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Determining the temporal trend in annual maximum flood series in the Large Karoun river (Iran)

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Abstract—**Annual maximum flood series in two main stations of Large Karoun river in Iran, measured during 1958 – 2009 period were examined to identify the temporal changes. Two approaches were used to evaluate the temporal changes in flood series during the period 1958-2009. The first approach is based on an analysis of standardized departures, and the second one is based on the multiple trend tests through varying the beginning and ending dates of the time series. Results indicate a noticeable step of increase in annual maximum flood series around 1983 relative to the gradual trend. The identification of an abrupt increase in annual maximum flood series rather than a gradual increasing trend is important because the implications of a step change are different from those of a gradual trend. The interpretation of a gradual trend is that the trend is likely to continue into the future, whereas the interpretation of a step change is that the climate system has shifted to a new regime that will likely remain relatively constant until a new shift or step change occurs.**

Keywords-Multiple trend, Climate Change, annual maximum flood series,Large Karoun river

I. INTRODUCTION

Climate change resulting from increasing anthropogenic greenhouse gas concentrations in the atmosphere is likely to shift the spatial and temporal distribution of water resources in river basins throughout the 21st century[1]. Because the capacity of the air to hold water vapor increases exponentially in a warming climate, water can be recycled at an accelerated rate[2] and potentially causing more frequent extreme hydrologic events. In the last decade, several studies have investigated changes and trends in streamflow to test whether such changes can already be seen in measured time series. They arrived at different conclusions. Delgado et al. (2010) showed an increasing likelihood of extreme floods during the last half of the century in the Mekong river in Southeast Asia, although the probability of an average flood decreased during the same period[3]. Schmacker-Fackel and Naef(2010) analysed temporal and spatial distribution of flood events with return periods larger than 10 years, and the large scale flood events of the last 150 years.They showed large regional differences especially between northern and southern in Switzerland and suggested that changes in large scale atmospheric circulation might be responsible for the fluctuations in flood frequency[4]. Petrow and Merz (2009) detected significant flood trends (at the 10% significance level) for a considerable fraction of basins.They showed in most cases, these trends are upward; decreasing flood trends are rarely found and arenot field-significant[5]. Cunderlik and Ouarda (2009) studied the trends in the timing and magnitude of seasonal maximum flood events across Canada and showed Trends in the magnitude of floods are more pronounced than the trends in the timing of floods [6]. Kundzewicz et al. (2005) detected upward and downward trends in annual maximum flow series in a worldwide dataset, but most of the series showed no significant trend[7]. Svensson et al. (2005) found no general pattern of increasing or decreasing numbers of floods or their magnitudes in 21 stations worldwide[8], while Milly et al. (2002) detected a significant increase worldwide in the monthly mean flood discharge of very large basins[9].

Most studies of historical changes in streamflow have made use of a non-parametric statistical trend test, such as Mann–Kendall trend test.This test distinguish gradual monotonic rising and falling trends in a time series. The distinction between a gradual trend and a step change is important, particularly for climatic-change impact studies. A gradual change usually is expected to continue into the future; step changes inherently are thought of as less predictable unless the cause for the abrupt change is known[10]. Therefore to identify temporal fluctuations in the annual maximum flood series of two main stations in Large Karoun river in Iran, we conducted standardized departures analysis and multiple trend tests as suggested by McCabe and Wolock (2002) by varying the beginning and ending date of the annual maximum flood series[10] in 5 year steps for the period 1958–2009. All periods with a minimum record length of 10 years were considered.

II. STUDY AREA AND DATA

The Large Karoun river basin is located in southwestern part of Iran, due to encompass the country's largest water potential, this basin meet the highest and the greatest water projects in Iran. The basin area of 67,257 km^2 is included about 5 percent of the total area of Iran. From this area, 67% is mountainous and the remaining 33% is made of high plains. Its two main tributaries including Karoun and Dez rivers flow over Khouzestan plain after journeying separately through high mountains and join to gether at Band Ghir located 50 km of north of Ahwaz city. The Large Karoun river eventually terminates in the Persian Golf (Figure1).Two main stations were selected in this study. Because these stations have longest time period, streamflow measured at these stations are considered to be natural and represent a mountainous region of Large Karoun river basin that is placed upstream two main dams(Table1). Pole Shalo station(place of karoun[3] dam) is assigned to mountainous region of Karoun river basin, Tale Zang station in the upstream Dez dam represents mountainous region of Dez river basin.The maximum, minimum and average annual discharges of Karoun river at Pole Shalo Station(Dam Karoun3) are 638, 126 and 300 m³/s, respectively. The average water yield of this river is 9.5 mcm. The maximum, minimum and mean annual streamflow of this river at the Talezang station(Dez Dam), are 582, 96 and 250 m³/s, respectively, while the average water yield of the river is 8 mcm annually. The time series of the annual maximum flood were used from 1958 to 2009. They were provided from Khouzestan Water and Power Authority ministry of energy.

III. METHODS

Two approaches were used to evaluate temporal changes in annual maximum flood series during the period 1958–2009. The first approach is based on an analysis of standardized departures, and the second approach based on a Multiple trend tests.

STANDARDIZED DEPARTURES ANALYSIS

Standardized departures of annual maximum flood series for each station were computed by subtracting the respective long-term (1958–2009) mean from the flood values for each station and then dividing by the respective standard deviation.

TABLE I. CHARACTERISTICS OF THE SELECTED RIVER STATIONS

Row	Station name	Long	Lat	Elevation m asl	Drainage area Km^2
1	Pol Shalo	50.08	31.45	700	23400
2	Tale Zang	48.46	32.49	480	16213

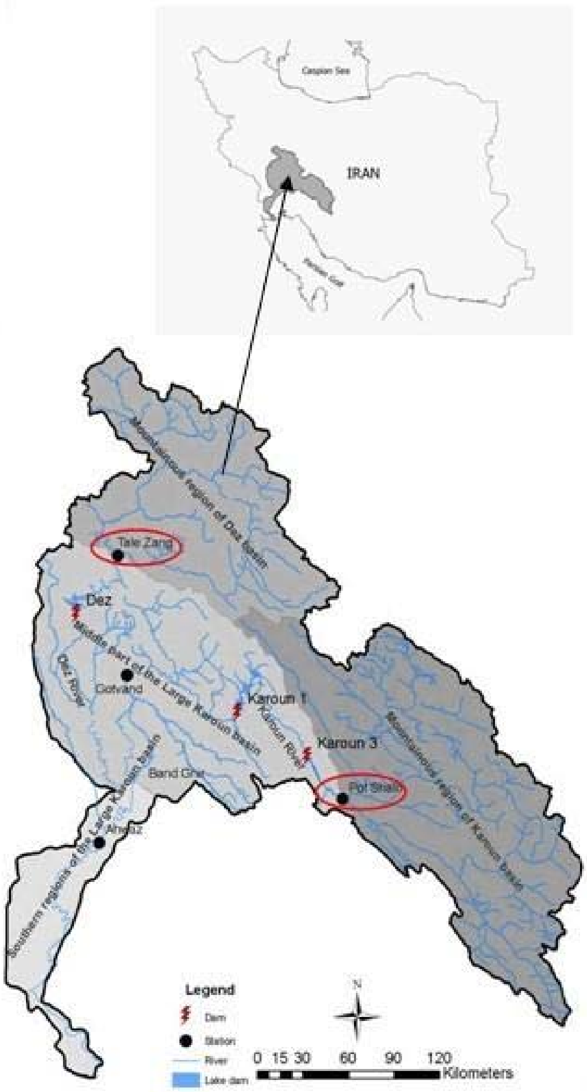

Figure 1. Location of the Large Karoun river basin in Iran and some of its important installations

TREND TEST

One of the most frequently used nonparametric tests for identifying trends in hydrologic variables is the Mann–Kendall test [11,12].The Mann–Kendall test is based entirely on ranks and such is robust to non-normality. The null hypothesis of the test states that the data are a sample of N independent and identically distributed random variables.It is based on the test statistic S defined as:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \mathrm{sgn}(Y_j - Y_i) \quad (1)$$

where Yi and Yj are the sequential data, N is the total number of data in the time series and

$$\mathrm{sgn}(\theta)=1 \text{ if } \theta>0; = 0 \text{ if } \theta = 0; = -1 \text{ if } \theta < 0 \quad (2)$$

A positive (negative) value of S indicates an upward (downward) trend. For $N \geq 8$, Mann (1945) and Kendall (1975) have documented that the statistic S is approximately normally distributed with the mean and variance as follows:

$$E(S) = 0 \text{ and} \quad (3)$$

$$Var(S) = \left[N(N-1)(2N+5) - \sum_{i=1}^{n} t_i i(i-1)(2i-5) \right] / 18 \quad (4)$$

where t_i is the number of ties of extent i (i.e. the number of data in the tied group) and n is the number of tied groups.The standardized test statistic Z, given below, follows the standard normal distribution

$$Z = \begin{cases} (S-1)/\sqrt{Var(S)} & S>0 \\ 0 & S=0 \\ (S+1)/\sqrt{Var(S)} & S<0 \end{cases} \quad (5)$$

At α_l (where 'L' stands for local) significance level, the null hypothesis of no trend is rejected if the absolute value of Z is greater than the theoretical value $Z_{1-\alpha_l/2}$.The presence of serial correlation in the analyzed time series can have serious impact on the results of a trend test. A positive serial correlation can overestimate the probability of a trend and a negative correlation may cause its underestimation. In this study, the Mann–Kendall test was used in conjunction with the widely used method of pre-whitening [13,14,15].The main steps one would take in implementing this approach are as follows: (1) compute the lag-1 serial correlation coefficient r_1, (2) if r_1 is found nonsignificant at the chosen significance level α_l then the trend identification test is applied to the original time series $(y_1, y_2, ..., y_n)$ and otherwise (3) the trend identification test is applied to the pre-whitened time series $(y_2 - r_1 y_1, y_3 - r_1 y_2, ..., y_n - r_1 y_{n-1})$. In the following Multiple trend tests were computed for two stations by varying the beginning date and the ending date analyzed. The multiple trend tests were computed for all possible periods of at least 10 years in length during the 1958–2009 period.The results of the Mann–Kendall test were evaluated at the 1%, 5% and 10% local significance levels for each time period.

IV. RESULTS

For annual maximum flood series, the departures indicate a shift around 1983 from primarily negative departures (red) to primarily positive departures (blue) (Figure 2).The visual pattern of temporal variability in the annual maximum flood series appears to be an abrupt increase in the flood regime near 1983, rather than a gradual increasing trend throughout the entire time period. Student's t-tests were used to identify the significant differences in mean annual maximum flood series between the 1958–1983 and the 1984–2009 periods. Results of Student's t-tests indicate that there were both two stations with significant ($P \leq 0.01$) differences in mean annual maximum flood magnitude between the two time periods.

Results of multiple trend analysis in Karoun river (Polshalo station) indicate an increase trend in the annual maximum flood series at 1% and 5% significance levels for most of the periods with a beginning year before 1983, and ending in a year after 1983. Only a few negative trends are observed, often related to the beginning and end of the mentioned time period (Figure 3).

Results of multiple trend analysis in Dez river (Talezang station) indicate an increase trend in the annual maximum flood series at 1% and 5% significance levels for most of the periods with a beginning year before 1983, and ending in a year after 1988 (Figure 3).

For both stations, the high positive values at 1% local significance level were obtained better, −especially when the periods of 2005–2007 were included− while in some periods, adding the recent years (2008, 2009) caused decreasing significance level of the trend.

The sensitivity of the trend results to time periods with beginning dates before 1983 and ending dates after 1983 suggests that an abrupt change in annual maximum flood series around 1983 is the dominant feature of temporal changes during the 1958–2009 period. A monotonic trend test such as Mann-Kendall cannot distinguish a gradual change from an abrupt change in a single data sequence. However, the temporal pattern of Mann-Kendall test for many time periods does support the hypothesis of a step change rather than a gradual change.

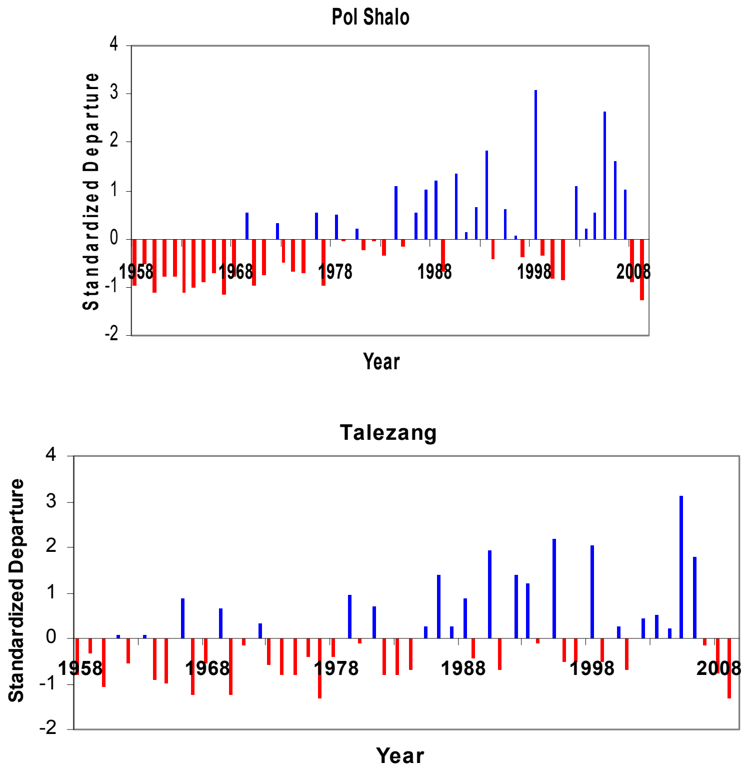

Figure 2. Mean standardized departures of annual maximum flood series for two main stations in Large Karoun river ,1958-2009

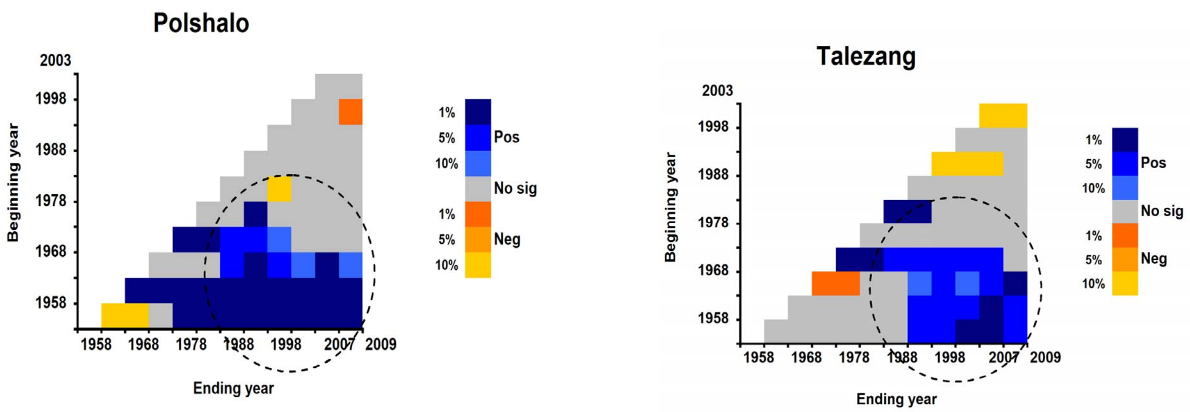

Figure 3. Multiple trend analysis at the 1% , 5% and 10% local significance levels increasing and decreasing trends in annual maximum flood series for various periods at least 10 years in length during 1958–2009.

V. Conclusions

Standardized departures analysis and trend tests of 52 years of annual maximum flood measurements in two main stations of Large Karoun river in Iran indicate that (1) there are relatively high significant changes in annual maximum flood series; (2) Increase in annual maximum flood series appear to have been the result of a step increase around 1983 rather than as a gradual trend. The identification of an abrupt increase in annual maximum flood series rather than a gradual increasing trend is important because the implications of a step change are different from those of a gradual trend. The interpretation of a gradual trend is that the trend is likely to continue into the future, whereas the interpretation of a step change is that the climate system has shifted to a new regime that will likely remain relatively constant until a new shift or step change occurs[10].

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