Shahid Chamran University of Ahvaz Irrigation Sciences and Engineering (JISE) Vol. 42, No. 3, Fall 2019, p. 197-212

EXTENDED ABSTRACT

Trend Analysis of Temperature, Precipitation, and Relative Humidity Changes in Iran

A. Eblaghian[1], A. M. Akhond Ali[2*], F. Radmanesh[3], and H. Zarei[4]

1- M.Sc. of Hydrology and Water Resource Engineering Department of Shahid Chamran University of Ahvaz, Iran.

2*- Corresponding Author, professor, faculty member of Hydrology and Water Resource Engineering Department of Shahid Chamran University of Ahvaz, Iran (aliakh@scu.ac.ir).

3- Associate professor, faculty member of Hydrology and Water Resource Engineering Department of Shahid Chamran University of Ahvaz, Iran.

4- Associate professor, faculty member of Hydrology and Water Resource Engineering Department of Shahid Chamran University of Ahvaz, Iran.

Received: 30 May 2016 Revised: 5 May 2018 Accepted: 13 May 2018

Keywords: Trend, Nonparametric Tests, Mann-Kendall Test, Sen's Slope Estimator.

DOI: 10.22055/jise.2018.17897.1299.

Introduction

In the pursuit of detecting the trend and the shift in trend in hydro-meteorological variables, various statistical methods have been developed and used over the years. Of the two methods commonly used (parametric and non-parametric), the non-parametric method has been favored over parametric methods. Long term trend analysis can reveal the beginning of the trend year, trend changes over time, and abrupt trend detection in a time-series. It is expected that the findings of this study will bring about more insights on understanding the regional hydrologic behavior over the last several decades in Iran.

Methodology

This paper analyzes the behavior of annual and seasonal temperatures, precipitation, and relative humidity. Datasets of 37 stations in Iran were analyzed from 1961 to 2010. The pre-whitening technique was used to eliminate the effect of the autocorrelation of data series. The Mann–Kendall (MK) test and the Sen's slope estimator were applied to quantify the significance of the trend and the magnitude of the trend at a 95% confidence level, respectively. The surface interpolation technique was used to prepare a spatial temperature, precipitation, and relative humidity data map over Iran from the point data measuring stations within the ArcGIS framework. For spatial distribution of trends in maps, contours are generated using an inverse-distance-weighted (IDW) algorithm.

Mann–Kendall (MK) trend test:

The MK test statistic S (Mann, 1945; Kendall, 1975) is calculated as:

$$s = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \tag{1}$$

In Eq. (1), n is the number of data points, x_k and x_j are the data values in time series k and j (j > k), respectively and in Eq. (2), sgn ($x_j - x_k$) is the sign function as:

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

The variance is computed as:

$$\operatorname{var}(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i (t_i - 1)(2t_i + 5)}{18} \tag{3}$$

In Eq. 3, n is the number of data points, m is the number of tied groups, and t_i denotes the number of ties of extent i. A tied group is a set of sample data having the same value. In cases where the sample size n is 10, the standard normal test statistic Z is computed using Eq. (4):

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

Positive values of Z indicate increasing trends while negative Z values show decreasing trends. The testing of trends is done at the specific α significance level. When $|z| > z_{1-\frac{\alpha}{2}}$, the null hypothesis is rejected and a significant trend exists in the time series. $z_{1-\frac{\alpha}{2}}$ is obtained from the standard normal distribution table. In this analysis, we applied the MK test to detect if a trend in the precipitation time series is statistically significant at the significance level α = 0.05 (or 95% confidence intervals). At the 5% significance level, the null hypothesis of no trend is rejected if |Z| >1.96.

Sen's slope estimator:

Sen (1968) developed the non-parametric procedure for estimating the slope of the trend in the sample of N pairs of data:

$$Q = \frac{X_j - X_i}{j - i} \qquad \text{For } 1,\ldots,N' \tag{5}$$

where x_j and x_i are the data values at times of j and i (j>i), respectively. If there is only one datum in each time period then $N' = \frac{n(n-1)}{2}$, where n is the number of time periods. The N values of Q_i are ranked from smallest to largest and the median of slope or Sen's slope estimator is computed. The Qmed sign reflects the data trend reflection, while its value indicates the steepness of the trend. To determine whether the median slope is statistically different from zero, one should obtain the confidence interval of Qmed at the specific probability. The confidence interval of the time slope can be computed as follows:

$$C_\alpha = Z_{1-\frac{\alpha}{2}} * \sqrt{Var(s)} \tag{6}$$

where Var(S) is defined in Eq. (6) and $Z_{1-\alpha/2}$ is obtained from the standard normal distribution table. In this study, the confidence interval was computed at 95% significance levels (α=0.05). Then, $M_1 = \frac{N' - C_\alpha}{2}$ and $M_2 = \frac{N' + C\alpha}{2}$ are computed. The lower and upper limits of the confidence interval, Q_{min} and Q_{max}, are the M_1th largest and the (M_{2+1})th largest of the N ordered slope estimates. The slope Q_{med} is statistically different from zero if the two limits (Qmin and Qmax) have a similar sign. Sen's slope estimator has been widely used in hydro-meteorological time series.

Results and Discussion

Statewide an increasing temperature trend and decreasing precipitation and relative humidity trend have been detected in most stations. In the entire country, apart from the high and mountainous stations, including Shahrekord, Khoramabad, and Saghez, an increasing temperature trend was found. The magnitude of the highest significant increasing temperature trend (confidence level ≥ 95%) was found in Mashhad, Zahedan, Zabol, Bam, Yazd, Babolsar, Kermanshah, Abadan, Tabriz, and Khoy about 1.5 °C during 50 years. The decreasing precipitation trend was found in the East, West, and Northwest of the country. The magnitude of the highest significant decreasing precipitation trend (confidence level ≥ 95%) was found to be about 3.2 mm/year in Northwest. The relative humidity decreasing trend was found in most stations, except a part of Northwest and South of the Caspian Sea. The magnitude of the highest significant decreasing relative humidity (confidence level ≥ 95%) was found to be about 4.1 percent/year in Abadan, Zahedan, and Kermanshah stations.

Conclusions

The given results indicated that there was a significant increasing trend in temperature in both annual and seasonal time series. The magnitude of the increasing trends in annual temperatures was 1 °C in 50 years. The analysis of the seasonal precipitation time series showed a negative trend, but a significant decreasing trend in annual precipitation series was found at 6 of the observed stations at northwestern and west of Iran. The magnitude of the decreasing trends in annual precipitation ranged between 0 to 3.2 mm in each year. However, the significant decreasing trend in annual relative humidity series was found at five of the observed stations, while the majority of the trends in the annual relative humidity series were not significant. In general, the results of using Mann-Kendall and Sen's slope estimator statistical tests pointed out the agreement of performance which exists in the detection of the trend of the meteorological variables.