Statistical Analysis and Modeling (Forecasting) of the Temperature Time Series of Ahvaz Metropolis

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Abstract

Forecasting of temperature and precipitation can be efficiently used in decision making and optimal use of water resources. Studies in Iran have indicated a significant increase in annual temperature. This issue should be further researched in the Ahvaz region because it is the population hub in the southwest of Iran and the pole of irrigation networks and traditional agricultural land with huge number of oil, petrochemical, steel, and electricity industries. The present study aimed to analyze the time series of annual temperature of Ahvaz in order to determine the components of time series and especially to clarify the component of share rate trend and their variations. The condition of the next 60 years was then predicted and simulated in this study using the theory of stochastic time series along with the ratio trend. Results indicated that the temperature had an increasing trend equal to 3.81 °C/100 year.

Keywords: temperature time series, temperature increment trend, temperature statistical modeling, Ahvaz.

1. INTRODUCTION

Forecasting temperature and precipitation can be efficiently used in decision making and optimal use of water resources. Temperature is an important climatic indicator that is read and recorded daily in meteorological stations. Temperature is the most important factor in determining the role and distribution of other climatic elements. In addition, temperature has undeniable effects on hydrological cycles, crop production cycles, water use (especially agriculture), soil microorganisms and moisture, human activities, human tolerance thresholds, heat crimes and offenses, and the environment. Evaporation and evapotranspiration potential are important in all studies of hydroclimatology, irrigation and drainage calculations, water balance, and water requirement of plants, and play an essential role in determining and estimating the temperature. The studies conducted in Iran, which will be referred to in the review of references, indicate a significant increase in annual temperature. Clarification of this situation for the Ahvaz region is important due to the concentration of oil, petrochemical, steel, and electricity industries in the region with it being the pole of irrigation networks and traditional agricultural land, as well as environmental issues. Therefore, this research can answer the question of whether the temperature in the Ahvaz region has an increasing trend. Is this trend statistically significant? If so, how much does it increase? This research is carried out aiming to analyze the time series of annual temperature of Ahvaz in order to determine the components of time series, especially to clarify the component of share rate trend and their changes. The condition of the next 58 years were then predicted and simulated in this study using the theory of stochastic time series along with the ratio trend.

2. THEORY AND BACKGROUND OF RESEARCH

Time series models are needed for understanding the processes and recognizing the time series patterns. The time series models include the multiplicative and additive model, regression model, and autoregressive moving average model. The multiplicative and additive model is one of the classical patterns of time series and is based on the analysis of the series into other components. This model consists of four components of Trend, Cyclical, Seasonal, and Irregular. The multiplicative and additive model is written as follows:

$$Y = T + C + S + I \qquad (1)$$

$$Y = T.C.S.I \qquad (2)$$

In this research, a multiplicative model was used, and hence the construction of components in this model is described.

Trend component (T): The trend function may be linear, exponential, bending, etc. The time series is considered to be Yn. If Xn is a code number that is assigned to a time or period a line is fitted to the real series (dependent variable) using the smallest sum of squares method. The trend component is used for short-term forecasting provided that the compound component of the irregular period is not large. Otherwise, this component is considered first, especially for long-term forecasting, in which the irregular component and then the trend component are considered.

Seasonal component (S): Initially, the main series is smoothed first; the smoothed values are the trend-cyclical (T.C) component. Then, the irregular-seasonal component is obtained by dividing the series into this component, that is, Y/(T.C)=%. If this component is stable, the seasonal component can be obtained through averaging this component. The seasonal component is used for short-term forecasting. If the seasonal component is ignored during the process, the Y/S=C.T.I component will be obtained, and the component C.S.I/S=C.I will help determine the location of the cycle.

Cyclical component (C): This component demonstrates the variable cycles, and changes both in terms of time and domain. There are certain periodic change patterns (progressive, delayed, etc.) for many commercial and economic or agricultural processes. The cyclical component is used in the diagnosis of the current situation and the return cycles (direction change cycle). Therefore, the cycle in which the changes are located and the short-term forecasting of future changes can be stated by referring to these cyclical models and comparing them with the real-time cyclical series component.

Irregular component (I): After calculating the cyclical, seasonal, and trend components, the residuals and the effect of other factors are called the irregular component. Sometimes distinction of this component from the cyclical component is difficult; therefore, both components are considered the same.

Since Iran has a short history of using methods for direct measurement of climatic data, less attention has been paid to climate modeling. Rasouli (2002) used time studies to analyze the temperature of Tabriz and separated the components of time series while identifying its initial indicators. It was shown that the temperature of Tabriz during the 50 years of the study had an increasing trend, so that the trend component had a slope of 0.0265 [1]. Asakereh and Kheradmandnia (2002) used SARIMA modeling to model the average monthly temperature of Jask. In this research, a very good statistical period of 104 years was used. The simulation of the final pattern indicated an upward slope (the time series of the monthly temperature) [2]. In a study entitled "the Impact of Climate Change on Iran Temperature and Precipitation over the Coming Decades, using the MAGICC-SCENGEN Model," Abbassi et al. (2010) predicted an average temperature increase of 3-3.6 °C by 2100 for Iran, using two general atmosphere circulation models of ECHAM4 and HadCM2; the spatial distribution of temperature match in these models [3]. In a study using hydrologic methods and the results of the trend test, different areas of Gorganrood-Ghareh-Sou basin were evaluated in terms of the occurrence of the climate change phenomenon. The results showed that the occurrence of climate change in most areas of this basin is evident in the form of an upward trend at minimum and maximum temperatures in the summer and winter (confidence level of at least 95%) (Modarresi et al., 2010) [4]. Jahanbakhsh et al. (2010) investigated the climate parameters of temperature and precipitation in Karkheh basin meteorological stations using non-parametric methods such as Mann-Kendall method. Results showed that annual rainfall in most of the sub-basins in the region had a decreasing trend, while the temperature had an increasing trend. The significance level in this test was 95%. This means that in the study region, the mean annual temperature increased and the amount of annual precipitation decreased during this period. The results of the Mann-Kendall test indicated a significant trend in some stations, although the statistics at all stations were positive for temperature and negative for precipitation. Meanwhile, it was determined that the temperature and precipitation trends in the region do not follow a specific pattern [5]. In a study using the usual time series (mean of difference, moving average, regression equations, and z-score standard), it was determined that in Kerman, two major climatic elements, namely temperature and precipitation, had different trends during the 29-year statistical period of 1971-2000; meaning that, temperature had an increasing trend and precipitation had a decreasing trend over these years. In addition, these elements had not a similar change trend during the whole period, therefore, the correlation coefficient of annual and seasonal temperature and precipitation during the period was small. The annual temperature increase was 0.05 °C per year, and the highest rainfall reduction was observed in the two thermal periods of 1986-1990 and 1996-2000 by 27 and 20 mm, respectively (Bakhtiari, 2003) [6]. In a study entitled "the Temperature Change in the Mashhad Plain as an Index of Climate Change in the Region," Ebrahimi et al. (2005) reported that the increase in the amount of carbon dioxide and other greenhouse gases in the atmosphere has led to an increase in the mean temperature of the Earth (0.6±0.2) in the 20th century [7]. It is predicted that by 2050 the temperature of the Gorganrood basin will increase by about 1-3.5 °C (Sheikh and Babaei, 2009) [8]. Agriculture based on the social economy of the region is vulnerable to climate change. In an article entitled

"Climate and its Long-Term Variability over the Western Himalaya during the Past Two Centuries," Pant et al. (1999) reported that the mean temperature in Srinagar (Kashmir state, India) has increased at a rate of 0.8% in 100 years between 1893 and 1990 [9]. Fowler and Archer (2006) carried out a study entitled "Conflicting Signals of Climatic Change in the Upper Indus Basin" and reported a significant increase in the average annual temperature in Srinagar at a rate of 0.07 °C per decade during the period 1894-2000 [10]. Time series are also widely used in meteorology in river flow parameters. Fernando and Jayawardena used various ARMA models to predict monthly rainfall [11]. Venema et al. studied the climatic changes in the Senegal River basin in the same way [12]. Yurekli and Kurn used the stochastic methods to predict the daily minimum discharge for each of the three hydrometric stations of Cekerek Stream basin for use in drought analysis. They used two models of ARIMA and Thomas-Fiering [13].

3. MATERIALS AND METHODS

In this research, the 60-year monthly and annual temperature data of Ahvaz were obtained from 1957 to 2016 from the Meteorological Organization of Khuzestan province. The data were organized and analyzed with Excel spreadsheet and SPSS. The data were based on the Gregorian Calendar and were not converted to the Solar Calendar due to the objectives of the study. However, in order to analyze the time series on a seasonal scale, the necessary conversions were made based on the Solar Calendar. The study was carried out through the following steps.

A) Collection of monthly and annual temperature data of Ahvaz and their analysis with SPSS.

B) Extraction of raw data, moving average, and variability.

C) Determination of different components of temperature time series using time series theories and techniques.

D) Using the stochastic statistical model, along with the trends and prediction of the future situation**.**

4. RESULTS AND DISCUSSION

4.1 Results of time series analysis of average annual temperature

In order to analyze the temperature time series, the time series graphic indices, namely raw and smoothed data, moving average, and variability, as well as main indices of time series such as Trend, Cyclical, Seasonal, and Irregular components were extracted from the main data. To determine the temperature behavior of Ahvaz synoptic station, the average annual temperature was analyzed by SPSS. The results of changes in the average annual temperature or raw observation index were also calculated (Fig. 1). As can be seen, the average annual temperature is 25.5 °C ranging from 23.44 °C to 27.4 °C. The standard deviation of the statistical period is less than 1 °C and the series skewness is slightly negative and close to zero, indicating the consistency of the data and their convergence with normal distribution. Moving mean of the observational data series revealed the annual fluctuations of the adjusted temperature and the smooth index. With repeated group average from observational data, the moving mean index was calculated which is a variability index of other indices that is used in the preliminary analysis of the time series and indicates the pattern of annual data changes. Figure 2 depicts the average moving index of 5 years. In order to more accurately analyze the temperature observations, the main components of temperature time series including Trend, Cyclical, Seasonal, and Irregular were considered, and the components were separated by the multiplicative mathematical model. To this end, the trend component was computed first through the least squares of the observational series, then the cyclical component was calculated. On the other hand, given that the annual observations of the temperature usually have no seasonal effects, the irregular component is easily available given the clarification of the trend and cyclical components. The results of these calculations are presented in Figures 3 to 5. As previously mentioned, the irregular component refers to residuals and the effect of other factors after calculating the trend, cyclical, and seasonal components. Sometimes distinction of this component from the cyclical component is difficult; therefore, both components are considered the same. In this study, it is hard to distinguish the difference between these two components.

In order to extract the seasonal component, the moving average coefficient method was used. In this method, observations were first smoothed through the integrated moving average. This results from the multiplication of trend and cyclical components by time series. Then, the result of seasonal and irregular components multiplication is obtained using Equation 2. In the next step, the seasonal component was extracted through removing the effects of the irregular component from the equation by means of averaging.

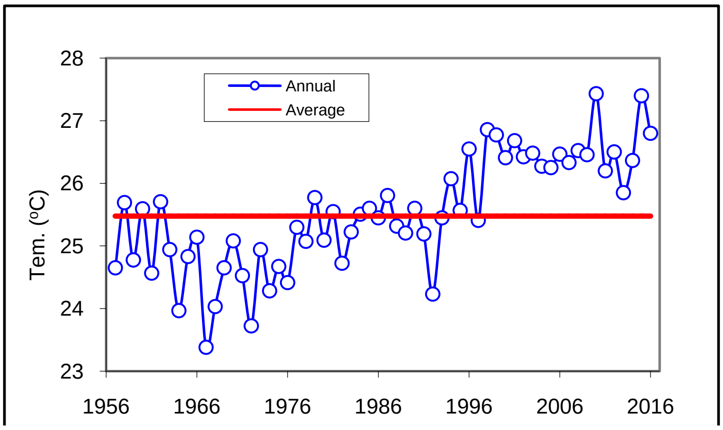

Figure 1. Average annual temperature changes in Ahvaz (raw observation index)

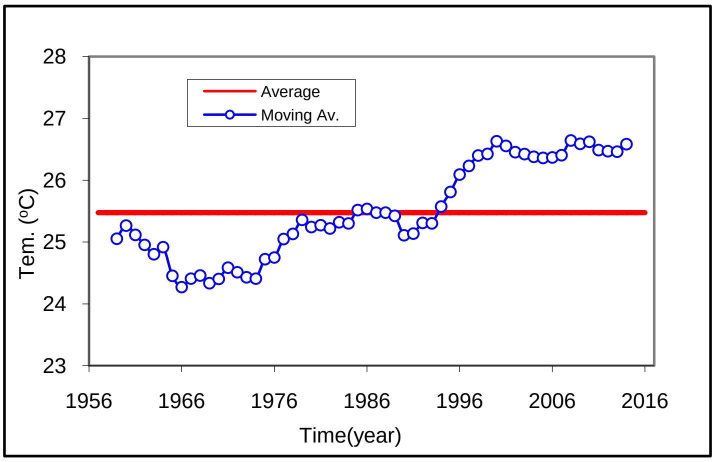

Figure. 2. The 5-year moving index average of Ahvaz annual temperature

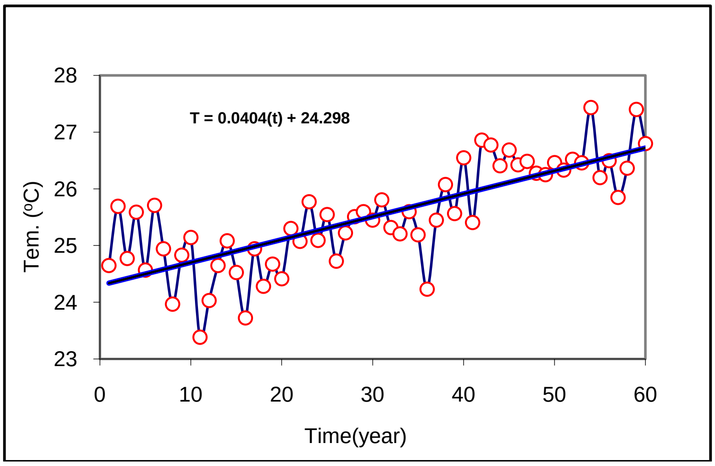

Figure 3. The trend of average annual temperature in Ahvaz

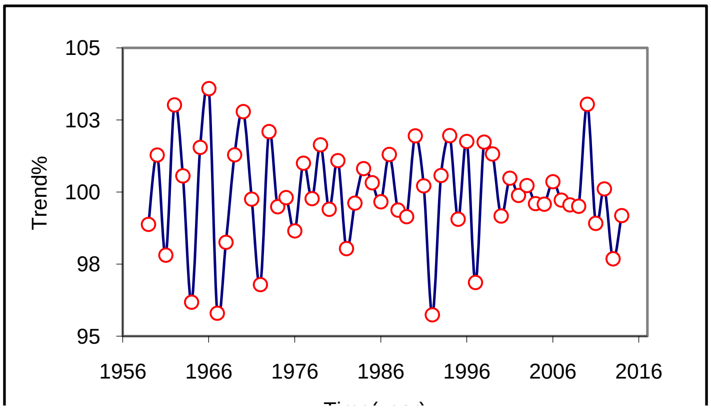

Figure 4. Variability component of trend of average annual temperature in Ahvaz

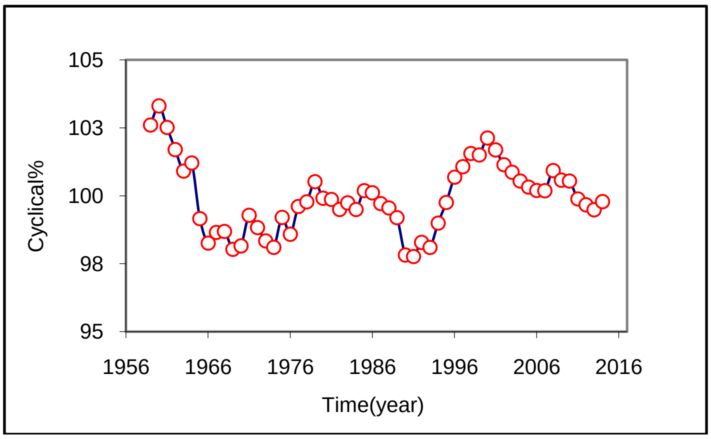

Figure 5. The rate of changes in the cyclical component of Ahvaz average annual temperature

4.2 Results of simulation of average annual temperature

As mentioned, the 60-year monthly and annual temperature data of Ahvaz were analyzed in this study from 1957 to 2016. Using the theory of stochastic time series and the trend, the conditions of the future 60 years were then forecasted and simulated. To this end, the pure time series of the average annual temperature was calculated. Figure 6 shows the pure time series of Ahvaz average annual temperature. As can be seen, the correlation coefficient between the observations time sequence is zero, which is a strong reason to eliminate the trend component. The autocorrelation values were then calculated in different delay steps. Thereafter, the future situation was forecasted using the autocorrelation, variance, and mean of the present series. The simulation of the average annual temperature series of Ahvaz during the past 60 years and the next 60 years is shown in Fig. 7. Finally, the monthly temperature statistics was produced and an exponential regression model was fitted between the average and absolute monthly temperatures. The model's coefficients and the coefficient of determination are significant at the 1% level. Using this model, the absolute temperature was estimated in the next 60 years. The correlation between the average and absolute monthly temperature in Ahvaz is shown in Fig. 8, and the comparison of the average monthly temperature of both past and future 58 years is shown in Table 1. Comparison of the average annual temperature groups of the two past and future 60 years was done using the independent samples test which results are presented in Table (2).

The results presented in Table 1 show that the average annual temperature of the past 60-year period was 25.48 °C and the next 60 years will be 27.68 °C. In other words, the average annual temperature increase in Ahvaz is expected to be 3.18 °C per 100 years, which represents an increase of about 15% over a century. But the absolute temperature of the past 60 years was 54 °C. This event was recorded on July 15, 1967. It is predicted that if the temperature rising trend continues with this rate, the absolute temperature will reach 56 °C in July of the next 60 years. It is worth noting that the used model is statistical and cannot accurately express the year of occurrence of this temperature, but the results of the model indicate the occurrence of this temperature in the next 60 years. Certainly, the chance of its occurrence will increase with approaching the end of the next 60 years.

The average annual temperature difference between the past and future 60 years is 2.4 °C. The independent samples test showed a significant difference at the 1% level between the average annual temperature of the two periods and indicates a confidence of 99% regarding the occurrence of the temperature variation attributed to the global warming phenomenon.

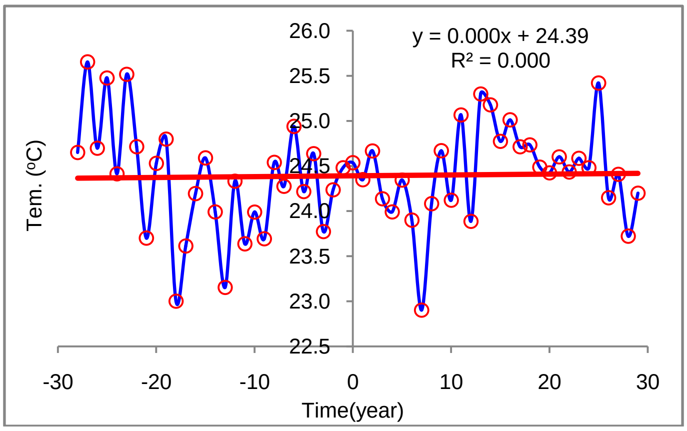

Figure 6. Relatively pure time series (r=0) of Ahvaz average annual temperature

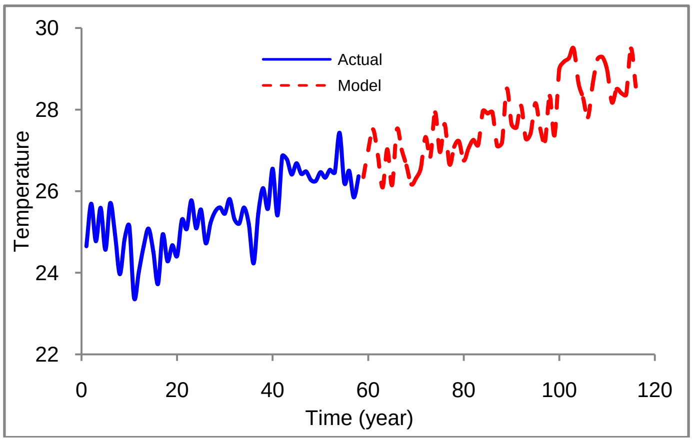

Figure 7. Simulation of the average annual temperature of Ahvaz (past 60 years and next 60 years)

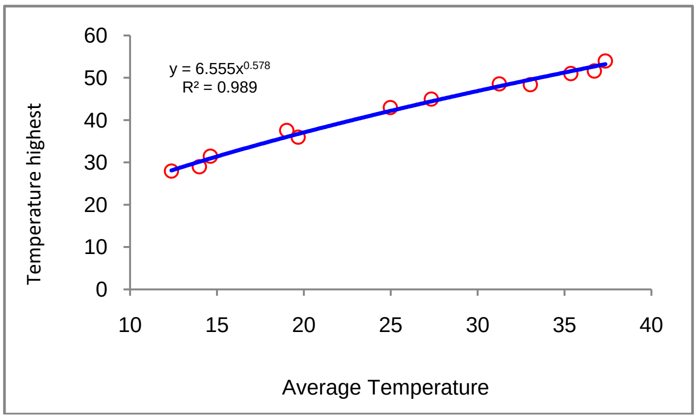

Figure 8. Correlation between the monthly average and absolute temperature in Ahvaz

Table 1. Comparison of the monthly average temperature of the past and future 60 years

Month	60-year average periods			60-year maximum absolute periods		
	Current	Future	Difference	Current	Future	Difference
Jan	12.38	13.45	2.21 °C difference equal to 8.7%	28.00	29.45	2.14 °C difference equal to 5.1%
Feb	14.63	15.90		31.50	32.43	
Mar	19.02	20.67		37.60	37.74	
Apr	24.97	27.14		43.00	44.17	
May	31.24	33.95		48.60	50.28	
Jun	35.36	38.43		51.00	54.01	
Jul	37.35	40.59		54.00	55.75	
Aug	36.72	39.90		51.60	55.20	
Sep	33.03	35.90		48.40	51.93	
Oct	27.33	29.70		45.00	46.54	
Nov	19.67	21.38		36.00	38.48	
Dec	13.99	15.21		29.00	31.61	
annual	25.48	27.68		54.00	55.75	

Table 2. Results of the independent samples test for comparison of the annual of average temperature groups of the past and future 60 years

Group		N	Mean	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Temp	1.0	60	25.48	-2.20	0.874	-13.3	114	0.000
	2.0	60	27.68		0.911			

5. CONCLUSIONS

The results of this study showed that time series at annual and seasonal scale have significant changes over time, so that the temperature variability index is 95.7-103.6, the cyclical component is 98-103.25, and the irregular component is 95.75-104.24. In addition, the 5-year moving average indicator shows an average annual temperature variation of 24.3-26.6 °C.

Analysis of the various time series components of the annual temperature indicates the increasing trend of this parameter. According to Figure 4, the relationship between the increasing trend of temperature and time is YT=0.0404T+24.298, from which the temperature increase trend can be calculated as 3.8 °C/100 years.

The average annual temperature of the past 60 years was 25.48 °C and the future 60 years will be 27.68 °C. In other words, an increase of 2.2 °C in the average temperature is expected in Ahvaz in 60 years; this figure is about 15% increase over a century.

The absolute temperature of the past 60 years was 54 °C. This event was recorded on July 15, 1967. It is predicted that if the temperature rising trend continues with this rate, the absolute temperature will reach 56 °C in July of the next 60 years. It should be added that the used model is statistical and cannot accurately express the year of occurrence of this temperature, but the results of the model indicate the occurrence of this temperature in the next 60 years. Certainly, the chance of its occurrence will increase with approaching the end of the next 60 years.

The difference between the average annual temperature of the past and future 60 years is 2.2 °C. The independent samples test showed a significant difference at the 1% level between the average annual temperature of the two periods and indicates a certainty of 99% regarding the occurrence of the temperature variation attributed to the global warming phenomenon.

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