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# Is Seasonal Precipitation Decreasing or Increasing in Turkey?

Ercan Kahya and Turgay Partal
Departmentof Civil Engineering, Istanbul Technical University 34469 Maslak, Istanbul, Turkey

**Abstract:** The purpose of this study is mainly to determine trends in precipitation variable for seasonal average of monthly totals using a non-parametric test, namely Mann-Kendall. The correlation structure in the data was accounted for in determining the significance level of the results of the Mann-Kendall test. We examined 96 precipitation stations across Turkey to reflect regional hydroclimatic conditions. Seasonal average precipitations of the monthly totals are formed at each individual station whose record length spans from 1929 to 1993. The analysis showed that the series of winter precipitation had decreasing trends (statistically significant at the 5% level) in 23 stations along the southwest-northeast direction. However, the other seasonal precipitation series showed less positive or negative significant trends.

**Key words:** Turkey, Mann-Kendall test, trend analysis, precipitation

## INTRODUCTION

Trends and long-term variability in meteorological and hydrologic variables have been studied by many researches (i.e., Lettenmaier, 1994; Zhang *et al*., 2000, 2001; Xu *et al*., 2003; Partal and Kahya, 2006; Kahya and Kalayci, 2004; Kalayci and Kahya, 2004; Yu *et al*., 1993). Correlations between hydrologic variables and meteorological variables were investigated by Burn and Elnur who explored that similarities in trends and patterns in the hydrologic variables and meteorological variables at various locations are connected to each other. They used the non-parametric Mann-Kendall test to detect trend for 18 hydrologic variables obtained from Canadian catchments.

In most previous studies regarding long-term trend analyses on hydroclimatological variables, the analysis technique used was the non-parametric Mann-Kendall test. Furthermore Lettenmaier (1994) studied whether there is an evidence for the long-term trends in streamflow as well as mean temperature and precipitation over the continental United States using the Mann-Kendall test. He also tried to investigate seasonal and spatial characteristic of climatic variables and showed that there were increase in precipitation starting from September to December at as many as %25 of the stations mostly in the central part of the country. Zhang *et al*. (2001), using the Mann-Kendall test, attempted to detect trends for 11 hydrometric variables in Canadian catchments by first applying a method proposed by Von Storch and Navarra (1995) to eliminate the effect of serial correlation. They found generally decreasing trend in streamflow data. Lins and Slack (1999) researched to the presences of the trends in selected quantiles at the USA streamflow records. They found that USA streamflow climatology is getting wetter but having less extreme events.

Kahya and Kalayci (2004) described the regions of western and south eastern Turkey as an area of significant decreasing trends. These streamflow trends were said to be all season-wise homogeneous; at the same time, some of those were noted to be homogeneous station-wise as well. Partal and Kahya (2006) used the Mann-Kendall test and Sen's T test for trend analysis of 96 precipitation stations across Turkey for monthly totals and annual means of the monthly totals. They found that some significant trends occur especially in the months of January, February and September precipitations as well as in annual means.

In this study we extended our earlier study (Partal and Kahya, 2006) to determine trends in precipitation data using seasonal averages of the monthly totals in 96 precipitation stations across Turkey. In other words, we were curious about possible changes in precipitation trend-type behavior if the length of time period of the variable under consideration is changed to 'season' from either 'month' or 'year'. For this purpose, we used only non-parametric Mann-Kendall test and compared the results with previous findings.

## MATERIALS AND METHODS

**Data:** The data network used in this study consists of 96 precipitation stations (Fig. 1), each spanning from 1929 to 1993. All stations have continuous observations over

**Corresponding Author:** Ercan Kahya Departmentof Civil Engineering, Istanbul Technical University 34469 Maslak, Istanbul, Turkey

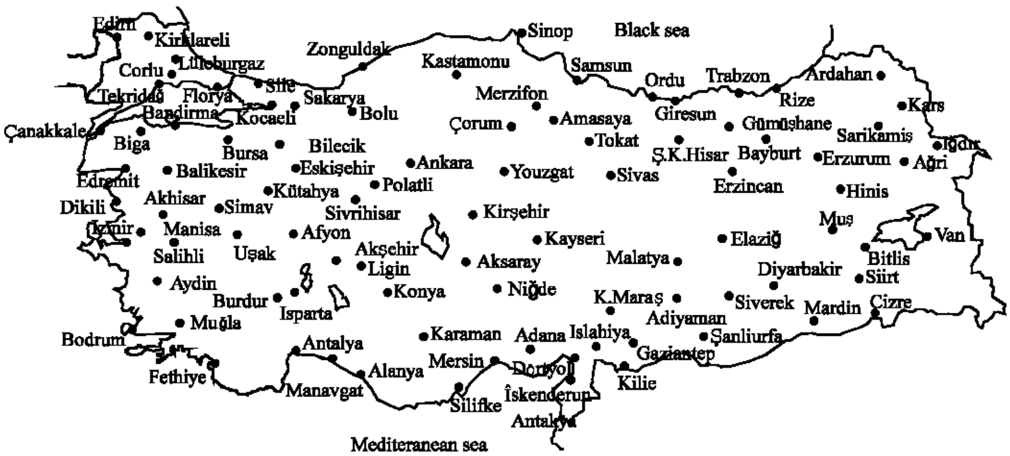


Fig. 1: Distribution of precipitation stations used inthis study (adapted from Partal and Kahya, 2006)

55 years with a maximum sample size of 65 years. Daily precipitation totals compiled by the Turkish State Meteorological Service (DMI) have been used to obtain monthly totals. We used then to calculate classical seasonal averages (winter, spring, summer and autumn) from the monthly totals. The homogeneity analysis of a large portion of the data network had been previously performed by Özçelik (1996).

**Serial correlation effects:** One of the problems in detecting and interpreting trends in hydrologic data is the confounding effect of serial dependence. In particular, if there is a positive serial correlation (persistence) in the time series, then the test will suggest a significant trend in a time series that is, in fact, random more often than specified by the significance level (Kulkarni and Van Storch, 1995). Because of this, Von Storch and Navarra (1995) suggest that the time series should be 'pre-whitened' to eliminate the effect of serial correlation before applying the Mann-Kendall test. Consequently, each precipitation time series ($x_1, x_2, \dots, x_n$) was examined using the following procedures; (i) compute the lag-1 serial correlation coefficient (designated by $r_1$); (ii) if the calculated $r_1$ is not significant at the 5% level, then the Mann-Kendall test is applied to original data; (iii) if the calculated $r_1$ is significant, then the 'pre-whitened' time series may be obtained as ($x_2$-$r_1x_1$, $x_3$-$r_1x_2$, … , $x_n$- $r_1x_{n-1}$) prior to application of the Mann-Kendall test; and finally (iv) the Mann-Kendall test is applied to the pre-whitened time series.

**Mann-kendall test:** The methodological description of Mann-Kendall test will be made based on Sneyers (1990). It is a rank-based procedure, which is robust to the influence of extremes and good for use with skewed variables. According to this test, the null hypothesis ($H_0$) states that the deseasonalized data ($x_1, x_2, \dots, x_n$) is a sample of n independent and identically distributed random variables. The opposite hypothesis ($H_1$) of a two-sided test is that the distributions of $x_k$ and $x_j$ are not identical for all $n \geq k, j$ ($k \neq j$). The test statistic S, which has mean zero and a variance computed by Eq. 3, is computed by Eq. 1 and 2 and behaves asymptotically normal (Hirsch and Slack, 1984).

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

$$\operatorname{sgn}(x_j - x_k) = \begin{Bmatrix} (x_j - x_k) & > 0 & \Rightarrow & +1 \\ (x_j - x_k) & = 0 & \Rightarrow & 0 \\ (x_j - x_k) & < 0 & \Rightarrow & -1 \end{Bmatrix} \tag{2}$$

$$\operatorname{Var}(S) = \frac{n*(n-1)*(2n+5)}{18} \tag{3}$$

In cases where the sample size n>10, the standard normal variate (z) is computed by using equation (4) (Douglas *et al*., 2000). In a two-sided test for trend evaluation, $H_0$ should thus be accepted if $z_{\alpha/2} \geq |z|$ at $\alpha$ level of significance. A positive value of S indicates an 'upward trend'; likewise, a negative value of S indicates 'downward trend':

$$z = \begin{Bmatrix} S > 0 \Rightarrow & \dfrac{S-1}{\sqrt{\operatorname{Var}(S)}} \\ S = 0 \Rightarrow & 0 \\ S < 0 \Rightarrow & \dfrac{S+1}{\sqrt{\operatorname{Var}(S)}} \end{Bmatrix} \tag{4}$$

## RESULTS AND DISCUSSION

As a first step, precipitation data at all stations were subjected to serial correlation analysis. Table 1 summarizes the total numbers of significant serial correlations The majority of the seasonal series in the data set appeared to have no significant lag-1 serial correlation coefficient; however, the winter season reveals a significant correlation value in 24% of 96 series (Table 1). Generally, stations with a significant serial correlation were scattered along Turkey. The stations with a significant serial correlation are subjected to pre-whitening procedures before applying the non-parametric test.

Afterwards, the four classical seasonal precipitation series were subjected to the Mann-Kendall test at each station. Table 1 presents the total numbers of stations which revealed a decreasing or increasing trends at 5% significance level. Moreover the spatial distribution of significant trends in seasonal precipitation is depicted in Fig. 2. Seasonal precipitation averages generally have a decreasing trend, especially in winter season. In this season, only negative trends are detected in stations along the southwest-northeast direction. These stations showing negative trend are Aksehir, Bodrum, Aydin, Biga, Burdur, Dikili, Edremit, Fethiye, Giresun, Ilgin, İskenderun, Isparta, Kars, Kastamonu, Kilis, Manavgat, Muş, Niğde, Ordu, Rize, Samsun, Şebinkarahisar and Ulukýþla. The geographical extents of these trends include western and southern of Turkey as well as Black Sea region. For spring season, a less number of stations showed either positive or negative trend at the 5% significance level. Downward trends are observed at Akşehir, Ordu, Rize and Kars stations (mostly located over the northeastern of Turkey), whereas upward trends are observed at Alanya, Bitlis and Malatya (mostly located over eastern Anatolia region). The series of summer season showed a downward trend in Dörtyol station as upward trends in Alanya, Adýyaman, Çanakkale, Edremit, Polatlý and Sivrihisar stations. However no trend existed in the series of autumn season.

Using monthly precipitation data, Partal and Kahya (2006) pointed out that January and February showed decreasing precipitation whereas December revealed less station with mix behaviors. However, as seen in the top panel in Fig. 2, the signal of negative trend in winter season spreading around the country is quite obvious than each of its individual monthly components. This could be speculated in such a way that the time period of variable based on season can be preferable than its counterparts (i.e., month and year) for trend search analysis which is directly related to the climatic aspects of the large scale atmospheric circulations over a relatively large scale domain. Looking over Fig. 2 from the standpoint of temporal change of trend signals, one may readily come to a conclusion that the season of spring acts as a transition phase in the trend direction (that is to say, change from decreasing to increasing).

Table 1: Trend test results and significant lag-1 serial correlations at the 5% level

| Variable | No. of significant serial correlation | No. of decreasing trends | No. of increasing trends | Significant trends (%) |
|---|---|---|---|---|
| Winter | 27 | 23 | - | 24 |
| Spring | 9 | 4 | 3 | 7.2 |
| Summer | 3 | 6 | 1 | 7.2 |
| Autumn | 2 | - | - | 0 |

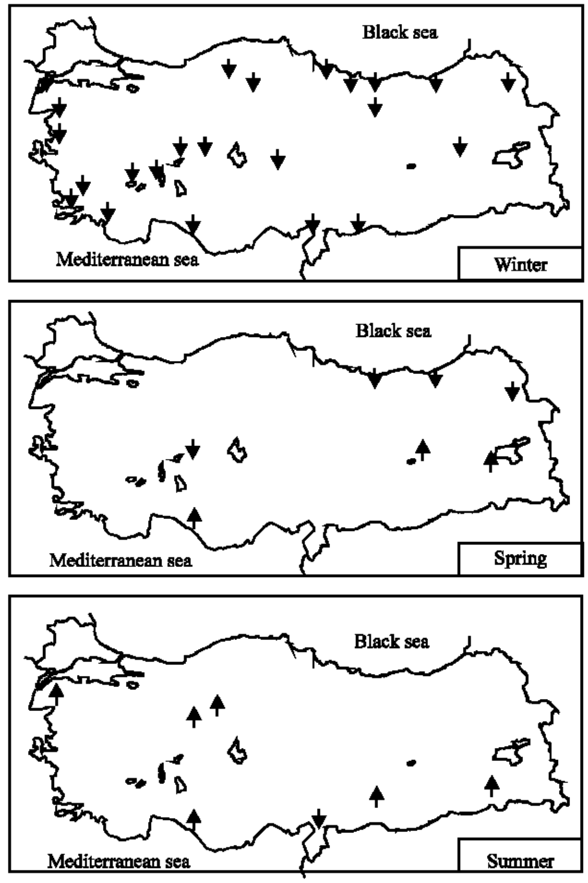


Fig. 2: Spatial distribution of significant seasonal precipitation trends at the %5 level. Downward trend is marked by "↓" and upward trend by "↑"

## CONCLUSION

We were concerned about trend detection in precipitation records at 96 stations in Turkey using seasonal series of monthly totals. After checking out the serial correlation effect, it was concluded that most of the precipitation data did not reveal a significant lag-1 correlation coefficient, except the series of winter season. The winter season demonstrated significant correlations in a quarter of the entire data set. The application of a trend detection work to seasonal Turkish precipitation data has resulted in the existence of some significant trends. In particular, the series of winter season were determined to have strong decreasing trends, mostly predominant in western and southern of Turkey and Black Sea region.

We discovered that trends were negative in winter and mostly positive in spring and summer seasons. This contrast may indicate a shift in the annual cycle of the hydrometeorological regime in Turkey (Partal and Kahya, 2006). Further analysis of this region is suggested to establish links between climate change and the observed hydrometeorological trends.

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