

Trend analysis method on vertical axis and comparison with Şen's ITA approach

Yavuz Selim Güçlü (✉ gucluya@itu.edu.tr)

Istanbul Technical University <https://orcid.org/0000-0002-9939-1157>

Research Article

Keywords: Rainfall, ITA, time series, trend test

Posted Date: April 12th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-412406/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

The classical trend tests are applied frequently in meteorological and hydrological data. Recently, Şen-innovative trend analysis (ITA) method provides the ability to visualize inspection and identification of trend conditions. The main objective of this paper is to attempt determination and visualization of trends by means of a special graphical representation based on alternative illustration of Şen-ITA method. The suggested methodology shows different trend information than classical Şen-ITA test on the Black Sea, Mediterranean, and continental climate regions in Turkey. This research comprises 50-year rainfall station records in Çanakkale, Edirne, Kocaeli, and Zonguldak stations located in North-West part of Turkey.

1 Introduction

Hydro-meteorological variables are under the effect of anthropogenic of greenhouse gases emissions in gradually growing form and consequently more detectable climate change impacts appear. From time to time, extreme event occurrences come to existence such as wet seasons (floods) and dry seasons (droughts) that are among the water resources risk assessments significant design, planning, and management works in addition to the trend identification.

Recently, trends due to the climate change are detected in hydro-meteorological measurements at different stations. In the literature, widely used trend identification approaches are Mann (1945)-Kendall (1975) (MK), Sen (1968)'s slope estimator, and linear regression analysis trend tests (Haan, 1977). For instance, Taylor and Loftis (1989) provided various trend test methods for ground water and lake quality records; Chiew and McMahon (1993) considered five statistical trend detection methods in Australian rivers annual streamflow time series; Burn (1994) did like study for Canadian west-central region; For auto correlated data, Hamed and Rao (1998) employed a modified MK trend approach; for some Indian pan evaporation records Jhajharia et al. (2009) analyzed trend possibility by using two tests. On the other hand, Gocic and Trajkovic (2013) analyzed the trends in many meteorological data obtained from twelve measurement stations using MK and Sen's slope estimator in Serbia during 1980–2010. Nalley et al.'s study (2013) tried to detect mean surface air temperature data trends in the southern Quebec and Ontario, Canada. In Tennessee River Basin, United States Jones et al. (2015) found out annual and seasonal precipitation trends.

It is by now well-known innovative trend analysis (ITA) including 1:1 straight-line presented by Şen (2012) has been applied and compared with classical trend tests in different researches. Sonali and Kumar (2013) reviewed trend test methodologies and implemented them to determine trend conditions in temperature data. Timbadiya et al. (2013) identified the trends using ITA for time series of annual peak flow in Tapi Basin, India. Saplioglu et al. (2014) searched runoff trends on the western of Mediterranean region in Turkey. Additionally, Dabanlı et al. (2016) used ITA comparing with classical trend analysis tests.

Şen (2014, 2017a) further enhanced the ITA and a new type of ITA was proposed by Alashan (2018). A given time series has been divided by Mohorji et al. (2017) and Şen (2017b) into 3, 4, 5, 6, 11, and 13 groups and then have compared the first group with all others. Tabari et al. (2017) presented the quantile perturbation methodology as an improved ITA version. Cui et al. (2017) drew ITA graphs of air temperature and rainfall data in the Yangtze River Basin, China during 1960–2015. Güçlü (2018a) suggested a mix of two methods, namely Şen-ITA and classical MK. Additionally, the comparative ITA approach was suggested by Güçlü (2018b) to compare different interrelated time series on the same ITA graph. Güçlü (2018c) have also suggested double-ITA and triple-ITA, which are improvements of ITA and partial MK test approaches. Güçlü et al. (2020) developed another approach namely innovative triangular trend analysis (ITTA) to show partial trends within a given time series data comparatively with each other. Güçlü (2020) proposed a new type of ITA illustration showing clearly the data number unlike the classical ITA implementations. Lastly, ITA performed by Ghate and Timbadiya (2021) on the partial duration maximum rainfall series and annual maximum rainfall series in India.

The goal of the study is to base trend identification possibilities in rainfall records for Çanakkale, Edirne, Kocaeli, and Zonguldak stations in Turkey. Herein, well-known Şen-ITA method and its new version are employed. Implementation of the suggested method is explained in steps under the methodology section.

2 Methodology

Trend detection in meteorological, hydrologic, water, and air quality etc. measurements is in the literature since three decades. Apart from the Mann-Kendall, linear regression, Sen's slope trend tests and recently, ITA approach are commonly used in different points of the world.

Şen's method offers great advantages with respect to its visual monotonic or non-monotonic trend identification. In this methodology, there are five different trend types as monotonic decreasing and increasing, non-monotonic decreasing and increasing, and no trend conditions, but other methods provide only three trend types as monotonic decreasing and increasing, and no trend conditions. Furthermore, Şen's ITA method presents visual results through the scatter of data points on the graph.

For the application of ITA approach, given records are divided into two halves as the the first (previous) and the second (next) halves that are ordered in descending (or ascending) manner. The scatter of these two part data on a Cartesian coordinate system is compared with the 1:1 straight-line on the same graph. "No significant trend" exists in case of all scatter data are around 1:1 straight line with insignificantly random deviations otherwise, there is a trend depending on the scatter points positions above this line (positive trend) or below then negative trend appears (see Fig. 1). There are five possible trend types called as monotonic positive and negative trend, non-monotonic positive and negative trend, and trendless time series.

As for the disadvantage, the classical 1:1 straight line graph in Şen's ITA approach although depicts mentioned trend types, but it cannot show the number of data. The proposed approach in this paper, which is an visualization type of ITA method, as not only depicts mentioned five trend conditions, but also

shows the real data number. Similar calculation steps of Şen-ITA method are as follows for the suggested method.

1) A given records including n data, x_1, x_2, \dots, x_n is divided into two halves $\{y_{1,n/2}\}$ and $\{y_{2,n/2}\}$ as,

$$\{y_{1,n/2}\} = \{x_1, x_2, \dots, x_{n/2}\} \quad (1)$$

and

$$\{y_{2,n/2}\} = \{x_{n/2+1}, x_{n/2+2}, \dots, x_n\} \quad (2)$$

2) Both halves are ranked in descending order, hereby, there are two ordered halves namely $\{r_1\}$ and $\{r_2\}$ with the same number of elements,

$$\{r_1\} = \{\min(y_{1,n/2}), \dots, y_i, \dots, \max(y_{1,n/2})\} \quad (1 < i < n/2) \quad (3)$$

and

$$\{r_2\} = \{\min(y_{2,n/2}), \dots, y_j, \dots, \max(y_{2,n/2})\} \quad (1 < j < n/2) \quad (4)$$

3) The values of $\{r_1\}$ and $\{r_2\}$ series are on horizontal axis against the values of 1, 2, 3, ..., $(n/2)-1, n/2$ values on vertical axis,

4) The difference $(\{r_2\}-\{r_1\})$ series are marked on horizontal axis against the values of 1, 2, 3, ..., $(n/2)-1, n/2$ values on vertical axis,

5) There is no significant trend condition in the time series if all the difference values fall on the vertical axis with insignificantly random deviations,

6) If the difference values are on left-hand (decreasing trend region) or right-hand (increasing trend region) side of the vertical axis, there is a significant trend. As a result, the trend type can be characterized according to visual inspection of the difference data positions relative to the vertical axis.

Hypothetical illustrations using the same random values are shown for the classical ITA (Şen, 2012) in Fig. 2a, where the horizontal axis trend analysis graph (Güçlü, 2020) in Fig. 2b, and the proposed visualization type of Şen-ITA in Fig. 2c.

In Fig. 2c, $x = 0$ line (vertical axis) runs like Şen's 1:1 straight-line. Right (left)-hand side of y-axis is for increasing (decreasing) trend region, and scatter data around or on the vertical line reflects no trend condition. The suggested trend method reveals on the graph without any negative aspect by comparing with the Şen-ITA. The suggested version of ITA reveals the data number like Güçlü's horizontal trend graph (Güçlü, 2020). In Fig. 2c, low data values have more measurements than high data values, however it is difficult to see how many number of sub-categories data are on the classical type of ITA. Low values have very few data and high values include many data as it can be seen in Fig. 2a.

3 Application

Turkey has four climate types in different seasons and is lies between the temperate and sub-tropical zone. Along the Black Sea coasts, all seasons are rainy because the moist air mass influences Black sea region throughout the year. Mediterranean region climate is always dominant in the south and west coastal areas, where is rainy-warm in winters and dry-hot in summers. The coastal regions surrounding the Marmara Sea connecting the the Black Sea and Aegean Sea have a transitional climate between Black Sea and Mediterranean types with wet winters, cool to cold and moderately dry summers, warm to hot. Lastly, continental climate type is dominant in Central and Eastern Anatolia, and a large part of the southeast Anatolia, where winter seasons are snowy-cold, but summer seasons are dry-hot.

Turkish Meteorological Service (MGM, in Turkish) obtained the highest daily total rainfall data (in millimeter) from 1966 to 2015 (totally 50 years) for each year at Çanakkale, Edirne, Kocaeli, and Zonguldak stations (Table 1 and Fig. 3) located in different points of North-West Turkey. On the other words, the same data with Güçlü's (2020) research are analyzed in this study for comparison.

Table 1
Geographical values for the stations

Station	Longitude	Latitude	Altitude (m)	Region
Çanakkale	26.3993	40.1410	6	Aegean
Edirne	26.5508	41.6767	51	Marmara
Kocaeli	29.9173	40.7663	74	Marmara
Zonguldak	31.7779	41.4492	135	Black Sea

For each year, the most extraordinary daily rainfall case is measured and there are 50 such records for the application. The first (previous) half including 25 years between 1966 and 1990, whereas the second (next) one has 1991–2015 period. The halves are ranked in descending manner. The trend conditions for the rainfall data according to classical and new methods are detected in Figs. 4–7 for all data sets, respectively. From these figures, the comparison of the results indicates different trend conditions for each data with significance of the proposed methodology.

Çanakkale station records have clearly increasing trend monotonically according to the suggested and classical type of ITA (Fig. 4). Additionally, suggested approach shows that the difference data are evenly distributed on right-hand side of vertical axis (Fig. 4b). Similarly, Edirne station's time series data have distinctive and monotonically increasing trend condition via Şen's classical methodology (Fig. 5a). The same decision is made visually on vertical trend analysis graph with uniformly scattered difference values (Fig. 5b).

Finally, the non-monotonic trend conditions are obtained from Kocaeli and Zonguldak stations data, because high values have decreasing trend and low values have another trend types. Low values of Kocaeli station have no trend and Zonguldak station's low values indicate increasing trend clearly (Figs. 6 and 7) according to both methods. However, additional trend information is shown by the suggested illustration graph because it reflects number and range of data (Figs. 6b and 7b), but the classical ITA type shows the range only (Figs. 6a and 7a).

4 Conclusion

The classical trend approaches namely Mann (1945)-Kendall (1975) test method, Sen (1968)'s slope estimator, and linear regression analysis trend test methods (Haan, 1977) detect monotonic trend conditions only. Fortunately, ITA method (Şen, 2012) determines and visualizes the trends monotonically or non-monotonically. In order to reveal more information about the trend, the suggested illustration method in this paper is very beneficial and useful with positive contribution to Şen's ITA approach, and the suggested version shows the data, clearly.

It is obvious that the results have shown significance of the suggested trend analysis type through the comparisons. The novel method has also revealed that the data scattered uniformly on Çanakkale station data although monotonic increasing trend condition by simple ITA. Similarly, the classical and suggested illustrations have visualized monotonic increasing trend on Edirne station records. Lastly, high values of Zonguldak and Kocaeli stations measurements have had increasing trend, but their low values' trends have displayed differently. However, number of the data have shown evidently unlike the classical graph through the suggested version of Şen's trend procedure.

Declarations

Declaration of interests

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Alashan S (2018) An improved version of innovative trend analyses. *Arab J Geosci* 11(3):50
- Burn DH (1994) Hydrologic effects of climatic change in west-central Canada. *Journal of Hydrology*, 160(1-4), 53-70
- Chiew FHS, McMahon TA (1993) Detection of trend or change in annual flow of Australian rivers. *Int. J. of Climatology* 13, 643-653

- Cui L, Wang L, Lai Z, Tian Q, Liu W, Li J (2017) Innovative trend analysis of annual and seasonal air temperature and rainfall in the Yangtze River Basin, China during 1960–2015. *Journal of Atmospheric and Solar-Terrestrial Physics*, 164, 48-59
- Dabanlı İ, Şen Z, Yeleğen MÖ, Şişman E, Selek B, Güçlü YS (2016) Trend assessment by the innovative-Şen method. *Water Resour Manag* 30(14), 5193–5203
- Ghate AS, Timbadiya PV (2021) Comprehensive Extreme Rainfall Analysis: A study on Ahmedabad region, India. *ISH Int J Hydraulic Eng*. doi: 10.1080/09715010.2021.1905566
- Gocic M, Trajkovic S (2013) Analysis of changes in meteorological variables using Mann-Kendall and Sen's slope estimator statistical tests in Serbia. *Global and Planetary Change*, 100, 172-182
- Güçlü YS (2018a). Alternative trend analysis: half time series methodology. *Water Resources Management*, 32(7), 2489-2504
- Güçlü YS (2018b). Fundamentals and applications of comparative innovative trend analysis. *J Nat Hazards Environ.*, 4(2), 182-191
- Güçlü YS (2018c). Multiple Şen-innovative trend analyses and partial Mann-Kendall test. *J Hydrol*, 566, 685-704
- Güçlü YS, Şişman E, Yeleğen MÖ (2018) Climate change and frequency–intensity–duration (FID) curves for Florya station, Istanbul. *J Flood Risk Manag* 11(S1):S403-S418
- Güçlü YS, Şişman E, Dabanlı İ (2020). Innovative triangular trend analysis. *Arabian Journal of Geosciences*, 13, 27
- Güçlü YS (2020). Improved visualization for trend analysis by comparing with classical Mann-Kendall test and ITA. *J Hydrol*, 584, 124674
- Haan CT (1977) *Statistical Methods in Hydrology*. The Iowa State University Press, Ames
- Hamed KH, Rao AR (1998) A modified Mann-Kendall trend test for autocorrelated data. *J Hydrol* 204:182-196
- Jhajharia D, Shrivastava SK, Sarkar D, Sarkar S, (2009) Temporal characteristics of pan evaporation trends under the humid conditions of northeast India. *Agricultural and Forest Meteorology* 149, 763–770
- Jones VJR, Schwartz JS, Ellis KN, Hathaway JM, Jawdye CM (2015) Temporal variability of precipitation in the Upper Tennessee. *Journal of Hydrol: Regional Studies* 3, 125–138
- Kendall MG (1975) *Rank Correlation Methods*. Charless Griffin, London
- Mann HB (1945) Nonparametric tests against trend. *Econometrica* 13:245–259

- Mohorji AM, Şen Z, Almazroui M (2017) Trend Analyses Revision and Global Monthly Temperature Innovative Multi-Duration Analysis. *Earth Syst and Environ* 1(1), 9
- Nalley D, Adamowski J, Khalil B, and Ozga-Zielinski B (2013) Trend detection in surface air temperature in Ontario and Quebec, Canada during 1967–2006 using the discrete wavelet transform. *Atmospheric Research* 132–133, 375–398
- Saplioglu K, Kilit M, Yavuz, BK (2014) Trend Analysis of Streams in the Western Mediterranean Basin of Turkey. *Fresenius Environmental Bulletin* 23(1A) 313-324
- Sen PK (1968) Estimates of the regression coefficient based on Kendall's tau. *J. Am Stat Assoc* 63:1379–1389
- Sonali P, Kumar ND (2013) Review of trend detection methods and their application to detect temperature changes in India. *J Hydrol* 476:212-227
- Şen Z (2012) Innovative Trend Analysis Methodology. *J Hydrol Eng* 17(9):1042–1046
- Şen Z (2014) Trend identification simulation and application. *J Hydrol Eng* 19(3), 635-642
- Şen Z (2017a) Innovative trend significance test and applications. *Theoretical and Applied Climatology* 127(3-4), 939–947
- Şen Z (2017b) Innovative trend methodologies in science and engineering. Springer, Heidelberg, Germany
- Tabari H, Taye MT, Onyutha C, Willems P. (2017) Decadal Analysis of River Flow Extremes Using Quantile-Based Approaches. *Water Resour Manage* 31(11), 3371-3387
- Taylor CH, Loftis JC, (1989) Testing for trend in lake and groundwater quality time series. *Water Resources Bulletin* 25(4), 715-726
- Timbadiya PV, Mirajkar A, Patel P, Porey P (2013) Identification of trend and probability distribution for time series of annual peak flow in Tapi Basin, India. *ISH Int J Hydraulic Eng* 19(1):11-20

Figures

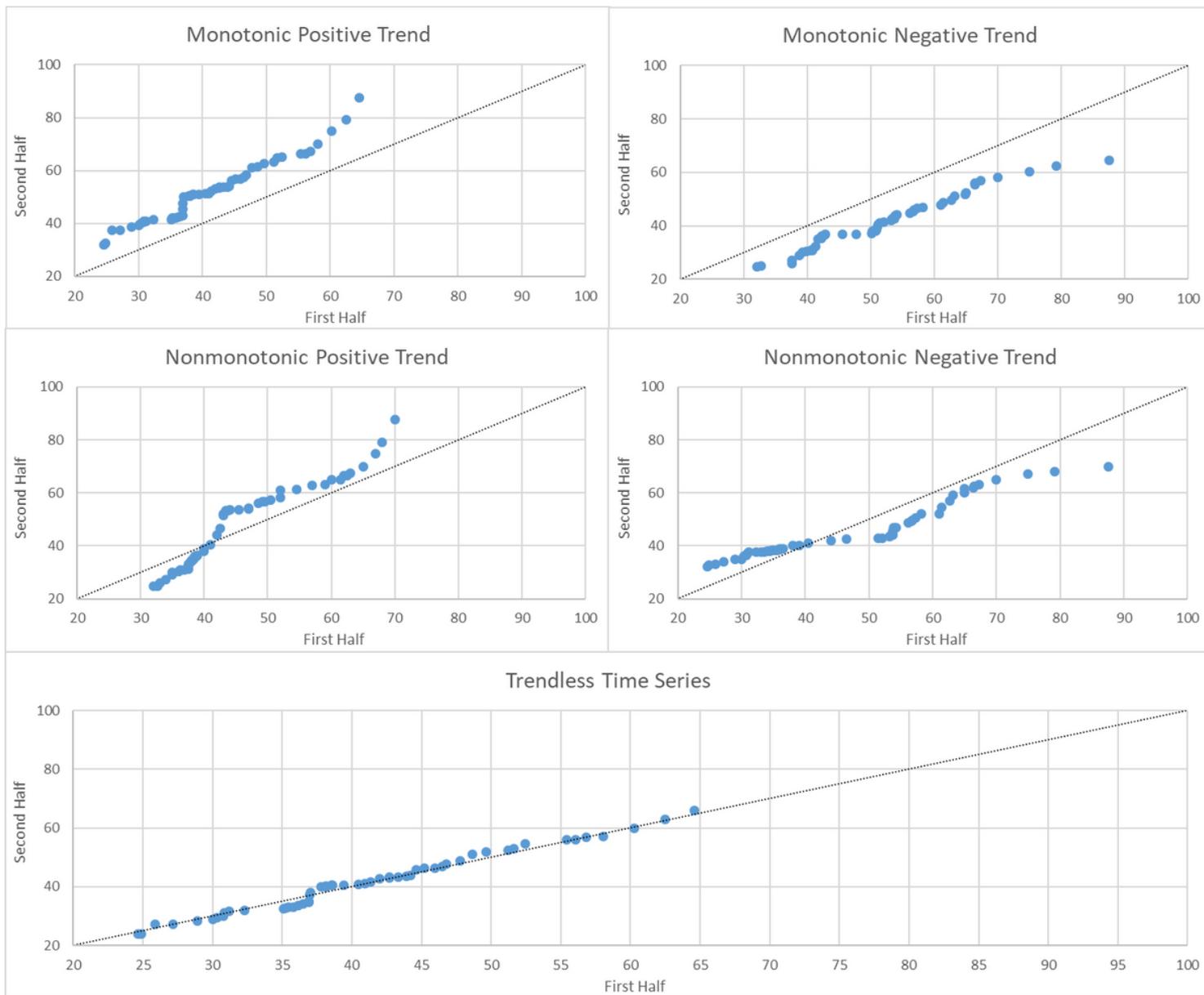


Figure 1

Trend conditions according to the classical Şen's ITA

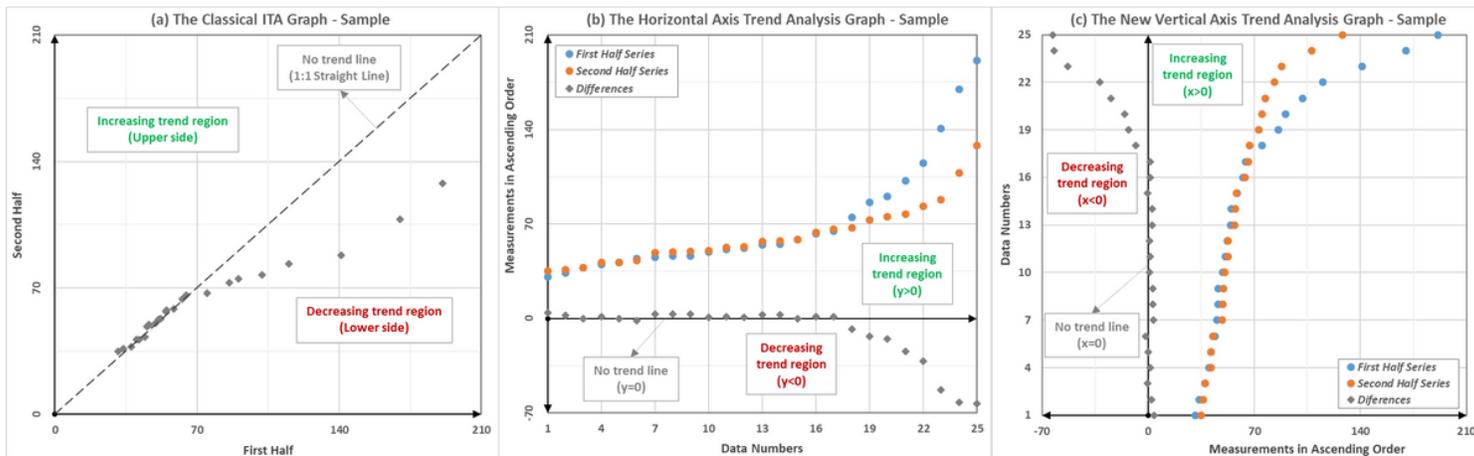


Figure 2

Sample trend identification by classical ITA (a), horizontal (b) and new vertical (c) graphs



Figure 3

Station points on Turkey Map (Google Earth©)

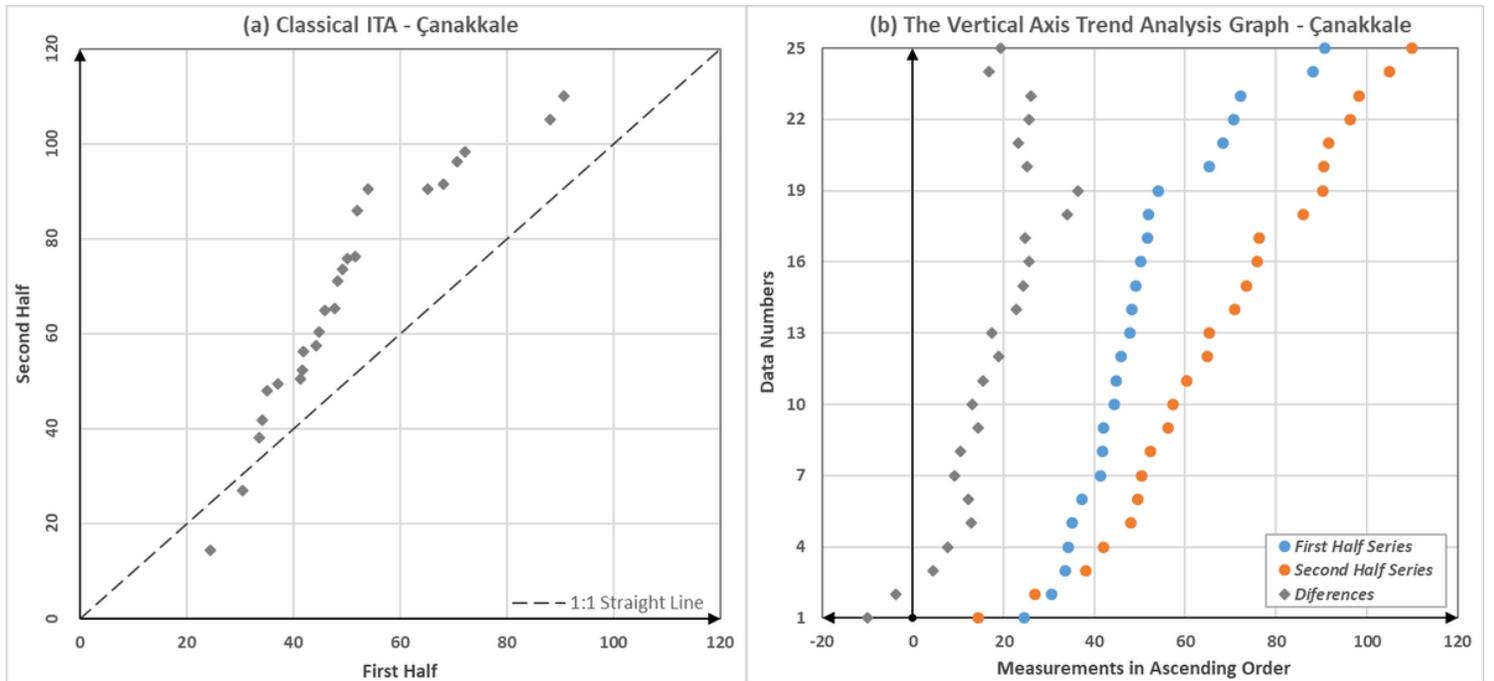


Figure 4

Trend identification by classical (a) and new (b) approach of ITA for Çanakkale station data

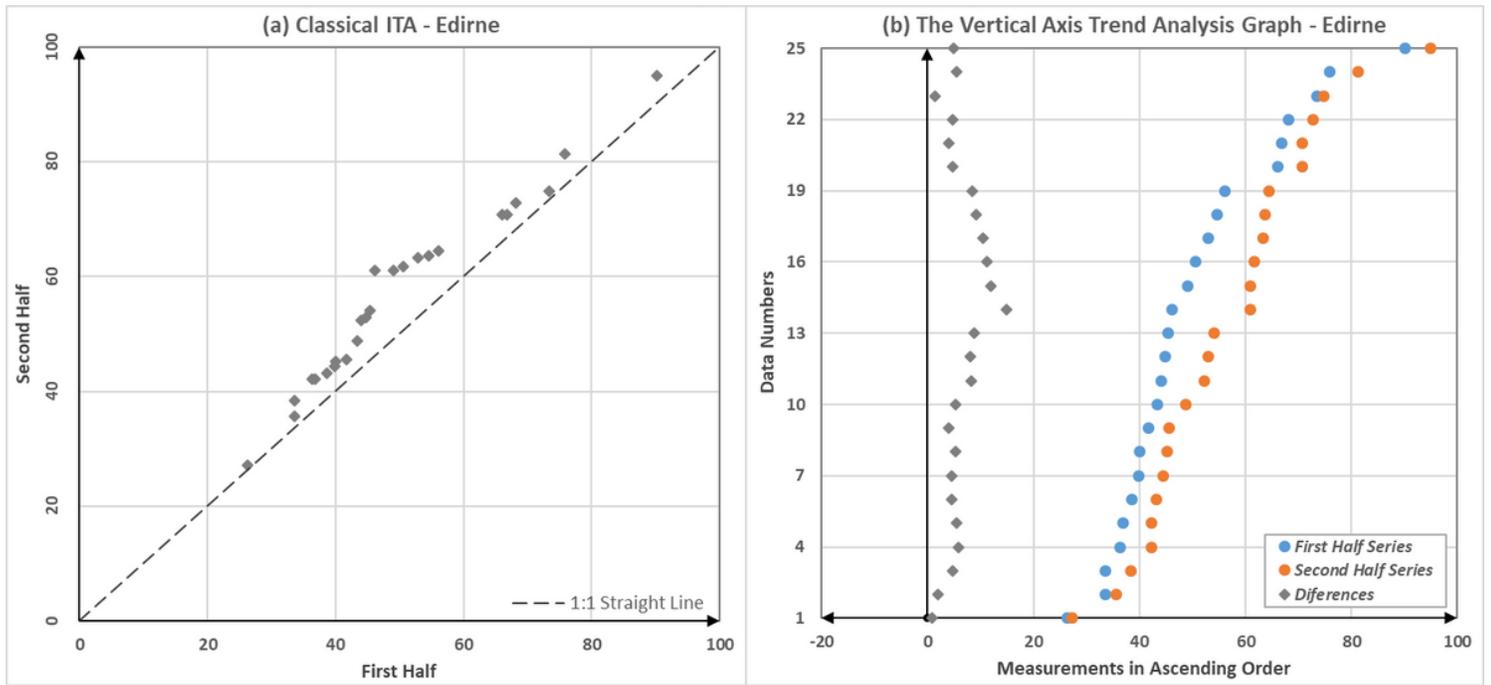


Figure 5

Trend identification by classical (a) and new (b) approach of ITA for Edirne station data

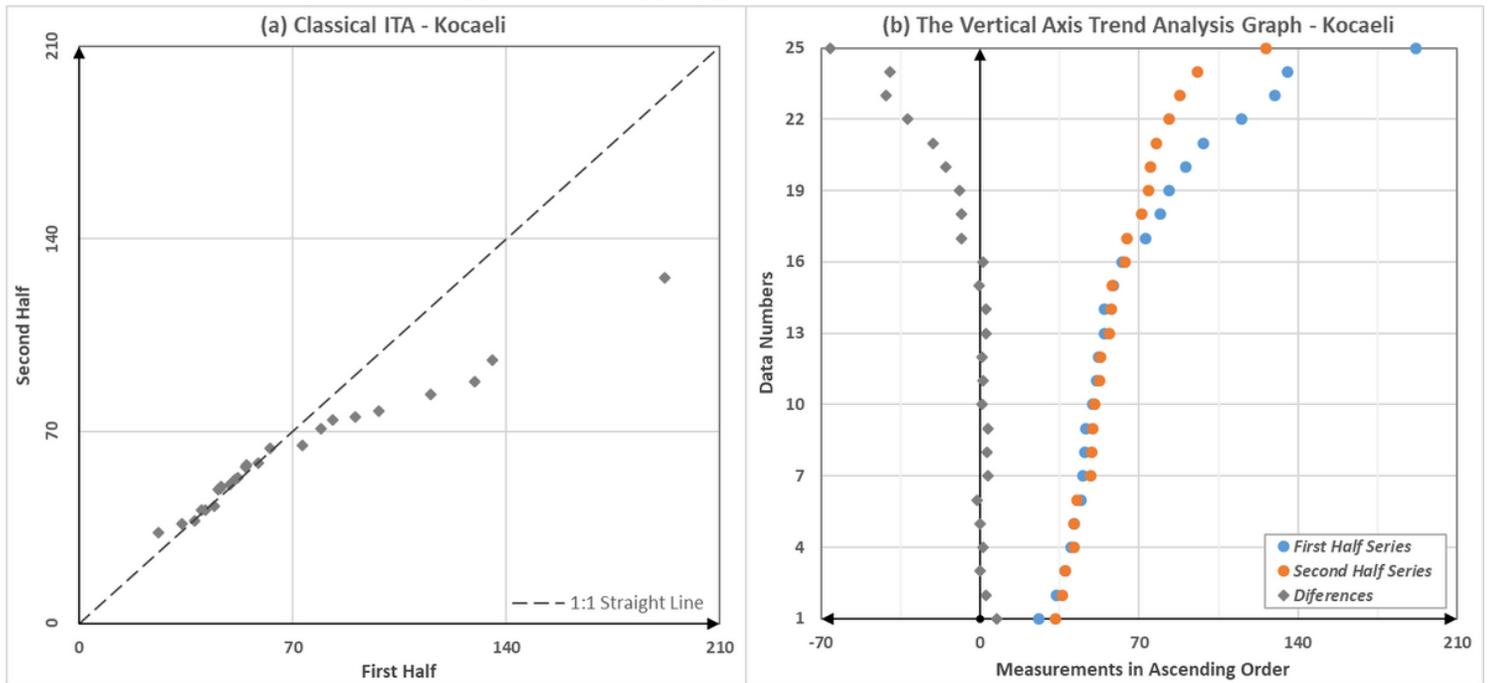


Figure 6

Trend identification by classical (a) and new (b) approach of ITA for Kocaeli station data

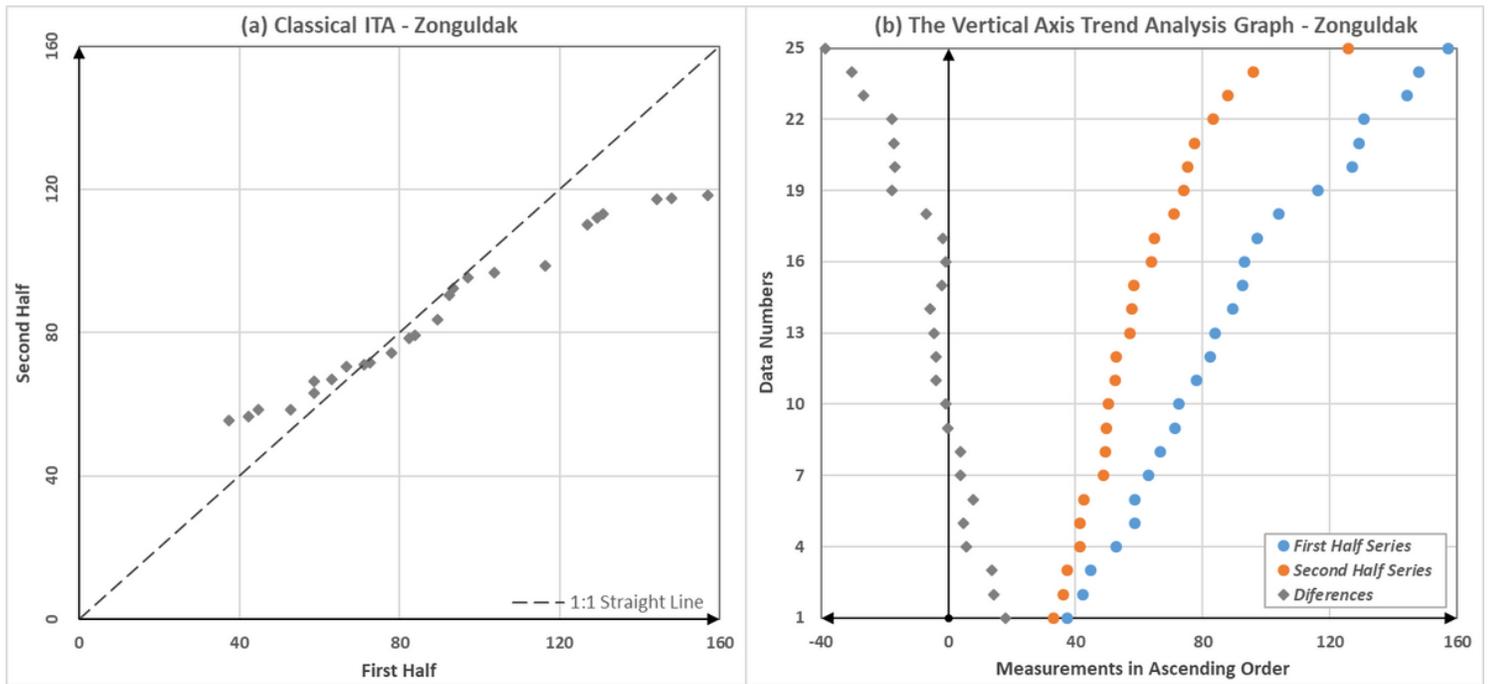


Figure 7

7 Trend identification by classical (a) and new (b) approach of ITA for Zonguldak station data