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Observed Changes in Annual and Seasonal Temperatures in Nevşehir (Central Anatolia, Turkey) for Period 1960-2016

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Abstract

This study investigated changes and trends in mean annual and seasonal temperatures together with temperature anomalies in the province of Nevşehir, Turkey for the period 1960-2016. Nevşehir is within the Central Anatolia Region which is potentially sensitive to climate change due to its semi-arid climate. Trends in temperature series were analysed using Mann-Kendall and Gaussian statistical tests. Results show statistically significant increases in mean annual and summer temperatures at 0.05% level. A significant increasing trend in spring and autumn temperatures is weaker than summer temperatures. In other words, a slight warming trend in all these three seasons was detected. For winter temperatures, an increasing trend was also detected in this period. The trends, both annually and in summer, are evident from 1994, when the mean annual temperatures were above the long-term average. The warmest year was 2010 and the coldest year was 1992.

Keywords: Climate change, trend, temperature, Mann-Kendall, Nevşehir

INTRODUCTION

Climate scientists have reported a warming tendency in the global average surface temperature. Their studies have shown that in the last 150 years there has been an increase of 0.8°C in global mean temperatures and 1°C in Europe (IPCC, 2012). The study area of Nevşehir province is located in the vicinity of Cappadocia within the Middle Kızılırmak Sub-Region of the semi-arid Central Anatolia Region, which is sensitive to climate change. While the results of studies indicate that there is an overall upward trend here in extreme and average temperatures (Türkeş *et al*., 1996; Türkeş, 1999, Türkeş *et al*., 2009; Toros, 2012), there have also been positive trends in minimum temperatures and a statistically significant upward trend in summer temperatures, especially in Nevşehir (Kızılelma *et al*., 2015). According to (Türkeş, 2005), Nevşehir and its environs is the most continental part of Cappadocia with high inter-annual variability and low temperatures.

Nevşehir has an arid and sub-humid climate, first mesothermal, (excess of water is too little during the year) and the summer concentration of temperature activity is equal to the third mesothermal (Türkeş, 2005). In another study (Türkeş and Akgündüz, 2011), the Cappadocia region is subject to desertification due to both natural factors (drought, climate-process system, tuff separation, erosion, climate change) as well as human influence (land degradation, intensive tourism). In studies on the tourism of Nevşehir, it was noted that it is possible to stay outdoors all day owing to comfortable weather conditions in the summer (Türkoğlu and Çalışkan, 2011; Çalışkan and Matzarakis, 2012). Türkoğlu and Çalışkan (2011)'s study detected that for the PET (Physiologically Equivalent Temperature) values of all hours of the day, an increasing trend has been found in Nevşehir (urban meteorological station). In a study on the effects of temperature and rainfall changes on the soil and water

resources of Nevşehir, it was suggested that a serious additive trend was observed in the average, maximum and minimum long term temperature (Bağdatlı *et al*., 2015).

Studies on Turkey in recent years show the occurrence of extreme temperature events in the summer and an increase in annual changes in the second half of the 20st century (Türkeş *et al*., 2011; Erlat and Türkeş, 2013; Öztürk *et al*., 2014). Türkeş (1998) pointed out that Turkey is influenced by the hot and arid climate prevailing in the Middle East and North Africa. Increases in temperature and anomalies there bring problems such as drought and floods in the Central Anatolia Region, especially in the case of natural vegetation cover, variety of agricultural products and water resources. The purpose of this study is to determine the trends of Nevşehir province in the last 57 years using monthly, annual and seasonal temperature data.

GEOGRAPHIC SETTING and CLIMATE

Nevşehir province is situated between the coordinates 38° 12'-39° 20' north (latitude) and 34° 11'-35° 06' east (longitude) (UTM, ED 50, Zone 36 N) and in the southern part of the Kızılırmak River valley. The province, which belongs to the Middle Kızılırmak Sub-Region, has different topographical features and elevations varying between 910-3900 metres. Moreover, Nevşehir is located within the area known as Cappadocia, which is a popular tourist destination and covers a large plateau formed by accumulation of the ash and lava from extinct volcanoes such as Mt. Erciyes (3916 m), Mt. Melendiz (2963 m) and Mt. Hasan (3268 m). It is surrounded by these mountains to the south and east (Figure 1). Thus, geographically, while Cappadocia is centred on the city and province of Nevşehir, it also encompasses parts of Kayseri, Niğde, Kırşehir and Aksaray provinces.

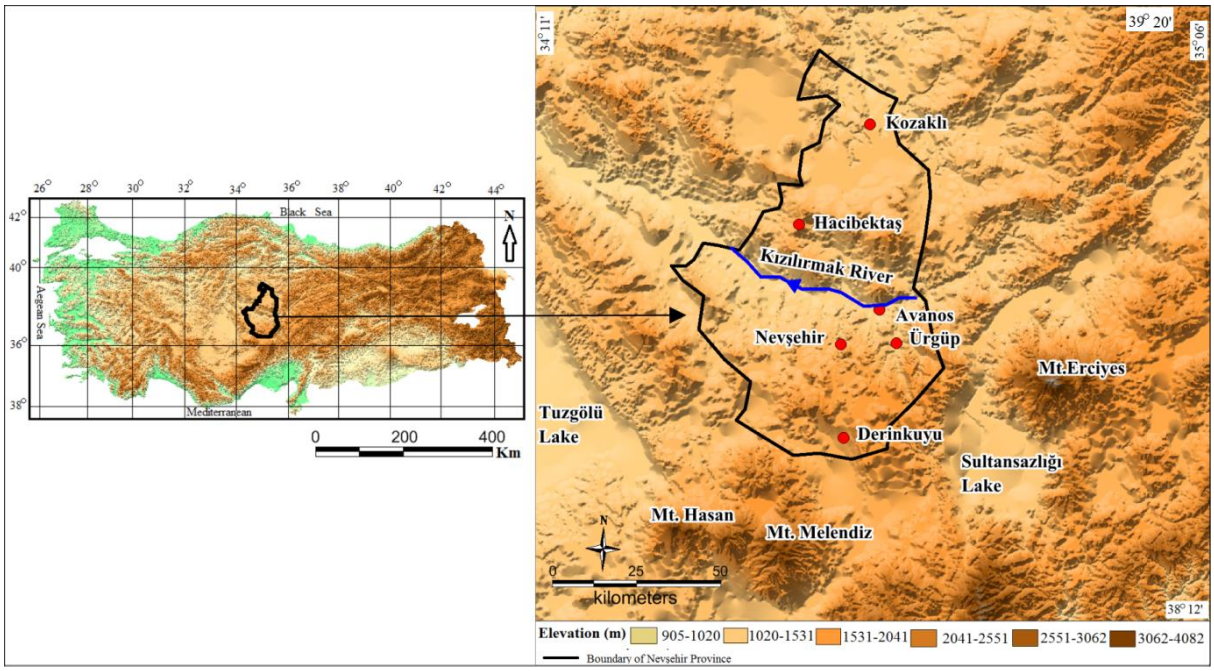


Figure 1. Location and DEM map of Nevşehir province.

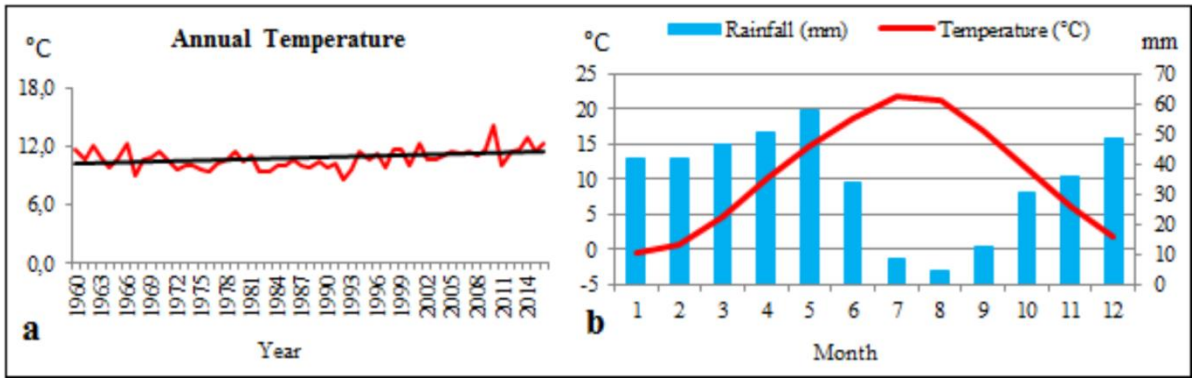


Figure 2. Variability in annual mean temperatures of Nevşehir province.

MATERIALS and METHOD

In this study, the changes and trends in the mean annual, seasonal temperature and anomaly series of Nevşehir using 57 years of data were examined. Gaussian Filter was used to examine the long-term fluctuations visually in the mean series. In this method of filtering, the weighting of successive terms of series varies symmetrically both backwards and forwards from a central weight (WMO, 1966; Türkeş *et al*., 1996). In addition, Mann-Kendall rank correlation coefficient was used to determine nonlinear trends in the time series. The u(t) curve obtained from this analysis shows the trend in the observation series.

The u(t) and u'(t) curves overlapping several times show that there is no significant trend in the series. Intersection of these curves shows the point where the trend begins (Sneyers, 1990).

RESULTS AND DISCUSSION

When the changes in annual temperature anomalies in Nevşehir from 1960 to 2016 are examined, periods occurred where decreasing and increasing trends can be distinguished, as well as the interannual variability (Figure 3).

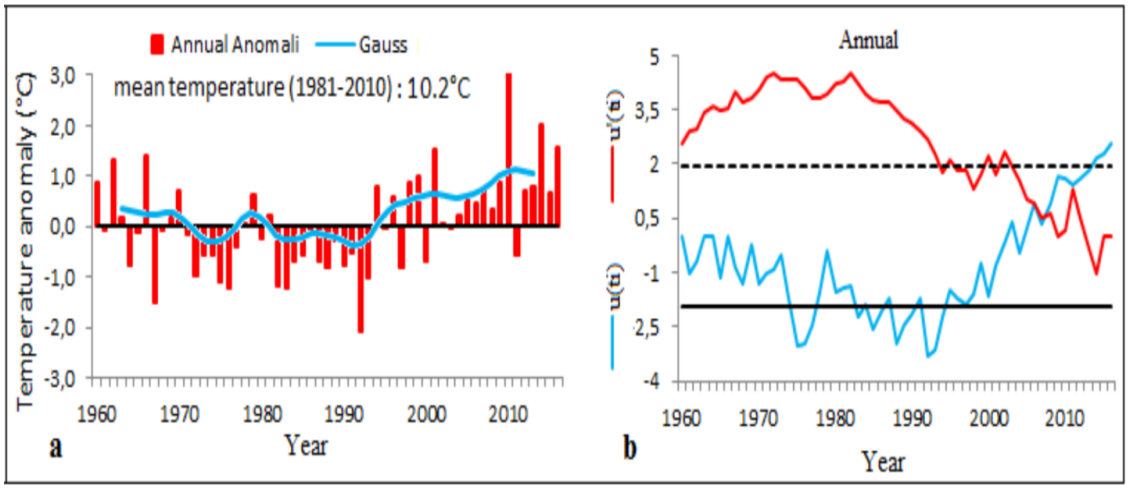


Figure 3. Changes and trends in mean annual temperatures of Nevşehir. (a) Red columns and blue curve show annual anomalies and 9-point Gaussian Filter, respectively. (b) Trend in annual temperature series according to u(t) and u'(t) obtained from Mann-Kendall test.

The Gaussian graph (Figure 3a) shows that a relatively warm period is observed between 1960 and 1966. This period was followed by a significantly cold period between 1971 and 1993. Following this period, a significant warming trend is observed despite the variable interannual during the period 1994-2001. Temperatures are above normal from 2014 to 2016. The year 2011 is distinctive in this period due to being below normal (Figure 3a). According to long-term annual anomalies, -3°C cooling is observed in1992. After this year, a warm period above the normal value occurred until 2016, except for the years 1994, 1997 and 2000. 2010 has the warmest maximum increase (+3°C). After this, there is no significant decrease, except for 2011.

These results based on Gaussian filter are also confirmed by results obtained from the Mann-Kendall test. As shown in Table 1, positive values indicate an increasing trend and a1 values (winter, spring, autumn) greater than 0.1 indicate that no significant increasing trend is observed. According to Mann-Kendall, a significant increasing trend is observed from 2006 (Figure 3b). The increasing trend in winter, spring and autumn temperatures is statistically not significant, while the increasing trend in annual temperatures is statistically significant at 0.05 level.

Table 1. Features of study area and analysis results (*: significant at 5%).

Meteorological Station	Period	Elevation (m)	Latitude and Longitude north	east	Mann-Kendall a1	u(t)	Gaussian t
Nevşehir	1960-2016	1150	37°59' and	34°42'	Annual: 0.0098	2.58*	2.64
					Winter: 0.337	0.096	
					Spring: 0.126	1.535	
					Summer: 0.0004	4.557	
					Autumn: 0.238	1.184	

As shown in Figure 4, the maximum cooling in winter temperatures occurred in the first half of the period, in 1972, with a decrease of -2°C. Generally, no significant increases were observed in this season; however, the most positive increase is observed in 2010 with an increase of 2.2°C. The maximum cooling occurred in 1992 with a decrease of 2.7°C (Figure 4a). The coldest spring with a negative anomaly of -2°C occurred in 1988 during the first period and the second highest negative anomaly occurred in 1997 with a decrease of -1.4°C. After this, a significant decrease is not observed. The highest positive anomaly is observed in 2008 with an increase of 2.1°C and 2014 with an increase of 1.9°C (Figure 4b).

The negative and positive anomalies in the summer temperatures follow each other between the years 1966 and 1979. The highest negative anomaly belonged to 1967 with a decrease of -1.85°C. After 1980, which has a significant positive anomaly (+1°C), the negative anomalies continue until 1986. Fluctuations are also observed from 1986 to 1997.

Interrupted positive anomalies are observed from 1998 to 2016. In other words, an increasing trend in summer temperatures continued over the last eighteen years. The positive anomalies range between +2.81°C (in 2010) and +0.54°C (in 2009). The highest positive anomaly is observed in 2010. As to autumn temperatures, positive and negative anomalies are observed from 1960 to 1975. This period is followed by fluctuations in temperature from 2000. Non-significant negative anomalies are observed between the years 2001 and 2016. In particular, a significant negative anomaly in temperature is remarkable in 2011, with a decrease of -2.18°C. The highest positive anomaly can be seen in 2010, with an increase of +3.83°C. The highest positive anomalies are observed in 2010 for all seasons in the period 1960-2016, except spring.

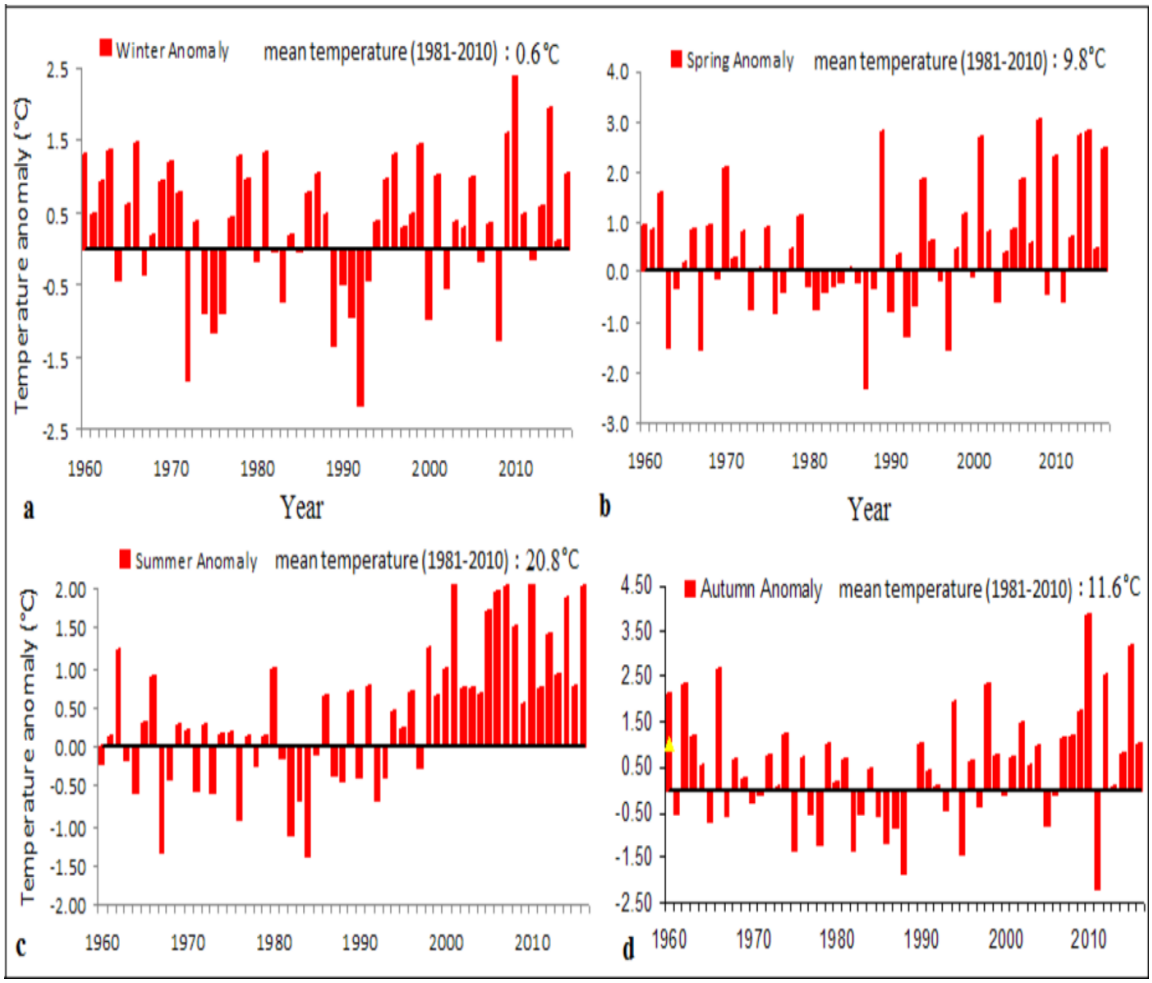
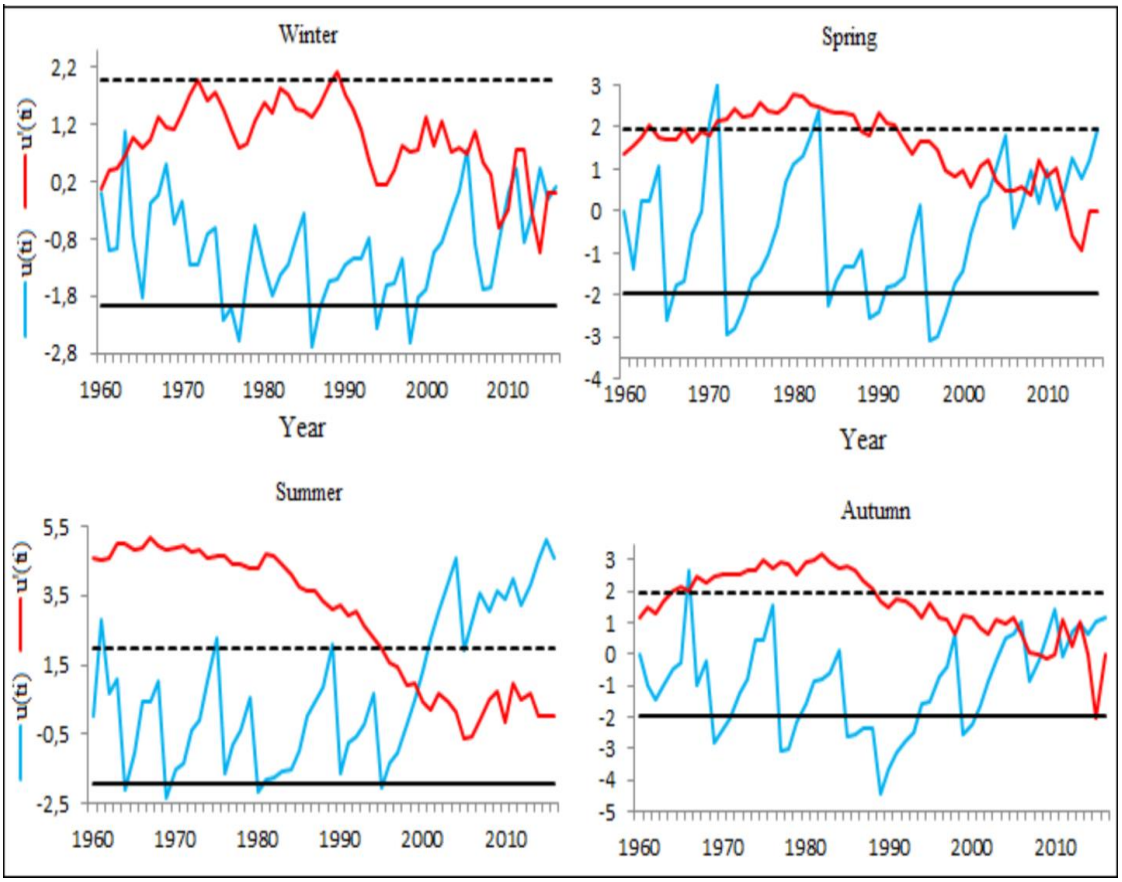


Figure 4. Seasonal anomaly values of Nevşehir province.

With respect to Mann-Kendall trend analysis, the increasing trend in summer temperatures is observed statistically significant at 0.05 level (see Table 1). For other seasons, no statistical significance is detected between 1960 and 2016 (Figure 5). The trends in summer temperatures are generally below the long-term average up to the beginning of the 1990s and show an increasing trend from this time onwards. A statistically significant increasing trend in summer temperatures is observed in Nevşehir from the year 2000. These results are consistent with those of previous studies (Türkeş *et al*., 2002; Türkeş, 2012; Kızılelma *et al*., 2015; Gökmen, 2016).

Figure 5. Trends in seasonal temperature series according to u(t) and u'(t) obtained from Mann-Kendall test.



CONCLUSION

It may be concluded that the warming trend in global mean air temperatures and warming trend in temperatures of Nevşehir province have increased significantly. In the annual temperature time series of Nevsehir from 1960 to 2016, three different periods were detected. These are: (1) Fluctuations in temperature and a slight warming trend until the beginning of the 1970s, (2) a general cooling trend from 1972 to 1993 ranging from -0.8°C to -2.3°C, and (3) a strong warming trend following 1993. Negative anomaly values are observed between the years 1972 and 1993, while positive anomaly values are observed from 1993. According to Mann-Kendall analysis, the increasing trend in annual and summer temperatures is statistically significant at 0.05 level. This shows that the increasing trend in summer temperatures plays an important role in amplifying the warming trend of annual temperatures. The highest warming is observed in 2010 for both annual and seasonal temperatures.

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