International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:5, No:1, 2011

Climate Change Finger Prints in Mountainous Upper Euphrates Basin

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Abstract—Climate change leading to global warming affects the earth through many different ways such as weather (temperature, precipitation, humidity and the other parameters of weather), snow coverage and ice melting, sea level rise, hydrological cycles, quality of water, agriculture, forests, ecosystems and health. One of the most affected areas by climate change is hydrology and water resources. Regions where majority of runoff consists of snow melt are more sensitive to climate change. The first step of climate change studies is to establish trends of significant climate variables including precipitation, temperature and flow data to detect any potential climate change impacts already happened. Two popular non-parametric trend analysis methods, Mann-Kendal and Spearman's Rho were applied to Upper Euphrates Basin (Turkey) to detect trends of precipitation, temperatures (maximum, minimum and average) and streamflow.

Keywords—Climate change, precipitation, snow hydrology, trend analysis and Upper Euphrates Basin

I. Introduction

INTERGOVERNMENTAL Panel on Climate Change (IPCC) reports state that climate is changing in a way that can't be explained by natural variability. Global average temperature has increased by $0\ 4 - 0\ 8\ ^{0}$ during the period of 1860-2000 [1]. Approximately $0\ 75\ ^{0}$ global warming has been detected over the last 100 years [2]. Also, IPCC scenarios project a temperature rise of $1\ 4 - 5\ 8\ ^{0}$ based on different greenhouse gases emission scenarios by 2100 [3]. Furthermore, it is a fact that climate will continue to change or earth surface temperature will continue to increase under any possible greenhouse emission scenario over the next several decades [4].

Climate change leading to global warming affects the earth through many different ways such as weather (temperature, precipitation, humidity and the other parameters of weather), snow coverage and ice melting, sea level rise, hydrological cycles, quality of water, agriculture, forests, ecosystems and health.

One of the most affected areas by climate change is hydrology and water resources. Climate change results increase in temperature and it changes precipitation patterns over many regions in the world. Change in temperature and precipitation leads to alteration of hydrological cycles resulting changes in streamflow regimes. As a result of global warming, changes in globally averaged water vapour concentrations, evaporation, precipitation, humidity and wind speed have been observed and it is expected to be observed with increasing intensity in following years [5]. However, each variable is defined in terms of its frequency distribution and its distribution over space and time, hence, each variable will be affected differently. Mentioned changes in climate variables lead significant changes on hydrological cycle. For example, any change in temperature and precipitation will directly influence runoff quantity and quality; moreover, it will also affect evapotranspiration. Therefore, any change in hydrological cycle and water resources will result significant effects on irrigation, hydro-electrical power generation and water supply. Furthermore, socio-economical consequences of climate change will show difference according to development levels of nations [3]. IPCC findings showed that developing countries such as Turkey are more vulnerable to climate change due to socio-economic and geographical characteristics. Although climate change impacts have been projected at continental or global scale, regional climate change impacts on many parts of the world are yet to be investigated.

Regions where majority of runoff consists of snow melt are more sensitive to climate change, particularly changes in temperature. Temperature is the decisive variable for precipitation type and snow melt timing [6]. Therefore, it is necessary to establish climate change-temperature-snow hydrology relations and to assess climate change impacts in a regional scale, especially for catchments having special characteristics. There are two main influences of climate change on snow dominated basins' hydrology. Firstly, it causes decreases in runoff amount which leads water insufficiency for vital sectors including agriculture, industry, hydro-electrical power generation and domestic needs. Secondly, it results shifts in melting times leading early floods and/or summer droughts.

Although it is a fact that climate change will continue under any plausible greenhouse emission scenario, it is not possible to imply that future change will be uniform over the globe. Thus, it is important to develop regional climate change impact studies. The first step of climate change investigation on hydrology over a region is historical climate and streamflow data trend analysis. It is important to investigate whether climate change finger prints have already been observed and what type of trends the climate variables are following. Moreover, it is very beneficial to compare Global Climate Models' future projections with historical data trends.

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The most effective climate variables on snow dominated basins’ flow are precipitation, maximum, minimum and average temperatures. Thus precipitation, maximum, minimum, average temperatures and streamflow trend analysis in Upper Euphrates Basin (Karasu Basin) were performed. For the purpose of detecting any trends in the above-mentioned data two non-parametric trend analysis methods, Mann-Kendal and Spearman’s Rho were utilised.

II. Study Area

Euphrates River located in the mountainous Eastern Anatolia in Turkey, is one of the major rivers within Middle Eastern countries and has a significant importance for the countries including Turkey, Syria and Iraq. Snow is the main water source of Euphrates Basin, particularly for Upper Euphrates Basin, which is also called Karasu Basin. High amount of Karasu Basin annual flow consists of snow melt runoff. Geographical location of Karasu Basin is longitudes from 38^{0}58’13”E to 41^{0}38’28” E and latitudes from 39^{0}23’18” N to 40^{0}24’26”N. Basin location in Turkey is shown in Figure 1.

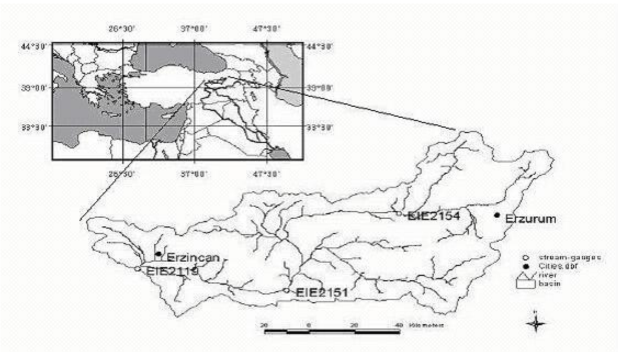

Fig. 1. Location map of Karasu Basin [7]

Karasu Basin has an area of 10215 km^2. It is the most mountainous part of Euphrates Basin with elevation range from 1125 m to 3487 m. Figure 2 shows the elevation map of the basin.

Meteorological data in Upper Euphrates Basin was obtained from Turkish State Meteorology Service (TSMS), while flow data was provided by General Directorate of Electrical Power Resources Survey and Development Administration (EIE). In Euphrates Basin, daily meteorological data including precipitation, minimum, maximum and average air temperatures, is available between 1 January 1975 and 31 December 2008. Meteorological stations in Karasu Basin are Erzurum, Erzincan and Tercan. Moreover, station 2119, which is at the outlet of Karasu Basin, provides daily flow data for the study. Flow data is available from 1 October 1975 to 30 September 1987 and from 1 October 1994 to 31 December

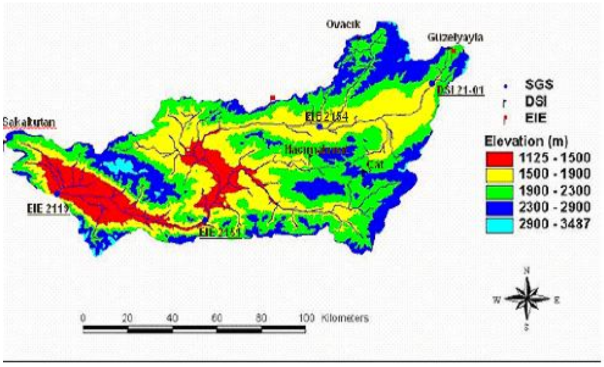

Fig. 2. Karasu Basin elevation map [8]

2004. Flow data is not available between 1 October 1987 and 30 September 1994 as the station 2119 was closed during this period.

Meteorological stations in Karasu Basin are geographically distributed over Karasu Basin. Latitude of Erzurum Meteorological station is 39^{0}54’ while longitude is 41^{0}17’. Moreover, elevation of Erzurum station is 1869 m. Latitude of Erzincan station is 39^{0}45’ while longitude is 39^{0}30’ and elevation of Erzincan station is 1218 m. Latitude of Tercan Meteorological station is 39^{0}47’ while longitude is 40^{0}23’ and its elevation is 1425 m. Physical locations of meteorological and flow stations in Karasu Basin are shown in Figure 3.

In Karasu Basin, minimum air temperature between 1975

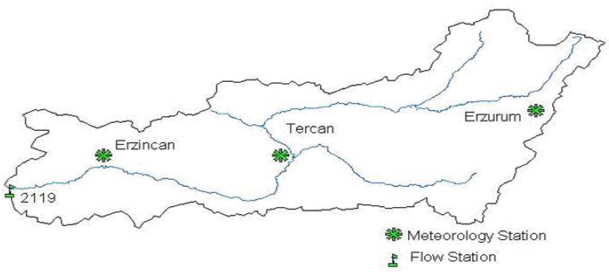

Fig. 3. Meteorology and Flow stations in Karasu Basin

and 2008 was -30^{0} , while maximum temperature was 28.3 ^{0} . Observed average air temperature was 5^{0} . Maximum rainfall measured between 1975 and 2008 is 59.6 mm observed on 23 February, 2004. Basin streamflows showed variation between 12.3 and 734 m^3/s. Maximum streamflow values were observed in spring seasons, when snow starts melting.

III. Methodology

Time series of hydrological data are widely used for water resources design and management. In literature, there are several statistical tools to evaluate trends in hydrological or other time series data [9], [10], [11], [12], [13], [14]. However, statistical tools to detect time series trends are grouped in two: parametric and non-parametric trend analysis [22]. The main reason of preference of non-parametric tests over parametric tests, is its suitability for non-normally distributed data and censored data, which are very frequent in hydro-meteorological time series [21]. In hydrological and meteorological studies two most commonly used non-parametric trend tests are Mann-Kendal and Spearman's Rho trend analysis. In this study, these tests were selected and applied to detect trends of hydro-meteorological time series data in Karasu Basin.

A. Mann-Kendal Non-Parametric Trend Analysis

The rank-based Mann-Kendall (M-K) trend analysis was applied to meteorological and streamflow time series to determine if there is a significant changing trend in climate variables. M-K is a popular non-parametric trend analysis method and commonly used in environmental studies [15], [16], [18], [19]. The formula of Mann-Kendall test statistic S is as follows:

$$= \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \quad (\ _j - \ _k) \tag{1}$$

$$\begin{cases} & 1 & \ _j - \ _k \quad 0 \\ (\ _j - \ _k) = 0 & \ _j - \ _k = 0 \\ & -1 & \ _j - \ _k \quad 0 \end{cases} \tag{2}$$

In formulas, $\ _1$, $\ _2$,........, $\ _n$ are defining time series while is number of observations [20].

Variance of S and normalized test statistic of z are calculated as follows:

$$(\ ) = \frac{(\ -1)(2 \ +5)}{18} \tag{3}$$

$$= \begin{cases} \frac{\ +1}{\sqrt{\ (\ )}} & 0 \\ 0 & = 0 \\ \frac{\ -1}{\sqrt{\ (\ )}} & 0 \end{cases} \tag{4}$$

Critical test statistic values for various significance levels can be found from normal probability tables. After calculating z-statistic, it is possible to determine any trend and its significance level by comparing z-statistic and critical test statistic values for different significance levels.

B. Spearman's Rho Trend Analysis

Spearman's Rho test is another popular non-parametric test which is widely used in hydrological trend analysis studies [21], [22]. Spearman's Rho test is a rank-based test determines if the correlation between two variables is significant or not. When it is used in trend analysis, one variable is time itself, and the second one is corresponding to time series data. Similar to Mann-Kendal tend test, the n time series values are ranked and replaced by their ranks.

Spearman's Rho test statistic $\ _s$ is the correlation coefficient, which is calculated by using following equations.

$$\ _s = \frac{\ _{XY}}{(\ _X \ _Y)^{0.5}} \tag{5}$$

$$\ _X = \sum_{i=1}^{n} ((\ _i - \overline{\ }))^2 \tag{6}$$

$$\ _Y = \sum_{i=1}^{n} ((\ _i - \overline{\ }))^2 \tag{7}$$

$$\ _{XY} = \sum_{i=1}^{n} (\ _i - \overline{\ })(\ _i - \overline{\ }) \tag{8}$$

In above equations, $\ _i$ refers to time, $\ _i$ is variable of interest, $\overline{\ }$ and $\overline{\ }$ correspond to the ranks.

IV. Results

A. Precipitation Trends

Spring is the rainiest season in Karasu Basin according to all meteorological stations. On the other hand, summer is the least rainy season for Tercan and Erzincan areas, whereas winter is the least rainy season in Erzurum. Summer is the second least rainy season in Erzurum. Average total annual precipitation between 1975 and 2008 in Erzurum was 407 4 mm while it was 379 mm in Erzincan and 449 mm in Tercan.

When precipitation data between 1975 and 2008 was investigated, there is an overall decreasing precipitation trend in Erzurum and Tercan. On the other hand, a very slight increasing precipitation trend was observed in Erzincan. Time series graph of total annual precipitation at meteorological stations are shown in Figure 4.

All annual precipitation trends in Karasu Basin are statistically insignificant based on Mann-Kendal and Spearman's Rho non-parametric trend tests. Nonetheless, the most important trend among three stations is Erzurum precipitation decline trend. Moreover, between 1979 and 1993, statistically significant downward trend was detected in Erzurum at 0.05 significance level. Mann-Kendal and Spearman's Rho trend analysis results for annual precipitation is shown in Table I.

There are downward trends in winter precipitations at all meteorological stations, nevertheless, only Erzurum station winter precipitation trend is statistically significant at 0.05 significance level. Erzurum station winter precipitation decrease is demonstrated in Figure 5 and Table III.

There is downward trend for spring precipitations at all stations. However, spring season precipitation trend in Erzurum showed increasing trend since 1990. All spring season precipitation trends are statistically insignificant according to Mann-Kendal and Spearman's Rho tests. Moreover, all meteorological stations' summer season precipitation demonstrated insignificant decreasing trends. Nevertheless, summer precipitation of Erzurum station showed insignificant upward trend since 2000.

Unlike from other seasons, an increasing precipitation trend was observed in autumn precipitation at all meteorological stations. Autumn season increasing trend at Erzincan station

TABLE I
MANN-KENDAL AND SPEARMAN'S RHO TREND ANALYSIS RESULTS FOR ANNUAL PRECIPITATION

Station	Mann-Kendal z statistic	Spearman's Rho-z statistic	Critical Values of Significance Levels			Mean	Median	Standard Deviation
			0.1	0.05	0.01			
Erzurum	-1.097	-1.024				407	396	63.32
Erzincan	0.296	0.347	1.645	1.96	2.576	379	368	78.99
Tercan	-0.148	-0.032				448	438	87.51

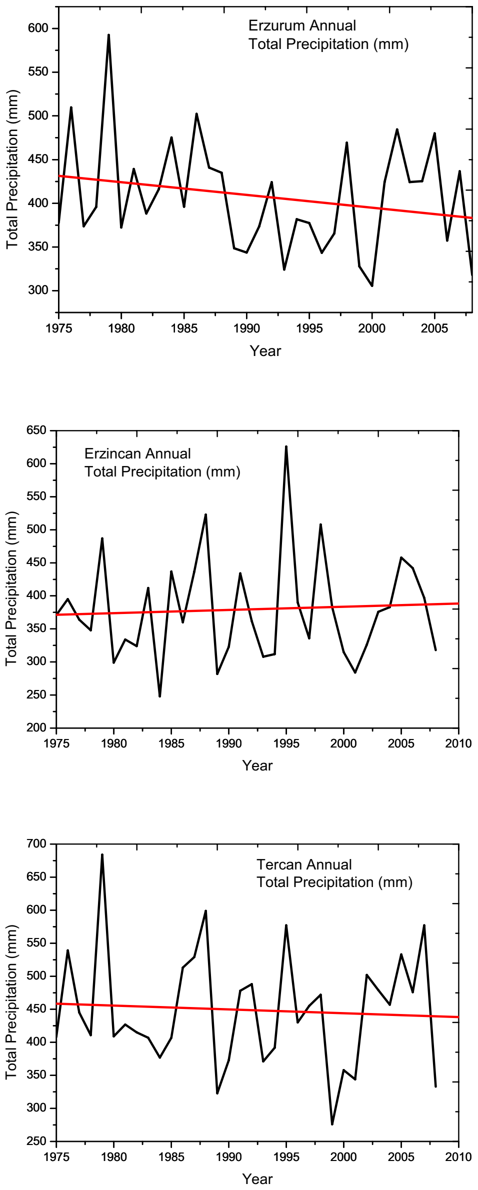

Fig. 4. Total annual precipitation graphs of meteorology stations in Karasu Basin

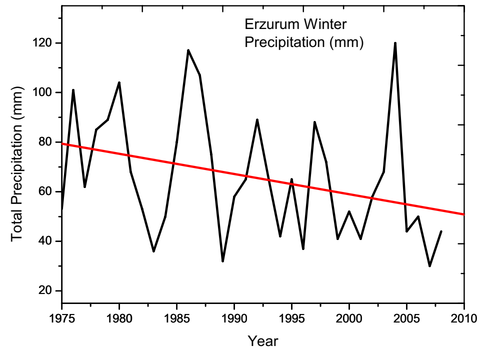

Fig. 5. Erzurum Station Winter Precipitation

TABLE II
WINTER PRECIPITATION DECREASE IN ERZURUM STATION

	Mann-Kendal z statistic	Spearman's Rho-z statistic	Critical Values of Significance Levels		
			0.1	0.05	0.01
Erzurum Winter Precipitation	-1.986↓ ↓	-1.976↓ ↓	1.645	1.96	2.576

is more significant than the others, however, all trends are statistically insignificant.

B. *Temperature Trends*

In this study, average, minimum and maximum air temperatures trends in Karasu Basin were evaluated. Investigations were performed in both annual and seasonal perspectives. From the temperature data between 1975 and 2008 in Erzurum, it is clear that 1992 was the critical year when significant warming trend started to be observed. Annual average and minimum temperatures showed significant cooling trend until 1992, then average and minimum temperatures commenced to rise and showed significant warming trend. On the other hand, maximum temperatures of Erzurum station showed constant significant upward trend. Annual average, minimum and maximum temperatures time series graphs of Erzurum station are shown in Figure 6. In addition, Erzurum station temperature trend analysis results are shown in Table III.

In Table III, arrows were added to represent statistically significant increasing or decreasing trends. In Table III, ↑ corresponds to significant trend with 0.1 significance level, while ↑ ↑ means statistically significant trend with 0.05 significance level and ↑ ↑ ↑ represents significant trend with 0.01 significance level.

Furthermore average, minimum and maximum temperature

TABLE III
AVERAGE, MAXIMUM AND MINIMUM TEMPERATURE TRENDS OF ERZURUM STATION

Erzurum	Mann-Kendal z statistic		Spearman's Rho- z statistic		Critical Values of Significance Levels			Mean	Median	Standard Deviation
					0.1	0.05	0.01			
Annual Average Temperature	1975-1991	1992-2008	1975-1991	1992-2008	1.316	1.568	2.061	5.36	5.28	1.037
	-1.68↓ ↓	0.865	-2↓ ↓	0.882						
Annual Minimum Temperature	1975-1991	1992-2008	1975-1991	1992-2008	1.316	1.568	2.061	-1.42	-1.875	1.749
	-1.93↓ ↓	1.31↑	-2.10↓ ↓ ↓	1.43↑						
Annual Maximum Temperature	1975-2008		1975-2008		1.645	1.96	2.576	12.11	12.19	0.944
	1.809↑		1.756↑							

TABLE IV
AVERAGE, MAXIMUM AND MINIMUM TEMPERATURE TRENDS OF ERZINCAN STATION

Erzincan	Mann-Kendal z statistic	Spearman's Rho- z statistic	Critical Values of Significance Levels			Mean	Median	Standard Deviation
			0.1	0.05	0.01			
Annual Average Temperature	1975-2008	1975-2008	1.645	1.96	2.576	10.911	10.88	0.925
	2.95↑ ↑ ↑	2.989↑ ↑ ↑						
Annual Minimum Temperature	1975-2008	1975-2008	1.645	1.96	2.576	4.942	4.91	0.968
	3.365↑ ↑ ↑	3.438↑ ↑ ↑						
Annual Maximum Temperature	1975-2008	1975-2008	1.645	1.96	2.576	17.377	17.37	1.03
	2.491↑ ↑	2.529↑ ↑						

observations at Erzincan station showed statistically upward trends. It is demonstrated in Figure 7.

It is seen in Table III and IV that temperatures in Erzurum and Erzincan showed upward trends, however, according to Mann-Kendal and Spearman's Rho tests, warming trends in Erzincan station is more significant than Erzurum station. Moreover, Erzincan station showed continuous upward trend, while Erzurum had warming trend after 1992.

Finally, Tercan meteorological station temperatures were investigated for the purpose of understanding significance levels of temperature increases. Temperature trends of Tercan station are shown in Figure 8 and Table V.

According to Table V, annual average and maximum temperatures showed significant warming, nevertheless, increase in maximum temperature is much more significant.
Moreover, seasonal trend analyses of minimum, average and maximum temperatures in Karasu Basin were performed based on non-parametric trend tests. Seasonal temperatures showed similar trends for minimum, maximum and average temperatures. In Erzurum, for average and minimum temperatures, decreasing temperature trends were observed from 1975 to 1992, followed by warming trends from 1992 to 2008 in all seasons. However, maximum temperatures in spring, summer and autumn seasons showed warming trends which are significant since 1992. Maximum temperature rising trends are particularly significant in summer and autumn seasons in Erzurum.

There are significant warming trends in spring, summer and autumn average temperatures in Erzincan. Especially, in summer season, average temperature increase is very clear. Also, there is an increasing trend in average temperature in winter season, however not statistically significant. Moreover, there are significant warming trends in spring, summer and autumn seasons minimum temperatures in Erzincan. Summer upward trend is very significant. Furthermore, increasing trend was observed in minimum temperature of winter season. In addition, seasonal temperature trend analysis of maximum temperature was performed in Erzincan. There are insignificant upward trends in maximum temperatures in Erzincan for autumn and winter seasons. Nonetheless, warming trends in maximum temperature are significant in spring and particularly in summer season.
There is no trend in winter season average temperature in Tercan. There is a slight warming trend in spring and autumn seasons average temperatures in Tercan. On the other hand, there is very significant upward trend in summer season's average temperature. Moreover, there is a slight decreasing trend in minimum temperature in Tercan during winter season. There is an insignificant upward trend in spring, summer and autumn seasons' minimum temperatures. Furthermore, there is an insignificant warming trend in winter season maximum temperature in Tercan. Nonetheless, maximum temperature between 1992 and 2001 showed substantial warming trend. There are significant increasing trends in spring and autumn seasons maximum temperatures and significant warming trend in summer season's maximum temperatures.

C. *Flow Trends in Karasu Basin*

Flow data for the period of 1975-1987 and 1995-2004 is available at the outlet point of Karasu Basin, station 2119.

TABLE V
AVERAGE, MAXIMUM AND MINIMUM TEMPERATURE TRENDS OF TERCAN STATION

Erzincan	Mann-Kendal z statistic	Spearman's Rho-z statistic	Critical Values of Significance Levels 0.1	0.05	0.01	Mean	Median	Standard Deviation
Annual Average Temperature	1975-2008 1.69↑	1975-2008 1.798↑	1.645	1.96	2.576	8.47	8.54	0.954
Annual Minimum Temperature	1975-2008 0.637	1975-2008 0.552	1.645	1.96	2.576	2.256	2.335	0.952
Annual Maximum Temperature	1975-2008 3.024↑ ↑ ↑	1975-2008 3.01↑ ↑ ↑	1.645	1.96	2.576	14.924	15.025	1.116

There are two main impacts of climate change on streamflows in snow dominated basins: first one is decreasing trend in streamflow amount and the second one is shifts to earlier snow melting time because of increase in temperatures.

There is a very slight decreasing trend in annual average runoff in Karasu Basin. Nevertheless, decrease in streamflow amount is not statistically significant. Time series graph of annual average runoff in Karasu Basin is shown in Figure 9. It is shown in Table VI that although there is downward flow trend in Karasu Basin, it is not statistically significant according to both Mann-Kendal and Spearman's Rho non-parametric tests.

Moreover, peak flow dates were investigated at flow station to detect any shift to earlier time due to climate change. It is established by temperature trend analysis that 1992 was the year when climate change impacts started to be experienced in Karasu Basin. So, available flow data after 1992 were considered for the purpose of determining peak flow dates. Dates of peak flows after 1995 are demonstrated in Table VII. As shown in Table VII, there is a very slight shifting trend to earlier melting date. Finally, based on runoff amount trend and peak flow date analysis, it can be stated that climate change impact on Karasu Basin catchment flows is not significant currently.

TABLE VII
PEAK FLOW DATES

Year	Peak Flow (m^3/s)	Date
1995	461	3-May
1996	375	16-May
1997	434	4-May
1998	718	19-April
1999	244	8-May
2000	293	7-May
2001	211	7-April
2002	291	18-April
2003	524	27-April
2004	456	1-May

V. CONCLUSION

Climate change has substantial influences on hydrological cycles and water resources. Snow dominated basins are more sensitive to climate change. Owing to global warming, less snowfall has been observed in snow dominated basins resulting less snow melt runoff, which is very important especially in late spring and summer seasons.

Climate change has two basic effects on snow melt runoffs. Firstly, it causes reductions in quantity-quality of runoff and secondly, it results shifts in snow melting time which leads floods and/or droughts in snow dominated basins. Decrease in total water potential will result very crucial problems to allocate enough water to sectors including agriculture, industry, hydro-electric power generation and urban water supply.

In this paper, climate change finger prints were investigated in Upper Euphrates Basin (Karasu Basin) based on trend analyses of historical meteorology including precipitation, minimum, maximum, average air temperatures and flow data by using two non-parametric trend tests, Mann-Kendal and Spearman's Rho. Meteorological data from three meteorological stations within Karasu Basin and flow data from a station at the outlet of basin were analysed. Findings of historical data trend analysis are summarized as follows:

- There are statistically insignificant decreasing trends in precipitation in Karasu Basin for all seasons except autumn season. All meteorological stations showed upward precipitation trend in autumn season.

- Significant warming trends were detected for Karasu Basin's temperatures. In Erzurum station, it is possible to discuss two distinct periods; one from 1975 to 1991 and the other from 1992 to 2008. In first period, decreasing trends were observed except maximum temperature, while there are significant warming trends since 1992.

- Maximum temperature warming trends are dramatic and occurred in all seasons for all stations.

- Summer season warming trend is more significant than all other seasons.

- Erzincan station temperature trends are more important and clear than Erzurum and Tercan stations.

- Tercan station temperature trends are the least significant

International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:5, No:1, 2011

TABLE VI
FLOW TREND ANALYSIS IN KARASU BASIN

2119	Mann-Kendal z statistic	Spearman's Rho- z statistic	Critical Values of Significance Levels			Mean	Median	Standard Deviation
			0.1	0.05	0.01			
Annual Average Flow (m^3/s)	-0.695	-0.645	1.645	1.96	2.576	81.81	84	16.741

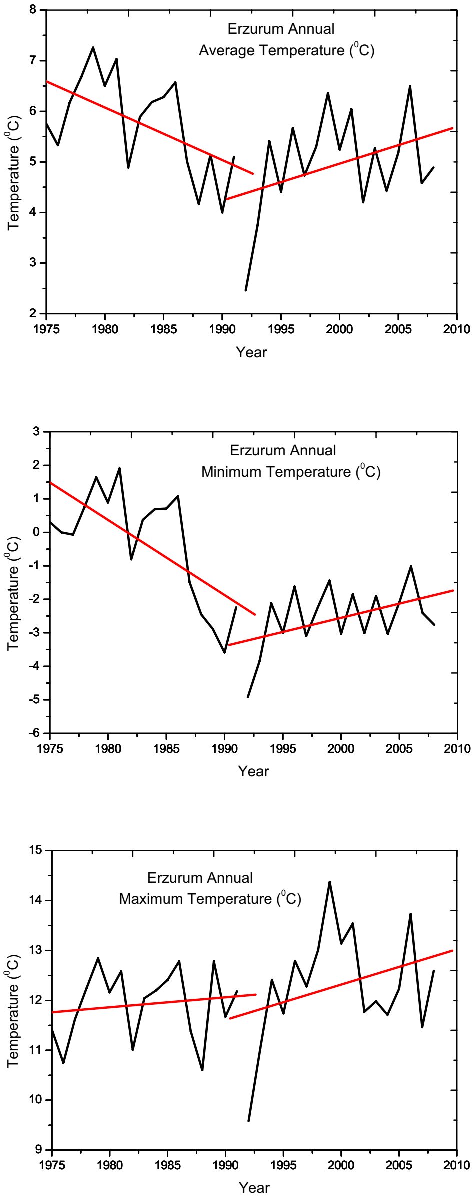

Fig. 6. Annual average, minimum and maximum temperatures of Erzurum station

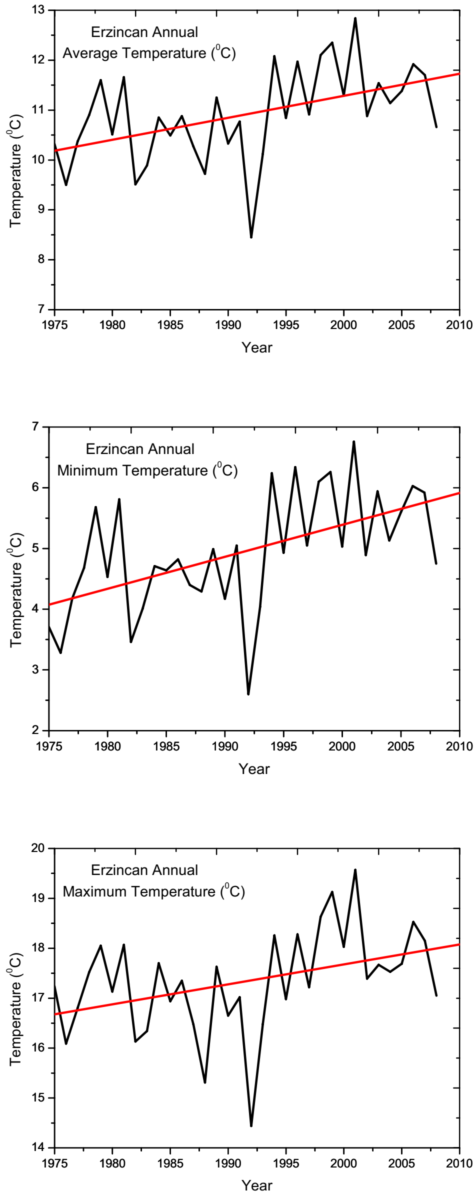

Fig. 7. Annual average, minimum and maximum temperatures of Erzincan station

among three meteorological stations.

- Temperature increases are mostly more important since 1992.

- There is an insignificant downward trend in Karasu

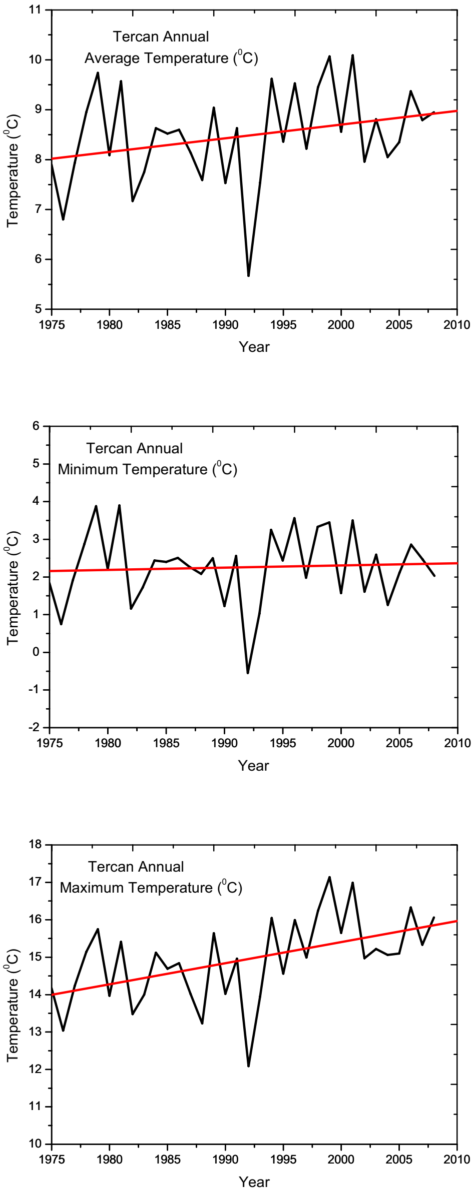

Fig. 8. Annual average, minimum and maximum temperatures of Tercan station

Basin's flow; moreover, very slight shift in snow melting time was detected.

Detected trends in Karasu Basin are in agreement with the trends stated by previous trend analysis studies performed in Turkey based on historical meteorological data [16], [18]. 1992 can be determined as the starting point when human induced climate change impacts have been commenced to be observed in Turkey. Temperature showed the lowest values in 1992 due to Mount Pinatubo eruption, when significant amount of particles were released into the stratosphere,

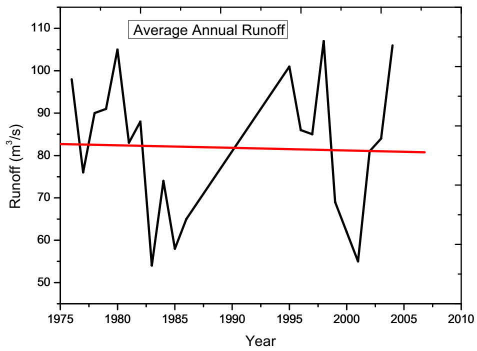

Fig. 9. Time series graph of annual average runoff in Karasu Basin

acting as anti-greenhouse agents. It is explained by Tayanc et al.(2009) that most meteorological stations in Turkey demonstrated substantial decrease in temperature due to Mount Pinatubo eruption. After 1992 to date, there is an obvious increasing trend in minimum, maximum and average temperatures in all seasons. Temperature trends in Karasu Basin are quite similar to Turkey average temperature trends. Demir et al. (2008) stated that Turkey average temperature has showed similar trend to global average surface temperatures, except that the global average surface temperature has shown rapid increasing trend since 1980s, while Turkey average temperature rising trend was observed from 1990s.

It should be noted that expected influences of climate change on middle and lower Euphrates Basin will be more significant than Upper Euphrates Basin. Because of current study focus (snow hydrology), mountainous Upper Euphrates Basin was chosen as study area. But, largest dams of Turkey and broad irrigation areas are located in middle and lower Euphrates Basin. Dams in Euphrates Basin are used for the purposes of domestic water supply, irrigation, hydroelectric power generation. Ataturk, Keban and Karakaya dams are the most significant ones amongst these. Most of the water in these dams comprises of snow melt (60-70 of all streamflow).

It is found that there is no significant decreasing trend in streamflows in Upper Euphrates Basin. However, previous studies showed that there are already significant decreasing trends in lower Euphrates streamflows based on historical flow data analysis [17].

Finally, current study showed that climate change effects have commenced in Karasu Basin. Although, there is no clear impact on snow runoffs in Karasu Basin, significant increasing temperature trends were detected. Moreover, decreasing precipitation trends were presented in this paper. Hence, sooner or later, snow runoffs of Karasu Basin will be influenced by climate change and it will have substantial consequences on water sectors. As a next step, it is imperative to perform studies on hydrological impacts of climate change using suitable hydrological models and accurate global and regional climate model outputs to simulate expected future runoffs in Upper, Middle and Lower Euphrates Basins. Through such studies future potential problems in Euphrates Basin can be envisaged and some appropriate solutions can be proposed. June 15, 2010

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