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Spatio-Temporal Analysis of Regional Trends and Shift Changes of Autocorrelated Temperature Series in Urmia Lake Basin

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Abstract Recently, the Urmia Lake located in northwestern Iran which is the second largest hyper saline in the world suffers from the significant fluctuations of water level and surface area. The current study tries to investigate the spatiotemporal trends of mean (T_{mean}), maximum (T_{max}) and minimum (T_{min}) temperatures of monthly, seasonal and annual time-series. To do so, the data of 15 temperature gauge stations within the Urmia Lake basin, for the period 1972–2011 was employed. The pre-whitening approach was applied to remove the effects of serial correlation in the air temperature series based on the Mann-Kendall (MK) test. The results of Ljung-Box test showed positive serial correlation in the T_{mean} and T_{max} series for all of the stations at the 0.05 significance level. In the monthly series, the significant warming trends in the T_{mean} series were more perceptible than the same ones in T_{max} series; however, T_{max} trend was found more than T_{min} series. The Mann–Whitney (MW) test detected a significance upward shift changes in the annual T_{mean}, T_{max} and T_{min} series of about 86, 73 and 80 % of the stations, respectively. The average magnitude of significant warming trends in annual T_{mean}, T_{max} and T_{min} series were (+) 0.58 °C, (+) 0.52 °C and (+) 0.69 °C per decade, respectively. Furthermore, the interpolation maps showed that warming trends in the east and west of Urmia Lake were more than southern area. Therefore, the results showed that the basin has suffered from increasing trends in the T_{mean}, T_{max} and T_{min} over the recent decades. Finally, significant changes were found in 1980s and 1990s based on the Mann-Kendall ranks and change point tests. In this study, it is interesting that the period of significant changes in warming trends were close to the beginning of decreasing water level of the Lake.

Keywords Climate variability · Trend · Serial correlation · Urmia Lake · Temperature series

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1 Introduction

Temperature, among the various dominant atmospheric variables, has a significant and direct influence on almost all hydrological variables (Sonali and Nagesh Kumar 2013). Several studies have reported that temperature is increasing owing to rise in greenhouse gases and human activities (Feidas et al. 2004). According to the Intergovernmental Panel on Climate Change (IPCC 2007), the mean air temperature of global surface has increased by 0.74± 0.18 °C during 1906–2005, which is likely related to the increased human activities and anthropogenic greenhouse gas concentrations (You et al. 2013). The analysis of long-term trends constituting such changes in climatic variables as temperature is a crucial target in studies on climate variability and change detection (Ghasemi and Khalili 2008). Several researchers have studied the long-term trend of temperature series across the world (Salinger 1995; Przybylak 2001; Yue and Hashino 2003; Machiwal and Madan 2006; Staudt et al. 2007; Esteban-Parra et al. 2007; Zhang et al. 2009; Mamtimin et al. 2011; Martinez et al. 2012; Dasha et al. 2012; Boccolari and Malmusi 2013; Gocic and Trajkovic 2013). Kousari et al. (2011) studied trend of mean, minimum and maximum air temperature, precipitation and relative humidity based on the Kendal test in Iran and suggested an increasing trend for air temperature while a decreasing one for precipitation and relative humidity at the majority of the studied stations. del Rio et al. (2013) employed statistical tests in Pakistan in order to determine the recent mean temperature trend and revealed that the temperature has generally increased in Pakistan at all-time analyzed scales over the past decades.

Urmia Lake basin, one of the six large basins in Iran, has been shrinking for the recent 15 years. As a consequence, the water surface area has decreased from 6100 to 4750 km^2, while its water level declining about 6 m (Fathian et al. 2014). Shokoohi and Morovati (2015) in their research showed that the Urmia Lake basin faced the most severe drought condition but it cannot be only reason for the lake dry up; however, some human activities such as dam construction, overexploiting of surface and groundwater during drought periods could be effective in intensifying the natural drought effects. The changes in hydrological parameters such as precipitation and evaporation may occur due to the perceptible increases in the surface temperature. The existence of an uptrend or downtrend in a hydrological time series can also be described by changes in surface air temperature as one of the most effective meteorological driver in the hydrological processes. Therefore, a trend analysis of air temperature is the first step to investigate the probable causes of declaring water level in Urmia Lake basin.

Several researches have been carried out to examine the surface air temperature trends in Iran over the last decades; however, no comprehensive basin scale based efforts have been to determine air temperature. In other words, most of the researches were focused on provincial boundary instead of the watershed boundary. Moreover, most of the former investigations did not consider the serial correlation of the air temperature time scales and their probable adverse impacts on such trend tests as MK test. The primary aim of present research is to assess the effect of serial correlation on T_{mean}, T_{max} and T_{min} series based on the MK test. The secondary objective is to analyze spatio-temporal trends in T_{mean}, T_{max} and T_{min} air temperature at the monthly, seasonally and annually scales by utilization of interpolation technique including Modified MK, Mann–Whitney (MW), linear regression and Sen's slope estimator tests. Finally, the shift and abrupt changes were considered based on the MK rank statistic and change point tests including; Buishand's, SNHT, Pettitt's tests. Thus, analysis of the variations in temperature will help us to better understand of the climate variability in the Urmia Lake basin (ULB).

2 Material and Methods

2.1 Study Area and Data

Located in northwest of Iran, Urmia Lake basin covers a catchment area of 51, 800 km^2. It is one of the six main river basins of Iran which consists of 14 main sub-basins. Urmia Lake basin has three most important rivers, namely, Aji Chai, Zarrineh Roud and Simineh Roud. Located in center of the basin, Urmia Lake is the second largest hyper saline lake in the world that experience serious decreasing in water level and surface area which has led to its alarmingly shrinking status. In this work, T_{mean}, T_{max} and T_{min} temperature series collected from the 15 gauging stations within the basin which had the valid and adequate data for the period of 1972–2011. The geographic location of temperature gauge stations are shown in Fig. 1.

2.2 Methods

2.2.1 Mann-Kendall Test

The Mann–Kendall test is a non-parametric test, with no requirement to the normal distribution of data. The null hypothesis H_o indicates that the depersonalized dataset ($x_{1,}\dots, x_n$) is a sample of n identically distributed and independent random variables while the alternative hypothesis of a two-sided test (H_1) means that the distribution of x_k and x_j are not identical for all $k, j \leq n$

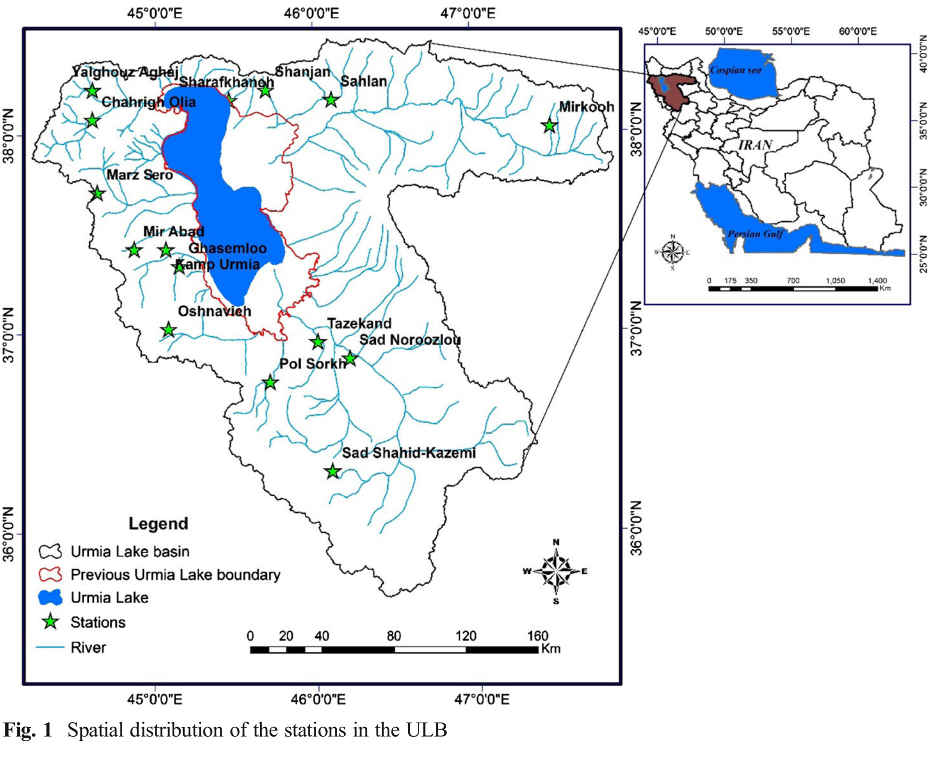

Fig. 1 Spatial distribution of the stations in the ULB

with $k \neq j$. The test statistic S is a asymptotically normal which has mean zero and a variance computed by Eqs. (1) and (2) (Partal and Kahya 2006):

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\left(x_j - x_k\right) \tag{1}$$

$$sgn\left(x_j - x_k\right) = \begin{cases} +1 & if \ \left(x_j - x_k\right) > 0 \\ 0 & if \ \left(x_j - x_k\right) = 0 \\ -1 & if \ \left(x_j - x_k\right) < 0 \end{cases} \tag{2}$$

$$Var(s) = \frac{n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)}{18} \tag{3}$$

where t is the extent of any given tie while $\sum t$ states the summation over all ties. When the sample size n >10, the standard normal variable Z is calculated using Eq. (4) (Tabari and Marofi 2011):

$$z = \begin{cases} x = \dfrac{s-1}{var(s)} \\ 0 \\ x = \dfrac{s+1}{\sqrt{var(s)}} \end{cases} \begin{cases} if \ s > 0 \\ if \ s = 0 \\ if \ s < 0 \end{cases} \tag{4}$$

In a two-sided trend test, the H_0 should be accepted if $|Z| \leq Z_{\alpha/2}$ at the α level of significant. Therefore, a positive value of S indicate an "upward trend" and a negative value indicate a "downward trend" (Partal and Kahya 2006). The significance levels of α=0.01 and 0.05 were considered in this research.

2.2.2 Sen's Slope Estimator

Sen (1968) introduced a simple non-parametric procedure to estimate the true slope of a linear trend in a time series. The slope which estimates N pairs of data are calculated by:

$$Q_i = \left(\frac{X_i - X_k}{i - k}\right) \text{for } i = 1, \ldots, N \tag{5}$$

where x_j and x_k are data value at time i and k (i>k), respectively. The Sen's estimator of slope is defined as the median of N values of Q_i. If N is even, then Sen's estimator is computed by Q_{med}=[$Q_{N/2}$+ $Q_{(N+2)/2}$]/2N while if it is odd, the estimator is computed by Q_{med}=$Q_{(N+1)/2}$. Finally, the true slope can be computed by a non-parametric test and Q_{med} is checked by a two-sided test at the 100 (1-α)% confidence interval (Partal and Kahya 2006; Tabari and Hosseinzadeh Talaee 2011).

2.2.3 Mann–Whitney Test

The Mann–Whitney test is a nonparametric approach and an alternative for the t- test for two independent samples. It can be used to test whether two independent samples have been taken from the same population (McCuen 2002). The MW test statistic U is given by Yue and Wang (2002) as follows:

$$U = min\{U_1\ ,\ U_2\} \tag{6a}$$

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \tag{6b}$$

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 \tag{6c}$$

where U_1 is the total number of sample I observations preceding sample II observations, and U_2 is the total count of sample II observations preceding sample I; n_1 and n_2 are the size of sample I (X_1) and sample II (X_2), respectively; and R_1 and R_2 are the rank sums of the samples X_1 and X_2, respectively. When the null hypothesis, H_0, is true and when n_1 and n_2 are both larger than 8, U is approximately normally distributed with mean of $E(U)$ and variance of $V(U)$ as (Yue and Wang 2002):

$$E(U) = \frac{n_1 n_2}{2} \tag{7}$$

$$V(U) = \frac{n_1 n_2(n_1 + n_2 + 1)}{12} \tag{8}$$

2.2.4 Linear Regression

In this research, the magnitude of the trends was considered to be statistically significant based on the Student's *t*-test at α=0.05 level.

2.2.5 The Effect of Serial Correlation on MK Test

According to the null hypothesis of the MK test, the dataset is independent and randomly ordered which means no serial correlation and trend among the observations (Hamed and Rao 1998). The existence of positive serial correlation will increase the possibility of rejecting the null hypothesis of no trend, while the null hypothesis is true. The temperature time series might show serial correlation more than other climatic variables (Yue and Hashino 2003). Hence, it is necessary to consider the effect of serial correlation on the MK test. The possible significant trends in air temperature observations are examined by using the following procedures:

I. Compute the lag-1 serial correlation coefficient (designated by r_1).
II. If the calculated r_1 is not significant at the 5 % level, then the Mann–Kendall test will be applied to original values of the time series.
III. If the calculated r_1 is significant, prior to application of the Mann–Kendall test, then the 'pre-whitened' time series may be obtained as (x_2-r_1x_1, x_3-r_1x_2, …, x_n-r_1x_{n-1}) (Partal and Kahya 2006; Tabari et al. 2011).

In this study, existence of serial correlation within air temperature dataset was examined by using Ljung-Box Q_k at α=0.05 significance level. At k lag, the Q_k statistic is calculated by using following formula (Ljun and Box 1978):

$$Q_k = n(n+2)\sum_{l-1}^{k} \frac{r_l^2}{n-l} \tag{9}$$

If n is large, Q_k has a chi-square distributions with degree of k-p-q, where p and q are autoregressive and moving average orders, respectively. The significance level of Q_{k} is calculated by chi-square distribution with k-p-q degree of freedom.

2.2.6 Change Point Analysis

There are many methods for analyzing change points or starting an increasing or a decreasing trend in temperature time series (Tabari et al. 2012). In this paper, four important methods for detecting change points including; Mann–Kendall rank (Sneyers 1990), Pettitt's test (Pettitt 1979), SNHT (Alexandersson 1986) and Buishand's (Buishand 1982) were used.

3 Results and Discussion

3.1 Lag-1 Serial Correlation

Generally, positive serial correlation was identified for 38, 53 and 31 % of whole time series for the T_{mean}, T_{max} and T_{min}, respectively. Annual series had the greatest number of significant positive correlation and summary of the lag-1 serial coefficient for area-averaged series are presented in Fig. 2. Area-averaged monthly series showed that March with coefficient values

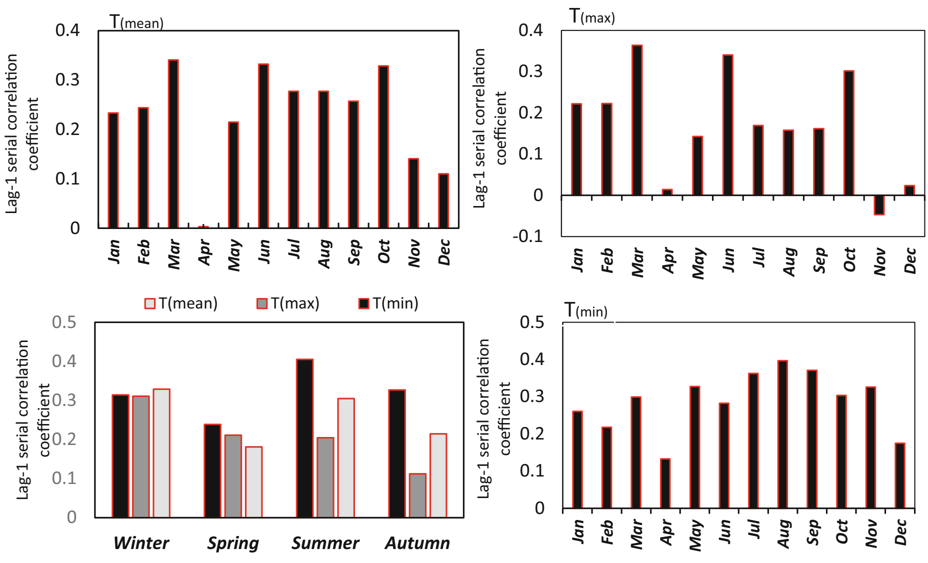

Fig. 2 Lag-1 serial correlation coefficient of area-averaged monthly and seasonal temperature series

of 0.34 and 0.36 had the highest Ljung-Box coefficient, while April with values of 0.003 and 0.014 resulted the lowest coefficient for the T_{mean} and T_{max}, respectively. Furthermore, similar to the T_{mean} and T_{max}, T_{min} had the lowest Ljung-Box coefficient with the value of 0.13 in the April, while the highest value (i.e. 0.39) was found in the August.

3.2 Trends in T_{mean}, T_{max} and T_{min}

The significant serial correlation was eliminated for analyzing the influence of serial correlation on the MK test (Fig. 3). The results of original and pre-whitening monthly series determined the different influences of serial correlation on the MK test. Generally, the positive serial correlation on the T_{min} had the most influence on increasing the possibility of rejecting the null hypothesis of no trend, while the null hypothesis is true. Therefore, in this study the influence of positive serial correlation on the MK test showed necessity of pre-whitening temperature series prior to implementation of MK test in the trend analysis as emphasized by some other researches (Yue et al. 2002; Kumar et al. 2009; Shadmani et al. 2012).

The results of the MK test show positive trends in the T_{mean}, T_{max} and T_{min} in most of months (Table 1). In the monthly T_{mean} series, the MK test in all of the stations identified

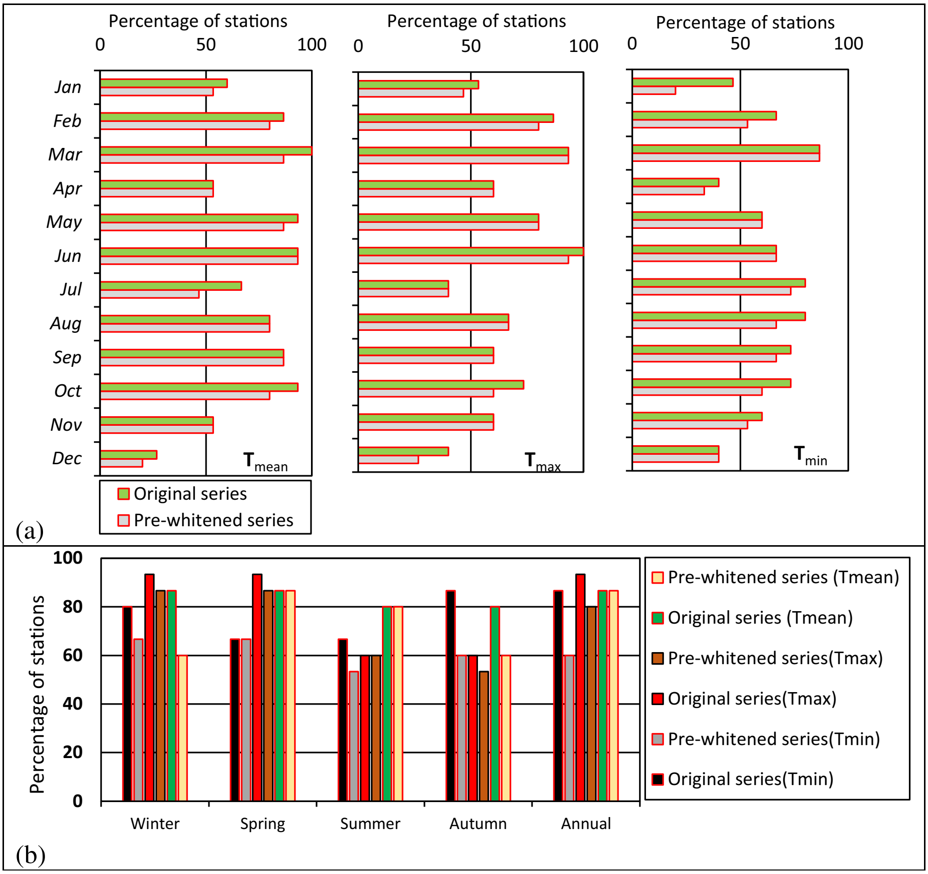

Fig. 3 Significant trends in original and pre-whitened series (**a** is monthly series and **b** is seasonal and annual series)

Table 1 The results of the MK test for the monthly temperature time series

Station	T(°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chahrigh Olia	T(mean)	1.76	5.08**	2.90**	-3.36**	4.94**	5.25**	5.71**	4.52**	4.81**	6.06**	3.11**	0.70
	T(max)	2.34*	3.51**	4.85**	-3.82**	4.66**	3.06**	4.23**	5.23**	4.24**	3.06**	3.65**	0.51
	T(min)	0.36	4.58**	5.49**	3.60**	4.82**	4.72**	5.37**	2.79**	3.88**	5.32**	4.17**	0.19
Ghasemloo	T(mean)	2.29*	3.33**	2.83**	1.64	3.52**	3.41**	1.64	4.36**	3.32**	2.92**	2.83**	1.79
	T(max)	2.38*	3.32**	4.04**	2.02*	3.73**	3.68**	-0.37	3.78**	0.58	1.98*	2.37*	2.70**
	T(min)	1.97*	2.69**	4.38**	1.12	1.29	3.72**	2.82**	2.92**	3.27**	3.02**	1.44	0.50
Kamp Urmia	T(mean)	2.70**	2.71**	2.50*	-3.36**	3.71**	3.86**	4.47**	2.95**	2.50*	2.04*	3.11**	0.70
	T(max)	2.34*	2.34*	4.85**	-3.82**	4.00**	3.18**	4.23**	5.23**	4.24**	5.82**	1.54	0.51
	T(min)	3.02**	2.02*	5.49**	4.82**	3.33**	2.94**	5.37**	1.72	2.20*	1.84	1.18	0.19
Marz Sero	T(mean)	2.21*	2.30*	1.88	2.67**	1.64	2.97**	2.62**	3.02**	2.33*	1.95	1.97*	2.52*
	T(max)	0.72	0.79	1.68	1.15	2.38*	2.06*	0.83	1.00	0.27	3.24**	2.33*	1.00
	T(min)	2.39*	2.48*	2.38*	3.23**	2.55*	2.95**	1.71	1.90	1.71	2.69**	1.81	2.16*
Mir Abad	T(mean)	3.25**	2.06*	1.64	0.56	2.74**	3.42**	4.09**	4.60**	5.07**	2.06*	3.28**	-0.92
	T(max)	3.29**	0.26	2.34*	0.20	1.47	2.76**	-0.49	4.14**	-0.26	3.97**	4.37**	-0.48
	T(min)	1.96	2.32*	3.05**	1.76	3.50**	3.27**	4.63**	4.23**	5.24**	4.49**	5.23**	0.41
Mirkooh	T(mean)	1.78	1.50	3.08**	1.13	2.82**	2.97**	2.30*	2.96**	2.33*	3.66**	1.18	2.02*
	T(max)	1.63	2.18*	2.50*	2.45*	2.93**	2.23*	1.35	2.82**	2.40*	2.16*	2.40*	2.14*
	T(min)	0.55	1.33	1.00	1.33	1.81	1.50	2.97**	2.68**	3.07**	3.20**	0.62	1.42
Oshnavieh	T(mean)	-0.21	3.29**	2.09*	0.89	3.54**	2.83**	1.18	1.73	3.23**	3.00**	1.46	0.50
	T(max)	-0.10	3.23**	1.98*	0.27	1.93	3.59**	-0.42	-1.03	-1.05	-1.84	-0.43	-0.34
	T(min)	-0.31	1.41	1.53	1.92	2.37*	2.88**	2.16*	2.30*	3.37**	1.85	3.43**	1.71
Pol Sorkh	T(mean)	-0.06	1.20	2.79**	0.08	2.84**	3.64**	0.13	1.57	0.45	2.48*	-0.10	-0.80
	T(max)	0.56	2.12*	3.15**	1.01	3.14**	3.91**	1.28	1.07	0.71	3.34**	-0.24	0.59
	T(min)	-0.71	-0.06	1.85	-1.30	1.95	1.54	-1.50	0.76	-0.34	1.92	-0.93	-2.32*
Sad Noroozlou	T(mean)	0.94	2.07*	1.18	-2.09*	2.22*	-1.08	-3.35**	-0.49	3.52**	3.92**	-2.66**	-1.90
	T(max)	1.93	2.76**	2.25*	2.58**	4.18**	3.79**	1.98*	4.72**	5.49**	2.90**	2.23*	2.05*
	T(min)	-0.97	-1.10	-3.71**	-5.26**	5.62**	-6.00**	-6.15**	-5.55**	-1.40	-1.64	-4.51**	3.81**
Sad Shahid-Kazemi	T(mean)	1.68	4.04**	2.52*	3.83**	3.74**	3.74**	-2.55**	-0.94	6.14**	2.38*	-1.73	-3.81**
	T(max)	3.31**	3.31**	2.11*	4.28**	3.51**	3.55**	2.78**	2.58**	4.63**	1.46	-1.31	-4.25**
	T(min)	-0.38	3.48**	3.60**	-0.01	1.29	-1.04	-3.06**	-2.73**	3.11**	3.33**	-3.54**	-4.98**

Table 1 (continued)

Station	T(°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sahlan	T(mean) T(max) T(min)	2.09*	2.22*	2.76**	1.44	2.99**	2.88**	2.83**	2.78**	3.81**	2.97**	2.95**	1.94
		2.41*	2.93**	3.08**	1.43	2.06*	2.62**	1.56	2.18*	2.51*	2.92**	2.36*	1.48
		1.41	1.79	3.46**	1.53	1.32	2.97**	3.25**	2.44*	2.76**	2.88**	3.46**	1.97*
Shanjan	T(mean) T(max) T(min)	2.23*	2.45*	3.87**	2.23*	2.45*	1.76	0.24	2.55*	1.20	1.47	1.41	0.25
		0.57	2.67**	3.51**	1.96	1.81	1.48	0.10	1.67	0.33	0.82	0.33	1.14
		1.94	1.56	3.36**	2.16*	2.03*	1.82	-0.21	0.27	-0.24	1.29	2.11	1.67
Sharafkhaneh	T(mean) T(max) T(min)	1.25	3.45**	3.44**	0.90	2.79**	2.59**	1.96	2.67**	2.92**	2.85**	2.79**	0.23
		1.48	2.58*	4.56**	2.20*	2.30*	2.92**	2.62**	3.60**	3.18**	2.26*	3.22**	1.08
		1.49	2.59**	2.99**	-0.91	0.30	1.48	0.35	0.73	1.01	1.47	1.35	-1.32
Tazekand	T(mean) T(max) T(min)	2.45*	3.00**	2.52*	3.90**	4.10**	3.74**	4.16**	5.12**	3.84**	4.96**	3.13**	-3.81**
		1.42	3.31**	2.11*	1.39	2.50*	3.55**	2.75**	3.10**	4.63**	3.57**	0.72	0.15
		-0.38	3.03**	3.55**	-0.01	4.44**	4.02**	-3.06**	4.96**	3.11**	4.58**	2.77**	1.85
Yalghouz Aghaj	T(mean) T(max) T(min)	2.02*	2.22*	2.64**	1.42	2.99**	4.43**	1.41	3.27**	3.81**	2.90**	2.95**	1.94
		2.41*	2.93**	2.41*	1.43	2.06*	3.86**	0.70	2.18*	2.51*	1.08	2.23**	1.48
		1.41	1.79	3.46**	1.53	4.37**	4.51**	3.11**	2.57*	3.04**	4.02**	3.46**	1.97*

** indicates significant trend at 99 % and * indicates significant trend at 95 % confidence level significant positive trends at the 0.05 significance level except April, July, November and December. In the T_{mean} series, the large number of stations (i.e. 93.33 %) had significant warming trends at the 0.05 significance level in May. Also, in the T_{max} series 93.33 % of the stations had a warming significance trend in March and June. Similar to T_{max}, analysis of T_{min} indicated the strongest significant warming trend in March for 80 % of the stations. However, the monthly T_{mean}, T_{max} and T_{min} series showed the highest significant warming trends in May, March to June and March, respectively.

Three stations, Sad Noroozlou, Pol Sorkh and Sad Shahid-Kazemi which located in the south of the basin mostly showed the significant cooling trends in the T_{mean} and T_{max}. This means that trend of temperature series in the ULB were positive and negative. Soltani and Soltani (2008) reported similar results in the northern Iran for the T_{min} and T_{max} series.

The inverse distance weighted interpolation technique was used for the seasonal and annual series in order to explore the spatial trends over ULB. Spatial distribution results of modified MK test for the seasonal and annual scales in the study region are shown in Fig. 4. In the winter series, 66, 86 and 53 % of the stations, which are located at the vicinity of the Lake, were found with increasing trend of T_{mean}, T_{max} and T_{min} at the 0.05 significance level. The increasing trends of T_{mean}, T_{max} and T_{min} series in this research have a good fit with the results in other regions such as China (Mamtimin et al. 2011), Turkey (Turkes and Sumer 2004) and Jordan (Smadi 2006).

The MW test was used to determine the shift changes after dividing the annual temperature series into two groups pre -1991 and post 1991 (Table 2). In general, 86, 73 and 80 % of the stations have experienced significance upward shift change at the 0.05 level over the four decades in the annual T_{mean}, T_{max} and T_{min} series, respectively. Furthermore, the results of MW test for shift change detection showed good fit with the outputs of MK test.

3.3 Magnitude of Trends

The Sen's slope estimator for temporal along with linear regression for spatial trend was used to identify the magnitude of increasing or decreasing trends in ULB. The results of the Q_{med} of Sen's estimator for the monthly air temperature series are given in Fig. 5. As shown, the Ghasemloo, Marz Sero, Sahlan, Tazekand and Yalghouz Aghaj stations which are located in the vicinity of Urmia Lake presented a warming trend in all of the series over 12 months. Among the above mentioned stations, the Marz Sero station located in the west of the Lake showed the most warming trends over the four decades in whole air temperature series Fig. 6.

Generally, area-averaged temperature series in the monthly scale indicated variation of T_{mean} from (+) 0.39 to (+) 1.22 °C per decade. Meanwhile, February and March with value of (+) 1.09 and (+) 1.22 °C had the highest magnitude of warming trends. In addition, results also showed the highest values in February and March with the value of (+) 1.11 and (+) 1.45 °C per decade in T_{max} and value (+) 1.11 and (+) 1.22 °C in T_{min}. Hence, among the air temperature series, magnitude of a warming trend in T_{max} in the mentioned months is more than T_{mean} and T_{min}. On other hand, magnitude analysis of the air temperature monthly series revealed considerable increase in March and February. We also identified the highest magnitude of warming trend in most of the stations in the monthly T_{max} series especially in February and March. This is a good point to understand the impacts of warming trends in temperature series of the Urmia Lake. At this semi-arid region, most of rainfall and snow falling occurs in the winter and extended time of shortage precipitation leads to scarcity of water yield in the rivers which drain to the Urmia Lake. Shifteh Some'e et al. (2012) suggested a noticeable

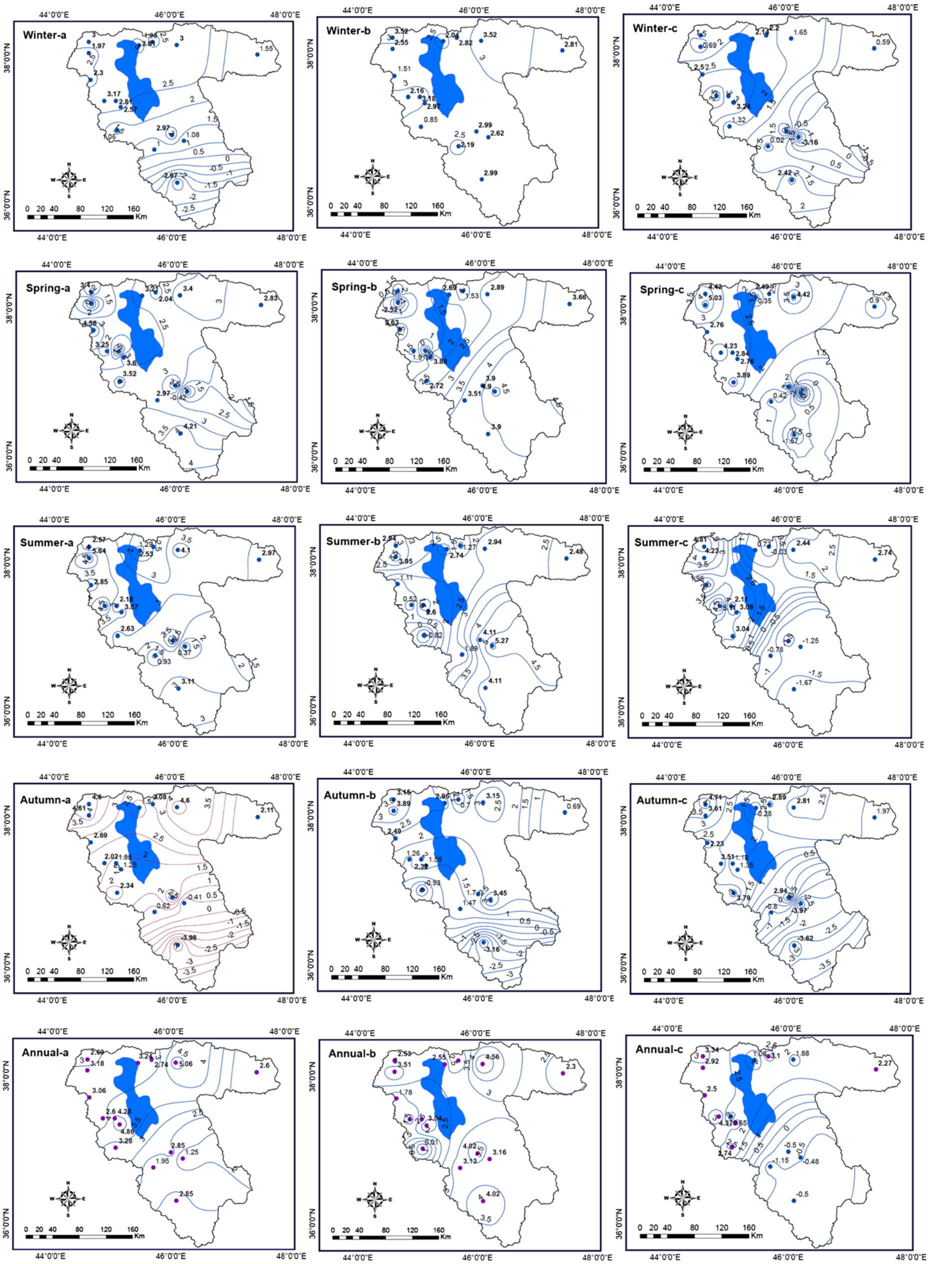

Fig. 4 Spatial distribution of the MK test for the seasonal and annual series (**a**, **b** and **c** indicate the T_{mean}, T_{max} and T_{min}, respectively, and bold values indicate the significant trends at the 0.05 level)

decreasing trend in winter precipitation series of the northern Iran. Meanwhile, increases in air temperature in February and March could increase the evaporation and evapotranspiration trends (Sabziparvar et al. 2010; Dinpashoh et al. 2011), which may lead to changes in water temperature. Moreover, the mountainous basins such as ULB, are relatively vulnerable

Table 2 The results of MW test for the annual temperature series in the ULB

Station	Tmean			Tmax			Tmin		
	Median (Pre-1991)	Median (Post-1991)	*p*-value	Median (Pre-1991)	Median (Post-1991)	*p*-value	Median (Pre-1991)	Median (Post-1991)	*p*-value
Chahrigh Olia	9.25	10.46	**0.0000**	14.49	15.93	**0.0000**	4.59	4.95	**0.0000**
Ghasemloo	10.17	11.60	**0.0000**	16.49	18.02	**0.0000**	3.78	5.03	**0.0000**
Kamp Urmia	10.84	12.30	**0.0000**	17.95	18.08	0.2340	3.79	6.36	**0.0000**
Marz Sero	7.51	10.07	**0.0000**	16.17	17.77	**0.0010**	−1.07	3.56	**0.0050**
Mir Abad	9.33	10.84	**0.0010**	17.66	17.80	0.9140	1.29	3.86	**0.0000**
Mirkooh	8.48	9.79	**0.0000**	14.61	16.17	**0.0000**	2.51	2.88	0.1480
Oshnavieh	12.64	13.30	**0.0000**	18.40	18.40	0.2730	6.97	8.44	**0.0000**
Pol Sorkh	13.12	13.33	0.0580	18.58	19.31	**0.0060**	7.44	7.12	0.6170
Sad Noroozlou	12.79	13.05	0.1440	17.74	20.02	**0.0000**	7.72	6.24	**0.0000**
Sad Shahid-Kazemi	12.25	13.00	**0.0000**	18.44	20.04	**0.0000**	6.13	6.30	0.2790
Sahlan	12.02	13.22	**0.0000**	18.30	19.45	**0.0000**	5.90	6.88	**0.0000**
Shanjan	9.98	11.23	**0.0010**	15.77	16.73	0.0620	4.26	5.85	**0.0000**
Sharafkhaneh	11.07	12.40	**0.0000**	16.29	18.46	**0.0000**	6.09	6.58	**0.0210**
Tazekand	9.48	12.63	**0.0000**	19.51	20.15	**0.0010**	0.87	4.92	**0.0000**
Yalghouz Aghaj	9.50	10.82	**0.0000**	16.88	17.88	**0.0170**	2.09	3.65	**0.0000**

Bold values indicate significant shift changes at the 0.05 level environments to the climate change, due to of their watershed properties which are very sensitive to temperature changes (Birsan et al. 2005; Abghari et al. 2013).

The spatial distribution of significant trends based on the slope of linear regression (*b*) for the annual air temperature series revealed increasing trends with the values ranging from 0 to 0.75 °C in the T_{mean}, T_{max} and T_{min} series at the 0.05 % significance level over the studied period. Therefore, results showed that the basin suffered from increasing trends of T_{mean}, T_{max}

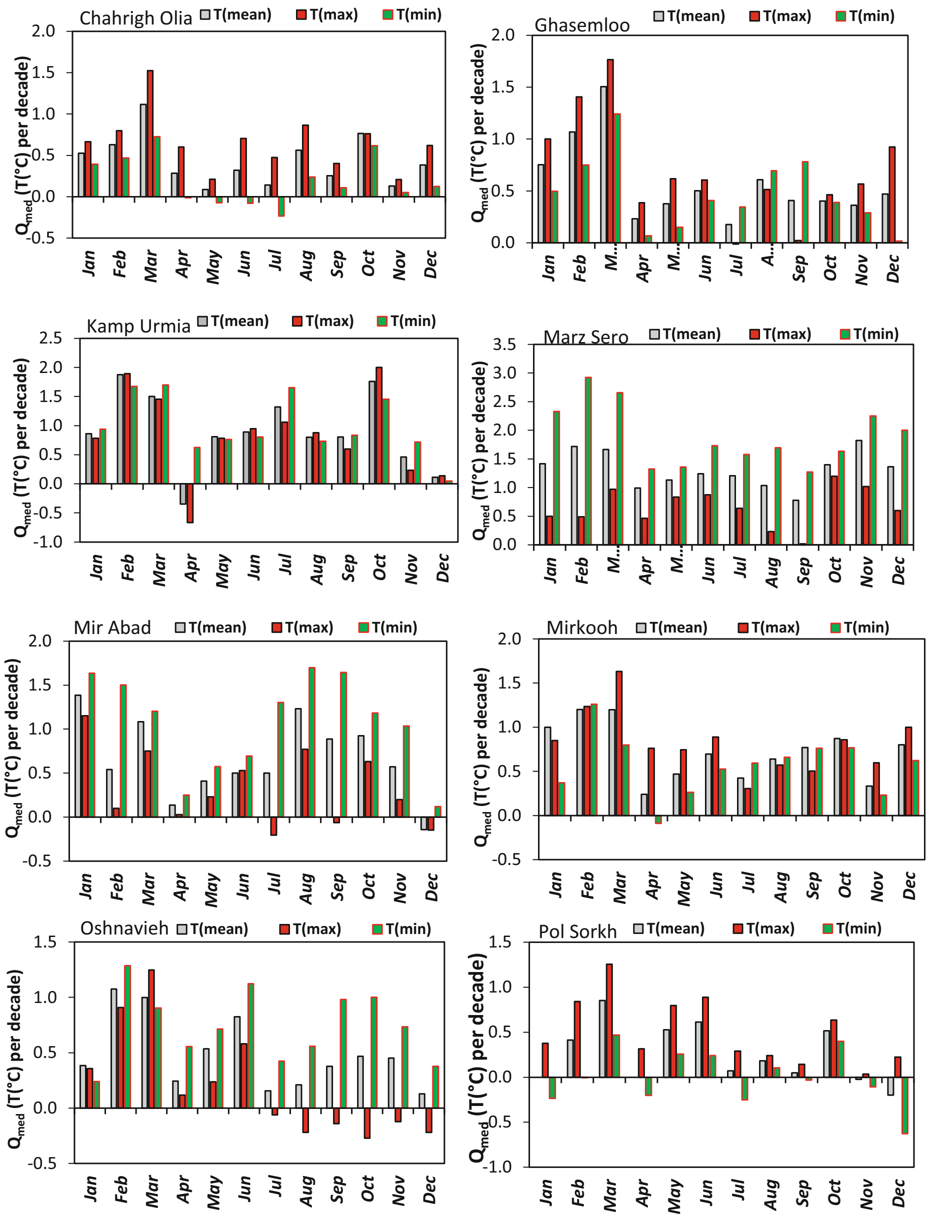

Fig. 5 The Q_{med} of Sen's estimator for the monthly T_{mean}, T_{max}, and T_{min} series in ULB

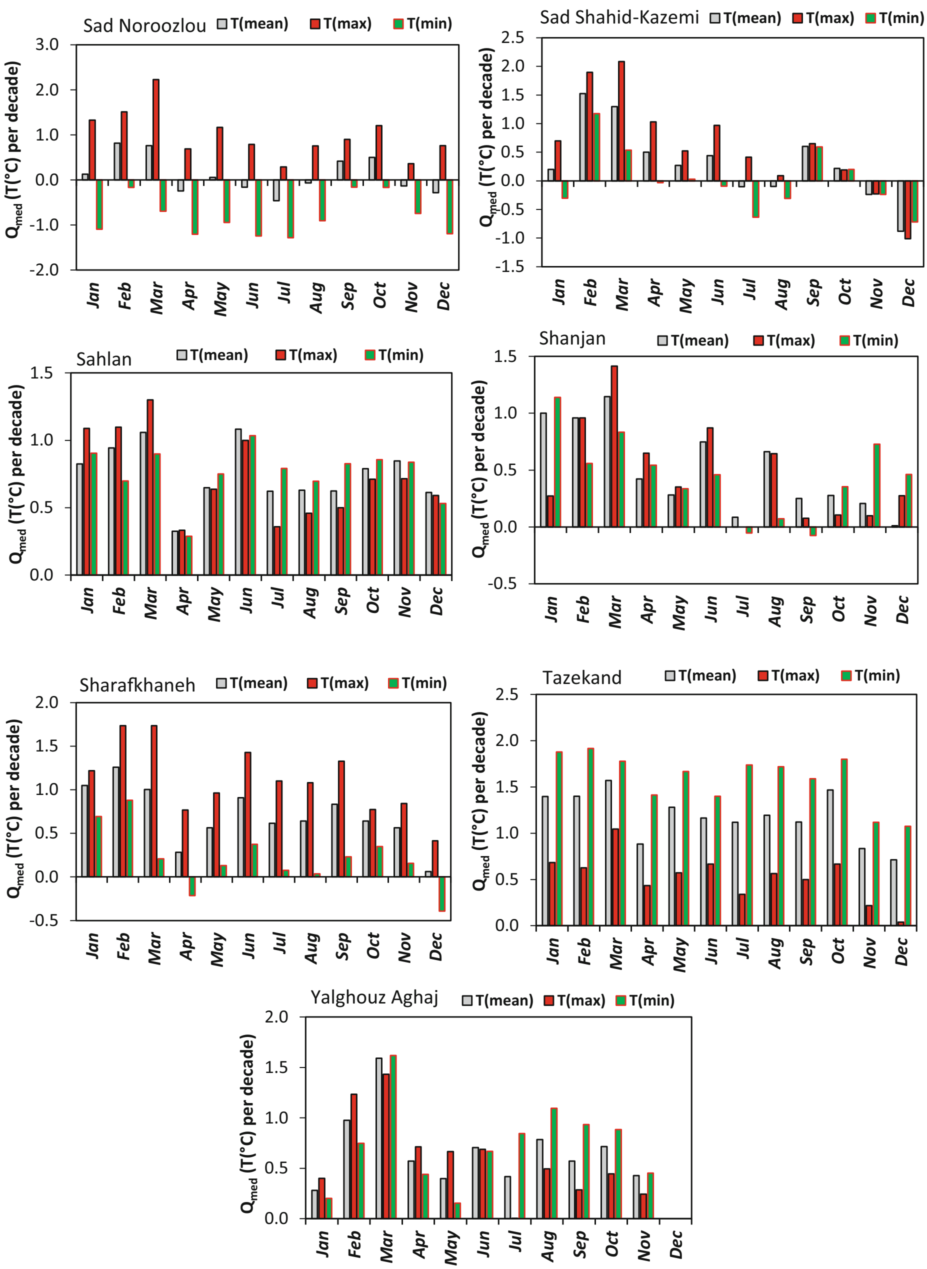

Fig. 5 (continued)

and T_{min} over the past decades. Consequently, interpolation maps suggested higher warming trends in the western and eastern parts of the basin than southern part.

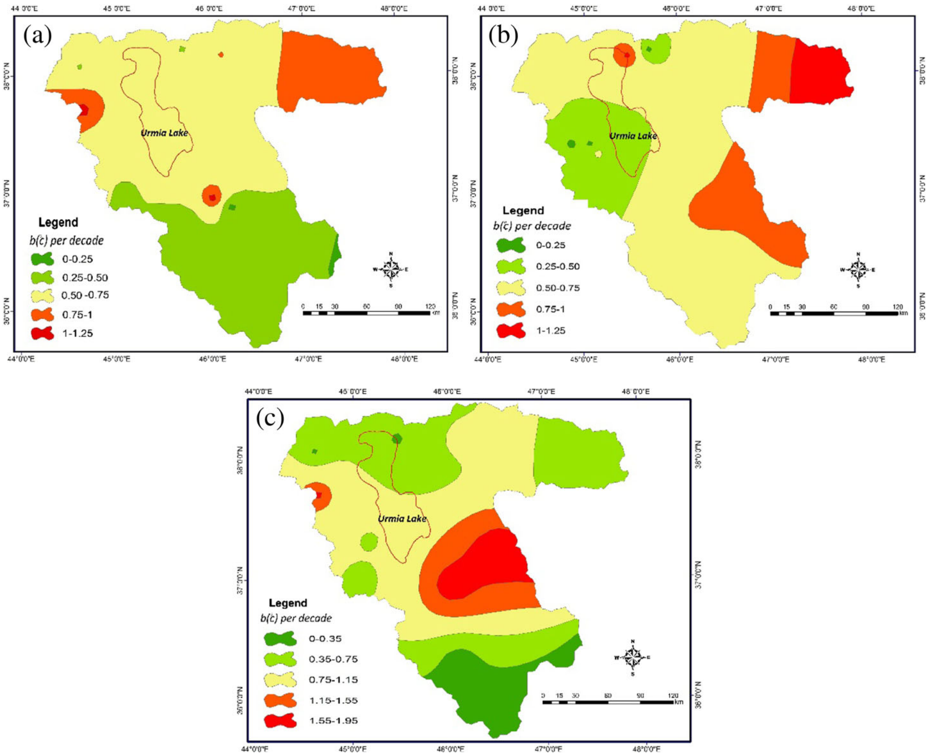

Fig. 6 The linear regression slope (*b*) for the annual T_{mean}, T_{max} and T_{min} series in the ULB

3.4 Change Points Analysis

Detecting the change points (or mutation point) in the surface air temperature series was considered to understand the correlation between the climate variability and decreasing water level of Urmia Lake. For determination of the approximate beginning year of the significant trends, the Mann-Kendall rank and change point tests were used. The results of this test for the annual air temperature series in the stations obviously showed the beginning of trend at the 0.05 significance level. In the Yalghouz Aghaj and Mir Abad stations the Mann-Kendall rank test showed the approximate years of beginning of the significant trends were in 1992 and 1983 for the T_{mean} series. In the T_{max} series, the Shanjan and Marz Sero stations showed that the beginning years were 1986 and 1984, and also for the T_{min} in the Oshnavieh and Tazekand stations the years were 1992 and 1982, respectively. However, the Mann-Kendall rank test for the air temperature series determined that beginning of significant trends in some stations showed at 1980s and others ones were in 1990s.

Three commonly used change points tests namely, Pettitt's test, SNHTz and Buishand's were chosen for the monthly, seasonal and annual temperature series (Table 3). The results showed that only April is homogenous in the monthly, seasonal and annual series. In contrary, most of the air temperature series are heterogonous around year of 1992 according to the three tests. On the other hand, in the T_{mean} series about 50, 70 and 57 % of significant change points are around 1992 by Pettitt's, SNHT and Buishand's tests, respectively. Furthermore, in 1992, we found 46, 57 and 66 % significant uptrend changes in T_{max} series while 66, 54 and 60 % in the T_{min} series by Pettitt's, SNHT and Buishand's tests, respectively. However, more than 90 %

Table 3 The most probable change year of the monthly, seasonal and annual temperature series

Test Series	T_{mean} Pettitt's test	T_{mean} SNHT	T_{mean} Buishand's test	T_{max} Pettitt's test	T_{max} SNHT	T_{max} Buishand's test	T_{min} Pettitt's test	T_{min} SNHT	T_{min} Buishand's test
Jan	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	(+) 1992	**(+) 1992**	**(+) 1992**	(+) 1992	**(+) 1992**
Feb	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**
Mar	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**
Apr	1979	1988	1988	1985	1988	1988	1996	1996	1996
May	**(+) 1994**	**(+) 1992**	**(+) 1992**	**(+) 1985**	(+) 1993	**(+) 1992**	**(+) 1992**	(+) 1992	**(+) 1992**
Jun	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1991**	**(+) 1991**	**(+) 1991**
Jul	**(+) 1996**	**(+) 1996**	**(+) 1996**	(+) 1996	(+) 2006	(+) 1996	**(+) 1995**	**(+) 1996**	**(+) 1996**
Aug	**(+) 1993**	(+) 1987	**(+) 1987**	**(+) 1993**	(+) 1987	(+) 1987	**(+) 1992**	**(+) 1997**	**(+) 1997**
Sep	(+) 1992	(+) 1992	(+) 1992	**(+) 1993**	(+) 1993	(+) 1993	**(+) 1996**	**(+) 1996**	**(+) 1996**
Oct	**(+) 1996**	**(+) 1996**	**(+) 1996**	**(+) 1996**	**(+) 1996**	**(+) 1996**	2002	1992	1992
Nov	**(+) 1989**	(+) 1982	**(+) 1989**	(+) 1989	(+) 2010	(+) 1989	**(+) 1992**	**(+) 1982**	**(+) 1992**
Dec	(+) 1986	(+) 1986	(+) 1986	(+) 1995	(+) 1995	(+) 1995	**(+) 1991**	(+) 1990	**(+) 1991**
Winter	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1992**
Spring	**(+) 1992**	(+) 2003	**(+) 1992**	**(+) 1992**	(+) 2003	(+) 1996	**(+) 1992**	(+) 1996	**(+) 1992**
Summer	**(+) 1993**	(+) 1987	**(+) 1987**	**(+) 1993**	(+) 1987	(+) 1987	**(+) 1992**	**(+) 1992**	**(+) 1992**
Autumn	**(+) 1995**	**(+) 1995**	**(+) 1995**	**(+) 1995**	**(+) 1995**	**(+) 1995**	**(+) 1987**	**(+) 1996**	**(+) 1996**
Annual	**(+) 1992**	**(+) 1992**	**(+) 1992**	**(+) 1993**	**(+) 1993**	**(+) 1993**	**(+) 1992**	**(+) 1992**	**(+) 1992**

Bold years indicate significant increasing or decreasing abrupt changes at 0.05 significance level of total significant change years in air temperature series were found in 1990s. Averagely, three tests confirmed the positive significant mutation points in the T_{mean}, T_{max} and T_{min} in 73, 71 and 60 % of the stations started in 1990s, respectively. The results of the change points showed a good fit to the results observed in southwestern Iran (Zarenistanak et al. 2014).

The results of Mann-Kendall rank and change year tests explained that, year of changing point up to increasing in most of the stations and temperature series was in the 1990s whereas, based on the Mann-Kendall rank test, some stations had such situation in 1980s. Generally, significant change year based on the mentioned methods was found in 1980s and 1990s. A drastic decrease of more than 5 m in the water level of Urmia Lake began in 1990s (Fathian et al. 2014). In this study, it is noticeable that the significant change years of warming trends are close to the beginning of water level decrease in Urmia Lake. Climate change and variability is expected to be more intensive over the next century, due to the ever increasing rate of greenhouse gases emissions (Ashrafi et al. 2012; Manju et al. 2012). Increasing temperature would have some influences on the regions including: increase of the energy demand for cooling, reduce the precipitation amount and consequently dramatic reduction of water resources of the Urmia Lake (Roshan et al. 2010; Roshan et al. 2011; Tisseuil et al. 2013).

4 Conclusions

The long-term trends in monthly, seasonal and annual mean, maximum and minimum air temperatures of the gauge stations of ULB were investigated over the period 1972–2011. The tests conducted on the monthly series detected significant warming trends in the T_{mean} series which were larger than those in T_{max} series, and also T_{max} was found more than T_{min} series. Furthermore, the significant warming trend of T_{max} in most of the stations in winter was more than of T_{mean} and T_{min}. The spatial distribution of the Modified MK test for the seasonal and annual scales demonstrated that most of the observed trends in the seasonal and annual air temperature series were positive at the 0.05 significance level. Moreover, the results of MW test in this study for shift change detection are in a good fit to outputs of MK test.

On average, the results of Sen's slope estimator showed the magnitude of significant warming trends in annual T_{mean}, T_{max} and T_{min} was (+) 0.58, (+) 0.52 and (+) 0.69 °C per decade, respectively. Overall, although T_{min} increased at the higher rate than T_{mean} and T_{max}, the results revealed similar increasing trends for the air temperature series. The interpolation maps showed that warming trends in the east and west of Urmia Lake were more than southern area. Intensive industrialization and urbanization in the west and mostly in the eastern part of the Lake could be considered as a reason of most warming trends in temperature series in the west and eastern sides.

Generally, in this research significant change year was found in 1980s and 1990s. In this study, it is interesting that significant change years of warming trends are close to the beginning of decreasing water level of the Lake. Consequently, it can be suggested that the warming trends in the temperature series had adversely impacted on the Lake over the past decades.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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