt test results (H_0: Homogeneous, H_a: Nonhomogeneous)

Station Number	Meteorological Variables	SNHT			Pettitt Test		
		p-value	Tk	Decision	p-value	U	Decision
17172	Seasonal total precipitation in Fall Season (mm)	0.5107	3.91	H_0	0.2867	280	H_0
	Seasonal mean temperature in Fall Season (°C)	0.0004	16.49	H_a	0.0008	563	H_a
	Seasonal total precipitation in Winter Season (mm)	0.8729	2.17	H_0	1	164	H_0
	Seasonal mean temperature in Winter Season (°C)	0.0000	29.13	H_a	0	774	H_a
	Seasonal total precipitation in Spring Season (mm)	0.7671	2.72	H_0	1	138	H_0
	Seasonal mean temperature in Spring Season (°C)	0.0001	22.88	H_a	0	713	H_a
	Seasonal total precipitation in Summer Season (mm)	0.3826	4.65	H_o	1	137	H_0
	Seasonal mean temperature in Summer Season(°C)	0.0000	20.43	H_a	0	666	H_a
17784	Seasonal total precipitation in Fall Season (mm)	0.0194	10.60	H_a	0.2564	254	H_0
	Seasonal mean temperature in Fall Season (°C)	0.0052	12.68	H_a	0.0139	395	H_a
	Seasonal total precipitation in Winter Season (mm)	0.1451	6.71	H_0	0.0678	326	H_a
	Seasonal mean temperature in Winter Season (°C)	0.0003	16.61	H_a	0.0040	442	H_a
	Seasonal total precipitation in Spring Season (mm)	0.4478	4.17	H_0	0.9307	155	H_0
	Seasonal mean temperature in Spring Season (°C)	0.0011	15.08	H_a	0.0233	374	H_a
	Seasonal total precipitation in Summer Season (mm)	0.0030	13.50	H_a	0.0370	354	H_a
	Seasonal mean temperature in Summer Season(°C)	0.0014	15.03	H_a	0.0370	354	H_a
17812	Seasonal total precipitation in Fall Season (mm)	0.1574	6.55	H_0	0.1019	355	H_a
	Seasonal mean temperature in Fall Season (°C)	0.0181	10.75	H_a	0.0141	458	H_a
	Seasonal total precipitation in Winter Season (mm)	0.5194	3.87	H_0	0.2287	303	H_0
	Seasonal mean temperature in Winter Season (°C)	0.0004	16.36	H_a	0.0002	626	H_a
	Seasonal total precipitation in Spring Season (mm)	0.3069	5.09	H_0	0.3439	273	H_0
	Seasonal mean temperature in Spring Season (°C)	0.0027	13.78	H_a	0.0003	611	H_a
	Seasonal total precipitation in Summer Season (mm)	0.3248	4.99	H_0	0.5487	234	H_0
	Seasonal mean temperature in Summer Season(°C)	0.2208	5.87	H_0	0.0831	367	H_a
17852	Seasonal total precipitation in Fall Season (mm)	0.6179	3.18	H_0	1	82	H_0
	Seasonal mean temperature in Fall Season (°C)	0.0054	11.93	H_a	0.0099	241	H_a
	Seasonal total precipitation in Winter Season (mm)	0.1801	6.02	H_0	0.2222	155	H_0
	Seasonal mean temperature in Winter Season (°C)	0.8320	2.20	H_0	0.8609	96	H_0
	Seasonal total precipitation in Spring Season (mm)	0.7615	2.54	H_0	0.6350	112	H_0
	Seasonal mean temperature in Spring Season (°C)	0.0205	9.96	H_a	0.0203	224	H_a
	Seasonal total precipitation in Summer Season (mm)	0.1208	6.77	H_0	0.0554	198	H_a
	Seasonal mean temperature in Summer Season(°C)	0.1931	5.80	H_0	0.2351	153	H_0
17880	Seasonal total precipitation in Fall Season (mm)	0.4387	4.31	H_0	0.4357	254	H_0
	Seasonal mean temperature in Fall Season (°C)	0.0013	15.01	H_a	0.0292	423	H_a
	Seasonal total precipitation in Winter Season (mm)	0.0367	9.36	H_a	1	147	H_0
	Seasonal mean temperature in Winter Season (°C)	0.0000	37.21	H_a	0.0006	588	H_a
	Seasonal total precipitation in Spring Season (mm)	0.0000	42.37	H_a	0.5487	234	H_0
	Seasonal mean temperature in Spring Season (°C)	0.0003	18.35	H_a	0	679	H_a
	Seasonal total precipitation in Summer Season (mm)	0.1691	6.41	H_0	0.0684	378	H_a
	Seasonal mean temperature in Summer Season(°C)	0.0075	12.25	H_a	0.0028	527	H_a

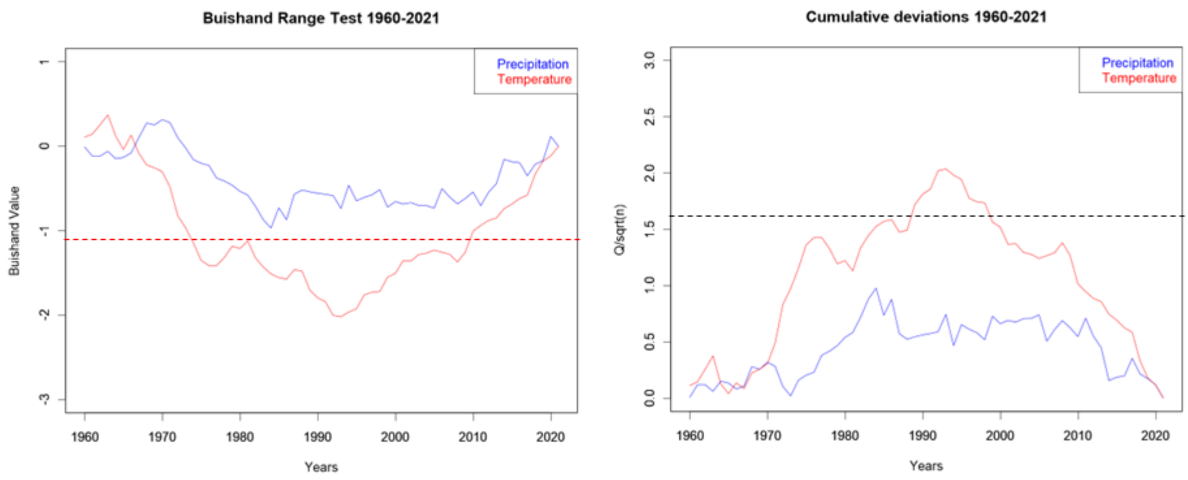

Figure 7. Buishand range and cumulative deviations test results of station 17172 on winter season.

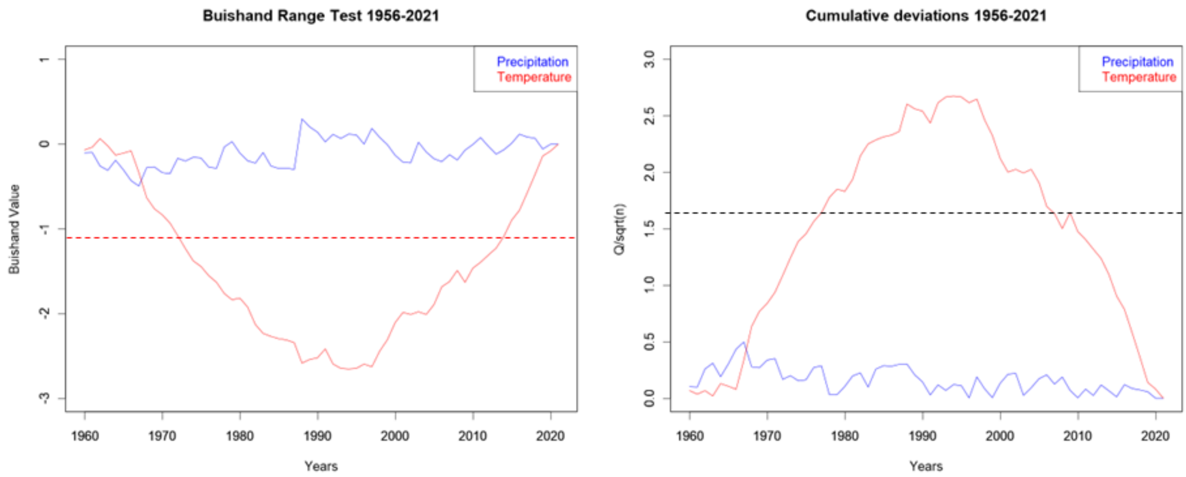

Figure 8. Buishand range and cumulative deviations test results of station 17172 on winter season.

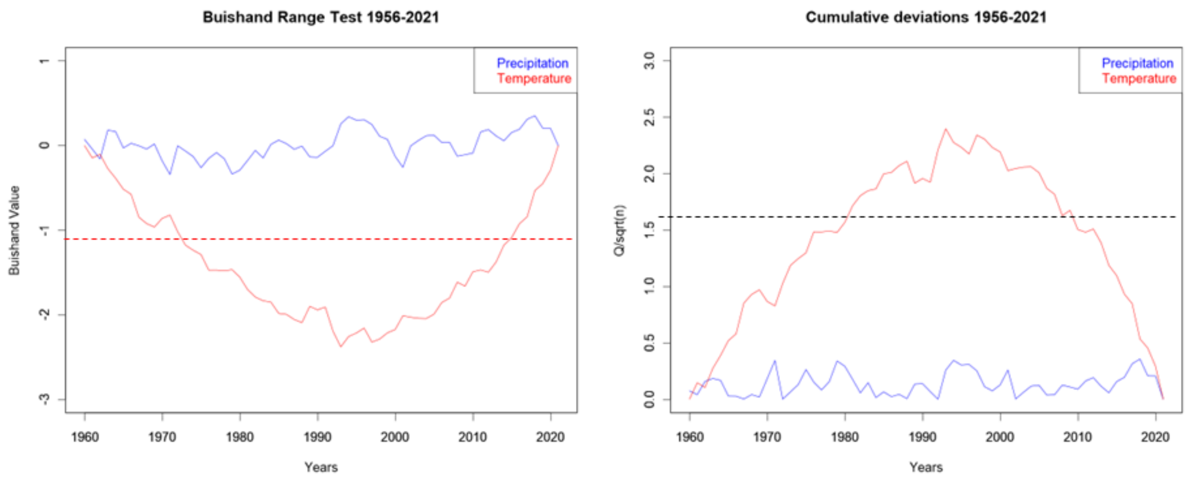

Figure 9. Buishand range and cumulative deviations test results of station 17172 summer season.

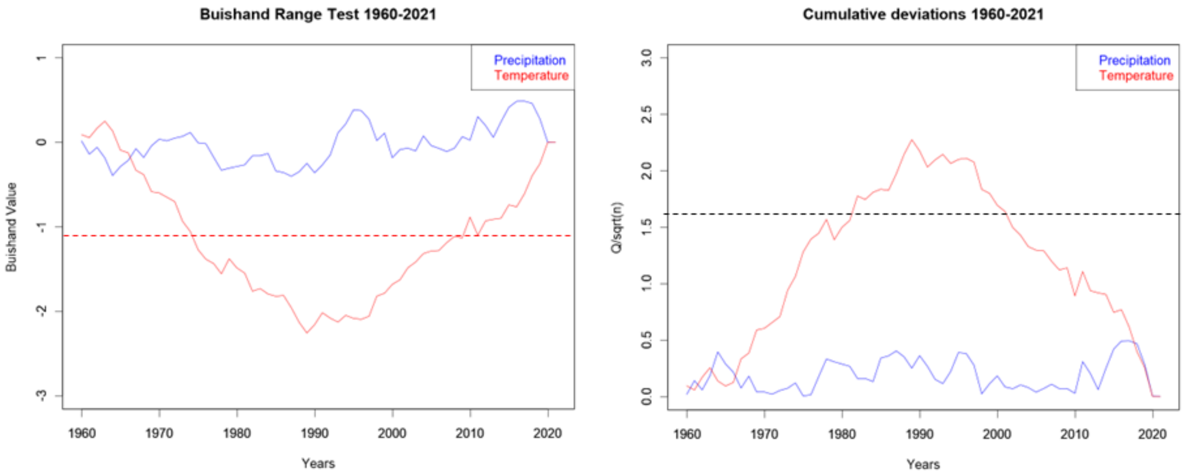

Figure 10. Buishand range and cumulative deviations test results of station 17172 fall season.

In Table 7 and Figures 11-15, critical years are given in the annual precipitation and temperature series, in which the break is seen in the non-homogeneous series. Since there is no change in the homogeneous series, it is classified as NC. The critical year in which the homogeneity deteriorated in the annual average temperature series of 17172 stations is 1993, as seen in Table 7 and Figure 11. The critical years of the annual temperature of the stations 17784, 17812,17852, and 17880 are 2009, 1993, 2009, and 1997, respectively. The change point of precipitation and temperature at station 17784 is given in Figure 12, station 17812 in Figure 13, and the change point of the temperature at stations 17852 and 17880 gives in Figure 14 and Figure 15. SHNT and Pettitt tests determined the change-point as the same year at all stations, except for the annual total precipitation series of stations 17784 and 17880.

Table 7. Change-point detection critical year (annual)

Station Number	**Meteorological Variables**	**SNHT**				**Pettitt Test**			
		p-value	**Tk**	**Decision**	**Year**	**p-value**	**U**	**Decision**	**Year**
17172	Annual total precipitation (mm/yr)	0.771	2.68	H_0	NC	0.545463	229	H_0	NC
	Annual mean temperature (°C)	0	30.69	H_a	**1993**	8.75E-08	827	H_a	**1993**
17784	Annual total precipitation (mm/yr)	0.00025	17.51	H_a	**1969**	0.093792	310	H_a	**1994**
	Annual mean temperature (°C)	0	21.19	H_a	**2009**	0.002303	461	H_a	**2009**
17812	Annual total precipitation (mm/yr)	0.05275	8.70	H_a	**2011**	0.057109	388	H_a	**2011**
	Annual mean temperature (°C)	0.0005	16.61	H_a	**1993**	6.8E-05	660	H_a	**1993**
17852	Annual total precipitation (mm/yr)	0.28635	5.02	H_0	NC	0.316282	142	H_0	NC
	Annual mean temperature (°C)	0.0016	13.86	H_a	**2009**	0.009435	242	H_a	**2009**
17880	Annual total precipitation (mm/yr)	0	21.82	H_a	**1959**	0.14802	332	H_0	NC
	Annual mean temperature (°C)	0	21.88	H_a	**1997**	1.6E-06	771	H_a	**1997**

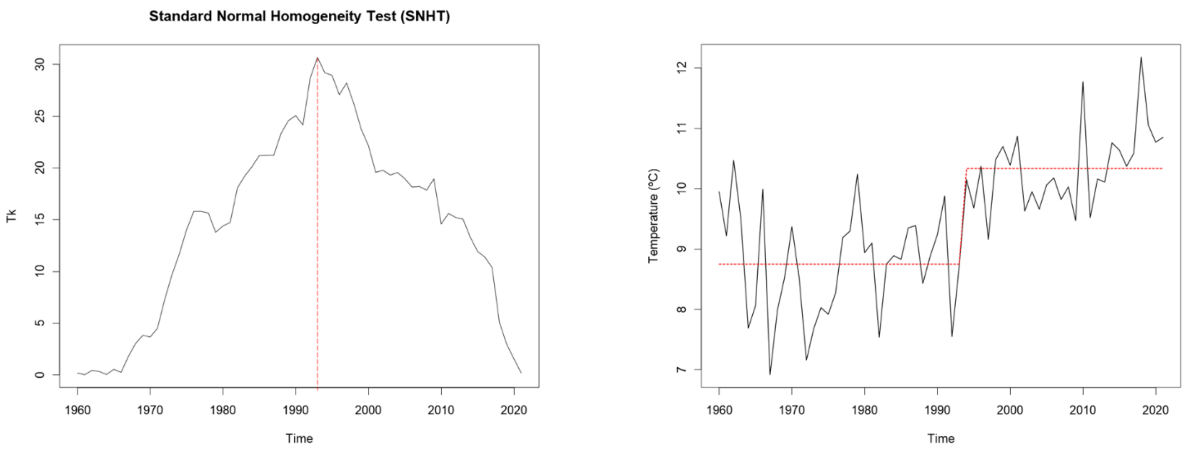

Figure 11. Annual SNHT and Pettitt test results for change-point detection critical year of station 17172.

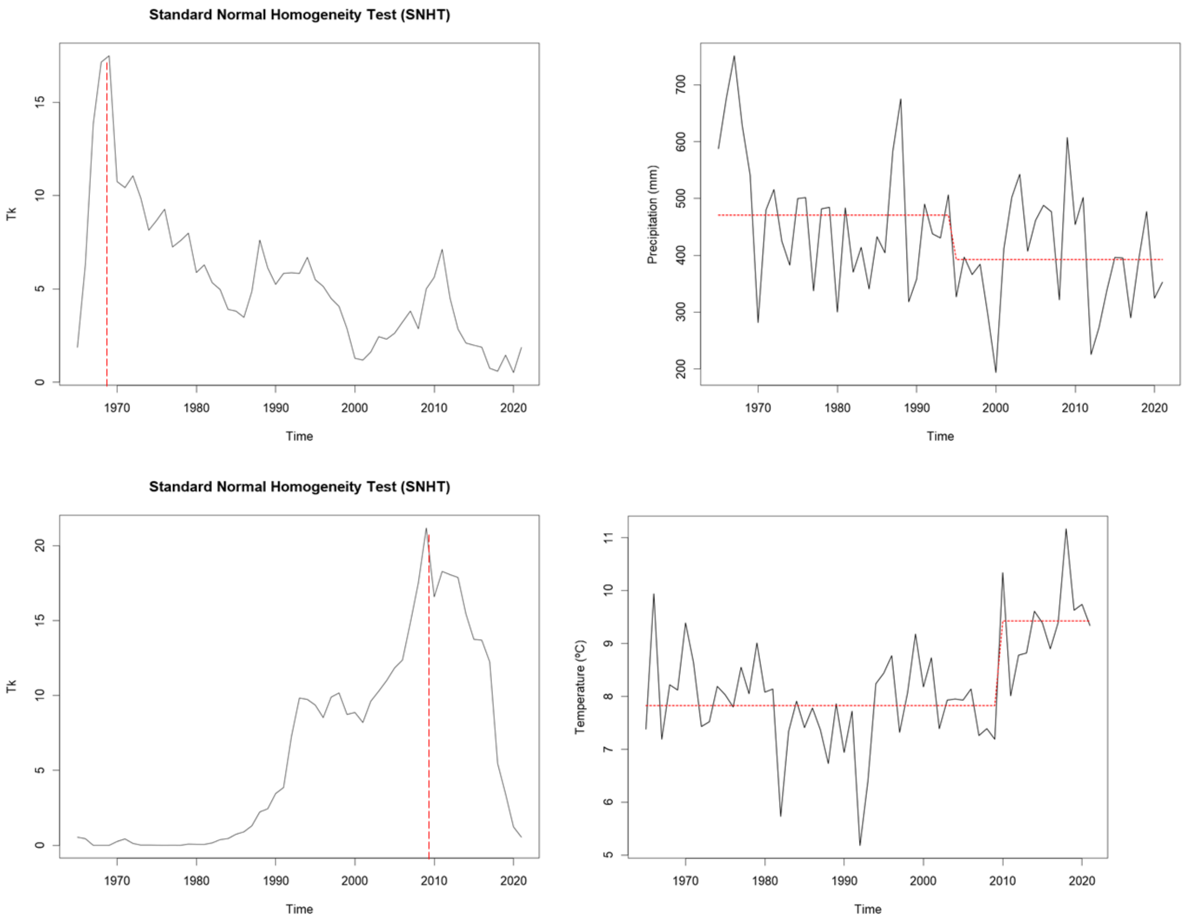

Figure 12. Annual SNHT and Pettitt test results for change-point detection critical year of station 17784.

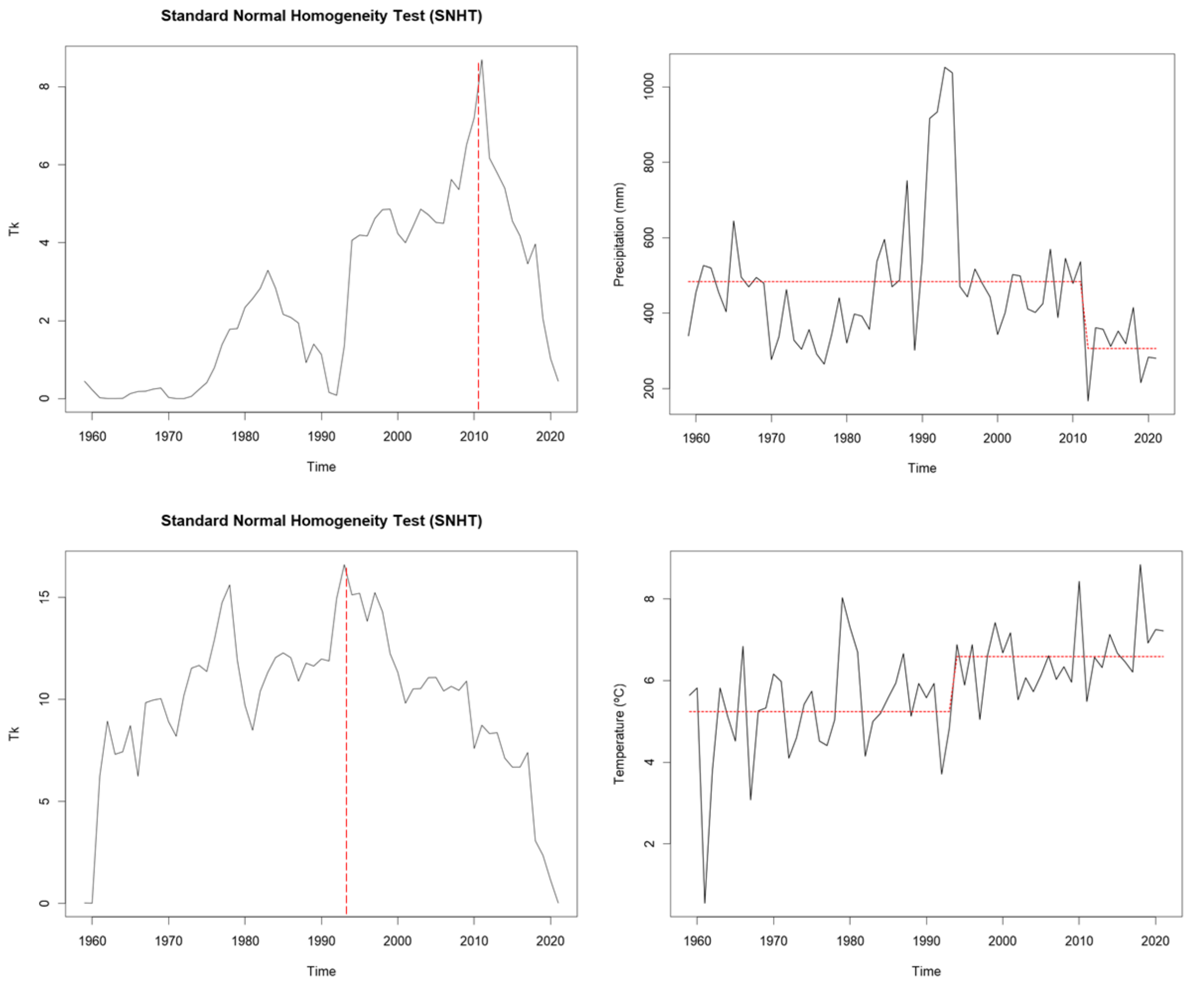

Figure 13. Annual SNHT and Pettitt test results for change-point detection critical year of station 17812.

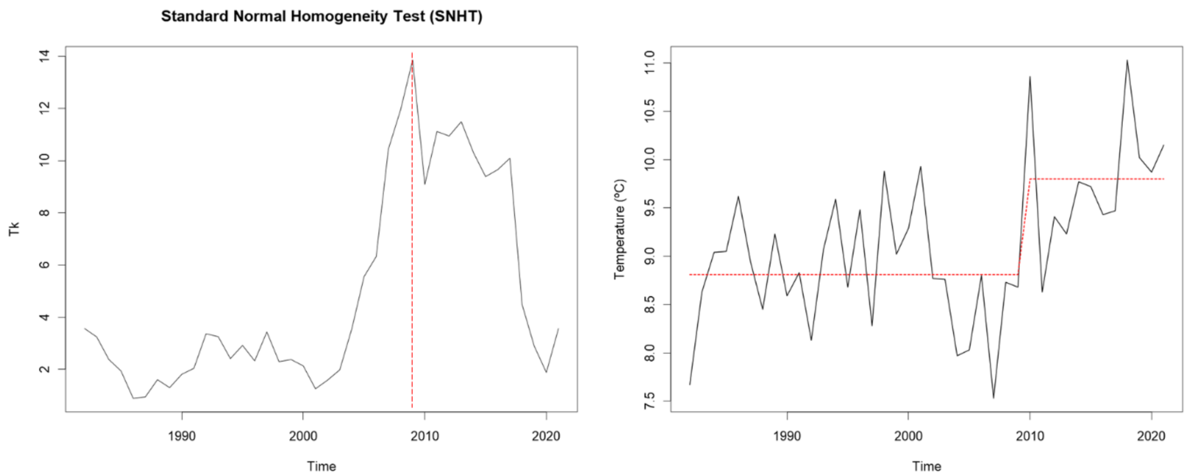

Figure 14. Annual SNHT and Pettitt test results for change-point detection critical year of station 17852.

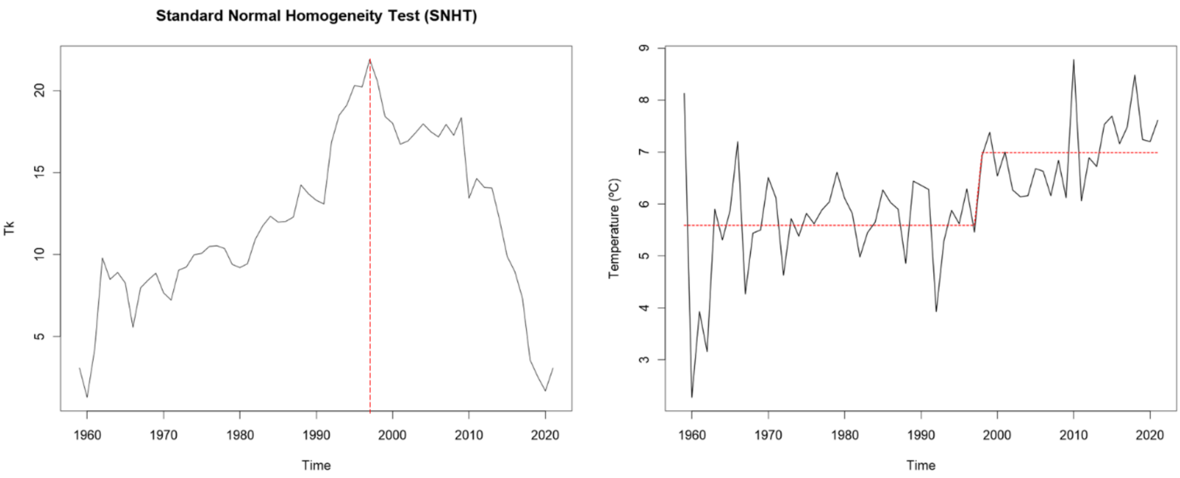

Figure 15. Annual SNHT and Pettitt test results for change-point detection critical year of station 17880.

The breaking years of the non-homogeneous series in the seasonal total precipitation and average temperature data series of 5 stations are shown in Table 8. When the table is examined, it has been determined that the years of change in the seasonal average temperatures of stations 17172, 17812, and 17880 occurred before the year 2000, but for stations 17784 and 17852 took place after 2000, according to SHNT and Pettitt tests.

Table 8. Change-point detection critical year (Seasonal)

Station Number	Meteorological Variables	SNHT				Pettitt Test			
		p-value	Tk	Decision	Year	p-value	U	Decision	Year
17172	Seasonal total precipitation in Fall Season (mm)	0.51065	3.907388	H_0	NC	0.286713	280	H_0	NC
	Seasonal mean temperature in Fall Season (°C)	0.00035	16.48691	H_a	**1993**	0.000777	563	H_a	**1993**
	Seasonal total precipitation in Winter Season (mm)	0.8729	2.170154	H_0	NC	1	164	H_0	NC
	Seasonal mean temperature in Winter Season (°C)	0	29.13425	H_a	**1997**	7.16E-07	774	H_a	**1994**
	Seasonal total precipitation in Spring Season (mm)	0.76705	2.721991	H_0	NC	1	138	H_0	NC
	Seasonal mean temperature in Spring Season (°C)	0.00005	22.88197	H_a	**1993**	6.78E-06	713	H_a	**1993**
	Seasonal total precipitation in Summer Season (mm)	0.38255	4.65401	H_0	NC	1	137	H_0	NC
	Seasonal mean temperature in Summer Season(°C)	0	20.43327	H_a	**1989**	3.38E-05	666	H_a	**1989**
17784	Seasonal total precipitation in Fall Season (mm)	0.01935	10.60395	H_a	**1968**	0.256393	254	H_0	NC
	Seasonal mean temperature in Fall Season (°C)	0.00515	12.67976	H_a	**2008**	0.013916	395	H_a	**2008**
	Seasonal total precipitation in Winter Season (mm)	0.14505	6.712626	H_0	NC	0.067834	326	H_a	**1998**
	Seasonal mean temperature in Winter Season (°C)	0.0003	16.6123	H_a	**2009**	0.003977	442	H_a	**2009**
	Seasonal total precipitation in Spring Season (mm)	0.4478	4.174467	H_0	NC	0.930708	155	H_0	NC
	Seasonal mean temperature in Spring Season (°C)	0.00105	15.07788	H_a	**2012**	0.023272	374	H_a	**2009**
	Seasonal total precipitation in Summer Season (mm)	0.003	13.50224	H_a	**1967**	0.036997	354	H_a	**1994**
	Seasonal mean temperature in Summer Season(°C)	0.0014	15.02594	H_a	**2011**	0.036997	354	H_a	**2011**
17812	Seasonal total precipitation in Fall Season (mm)	0.15735	6.549335	H_0	NC	0.101913	355	H_a	**2006**
	Seasonal mean temperature in Fall Season (°C)	0.0181	10.75479	H_a	**1974**	0.0141	458	H_a	**1993**
	Seasonal total precipitation in Winter Season (mm)	0.51935	3.874483	H_0	NC	0.22868	303	H_0	NC
	Seasonal mean temperature in Winter Season (°C)	0.0004	16.35659	H_a	**1988**	0.000191	626	H_a	**1983**
	Seasonal total precipitation in Spring Season (mm)	0.30685	5.090589	H_0	NC	0.343946	273	H_0	NC
	Seasonal mean temperature in Spring Season (°C)	0.0027	13.77817	H_a	**1998**	0.000296	611	H_a	**1998**
	Seasonal total precipitation in Summer Season (mm)	0.32475	4.994811	H_0	NC	0.548691	234	H_0	NC
	Seasonal mean temperature in Summer Season(°C)	0.22075	5.869274	H_0	NC	0.083053	367	H_a	**1996**
17852	Seasonal total precipitation in Fall Season (mm)	0.6179	3.182257	H_0	NC	1	82	H_0	NC
	Seasonal mean temperature in Fall Season (°C)	0.00535	11.93395	H_a	**2008**	0.009861	241	H_a	**2008**
	Seasonal total precipitation in Winter Season (mm)	0.18005	6.020096	H_0	NC	0.222181	155	H_0	NC
	Seasonal mean temperature in Winter Season (°C)	0.83195	2.196069	H_0	NC	0.860898	96	H_0	NC
	Seasonal total precipitation in Spring Season (mm)	0.7615	2.53747	H_0	NC	0.634975	112	H_0	NC
	Seasonal mean temperature in Spring Season (°C)	0.02045	9.962784	H_a	**2012**	0.020321	224	H_a	**2007**
	Seasonal total precipitation in Summer Season (mm)	0.1208	6.773716	H_0	NC	0.055433	198	H_a	**1995**
	Seasonal mean temperature in Summer Season(°C)	0.1931	5.798922	H_0	NC	0.235059	153	H_0	NC

Table 8. Change-Point Detection Critical Year (Seasonal) (continued)

Station	Meteorological Variables	SNHT				Pettitt Test			
		p-value	Tk	Decision	Year	p-value	U	Decision	Year
17880	Seasonal total precipitation in Fall Season (mm)	0.43865	4.309364	H_0	NC	0.435719	254	H_0	NC
	Seasonal mean temperature in Fall Season (°C)	0.0013	15.00843	H_a	**1962**	0.02921	423	H_a	**2008**
	Seasonal total precipitation in Winter Season (mm)	0.0367	9.357873	H_a	**1962**	1	147	H_0	NC
	Seasonal mean temperature in Winter Season (°C)	0	37.21032	H_a	**1962**	0.000568	588	H_a	**1997**
	Seasonal total precipitation in Spring Season (mm)	0	42.37101	H_a	**1959**	0.548691	234	H_0	NC
	Seasonal mean temperature in Spring Season (°C)	0.0003	18.34938	H_a	**1998**	3.73E-05	679	H_a	**1997**
	Seasonal total precipitation in Summer Season (mm)	0.16905	6.411269	H_0	NC	0.068436	378	H_a	**1995**
	Seasonal mean temperature in Summer Season(°C)	0.0075	12.25233	H_a	**1997**	0.002831	527	H_a	**1997**

4. Discussion and Conclusion

In this study, the homogeneity of seasonal and annual temperature and precipitation is examined using Standard Normal Homogeneity (SNHT), Pettitt (PT), Buishand Range (BR), and Cumulative Deviation (CD) tests at a significance level of 0.05. The four homogeneity tests are assessed using long-term annual and seasonal precipitation and temperature records obtained from five meteorological stations located in Van, Turkey. Finally, change point detection is investigated for each station. According to the results, In the annual average temperature, homogeneity was deteriorated at all stations, the homogeneity of stations 17172 and 17852, and 17880 was doubtful in annual total precipitation, and stations 17784 and 17812 showed homogeneity. It can be seen that stations 17784 and 17852 generally experienced changes after 2000, whereas stations 17172, 17812, and 17880 experienced changes before this year in the series. Seasonal results revealed that although it is rarely seen that there is homogeneity, it can be concluded that the homogeneity is broken in the precipitation and temperature data, especially in the temperature data. The results of most temperature series indicating non-homogeneity may be due to the effects of climate change in the Van Region. In past studies, homogeneity analysis was applied to the total precipitation, maximum, minimum, and average temperature series in different regions of Turkey. When we examine the studies conducted, we can observe that while the homogeneity of the temperature series has deteriorated (Ay, 2020; Yaman & Ertuğrul 2020), it is generally homogenous in the precipitation series (Hırca et al., 2022, Hırca ve Eryılmaz Türkkan, 2020, Yaman & Ertuğrul 2020, Koycegız & Buyukyıldız 2020). These studies were found to be similar to the results of our results regarding the Van region. This supported the accuracy of our study. As a result, the reliability of the data should be questioned in the studies to be carried out in the Van region. It is recommended to either eliminate from the analysis any stations having inhomogeneous series or to ensure the homogeneity of these stations.

References

Agha, O., Bağçacı, S. Ç., & Şarlak, N. (2017). Homogeneity analysis of precipitation series in North Iraq. *IOSR Journal of Applied Geology and Geophysics,* 5(3), 57-63. doi:10.9790/0990-0503025763

Ahmad, N. H., & Deni, S. M. (2013). Homogeneity test on daily rainfall series for Malaysia. *Matematika: Malaysian Journal of Industrial and Applied Mathematics*, 29, 141-150.

Alexandersson, H. (1986). A homogeneity test applied to precipitation data. *Journal of Climatology,* 6(6), 661-675. https://doi.org/10.1002/joc.3370060607

Alexandersson, H., & Moberg, A. (1997). Homogenization of Swedish temperature data. Part I: Homogeneity test for linear trends. *International Journal of Climatology: A Journal of the Royal Meteorological Society,* 17(1), 25-34. doi:10.1002/(SICI)1097-0088(199701)17:1<25::AID-JOC103>3.0.CO;2-J

Ay, M. (2020). Trend and homogeneity analysis in temperature and rainfall series in western Black Sea region, Turkey. *Theoretical and Applied Climatology,* 139(3-4), 837-848. doi:10.1007/s00704-019-03066-6

Buishand, T. A. (1982). Some methods for testing the homogeneity of rainfall records. *Journal of Hydrology,* 58(1-2), 11-27. doi:10.1016/0022-1694(82)90066-X

Dikbas, F., Firat, M., Koc, A. C., & Güngör, M. (2010). *Homogeneity test for Turkish temperature series.* Paper presented at the 4th BALWOIS 2010 International Conference.

Elzeiny, R., Khadr, M., Zahran, S., & Rashwan, E. (2019). Homogeneity analysis of rainfall series in the Upper Blue Nile River Basin, Ethiopia. *Journal of Engineering Research,* 3, 46-53. https://doi.org/10.21608/erjeng.2019.125704

Hawkins, D. M. (1977). Testing a sequence of observations for a shift in location. *Journal of the American Statistical Association,* 72(357), 180-186. doi:10.1080/01621459.1977.10479935

Hırca, T., Eryılmaz Türkkan, G. & Niazkar, M. (2022) Applications of innovative polygonal trend analyses to precipitation series of Eastern Black Sea Basin, Turkey. *Theoretical and Applied Climatology*, 147, 651-667. doi:10.1007/s00704-021-03837-0

Hırca, T., & Eryılmaz Türkkan, G. (2022) Comparison of Statistical Methods to Graphical Method in Precipitation Trend Analysis, A Case Study: Coruh Basin, Turkey. *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, 46, 4605-4617. doi:10.1007/s40996-022-00869-y

Ho Ming, K., & Yusof, F. (2012). Homogeneity tests on daily rainfall series in Peninsular Malaysia. Int. *Journal of Contemporary Mathematics and Sciences,* 7(1), 9-22.

Jaruskova, D. (1996). Change-point detection in meteorological measurement. *Monthly Weather Review,* 124(7), 1535. doi:10.1175/1520-0493(1996)124<1535:CPDIMM>2.0.CO;2

Karl, T. R., & Williams Jr, C. N. (1987). An approach to adjusting climatological time series for discontinuous inhomogeneities. *Journal of Applied Meteorology and Climatology,* 26(12), 1744-1763. doi:10.1175/1520-0450(1987)026<1744:AATACT>2.0.CO;2

Kazemzadeh, M., & Malekian, A. (2018). Homogeneity analysis of streamflow records in arid and semi-arid regions of northwestern Iran. *Journal of Arid Land,* 10(4), 493-506. doi:10.1007/s40333-018-0064-4

Khaliq, M. N., & Ouarda, T. B. (2007). On the critical values of the standard normal homogeneity test (SNHT). *International Journal of Climatology: A Journal of the Royal Meteorological Society,* 27(5), 681-687. doi:10.1002/joc.1438

Koycegız, C., & Buyukyıldız, M. (2020). Determination of change point and trend analysis of annual temperature data in Konya closed basin (Turkey). *Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi*, 9(1), 393-404. doi:10.28948/ngumuh.598289

Pettitt, A. N. (1979). A non-parametric approach to the change-point problem. *Journal of the Royal Statistical Society: Series C (Applied Statistics),* 28(2), 126-135. doi:10.2307/2346729

Şahin, S., & Cığızoğlu, H. K. (2010). Homogeneity analysis of Turkish meteorological data set. *Hydrological Processes: An International Journal,* 24(8), 981-992. doi:10.1002/hyp.7534

Şaroğlu, F., & Yılmaz, Y. (1986). Doğu Anadolu'da neotektonik dönemdeki jeolojik evrim ve havza modelleri. *MTA dergisi,* 107, 73-94.

Şenocak, S., & Emek, M. F. (2019). Trend analizi yöntemleri kullanılarak Doğu Anadolu Bölgesi aylık yağış miktarlarının değerlendirilmesi. *Avrupa Bilim ve Teknoloji Dergisi,* 17, 807-822. doi:10.31590/ejosat.646266

Wijngaard, J., Klein Tank, A., & Können, G. (2003). Homogeneity of 20th century European daily temperature and precipitation series. *International Journal of Climatology: A Journal of the Royal Meteorological Society,* 23(6), 679-692. doi:10.1002/joc.906

Wong, H., Hu, B., Ip, W., & Xia, J. (2006). Change-point analysis of hydrological time series using grey relational method. *Journal of Hydrology,* 324(1-4), 323-338. doi:10.1016/j.jhydrol.2005.10.007

Yaman, B., & Ertuğrul, M. (2020). Change-point detection and trend analysis in monthly, seasonal and annual air temperature and precipitation series in Bartın province in the western Black Sea region of Turkey. *Geology, Geophysics and Environment,* 46(3), 223-223. doi:10.7494/geol.2020.46.3.223

Yılmaz. (2021). Kuzey Atlantik salınımının Karadeniz Bölgesi yağış ve sıcaklıkları üzerindeki etkisi. (M.Sc Thesis), KTO Karatay University, Lisansüstü Eğitim Enstitüsü, Konya, Türkiye.

Yildirim, G., & Rahman, A. (2022). Homogeneity and trend analysis of rainfall and droughts over Southeast Australia. *Natural Hazards,* 112(2), 1657-1683. doi:10.1007/s11069-022-05243-9

Yozgatligil, C., & Yazici, C. (2016). Comparison of homogeneity tests for temperature using a simulation study. *International Journal of Climatology,* 36(1), 62-81. doi:10.1002/joc.4329

Yuce, M. I., Esit, M., & Kalaycioglu, V. (2022). Investigation of trends in extreme events: a case study of Ceyhan Basin, Turkey. *Journal of Applied Water Engineering and Research*, 11(3), 1-16. doi:10.1080/23249676.2022.2113462

Yuce, M. I., & Esit, M. (2021). Drought monitoring in Ceyhan basin, Turkey. *Journal of Applied Water Engineering and Research*, 9(4), 293-314. doi:10.1080/23249676.2021.1932616

Yüce, M. İ., Aksoy, H., Onoz, B., Çetin, M., Eriş, E., Eşit, M., …, & Kalaci, V. (2019). *İklim değişikliğinin yağişlar üzerine etkisi: Kahramanmaraş ve Osmaniye örneği.* 10. Ulusal Hidroloji Kongresi, Muğla Sıtkı Koçman Üniversitesi, Muğla.

Yüce, Ş., Ercan, B., Musa, E., Ünsal, M., & Yüce, M. İ. (2018). Seyhan Havzası yağış verilerinin eğilim analizi. *İklim Değişikliği ve Çevre,* 3(2)*,* 47-54.