Seasonal and annual trend analysis of meteorological data in Sanliurfa, Turkey

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Abstract: Global rising temperature has become more of an issue among societies and governments worldwide due to the environmental changes and climate warming. In this regard, the trend analysis of hydro-meteorological variables (such as precipitation, temperature, wind speed, humidity etc.) provides reliable outcomes for a better planning and management of water resources. Historical data possess time dependent characteristics that are generally being affected by climate variability and changes. For this reason, it is vitally important to scrutinize the changes in hydro-meteorological parameters for water supply management. In this study, minimum temperature (MiT), maximum temperature (MaT), mean temperature (MeT), mean humidity (MH), mean wind speed (MWS) and total precipitation (TP) data are obtained for the period from 1975 to 2015 for Sanliurfa region which is an important agricultural area located at the southern east of Turkey. According to the meteorological data, the trend analysis is carried out using non-parametric Mann Kendall and Spearman's Rho tests. Sen's slope trend method is employed for detecting the slopes of trend. The beginning years for the trend of the stations which present statistically significant trend are estimated using Mann-Kendall Rank Correlation test. Accordingly, the variations in hydro meteorological data in Şanlıurfa province during 1975 to 2015 have been examined in detail.

Key words: Sanliurfa region, Trend Analysis, Mann-Kendall Test, Spearman's Rho Test, Sen's slope

1. INTRODUCTION

Climate change can be described as major variations in the average climate in long terms. Although the climate change is taking place on a global scale, its effects are generally varying from region to region (Trajkovic and Kolakovic, 2009). For this reason, the trend analysis on the meteorological variables represents an important task in determining the climate change and water resources planner. In recent times many researchers have given great importance to the trend analysis for the hydro-meteorological variables due to climatic changes. A number of studies have been conducted to identify trends in climate change occurred worldwide. (Erlat and Türkeş, 2012, Sayemuzzaman et al., 2015, Chowdhury et al., 2015, Adarsh and Janga Reddy, 2015, Mohsin and Gough, 2009, Madsen et al., 2014). However, most of these studies have focused only on temperature and precipitation variations. Bahadır and Özdemir (2011) carried out the statistical analysis on the changes in the watershed climate and the level of Iznik Lake to determine the trend analysis. For the determination of the relationship between the climate elements and the variations in the lake elevation, the correlation and the regression analyses were carried out. The trend inclinations were determined using Quadratic and Linear Trend models. As a result, it was estimated that according to the trend analysis carried out in order to determine the level changes of Iznik lake, the lake level may decrease approximately 30 cm until the year of 2025. Altın et al. (2012) examined the variations in precipitation and temperature data from 1975 to 2007 for the 33 stations at the borders of the Central Anatolian Region. According to the Mann-Kendall test results, it was stated that the intensity of rainfall decreases in winter and spring, and increases in summer and autumn. Gocic and Trajkovic (2013) analysed the annual and seasonal trends of seven meteorological variables for the twelve weather stations in Serbia during 1980-2010. The non-parametric Mann-Kendall and Sen's methods were used to determine the trend in weather data.

They stated that the results of using the Mann-Kendall and Sen's tests demonstrated the good agreement of performance in detection of the trend for meteorological variables. Kisi (2015) performed a trend analysis of monthly pan evaporations by using recently developed innovative trend analysis (ITA) method for the six different locations in Turkey. They investigated the monthly trends of pan evaporation by non-parametric Mann–Kendall (MK) method. According to ITA and Mann-Kendall method results, the trends for six locations were estimated. Wu and Qian (2016) investigated the trends in annual and seasonal rainfall at the 14 rainfall stations in Shaanxi Province, China, using the methods of ITA, Mann–Kendall test and linear regression analysis. The aim of their study was to evaluate the results from ITA with the Mann-Kendall test and linear regression analysis and to identify the statistical significant trends.

In this study, the trend analysis on the six meteorological variables (i.e. minimum temperature-MiT, maximum temperature-MaT, mean temperature-MeT, mean humidity-MH, mean wind speed-MWS and total precipitation-TP) for Sanliurfa station located in the southeast of Turkey. It is performed for seasonal and annual data. The non-parametric Mann-Kendall and Spearman's Rho tests are used to determine the significant trend. Sen's slope trend method is used to determine the slopes of trend. The beginning years for the trend of the stations which present the significant trend are determined using the Mann-Kendall Rank Correlation test.

2. MATERIALS AND METHODS

2.1 Study area and data

Since Sanliurfa region is having important characteristics for the economic and social developments in Turkey, this region is selected in this study to determine the trend of the meteorological variables for this region.
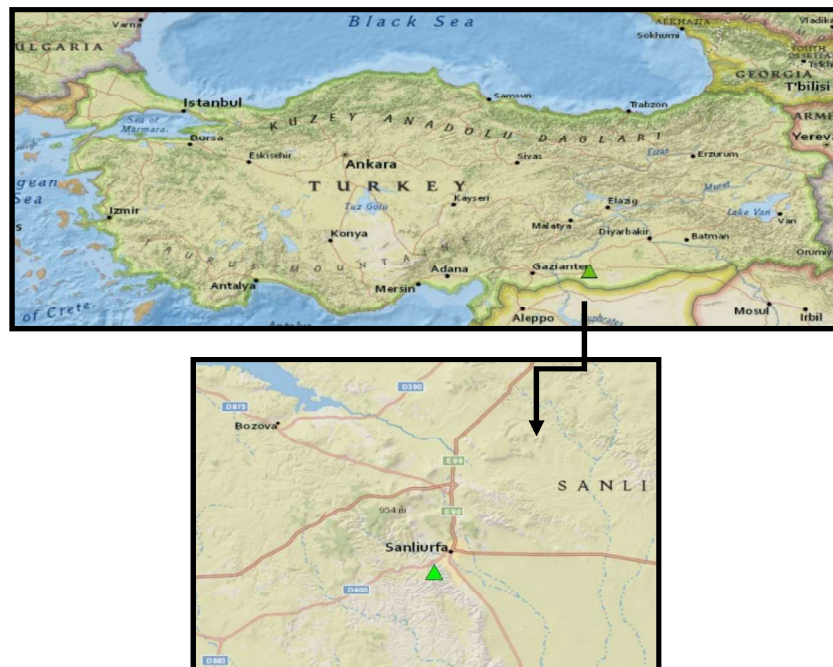

Figure 1. Study Area

The 41-year (1975-2015) monthly mean, maximum and minimum temperature, wind speed, humidity and total precipitation values from Sanlıurfa station obtained from Turkish State Meteorological Service and used to determine the seasonal and annual trend analysis. The seasonal and annual mean values of the meteorological variables are given in Table 1.

Table 1. The seasonal and annual mean values of the meteorological variables

	MeT (^{o}C)	MiT (^{o}C)	MaT (^{o}C)	MWS (m/s)	MH (%)	TP (mm)
Winter	6.82	-1.62	17.10	1.24	69.18	225.8
Spring	16.70	5.34	29.65	1.67	54.14	131.6
Summer	30.66	18.60	41.58	2.19	33.70	5.7
Autumn	19.95	9.54	32.43	1.43	49.27	79.5
Annual	18.53	7.96	30.19	1.63	51.57	443.8

2.2 Methods

In this study, the Mann–Kendall test (Mann, 1945, Kendall, 1948) and Spearman's Rho test (Yue and Wang, 2002) are used to determine statistically significant trend for the meteorological variables. These tests are popular and reliable non-parametric tests for the hydro-climatological time series and widely used worldwide. Since the Mann–Kendall and Spearman's Rho tests requires time series to be serially independent, in order to remove the serial correlation from the data sets, Von Storch and Navarra (1995) have suggested to pre-whiten the time series data in advance. Therefore, the serial correlation is tested before applying the Mann–Kendall and Spearman's rho tests. The detail of this procedure is given in Gocic and Trajkovic (2013).

The Mann–Kendall rank correlation test is used to determine the trend-initiating year. This test does not take differences in magnitude of the values into account, it only counts the number of consecutive values where the value increases or decreases compared with the prior values (Yenigün ve ark. 2008). The true slope in terms of the per unit time is estimated by adopting a following non-parametric procedure developed by Sen (1968) for the case of a linear trend (Kahya and Kalaycı, 2004, Yenigün et al., 2008).

3. RESULTS

Figure 2 provides the Lag-1 serial correlation coefficients for the considered parameters of mean, maximum and minimum temperature, wind speed, humidity and total precipitation (denoted as MeT, MiT, MaT, MWS, MH and TP, respectively) based on the seasonal and annual periods. The bold lines in Figure 2 represents the probability limits on the correlogram for an independent series of r_1. Figure 2 shows both positive and negative serial correlation for all variables. Figure 2 indicates that the positive serial correlation is determined to be significant in all meteorological variables except TP, and the corresponding negative serial correlation is obtained for only the summer session of TP values. The trend analysis is undertaken using the pre-whitened time series, in order to remove serial correlation from the data sets.
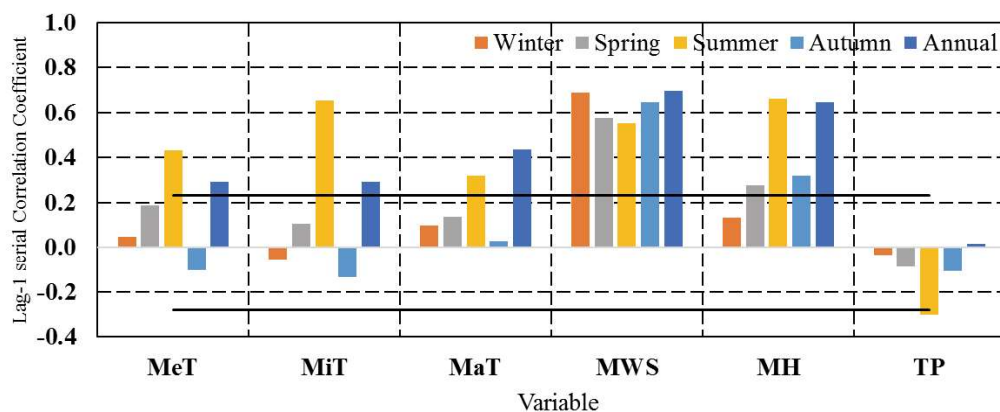

Figure 2. Lag-1 serial correlation coefficient for the seasonal and annual parameters of MeT, MiT, MaT, MWS, MH and TP (the bold line represents the probability limits on the correlogram for an independent series, r_1)

The results of Mann–Kendall and Spearman's rho tests are given in Figure 3. According to the figure, it can be stated that both methods provide the same results, except MeT for winter considering the statistically significant trends at 5% significant level. Figure 3 demonstrates that a positive trend at a 5% significance level is determined in all seasons and annual temperatures values except MeT and MiT for winter. The negative trend at 5% significance level is detected only for MH in the spring period. According to Figure 3, the significant positive trend for TP is only determined in the summer period.
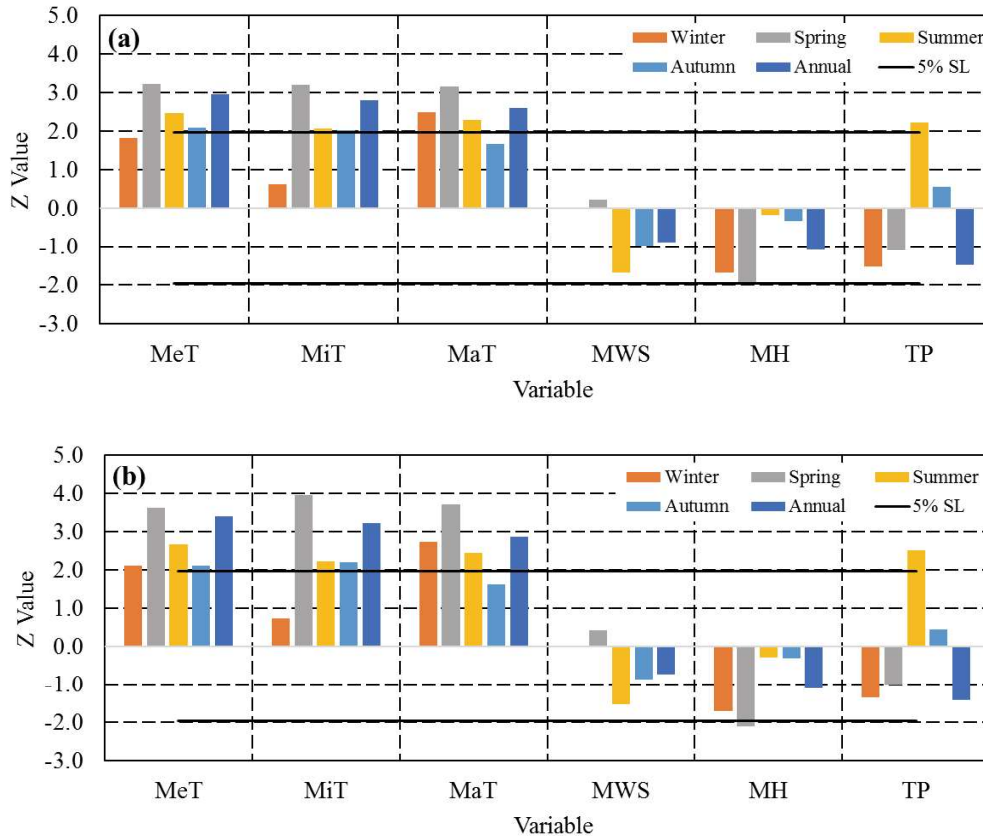

Figure 3. The results of trend analysis (a) Mann–Kendall test (b) Spearman's rho test

Figure 4 shows the linear slope values calculated by using Sen's Trend slope method on the meteorological data. Accordingly, the highest change for MeT is obtained in the spring season with 0.053 C/year, while the lowest value is observed in the autumn with about 0.022 C/year. According to Figure 4 (b), the highest change of the MiT values is determined at summer as 0.08 C/year. In Figure 4 (c), it is also determined for MaT, similar to the results for MeT, the highest change is set at 0.061 C/year in the spring period and the lowest change is set as 0.025 C/year in the autumn period. According to Figures 4 (d-f) the highest changes are determined as -0.014 m/s/year in the summer period for MWS, -0.152 m/s/year in the spring for MH and -1.5 mm/year in the annual data for TP.

Table 2 shows the trend initiate years determined by the Mann-Kendall rank correlation test for the six meteorological variables for Şanlıurfa station. According to the results, the beginning years for the trend variations are between 1979-1987 for winter, 1988-2010 for spring, 1978-1995 for summer, 1993-2007 for autumn and 1993-2003 for annual values. Additionally, the increasing trend of the temperature starts especially from the middle of 1990s and the early 2000s.

The graphs of $u(t)$ -$u'(t)$ obtained by the Mann-Kendall rank correlation test for the temperature values are given in Figure 5. It shows that the increasing trend is clearly visible at 5% significance level.
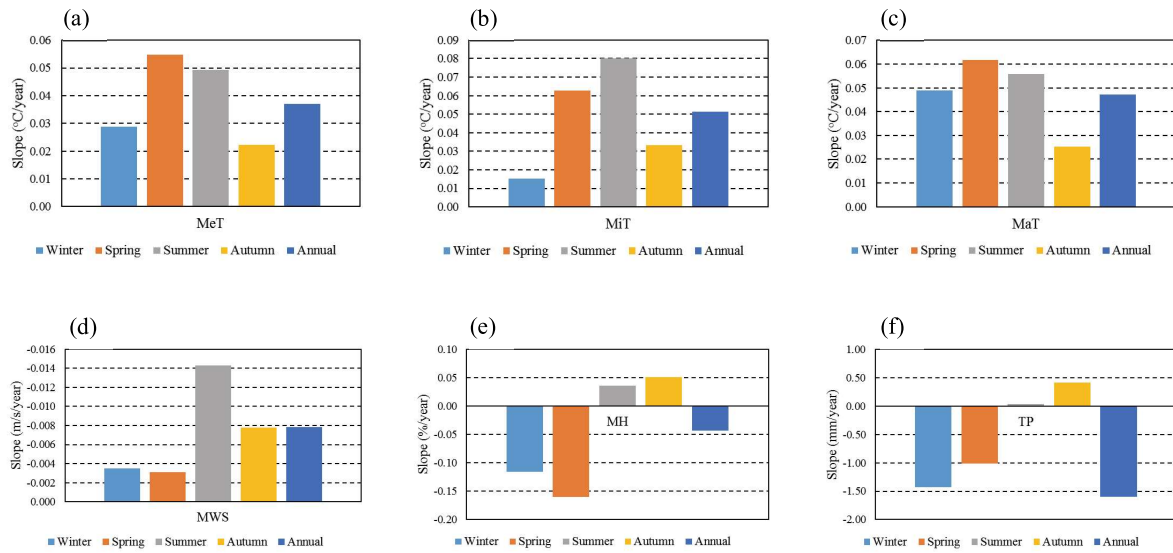
Figure 4. The linear slopes of (a) MeT (b) MiT (c) MaT (d) MWS (e) MH (f) TP

Table 2. The beginning year of the trends according to the Mann-Kendall rank correlation test

	Winter	Spring	Summer	Autumn	Annual
MeT	1979	2001	1995	1993	2003
MiT		1994	1991	2007	1997
MaT	1987	1988	1995	1994	1993
MWS			1980		
MH	1983	2010			
TP			1978		

Figure 5. The Mann-Kendall rank correlation results of (a) (b) (c)

4. CONCLUSION
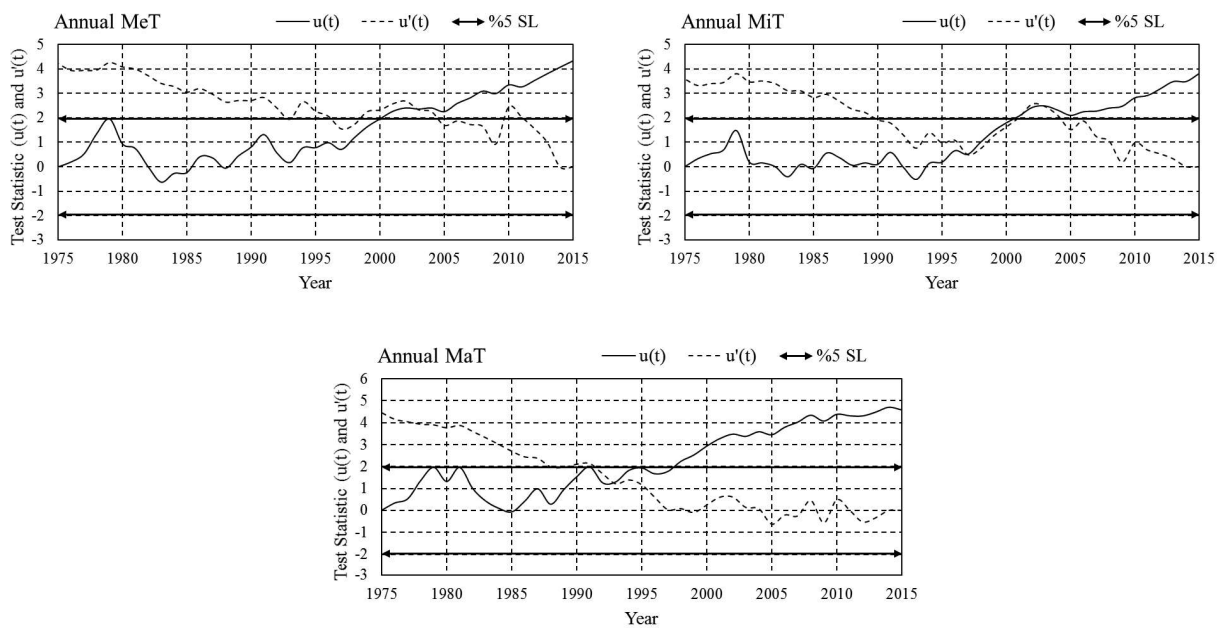
Based on the findings from the presented study, the following conclusions may be drawn:

- Both positive and negative serial correlation are determined for all variables. The trend analysis is undertaken using the pre-whitened time series in order to remove serial correlation from the data sets.
- The Mann–Kendall and Spearman's rho tests give the same results for 5% significant level. The positive trend at a 5% significance level is determined in all seasons and annual temperatures values except MeT and MiT for winter. Negative trend at 5% significance level is detected only in MH for Spring period.
- The highest change for MeT is obtained in the spring season with 0.053 C/year, while the lowest value is observed in the autumn period with about 0.022 C/year. According to Figure 4 (b) the highest change for the MiT values is determined at summer period about 0.08 C/year. In Figure 4 (c), it is also determined for MaT, similar to the results for MeT, the highest change is set at 0.061 C/year in the spring period and the lowest change was set at 0.025 C/year in the autumn period.
- The highest changes are determined 0.053 C/year in the spring period for MeT, 0.08 C/year in the summer period for MiT, 0.061 C/year in the spring period for MaT, -0.014 m/s/year in the summer period for MWS, -0.152 m/s/year in the spring period for MH and -1.5 mm/year in the annual data for TP.
- The increasing trend of the temperature starts especially from the middle of 1990s and the early 2000s.

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