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-RESEARCH ARTICLE-

Climatic Trends in the Temperature of Çanakkale City, Turkey

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Abstract

Climate is a dynamic process changing in both temporal and spatial scales. Climate change and global warming has been extensively accepted and commonly described as rising of the temperature. Long-term trends and changes in the series of monthly, seasonal and annual temperature of Çanakkale station (Çanakkale, Turkey) of Turkish State Meteorological Service (TSMS) were analyzed by considering temporal characteristics. Climatic data for temperature encompasses the period of between 1970 and 2012. Temperature data set has been arranged as climatological seasons that spring (March, April, May), summer (June, July, August), autumn (September, October, November), and winter (December, January, February). Non-parametric tests and Box-Jenkins method were used to determine climatic trends. Pettitt change-point analysis was applied for determining the change point of temperature dataset. Results of trend analysis revealed that there was a statistically significant increasing trend in the temperature. Mean annual temperature is predicted to increase 0.02977°C per year and it is forecasted to reach 15.9946°C in 2022. On the other hand, mean seasonal temperatures are predicted to increase 0.0121°C, 0.05877°C, 0.0350°C, and 0.0031°C per year for spring, summer, autumn, and winter, respectively. The increase in temperature trends indicates that global warming is causing to climate change. In light of the results, it is crucial to state that Çanakkale city will be affected by global warming and climate change, and also will have a warmer climate in the future.

Keywords:

Climate change, Change-point analysis, Temperature, Trend analysis

Article history:

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Introduction

Climate change related with rise in global temperatures is based on increases in the emissions of greenhouse gases (Arnell, 2003). Climate changes by anthropogenic activities are associated with increases in atmospheric CO_2 and other gases (Tabari & Talaee, 2011). These changes in climate because of the increased greenhouse influence are estimated to be a reason for major changes in different climatic variables for instance surface temperature, precipitation, solar radiation, and humidity (Haskett et al., 2000; Yu et al., 2002). Recently, it has been observed that there was an increase of 0.7°C in mean global surface temperature from the initial of the century and it is predicted to increase 3°C in the next century (Ejder et al., 2016b). The Intergovernmental Panel on Climate Change (IPCC, 2007) expected that climate change and global warming will have potential effects on mean temperature, precipitation regime, drought, and sea level rising.

Climatic trends are one of the most common aspects of the climate due to anthropogenic activities affect the atmosphere composition (Kadıoğlu, 1997). Trends are also one of the most unclear aspects of climatological researches as a consequence of difficulties and uncertainness in providing consistent climatological time series.

Long-term temporal trends in time series of the temperature have been studied in America (DeGaetano, 1996; Stafford et al., 2000; Zhang et al., 2000; Vincent et al., 2012), Europe (Klein Tank et al., 2002; Klein Tank & Können, 2003; Wijngaard et al., 2003; Feidas et al., 2004; del Río et al., 2007; Mohsin & Gough, 2009), Asia (Shrestha et al., 1999; Su et al., 2006; Dhorde et al., 2009; Tabari et al., 2011; Tabari & Talaee, 2011; Jain & Kumar, 2012). In Turkey, Türkeş et al. (1996) investigated mean seasonal daily temperature during the period 1930–1993. Authors reported that there was a general warming in the series of average seasonal minimum temperature, especially in spring, while a general decrease was evident in the series of maximum temperature for all seasons, excluding spring. Türkeş et al. (2002) documented that there was a strong increase in temperature. Türkeş & Sümer (2004) found a weak increasing and decreasing in maximum temperature in spite of significant increase of minimum temperature in most seasons. Furthermore, several authors reported that there was a significantly increase in temperature (Ejder et al., 2016a, 2016b; Kale et al., 2016a, 2016b).

Trends in global mean surface temperature are a valuable indicator of climate change and variability (Tabari & Talaee, 2011). Therefore, the main purpose of the study was to determine trends in the time series of monthly, seasonal and annual temperature in Çanakkale for the period of 1970–2012. Furthermore, possible climatic changes in temperature will be forecasted.

Materials and Methods

Study Area and Data

Çanakkale is located in the western part of Turkey. It is surrounded by Aegean Sea, Çanakkale Strait, and Marmara Sea (Figure 1). The climate is typically of the transition climate type that characterized by hot and dry summers, and cold and rainy winters. Mean monthly temperatures of Çanakkale pointed out that July is the warmest month and January is the coldest month with long-term averages of 25°C and 6.4°C, respectively (Cengiz & Akbulak, 2009).

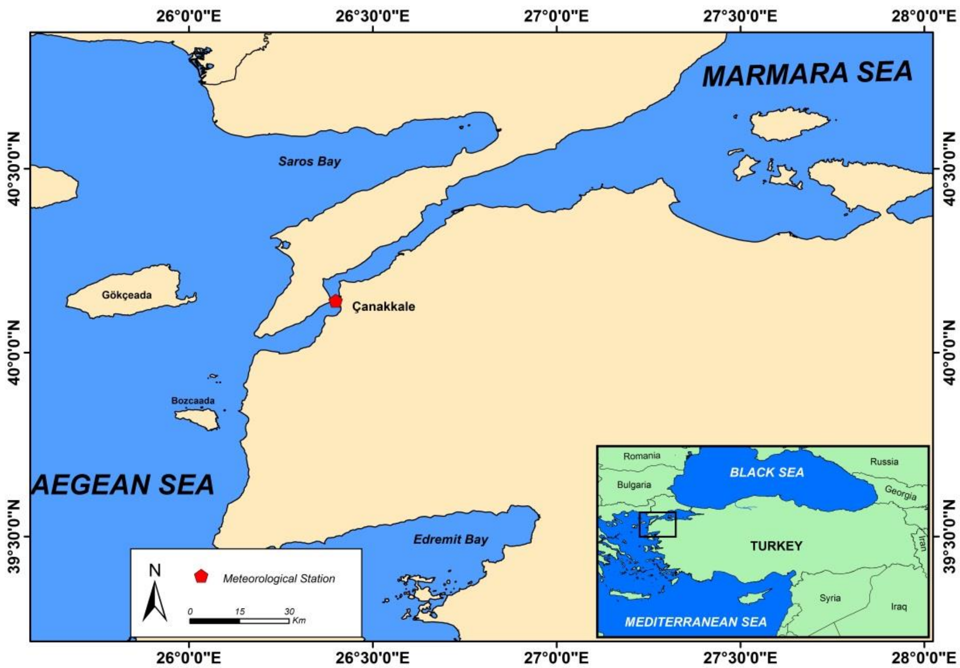

Figure 1. Study area and location of meteorological station

Data for the temperature obtained from Çanakkale station of Turkish State Meteorological Service (TSMS) for the period of 1970-2012 were used in this study. Time series of temperature data set has been arranged as climatological seasons that spring (March, April, May), summer (June, July, August), autumn (September, October, November), and winter (December, January, February).

Methods

In this study, change point analysis, trend analysis, and non-parametric tests were applied.

Change-point Analysis

There are numerous approaches for change-point detection in a time series (Radziejewski et al., 2000; Tomozeiu et al., 2000; Fealy & Sweeney, 2005; Li et al., 2005; Beaulieu et al., 2012; Chen & Gupta, 2012; Salarijazi et al., 2012). In this study, a non-parametric approach change-point analysis developed by Pettitt (1979) was used for detection the change-point. Change-point analysis is distribution free and rank based test for detecting an important variation in a time series. It is extensively applied to climatic time series (Tomozeiu et al., 2000; Bates et al., 2012; Ejder et al., 2016b, 2016a; Kale et al., 2016a, 2016b) Pettitt's change-point analysis was executed by "trend" package (Pohlert, 2017) in R statistical software (R Core Team, 2017).

The null hypothesis of the Pettitt's change-point test is that there is no change point exists. K_T is the statistic of null hypothesis in Equation (1).

$$K_T = \max\left|U_{t,T}\right| \tag{1}$$

where

$$U_{t,T} = \sum_{i=1}^{t} \sum_{j=t+1}^{T} sgn(x_i - x_j), \text{for } t = 2, \ldots\ldots, T \quad (2)$$

In Equation (2), $U_{t,T}$, confirms in this formula whether two examples $x_1, \ldots\ldots, x_t$ and $x_{t+1}, \ldots\ldots, x_T$ are in the same population or not. Associated probability (p) is used in significance calculating. The significance probability of K_T is predicted for $p \leq 0.05$ with the formula in Equation (3).

$$\mathrm{p} \cong 2\exp\left(\frac{-6\ \mathrm{K_T}^2}{\mathrm{T}^3+\mathrm{T}^2}\right) \quad (3)$$

Trend Analysis

The most commonly used method for determining the tendency of climatic time series is trend analysis (Hamed & Ramachandra Rao, 1998). Therefore, trend analysis and Box-Jenkins method (Box & Jenkins, 1976) was used in this study for determining the tendency of temperature time series. Box-Jenkins technique is based on linear, discontinuous, and stochastic processes. This method used for forecast and analysis of a time series. An autoregressive integrated moving average (ARIMA) is applied for non-stationary processes whereas autoregressive (AR), moving average (MA), autoregressive-moving average (ARMA) models are applied for stationary processes. The main purpose of these models is to determine the model which fits best to the time series and which contains the fewest parameters (Box & Jenkins, 1976).

ARIMA models utilize a linear combination for the prediction of a time series. In the ARIMA model (p, d, q), p designates the number of AR terms, q designates the number of MA terms and d designates the order of differencing. The ARIMA model used in this study is formulated in Equation (4).

$$X_t = c + \Phi_1 X_{t-1} + \cdots + \Phi_p X_{t-p} + \theta_1 e_{t-1} + \theta_q e_{t-q} + e_t \quad (4)$$

X_t is the variable that will be described in t time, c is the constant, Φ is the coefficient of per p parameter, θ is coefficient of per q parameter, and e_t are the errors in t time.

The ARIMA (*1, 0, 1*) model was used in trend analyses and autocorrelation analyses were also performed to define the reliability of the results achieved from analyses. It was aimed to suggest practical quantitative results by forecasting the statistical data analysis in the climatic data assessment stage of the study. It is attempted to predict future projections by forecasting a 5-year range applied to the time series.

Mann-Kendall Test

Mann-Kendall test is a regularly used test to determine the trends in a time series (Mann, 1945; Kendall, 1955). Extreme values in the dataset have impacts on the average. Mann-Kendall test is an effective test for determining trends in a time series with extreme values (Durdu, 2010). In this study, a non-parametric Mann-Kendall test (Mann, 1945; Kendall, 1955) was executed to examination of potential trends in the temperature. *Kendall's tau* and *Spearman's rho* tests were also applied. Non-parametric Mann-Kendall and Spearman's rho tests provide more reliable and appropriate results than parametric tests. The statistic formula of Mann-Kendall test is explained in Equation (5-8).

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} sgn(x_k - x_i) \tag{5}$$

where the time series x_i is from $i = 1, 2, \ldots, n\text{-}1$, and x_k from $k = i + 1, \ldots, n$.

$$sgn(\theta) = \begin{cases} +1, & \theta > 0 \\ 0, & \theta = 0 \\ -1, & \theta = 0 \end{cases} \tag{6}$$

Zc and β are given as

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{var(S)}}, & S > 0 \\ \frac{S+1}{\sqrt{var(S)}}, & S = 0 \\ & S < 0 \end{cases} \tag{7}$$

where Z_c is the test statistic. H_0 will be rejected while $|Z_c| > Z_{1-\alpha/2}$, wherein $Z_{1-\alpha/2}$ are the standard normal variables and α is the significance level for the test. The magnitude of the trend is given in Equation (8).

$$\beta = Median\left(\frac{x_i - x_j}{i-j}\right), \forall_j < i \tag{8}$$

A positive value of β indicates an increasing trend, while a negative value of β indicates a decreasing trend where $1 < j < i < n$.

Results

Results of Pettitt change-point analysis specified that the change point for mean annual temperature was 1997 (Table 1). Trend analysis results showed that temperature has an upward trend (Figure 2). Mean annual temperature is predicted to increase 0.02977°C per year and it is forecasted to reach 15.9946°C in 2022 (Table 2).

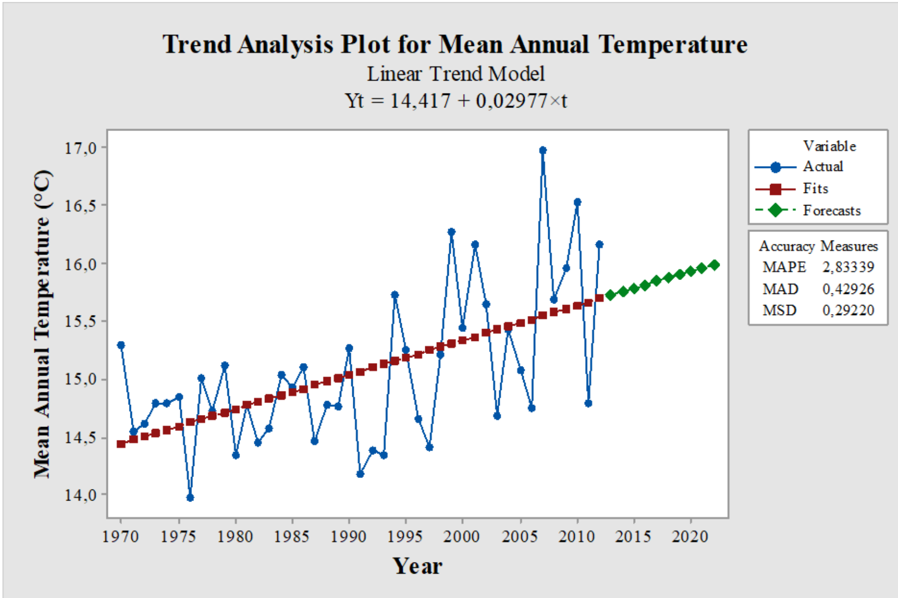

Figure 2. Trend analysis result of mean annual temperature

Change points for mean seasonal temperature were determined 1998, 1993, 1989, and 1993 for spring, summer, autumn, and winter, respectively (Table 1). Trend analysis results displayed that temperature has an upward trend for all seasons (Figure *3*). Mean seasonal temperature is expected to increase 0.0121°C, 0.05877°C, 0.0350°C, and 0.0031°C per year for spring, summer, autumn, and winter, respectively (Table 2).

Table 1. Change-point years and results of the non-parametric tests

Temperature (°C)		***Pettitt Change Year***	***Mann-Kendall***		***Spearman***	
			tau	***p***	***rho***	***p***
Mean Annual		1997	0.338**	0.001	0.488**	0.001
Mean Seasonal	*Spring*	1998	0.108	0.313	0.183	0.245
	Summer	1993	0.544**	0.000	0.759**	0.000
	Autumn	1989	0.325**	0.002	0.453**	0.003
	Winter	1993	-0.004	0.967	-0.005	0.976
Mean Monthly	*January*	1983	0.003	0.975	0.002	0.987
	February	2002	-0.064	0.551	-0.067	0.672
	March	2001	0.041	0.704	0.079	0.618
	April	1996	0.036	0.737	0.060	0.705
	May	1993	0.218*	0.046	0.319*	0.040
	June	1994	0.378**	0.000	0.532**	0.000
	July	1993	0.475**	0.000	0.68**	0.000
	August	1984	0.502**	0.000	0.709**	0.000

September	1981	0.281**	0.010	0.393**	0.010
October	1989	0.206	0.056	0.296	0.057
November	1983	0.140	0.193	0.198	0.208
December	1977	0.102	0.341	0.147	0.347

[*] Correlation is significant at the 0.05 level (2-tailed).

[**] Correlation is significant at the 0.01 level (2-tailed).

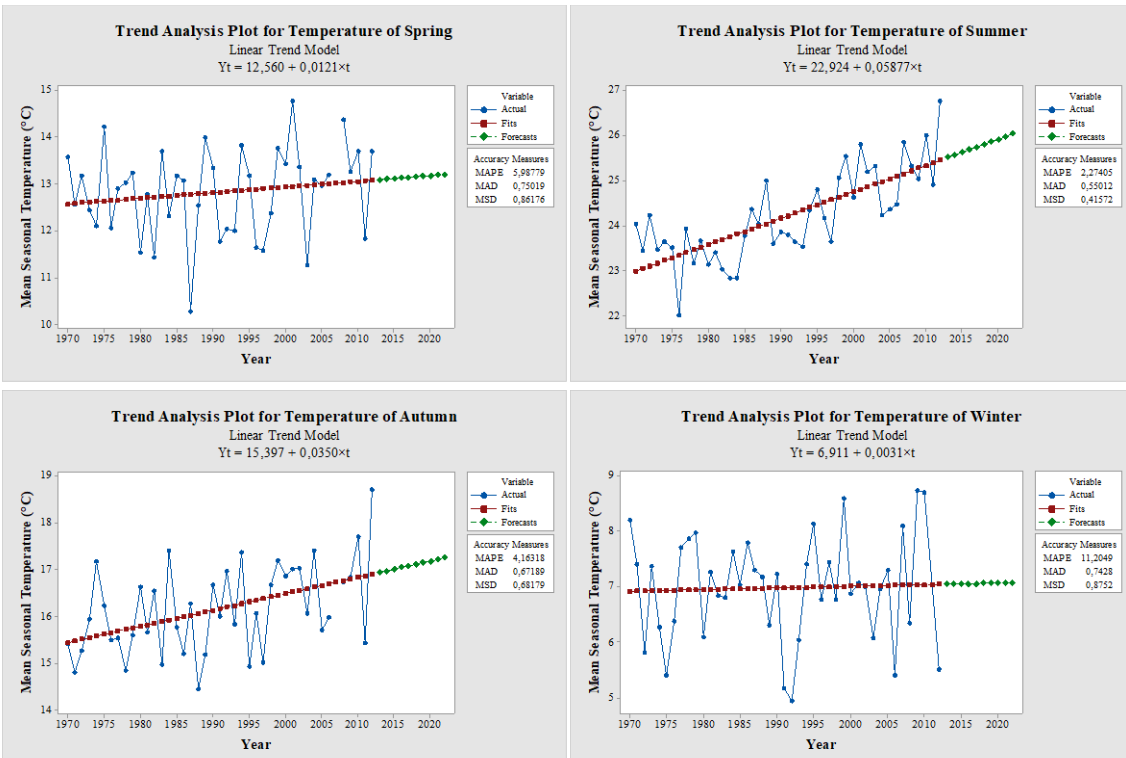

Figure 3. Trend analysis results of mean seasonal temperature.

Table 2. Predicted temperature values for 2018-2022

Temperature (°C)		***Year***				
		2018	***2019***	***2020***	***2021***	***2022***
	Mean Annual	15.8755	15.9053	15.9350	15.9648	15.9946
Mean Seasonal	*Spring*	13.1530	13.1651	13.1772	13.1893	13.2014
	Summer	25.8043	25.8631	25.9219	25.9807	26.0394
	Autumn	17.1104	17.1454	17.1804	17.2153	17.2503
	Winter	7.0621	7.0652	7.0683	7.0713	7.0744
Mean Monthly	*January*	6.3028	6.3040	6.3052	6.3065	6.3077
	February	6.1158	6.1032	6.0907	6.0781	6.0655
	March	8.6563	8.6680	8.6798	8.6915	8.7032
	April	12.7375	12.7419	12.7463	12.7507	12.7552
	May	18.0651	18.0853	18.1055	18.1257	18.1459
	June	23.6016	23.6423	23.6830	23.7237	23.7644

July	26.9460	27.0101	27.0743	27.1384	27.2026
August	26.8871	26.9591	27.0312	27.1032	27.1753
September	21.9233	21.9595	21.9958	22.0320	22.0683
October	17.0160	17.0531	17.0903	17.1274	17.1645
November	12.3920	12.4236	12.4551	12.4866	12.5182
December	8.6044	8.6205	8.6366	8.6527	8.6688

Pettitt's analysis stated that the change points for mean monthly temperature were determined 1983, 2002, 2001, 1996, 1993, 1994, 1993, 1984, 1981, 1989, 1983, and 1977 for the months from January to December, respectively (Table 1). The results of trend analysis demonstrated that temperature has an increasing trend for all months excepting February (Figure 4). Temperature values are forecasted to decrease for February. Mean monthly temperature values are estimated to increase 0.0012°C, -0.0126°C, 0.0117°C, 0.0044°C, 0.0202°C, 0.0407°C, 0.0641°C, 0.0720°C, 0.0362°C, 0.0371°C, 0.0315°C, and 0.0161°C per year for the months from January to December, respectively (Table *2*).

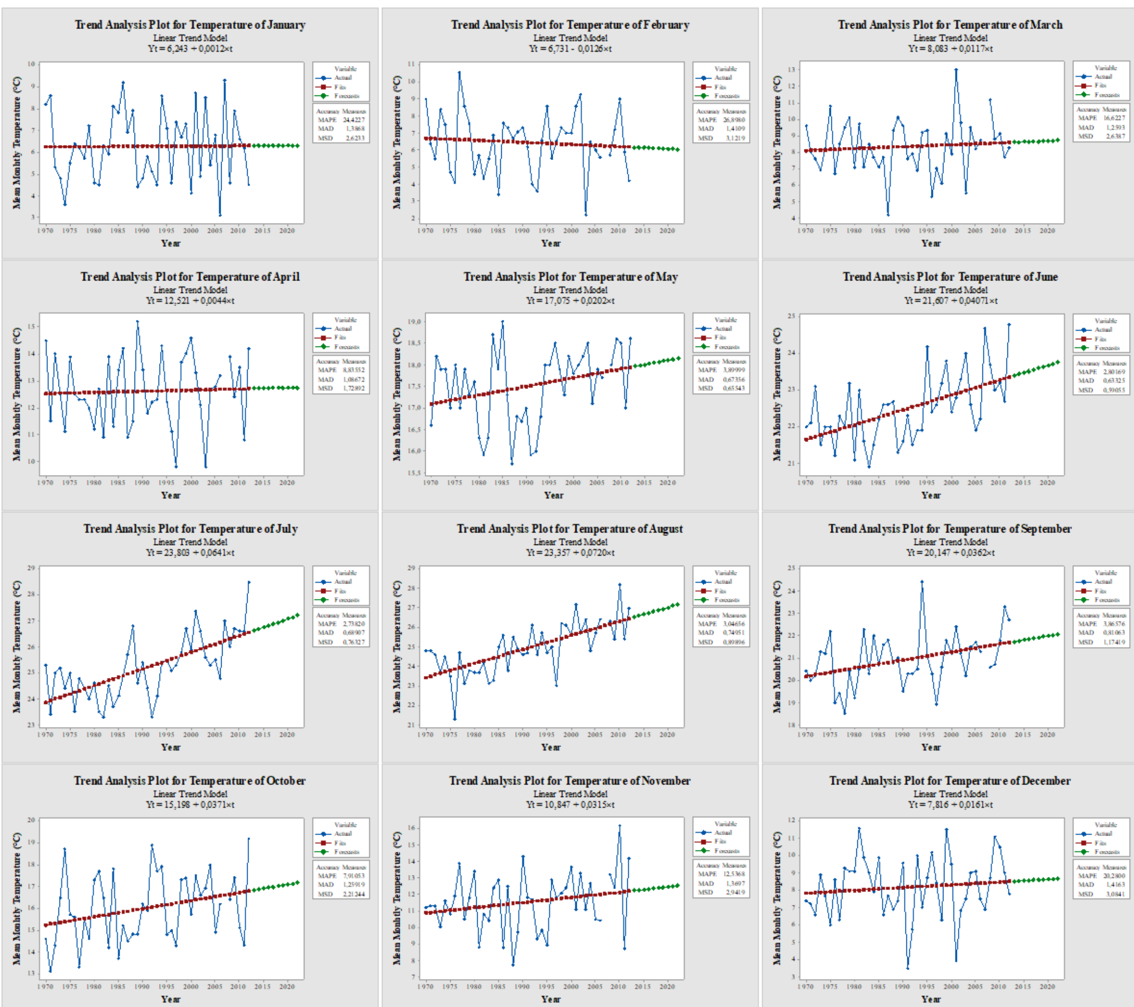

Figure 4. Trend analysis results of mean monthly temperature

Discussion

It is important that to investigate the climate change impacts and to take into account the outcomes of different climate change projects. One of the most important and fundamental indicators of global climate change is the variation in temperature. Most climate models expect an increase in temperature at the end of the 21st century (García-Ruiz et al., 2011). It is reported that increased temperature could be related to the global warming by (Chen & Xu, 2005).

In this study change points were found in 1990s. Similarly, previous studies on climatic changes in western part of Turkey specified that increasing trends in temperature over the study area were started in 1970s and progressively was clarified during 1990s (Aksoy, 2007; Aksoy et al., 2007; Türkeş & Acar Deniz, 2011).

Non-parametric Mann-Kendall and Spearman's rho tests pointed out that there were statistically significant correlation. Particularly, the correlation of mean annual temperature, mean seasonal temperature for summer and autumn, and mean monthly temperature for June, July, August, and September are significant at the 0.01 level. Also, the correlation of the mean monthly temperature for May is significant at the 0.05 level.

It was reported that the temperature increased in a statistically significant way in the Middle East between 1950 and 2003 (Zhang et al., 2005), in the south of Europe (Alcamo et al., 2007), in Turkey between 1971 and 2004 (Sensoy et al., 2008), between 1963 and 2007 (Durdu, 2010) and between 1975 and 2010 (Sütgibi, 2015). Particularly, Ejder et al. (2016a, 2016b) and Kale et al. (2016a, 2016b) reported that temperature has a statistically significant upward trend in Çanakkale. On the other hand, seasonal and monthly temperature trends were investigated by several authors (Karabulut et al., 2008; Şimşek et al., 2013; Ertaç et al., 2015; Tatlı & Altunay, 2015). Tatlı & Altunay (2015) investigated possible climate change effects in Turkey using monthly temperature dataset and reported that there were increasing trends for all seasons. Ertaç et al. (2015) forecasted monthly mean temperature for İstanbul (Turkey) and indicated that temperature has increased. Karabulut et al. (2008) studied temperature trends in Samsun (Turkey) and found that temperature increased both annually and seasonally. The authors have documented that summer season has a statistically significant increasing trend. Şimşek et al. (2013) examined annual and seasonal trends in meteorological data in Hatay (Turkey) and reported that all seasons have increasing trends excluding the winter season. Turan et al. (2016) investigated changes in sea surface temperature (SST) and possible effects on the biodiversity in the Turkish coasts of the Mediterranean, Marmara and Black Sea. They found that SST for all seas have increasing trends. Also, it is reported that the number of alien fish species in these seas have a highly increasing trend for the last two decades. Authors indicated that biodiversity will have significant change and there will be more invasion of the alien species in the Mediterranean. They highlighted that one of the major reasons of the alien species invasion in these seas is the increase of SST. Therefore, the results of this study are agreed with the results of other published papers and pointed out that temperature is increasing.

Mean annual and seasonal temperature values are estimated to increase year by year. Furthermore, mean monthly temperature values are predicted to increase for all months excluding February. Average values for February is forecasted to decrease between 2018 and 2022. Dixon et al. (2009) put excessive emphasis on some scientists anticipate winter seasons to have more precipitation in global circulation scenarios. On the other hand, February is one of the months of the winter season. Therefore, the decrease in the predicted temperature values for February could become understandable.

Climate projections are generated by using simulations of the climate change. These simulation studies could be inadequate caused by absence or unreliability of the data. Globally projected simulations may possibly not be usable locally. Limitations of this investigation may perhaps be incompleteness of the data or variability of climate systems. Long-term and continuous data have been used to eliminate these limitations in this study.

Conclusion

It was found that there was a statistically significant upward trend in temperature in Çanakkale. Mean annual, seasonal and monthly temperature are predicted to increase in general manner. It is crucial to state that Çanakkale city will be affected by global warming and climate change, and also will have a warmer climate in the future.

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