CLIMATE CHANGES AND TRENDS IN TEMPERATURE AND PRECIPITATION OF RIZE (NORTHEASTERN TURKEY) FOR THE PERIOD 1975-2001

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ABSTRACT
In this study, Statistical analysis were applied a historical set of rainfall and temperature data collected at the Rize (Northeastern Turkey, $41^0.00$ N; $40^0.50'$ E). In the climate change analysis, increasing trends of approximately 0.9 ^{0}C and 2.3 ^{0}C in 27 years in the mean annual and mean maximum annual temperature were found, respectively. There was variability among years, with a standard deviation of 0.6 ^{0}C where the average for 27 years period is 14 ^{0}C. The trend is towards a warmer climate and two periods were detected: 1975-1993 and 1994-2001, which had average temperature 13.8 ^{0}C and 14.6 ^{0}C respectively. The trend of the first period is towards a cooler climate, whereas the trend of the second period is towards a warmer climate.
In the analysis, annual, seasonal and monthly precipitations were considered. Results showed that the trend is towards a wetter climate, with an estimated increase of about 222 mm in the whole period. Two period, averaging 2092 mm and 2279 mm respectively were detected from fluctuation in rainfall. The trend of the first period (1975-1984) is towards a drier climate, whereas the trend of the second period (1985-2001) is towards a wetter climate.

1. Introduction
There is increasing evidence that the global climate is changing as a result of anthropogenic activity [1]. Measurements of surface temperature, primarily over land region, show an approximately 0.6 ^{0}C warming of global temperatures over the last century [2]. Global circulation model used to study the effects of greenhouse gases concentrations on the Earth's climate give predictions of the changes in temperature, in the amount and distribution of precipitation and other climatic parameters [3].

The objective of this paper is to study temperature and rainfall change in Rize (Turkey) from data set for the period 1975-2001. It is aimed to give detailed information on temperature and rainfall data of Rize, to reveal the nature and magnitude of trends and the change points and significant warming/cooling and wet/dry periods and trend rates in data series of Rize.

2. Description of study area
The climatology station in Rize is located at about 41^o 00' N / 40^o 30' E and height about 4m above sea level. In the area, due to very high slope and very little flat area, there are many short, fast and unstably flow rivers. Winter and summer seasons are warm in Rize. Annual average temperature doesn't go below +14 ^{o}C. The lowest temperature is normally found in January, averaging 6.7 ^{o}C and the highest temperature in July, averaging 22.2 ^{o}C. The annual total precipitation is 2300 mm in Rize. The rainfall comes in all seasons with lowest concentration in spring. The humidity is high in all seasons and the average relative humidity is 80%.

4. Methods
In order to identify recent trends, the change points and warming/cooling and wet/dry periods in temperature and rainfall series, a number of databases have been assembled from

exiting records held by the Turkish State Meteorological Service. The Rize databases used here consist of annual, seasonal temperature and rainfall from 1975 to 2001.

The Thom test has been performed on the data to test the series for homogeneity as recommended by the World Meteorological Organisation. The Thom test being a non-parametric test studies variation in the series with regard to median [4]. All time series have been checked for normality with the skewness and kurtosis coefficients. A set of temperature and rainfall suitable indices was chosen for detecting climate changes, trends and trends rates. The following three basic terms of climatic changes is used:

1. *Non-abrupt change*; The cumulative sums of deviations were calculated over the 27 years period, in order to analyze non-abrupt changes in the temperature and rainfall series and differentiate warming/cooling or wet/dry periods.

2. *Trends;* The Mann-Kendall test, a non-parametric test, is used to test the presence of a monotonic increasing or decreasing trend [5, 6].

3. *Trends rates*; To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used.

5. Results

In this study, temperature and rainfall changes, trends and trend rates in Rize were investigated. Results are presented the annual and seasonal time series changes and various statistical test applications.

5.1. Annual and seasonal temperature

According to homogeneity test (Thom's z test), annual and seasonal time series may be considered homogeneous series. The temperature series for the 27 years period followed a normal distribution. For a better understanding of changes in the temperature series, the cumulative sums of deviations were plotted in Figure 1(b). Two periods were detected by the cumulative sums of deviations: 1975-1993 and 1994-2001, which had average temperature of 13.78 ^{0}C and 14.61 ^{0}C, respectively. A *t* test analyzing independent samples shows that the positions of the means of the first and second periods are significantly different ($\alpha = 0.01$). The trend of the first period is towards a cooler climate, whereas the trend of the second period is towards a warmer climate. Annual series showed a decreasing trend until approximately 1993 and an increase after that year, which had a perfect agreement with the recent results by Türkeş et al. [7] compared with cooling trends found by Türkeş et al. [8].

Figure 1(a) shows the inter-annual variations of mean temperature and its trend in the studied period. The Mann-Kendall test confirmed that the positive trend is significant with a 95 % confidence limit. There was variability among years, with a standard deviation of 0.6 ^{0}C where the average for 27 years period is 14 ^{0}C. The trend is towards a warmer climate, with an estimated increase of about 0.9 ^{0}C/ 27 years in the whole period.

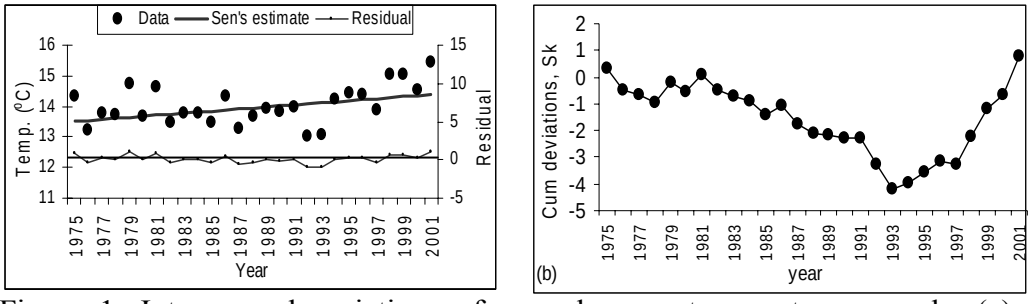

Figure 1. Inter-annual variations of annual mean temperature records. (a) Annual mean temperature and its trend, (b) cumulative sum of deviations from the average of annual mean temperature.

The seasonal series showed a similar trend of annual mean temperature. The Mann-Kendall test confirmed that the positive trend observed is significant with a 99 % and 95 % confidence limit for summer and autumn mean temperatures, respectively. For these seasons, a general warming is seen over the whole period. Slightly increasing trends characterize the winter and spring mean temperature.

Trend rates in temperature series

The changes per year are calculated using the Sen's nonparametric method. For annual mean temperature, there has been a significant increasing trend at 0.033 ^{0}C/year (≅ 0.9 ^{0}C/27 years) (Figure 1a). The annual maximum temperature indicates a dramatically increase of 2.26 ^{0}C (0.084 ^{0}C/year) over the last 27 years. However, the annual minimum temperature has increased slightly by 0.54 ^{0}C over the same period. For annual minimum temperature, the trend rates of the series are weak and insignificant statistically (Figure 2a, b).

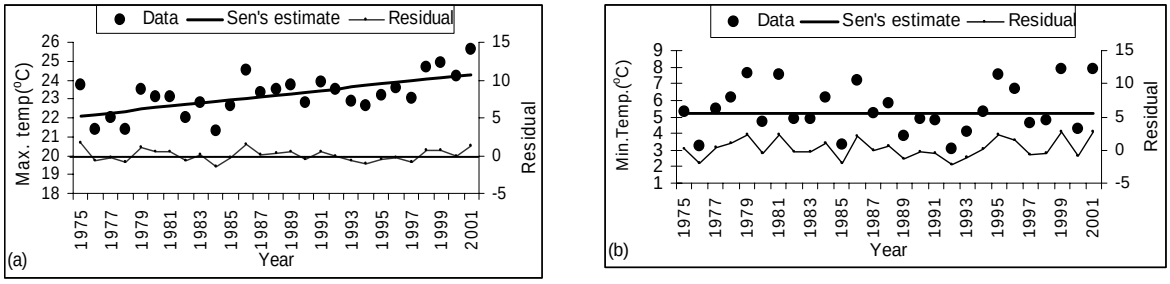

Figure 2. Linear trends over the annual (a) minimum and (b) maximum temperatures series

The trend rates of the winter mean temperature have revealed a decreasing trend, which is weak an insignificant. For spring mean temperature, the trend rate indicates a slight increase, which is insignificant, with 0.008 ^{0}C per year (≅ 0.2 ^{0}C/27 years). The highest significant warming season is summer, with a trend rate of 0.074 ^{0}C per year (≅ 2.0 ^{0}C/27 years) at the 0.01 level. This trend rate is the highest warming among seasons. Autumn mean temperature have showed an increase trend. The trend is statistically significant at 0.05 level, with a trend rate of 0.044 ^{0}C per year (≅ 1.2 ^{0}C/27 years) (Figure 3).

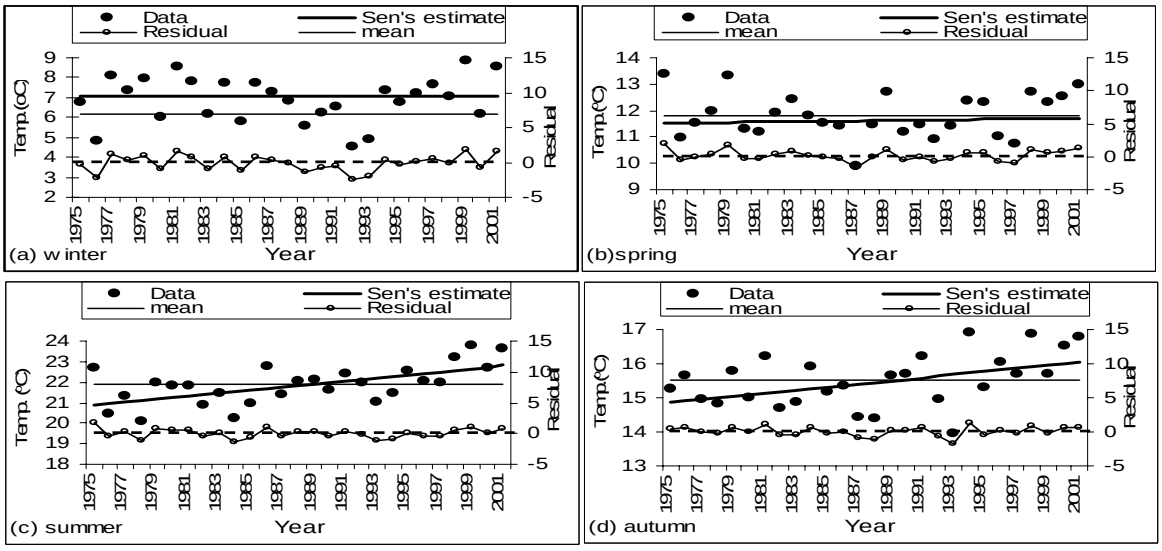

Figure 3. Linear trends over the seasonal mean temperatures series

4.2. Annual and seasonal rainfall

According to homogeneity test (Thom's Z test), annual and seasonal time series may be considered homogeneous series. Annual and seasonal rainfall values for the 27 years

period followed a normal distribution. Figure 4(a,b) shows the total annual rainfall and its trend in the studied period. There was variability among years, with a standard deviation of 227 mm where the average for 27 years period is 2214 mm. The trend is towards a wetter climate, with an estimated increase of about 222 mm in the whole period.

For a better understanding of variability among years, the cumulative sums of deviations were plotted in Figure 4(c). Two periods were detected by the cumulative sums of deviations: 1975-1984 and 1985-2001, which had average rainfall of 2092 and 2279, respectively. The trend of the first period is towards a drier climate, whereas the trend of the second period is towards a wetter climate. The trends of two periods were confirmed by the sequential version of the Mann-Kendall test with 95% confidence. Annual series showed a decreasing trend until approximately 1984 and an increase after that year (Figure 4(d)). The seasonal series showed a similar trend of annual rainfall (Figure 5).

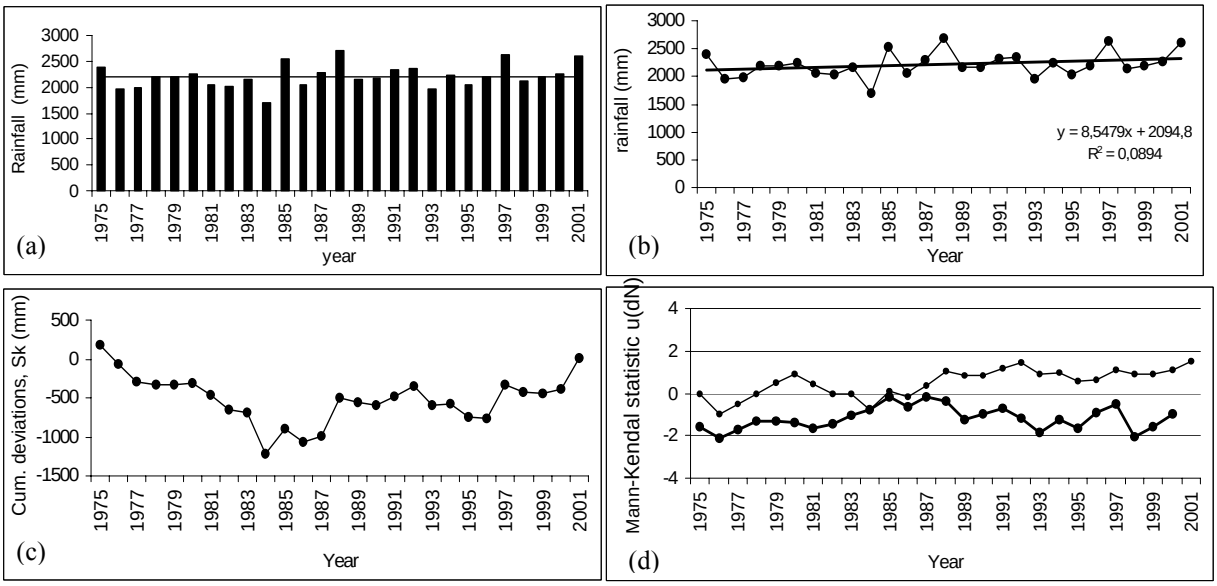

Figure 4**.** Distribution graphics of annual rainfall values at Rize region **(a)** The total rainfall time series from Rize.**(b)** The trend of the whole period. **(c)** Cumulative sum of deviations from average rainfall. **(d)** Results of the Mann-Kendall test. The solid line is the $u(d_i)$ statistic and the thin line is the retrograde series $u'(d_i)$.

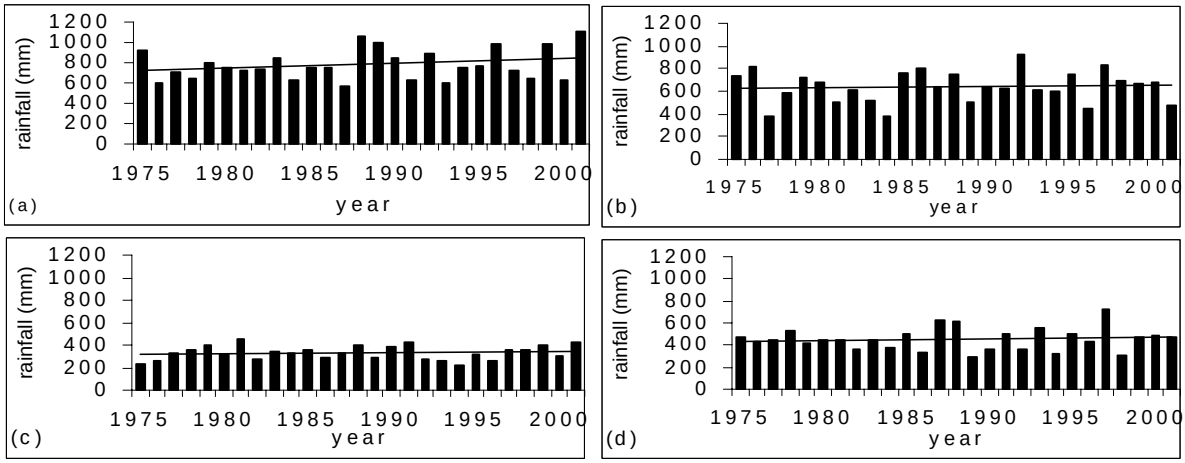

Figure 5. Total seasonal rainfall during 27 years period. (a) Autumn; (b) Winter; (c) Spring; (d) Summer.

6. Summary and Conclusions

Temperature

The analysis of short-term temperature observations recorded at only one station was carried out for the period 1975-2001 with respect to the local climatic variability. Annual mean temperature changes of Rize are characterized by a warming trend. Since 1975, there has been an increase in the annual mean temperature of about 0.9 ^{0}C/27 years. This trend rates are verified by a significant Sen's nonparametric test. It is reported that, in Turkey, the warming trend vary particularly at the highly urbanized stations of the Mediterranean and Southeastern Anatolia region between 0.07 ^{0}C and 0.34 ^{0}C per decade [7]. There have been reported increases in temperature over some part of the world [9].

The use of cumulative deviations detected two main periods in the temperature of Rize region. A relatively cool period from 1975 until 1993 has been succeeded by the warm period on record from 1994 to present.

Over whole period, summer mean temperature series show the most significant increasing trend. Significant trend rate in summer is 0.074 ^{0}C ($\cong$ 2.0 ^{0}C/27 years), at the 0.01 level. Turkes et al. [7] found that summer mean temperature series have shown a slight warming at many stations over the western part of Turkey, whereas the rest of country has experienced a general cooling. Cooling trend, which is insignificant, in Rize station, was found in winter season, with -0.002 ^{0}C per year ($\cong$ 0.05 ^{0}C/27 years). Autumn and spring mean temperatures have showed an increased trend.

Summer months mean temperatures have generally increased at a large rate than in winter and autumn months mean temperatures. Due to the urban warming, the energy consumption for air conditioning is expected to increase in the summer months. Similar results are reported by [10], where urban warming is found to be more or less equally distributed over the year with a slight increase in the autumn month for four large cities of Turkey. Turkes et al. [7] have stated that significant and very rapid night-time warming trends over much of the country can be related to the widespread, rapid and increased urbanization in Turkey, in addition to long-term and global effects of the human climate change on air temperatures.

Rainfall

Short-term records at Rize precipitation site were examined for evidence of climate change. Since 1975, there has been an increase in the annual precipitation of about 10% (122 mm). This result is consistent with the analysis of the climate for many regions of the world. Overall, global land precipitation has increased by about 2% since the beginning of the 20th century [11,12]. Regionally, Kiely (1999) [13] showed that precipitation in Ireland has increased by an average of 10% after 1975. It is reported that, in British Colombia, the mean annual precipitation increases by about 13% [14]. There have been marked increases in precipitation in the latter part of the 20th century over northern Europe, with a general decrease southward to the Mediterranean [15].

The use of cumulative deviations detected two main periods in the precipitation of Rize region. A relatively dry period from 1975 until 1984 has been succeeded by the wetter period on record from 1984 to present. This increase in precipitation of second wetter period has been concentrated in the autumn. This type of sequence of dry and wet periods of years is reported for many regions [4,16].

Figure 4 shows seasonal timescales precipitation totals and a significant increase in autumn. Over whole period, autumn have become wetter and spring drier. A similar seasonal

trend was reported by Werrity, (2002)[15]. Intra-annual variability is characterized by a maximum, often in November and a minimum in April.

It is noteworthy that the influence of warmer temperatures and the increase of water vapor in the atmosphere are not independent events, and are likely to be jointly related to increases in heavy and extreme precipitation events. Based on new analyses presented Second Assessment Report (SAR) of the Intergovernmental Panel on Climate Change (IPCC, 2001) [1], it is likely that there has been a widespread increase in heavy and extreme precipitation events in regions where total precipitation has increased, e.g., the mid-and high latitudes of the Northern Hemisphere)[1]. Peak stream flow is closely related to precipitation extremes as well as other hydrometeorological factors [16]. From 1929 to present, floods killed 424 people in eastern Black Sea region in which Rize is located. Also, these floods had displaced and affected houses, roads, railways, agricultural crops and lifelines. It is reported that floods in Bangladesh are caused by intense monsoon precipitation over the basin area of the Ganges, Brahmaputra and Meghna rivers. Mirza (2002) [17] have emphasized that future change in precipitation regime have distinct implications; the timing of occurrence, the magnitude, frequency, dept, extend, duration of floods may change.

7. References

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