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TRENDS IN THE TIMING AND MAGNITUDE OF FLOOD IN THE LARGE KAROUN RIVER BASIN

Narges Zohrabi[1], Ali Reza Massah Bavani [2], Samaneh Abdeveis [3], Laleh Ranjbaran [4]

ABSTRACT

In this study, Mann-Kendall test and pre-whitening procedure were used to investigate trends in the magnitude and timing of seasonal maximum flood events in the Large Karoun River Basin in Iran. In order to study seasonal changes in flood timing directional statistics (DS) approach was applied. Nine stations with statistical period of 52 years (1958-2009) data in the upstream of the Large Karoun Basin with normal flow conditions were used. The results showed that the signals of variability and/or changes of climate in the timing of flood events in the five recent decades in the Large Karoun River Basin are not very strong. Most of the significant trends in the timing of winter-spring maximum floods are in the mountainous region north of the Large Karoun River Basin which has large share of snowmelt and it is emphasized that the timing of flood events caused by melting snow has been shifted to earlier times in the year. Studies conducted on the mean day of flood occurrence (MDF) showed reduction in mean day of flood occurrence (MDF) in the past two decades with respect to the step change observed in previous studies on this Basin. No significant trend in the fall flood timing due to rainfall is observed. The results also showed that trends in the magnitude of winter-spring floods are more significant than trends in the timing of their occurrence. Most of the significant trends in the magnitude of flood are positive and the increasing trend in the flood magnitudes is caused by melting snow in the Large Karoun River Basin over five decades ago. No significant trend is found in the magnitude of fall floods except one station. Results show that changes and shifts in the timing of the floods may be partly normal, but likely of future changes and shifting may be affected by increased greenhouse gas due to by human activities.

1. INTRODUCTION

Given the interest in relations between the greenhouse effect and an intensified hydrologic cycle in the last decade, several studies have investigated changes and trends in the timing and magnitude of hydrologic extremes may be one of the most significant consequences of climate change. Kundzewicz et al., (2005) detected upward and downward trends in the annual maximum flow series

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in a worldwide dataset; however, most of the series showed no significant trend. Svensson et al. (2005) found no general pattern of increasing or decreasing numbers of floods or their magnitudes in 21 stations worldwide; while, Milly et al. (2002) detected a significant increase worldwide in the monthly mean flood discharge of very large basins. Petrow and Merz (2009) detected significant flood trends (at the 10% significance level) for a considerable numbers of basins in Germany. Cunderlik and Ouarda (2009) studied the trends in the timing and magnitude of seasonal maximum flood events across Canada Schmacker Fackel and Naef (2010) analyzed temporal and spatial distribution of flood events in Switzerland with return periods larger than 10 years, and the large scale flood events of the last 150 years. 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. Zohrabi et al., (2011b) identified temporal fluctuations in the annual maximum flood of seven main stations in Karoun and Dez Rivers in Iran. Their results, using standardized departures analysis and multiple trend tests as suggested by McCabe and Wolock (2002), showed increasing trend in the magnitude of the annual maximum floods. They also identified a step increase around 1983 rather than as a gradual trend.Magilligan and Graber (1996) suggested using contour maps of daily mean and variance of flood occurrences to depict the flood regime. They constructed these contour maps for New England floods, USA, and analyzed the relationships between physiographic controls and flood timing using multiple regression models. Parajkaet al. (2009) compared the seasonality of selected precipitation and runoff characteristics in Austria and Slovakia. Monthly seasonality indices are analyzed to interpret the long-term climatic behavior, while the seasonality of extremes is analyzed to understand flood occurrence. Koutroulis et al. (2010) identified seasonality of floods and their hydrometeorologic characteristics in the Island of Crete.

According to the above literature, most of the studies on identifying trends and seasonality in the hydrological variables have been conducted in the Northern America, Europe and South East of Asia (China). Investigations on the identifying trends in the hydrological variables, particularly flood, in the Iranian River Basins are very limited. It can be noted that this study is among the first researches for examining trends in the magnitude and timing of seasonal maximum flood events in the Large Karoun River Basin of Iran. Therefore, the main objective of the work is detecting trends in the magnitude and timing of seasonal maximum flood events in the Large Karoun River Basin. The question is that if the changes in the magnitude and timing of annual maximum flood are because of climate change? For this purpose, magnitude and timing of annual maximum flood were investigated in forms of fall and winter-spring floods. Next headlines will explain study area, methods used in examining trends and seasonal variations and at the end the results will be discussed and concluded.

2. MATERIAL AND METHODS STUDY AREA

2.1 Study Area

Case study of this work is Large Karoun River Basin located at longitude 47º 58' to 52º 00º north and latitude 29º 59' to 34º 07' East in southwestern of Iran. Its two main rivers (Karoun and Dez) pass mountainous paths separately and enter to Khouzestan plain and are connected to each other at Band Ghir place, located 50 km north of the Ahvaz city in Khouzestan province and at the end shed to the Persian Gulf (Fig. 1). The most important issues in investigating changes in hydrological time series in the studies related to climate change are normality of flow, data accuracy, and using data with a wide period (Pilon, 2000). Therefore, this work has been done on the annual maximum floods of Karoun and Dez Rivers Basin in the mountainous parts of the basin which has not been affected by construction of dams.

The common statistical period for complete stations was 1958-2009. The aforementioned data were acquired from “Iran Meteorological Organization” and “Ministry of Energy” [Iran Water Resource Management Company and Khouzestan Water and Power Authority (KWPA)]. Figure 1 and table 1 show location and information related to selected hydrometric stations in the Karoun and Dez Basins.

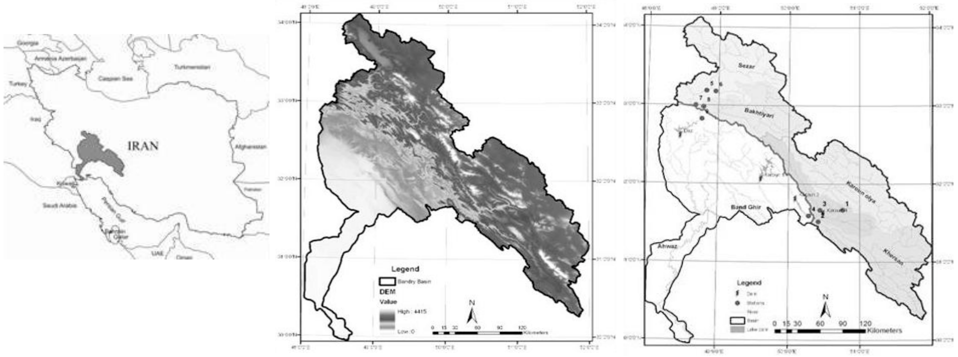

Figure 1 Location of selected hydrometric stations in the Karoun and Dez Basins.

Table 1 properties of the selected hydrometric stations in the mountainous regions of Karoun and Dez Basins.

Number	Regions of Large Karoun River Basin	River	Station	Geographical location (Long/Lat)	Elevation (m)	Area under drainage (KM^2)
1	Mountainous region of Karoun River	Karoun	Armand	´ 41° 31´ – 46 °50	1050	9900
2		Khorsan	Barez	´ 31° 31´ – 25 °50	860	8900
3		Bazoft	Morghak	´ 39° 31´ – 28 °50	815	2355
4		Karoun	Pole Shalou	´ 45° 31´ – 08 °50	700	23400
5	Mountainous regions of Dez River	Sezar	Sepid Dasht	´ 13° 33´ – 53 °48	970	7174
6		Zaz	Sepid Dasht	´ 13° 33´ – 53 °48	970	680
7		Sezar	Tang Panj	´ 56° 32´ – 45 °48	600	9410
8		Bakhtiyari	Tang Panj	´ 56° 32´ – 46 °48	540	6432
9		Dez	Tale Zang	´ 49° 32´ – 46 °48	480	16213

2.2 Mann–Kendall test

One of the most frequently used nonparametric tests for identifying trends in hydrologic variables is the Mann–Kendall test (Mann, 1945; Kendall, 1975). 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 sgn(θ)=1 if θ >0; =0 if θ = 0;=-1 if θ<0 (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 (Von Storch and Navarra, 1995; Zhang et al., 2001; Cunderlik and Burn, 2002; Cunderlik and Ouarda 2009).

2.3 Directional Statistics(DS)

In order to examine the flood series for a preferred orientation (i.e. seasonality), the annual flood data were analyzed with directional statistics, as described in (Fisher, 1993; Burn, 1997; Bayliss & Jones, 1993; Mardia, 1972).In this method The mean direction $\bar{\theta}$ of the event dates or the Mean Day of Flood occurrences is *MDF* . while the directional statistic of a single event has a unity magnitude, for the mean vector of *n* events, $\bar{r}$ can be defined as the measure of variability of the date of occurrence of the flood (Burn, 1997).Various applications of the directional flood seasonality measures $\bar{\theta}$ and $\bar{r}$ can be found in the literatures (Magilligan and Graber,1996; Cunderlik and Ouarda, 2009; Parajka et al., 2009; Koutroulis et al., 2010).

3. RESULTS

3.1 Trend Analysis

Table (2 , 3) summarizes the results of analysis of Mann–Kendall test for trend in the timing and magnitude of winter-spring (due to rain and snow melt) and fall (of rain), respectively, at different significance levels. It should be mentioned that because of less available data in fall, Mann–Kendall test was ran for four stations; while, for winter-spring floods all the nine stations data were used.

Table 2 Trend in timing and magnitude of witer – spring maximum floods

Trend significance	Positive trend						No significant trend		Negative trend					
M:Magnitude	M	T	M	T	M	T	M	T	M	T	M	T	M	T
T:Timing	1%		5%		10%				1%		5%		10%	
Pol Shalo	*							*						
Armand			*									*		
Barz					*									*
Marghak							*	*						
Talezang	*							*						
Tangpanj bakhtiyari	*							*						
Tangpanj Sezar							*	*						
Sepid dasht Sezar					*			*						
Sepid dasht Zaz			*					*						

Table 3 Trend in timing and magnitude of fall floods

Trend significance	Positive trend						No significant trend		Negative trend					
M:Magnitude	M	T	M	T	M	T	M	T	M	T	M	T	M	T
T:Timing	1%		5%		10%				1%		5%		10%	
Pol Shalo							*	*						
Barz	*							*						
Marghak							*	*						
Talezang							*	*						

Comparison between seasonal trends in the magnitude and timing of the annual maximum floods (tables 2 , 3) showed that only two stations, Armand and Barz, have a significant shift in the direction of both the timing and magnitude of the winter-spring annual maximum floods. In both stations, timing of spring flood is downward and magnitude is increasing. The two stations are located in the mountainous regions north of Karoun basin with great share of the produced floods caused by melting snow.

3.2 Directional Statistics(DS)

Seasonal variability index $(\bar{r},\bar{\theta})$ indicates that fluctuations in the timing of annual maximum floods in the Karoun and Dez Basins are not wide. Range of changes in the Karoun Basin ($\bar{r}$) is between 0.67 to 0.73 and the average time of occurrence within the period 20 February to early April. Variability in the Mean Day of Flood occurrence ($\bar{r}$) in the Dez basin are within 0.71 to 0.8 and on March. The consistence of different stations in the Dez Basin for mean date of flood occurrence (MDF or $\bar{\theta}$) is more and all are in March. This range for the Karoun Basin is slightly wider. This is because of more climatic variability in the Karoun Basin than Dez Basin. Figure 2 shows consistence in mean date of flood occurrence in the timing and magnitude of winter-spring snowmelt maximum floods at the selected stations in the Karoun and Dez basins Analyzing relationship between trends of the timing and magnitude of winter-spring floods with seasonal variability index $(\bar{r},\bar{\theta})$ showed significant decreasing trends in (*MDF*) occurrence were observed more on areas with snowy regime and the consistence in timing of flood occurrence is less. In addition, significantly increasing trends of magnitude of flood were observed in different regions with different climatic and hydrological regimes (Figure 2).

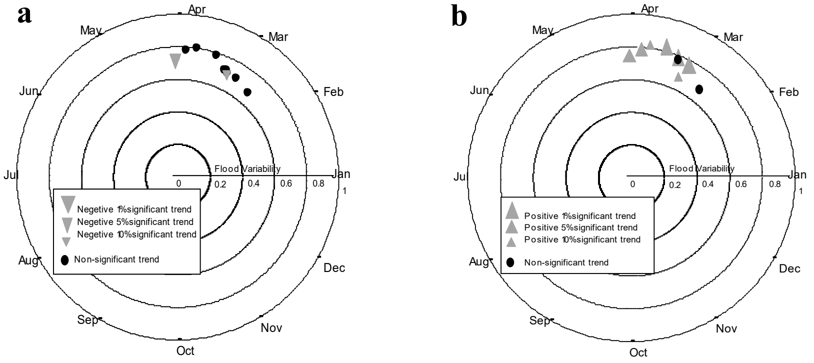

Figure 2 Trends in the timing (a) and magnitude (b) of winter-spring snowmelt maximum floods as a function of the mean day of the occurrence and variability of the floods.

Since a step change around 1983 in magnitude of annual maximum floods has been observed by Zohrabi et al. (2011b) through the analysis of multiple Mann- Kendall test and standard deviation in the selected stations of Karoun and Dez basins the highest common period, the seasonal variability index $(\bar{r},\bar{\theta})$ for the period before and after 1983 was determined. Figure 3 shows seasonal variability index $(\bar{r},\bar{\theta})$ in polar coordinates for the periods before and after 1983 in the selected stations of the Karoun Basin (stations with consistence statistical period).

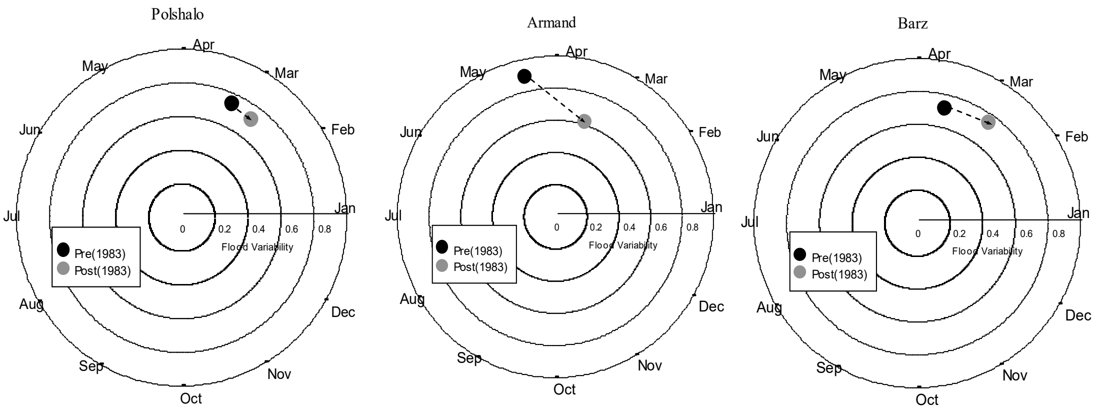

Figure 3 Seasonal variability index $(\bar{r},\bar{\theta})$ for the selected stations of Karoun Basin

The results of Figure 3 show seasonal variability in the Karoun Basin in which the mean day of flood occurrence (MDF) has decreased after 1983 rather than before 1983. The greatest difference was seen in Armand station that it is one month. This means that the mean date of annual maximum flood is 14th of April before 1983 and 14th of March after 1983. In Barz station, the mean date of annual maximum flood is 18th of March before 1983 and 24th of February after 1983 and the difference between the two periods is 23 days. In Pole Shalou station, the mean date of annual maximum flood is 7th of March before 1983 and 23th of February after 1983 and the difference between the two periods is 12 days.

4. CONCLUSIONS

This study tried to investigate trends in the magnitude and timing of seasonal maximum flood events of large Karoun Basin in Iran. In order to examine trends in the magnitude and timing of seasonal maximum flood events, Mann-Kendall test was used with pre-whitening procedure. In order to study seasonal changes in the timing of the floods, Directional statistics (DS) approach with characterized $(\bar{r},\bar{\theta})$ was used. The study was conducted for the past half century on the 9 stations located at five main sun-basins in the upstream of Large Karoun Basin in Iran, in which flow condition is natural.

The results showed most of the significant trends in the timing of winter-spring maximum floods are in the mountainous region north of the Large Karoun River Basin which has large share of snowmelt and it is emphasized that the timing of flood events caused by melting snow has been shifted to earlier times in the year. The main reason for the negative trends in the melting snow could be the warming effect of climate change. Researches of Zohrabi et al. (2011 a) in the detection and attribution of climate change on Large Kaorun Basin also showed that moving from past to recent years, the effect of increasing greenhouse gases on the temperature variation is more evident.

Studies conducted on the mean day of flood occurrence (MDF) showed reduction in mean day of flood occurrence (MDF) in the past two decades with respect to the step change observed in previous studies (Zohrabi et al , 2011b) on this Basin. No significant trend in the fall flood timing due to rainfall is observed. The results also showed that trends in the magnitude of winter-spring floods are more significant than trends in the timing of their occurrence. Most of the significant trends in the magnitude of flood are positive and show an increase in the magnitude of the floods caused by melting snow in the Large Karoun River Basin over five decades ago. No significant trend found in the magnitude of fall floods except one station. In general, the results of the study of seasonal changes in the magnitude of floods of winter - spring are consistence with results of with Zohrabi et al. (2011 b) indicating an increasing trend in the magnitude of annual maximum flood.

These results indicate that while historical variability/shifts in occurrence of floods can be somehow normal, but the risk of future shifts and changes can be strongly affected by increase of greenhouse gases because of by human activity. Therefore, acceptance of this probability raises the question whether the experimental common methods are appropriate for predicting future flood and hydrologic risks? Therefore, AOGCMs are key models for understanding and predicting future climate conditions that ultimately lead to the better estimates for risk of floods in the future.

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