Acta Geophysica (2021) 69:1949–1961
https://doi.org/10.1007/s11600-021-00632-3

RESEARCH ARTICLE - ATMOSPHERIC & SPACE SCIENCES

Analysis of temperature data by using innovative polygon trend analysis and trend polygon star concept methods: a case study for Susurluk Basin, Turkey

Gokmen Ceribasi[1] · Ahmet Iyad Ceyhunlu[1] · Naveed Ahmed[2,3]

Received: 18 May 2021 / Accepted: 29 June 2021 / Published online: 12 July 2021

Abstract
Climate change is an event that has significant effects as direct or indirect on ecosystem and living things. In order to be prepared for the effect of climate change, it is necessary to anticipate these changes and take measures for this change. Therefore, many studies have been carried out on changes in climate parameters in recent years. The most common method used in these studies is trend methods. Innovative Polygon Trend Analysis (IPTA) and Trend Polygon Star Concept are trend analysis methods. IPTA Method divides data series into two as first and second data set and analyzes these two data sets by comparing them with each other. Trend Polygon Star Concept analyzes distance between two months in data set in graph, which is result of IPTA, and shows analysis result by dividing it into four regions. Therefore, in this study, monthly average temperature data are analyzed by using this two-polygon method. This data set is for 22 years (1996–2017). Polygon graphics were created as a result of study. Besides, trend slopes and lengths of temperature data with IPTA Method were calculated. The values of graphs created with Trend Polygon Star Concept Method on x- and y-axis were given in a table. When the results of both analysis methods were examined for a station, the following results were observed. For example, a regular polygon was not seen in arithmetic mean and standard deviation graphs of IPTA Method of Bandirma Station. Besides, when general evaluation of arithmetic mean analysis results was examined an increasing trend in most months. When arithmetic average graph created by Trend Polygon Star Concept Method of Bandirma Station was examined, transition between two months was seen first and third region. When standard deviation graph was examined, transitions between two months were seen in all four regions.

Keywords Temperature · IPTA · Trend polygon star concept · Susurluk Basin · Turkey

Introduction

Although global climate change is seen as a problem in which necessary measures should be taken urgently to prevent or reduce its effects, it is also accepted that this situation is not possible in near future. Therefore, to be prepared for the effects of global climate change, it is recommended to take some measures on a regional scale by predicting possible changes (Aktas 2020). Many countries in the world conduct various researches on the effects of future climate changes on precipitation, temperature, energy, agriculture, water resources and socio-economic life (Aksay et al. 2005; Aktas 2020).

The most common researches methods are trend analysis tests. It is seen that tests of this trend analysis tests are used in scientific studies. Mann–Kendall Tests, Sen T Test and Innovative Trend Analysis tests are the most used of these methods in scientific studies (Mann 1945; Sen 1968; Kendall 1975, Sen 2012).

IPTA and Trend Polygon Star Concept Methods are new trend test. IPTA Method divides data series into two as first and second data set and analyzes these two data sets by comparing them with each other. Trend polygon Star Concept

Communicated by Prof. Ewa Bednorz (ASSOCIATE EDITOR) / Prof. Theodore Karacostas (CO-EDITOR-IN-CHIEF).

✉ Gokmen Ceribasi
gceribasi@subu.edu.tr

[1] Department of Civil Engineering, Faculty of Technology, Sakarya University of Applied Sciences, Sakarya, Turkey

[2] Key Laboratory of Mountain Surface Process and Ecological Regulations, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu, China

[3] University of Chinese Academy of Sciences (UCAS), Beijing, China

Method analyzes the distance between two months in data set and shows analysis result by dividing it into four regions. When studies are conducted according to other trend tests in the literature are examined, it is seen that there are many studies. (Saris et al. 2010; Karmeshu 2012; Yang et al. 2012; Demircan et al. 2014; Jones et al. 2015; Ozkoca 2015; Yildirim 2015; Zhang et al. 2015; Altunay 2016; Dabanli et al. 2016; Tabari et al. 2017; Ceribasi 2018,2019; Guclu 2018; Sezen 2018; Zeybekoglu and Partal 2018; Han and Singh 2020; Li et al. 2020; Nikakhtar et al. 2020; Tokgoz ve Partal 2020). In addition, Coban (2013) do an extensive nationwide trend analysis by using annual total rainfall in 80 city centers of Turkey between years of 1971 to 2010. He used Mann–Kendall, Regression and Sen Trend Methods in his analysis. As a result of analysis was determined trend in 13 city centers of Turkey (Coban 2013). Topuz et al. (2021) researched the trends of seasonal and annual precipitation time series of 29 stations for the period 1955–2013 by using a simple linear regression model and the well-known Mann–Kendall test in their study. Moreover, they used non-parametric Sen's slope estimator to estimate the slope of the trend (Topuz et al. 2021).

Considering studies in literature using IPTA and Trend Polygon Star Concept Methods, it is seen that there are very few studies. Ceribasi and Ceyhunlu (2020) have analyzed perception data of Susurluk Basin in turkey with IPTA. They used data of 10 rainfall monitoring stations in Susurluk Basin. The length of these data series has been determined as 12 years. As a result of study, they created IPTA graphics for each station (Ceribasi and Ceyhunlu 2020). Sen (2021) proposed Trend Polygon Star Concept Method. In this study, different versions of monthly polygonal trends were suggested for detection of possible climate change impacts. Among these were suggested serial, cross and double trend polygon methodologies in addition to trend polygon stars. Applications of suggested methodologies were presented for a set of monthly precipitation records from Istanbul, Turkey in addition to New Jersey, USA monthly precipitation records and also for monthly Danube River discharges, Romania (Sen 2021).

In this study, IPTA and Trend Polygon Star Concept Methods are applied to monthly average temperature data of Susurluk Basin in Turkey. Data of 6 meteorological stations (Bandirma, Bursa, Dursunbey, Keles, Simav and Uludag) in Susurluk Basin are used. Length of this data is 22 years (1996–2017).

Materials and methods

Study Area

Vegetation of Susurluk Basin is steppe. One of the most important streams of Susurluk Basin is Simav Stream. Simav Stream originates in Kutahya and flows into Marmara Sea. The approximate length of Simav stream is 175 km. (Bulut and Saler 2018; Karinca, 2018; Albayrak et al. 2019; Ceribasi and Ceyhunlu, 2020; Gungor, 2020). Figure 1 shows the stations in the basin.

Table 1 contains detailed information of selected stations.

Figure 2 shows course line of data.

IPTA method

The time series to be used with this method produced by Sen can be monthly or yearly. For example, if monthly data set is analyzed with this method, the monthly data set is written in matrix format (Sen et al. 2019):

$$\begin{bmatrix} X_{1,1} & X_{2,1} & \ldots & X_{i,1} & \ldots & X_{12,1} \\ X_{1,2} & X_{2,2} & \ldots & X_{i,2} & \ldots & X_{12,2} \\ X_{1,3} & X_{2,3} & \ldots & X_{i,3} & \ldots & X_{12,3} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ X_{1,n} & X_{2,n} & \ldots & X_{i,n} & \ldots & X_{12,n} \end{bmatrix}$$

Upper Series (First Half)
n = 1,2,3,…..,n/2

Lower Series (Second Half)
n = n/2+1, n/2+2,….,n,

where:

i: represents months.

n: represents years.

Monthly data set is divided into two equal parts and arithmetic mean or standard deviation of each data set is calculated. Then, the first monthly data set is placed on x-axis and second monthly data set is placed on y-axis in coordinate system. Hypothetical Innovative Polygon Trend Analysis (IPTA) method for monthly data formed in this way is given in Fig. 3.

Trend polygon star concept method

Trend Polygon Star Concept analyzes distance between two months in data set in graph, which is result of IPTA,

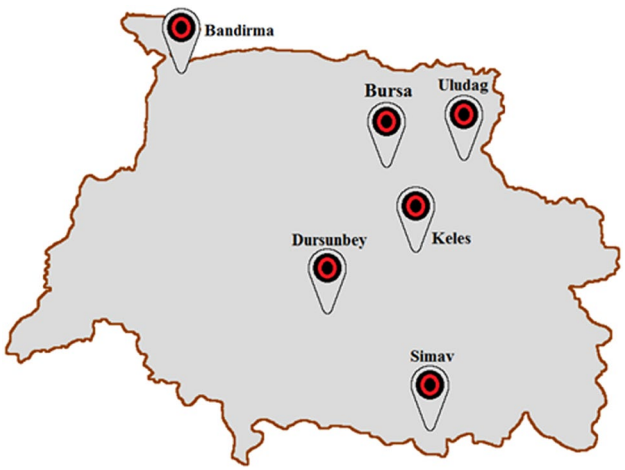

Fig. 1 Location of selected stations and Susurluk Basin

Table 1 Information of observation stations

No	Station name	Station no	Location		Altitude (m)
			Latitude	Longitude	
1	Bandirma	17,114	40°19′53.4"N	27°59′47.4"E	20.00
2	Bursa	17,116	40°20′77.6"N	29°01′47.7"E	155.00
3	Dursunbey	17,700	39°34′40.1"N	28°37′55.9"E	672.00
5	Keles	17,695	39°54′54.0"N	29°13′52.7"E	1.240.00
6	Simav	17,748	39°05′33.0"N	28°58′43.0"E	830.00
7	Uludag	17,676	40°06′27.0"N	29°07′44.4"E	2.543.00

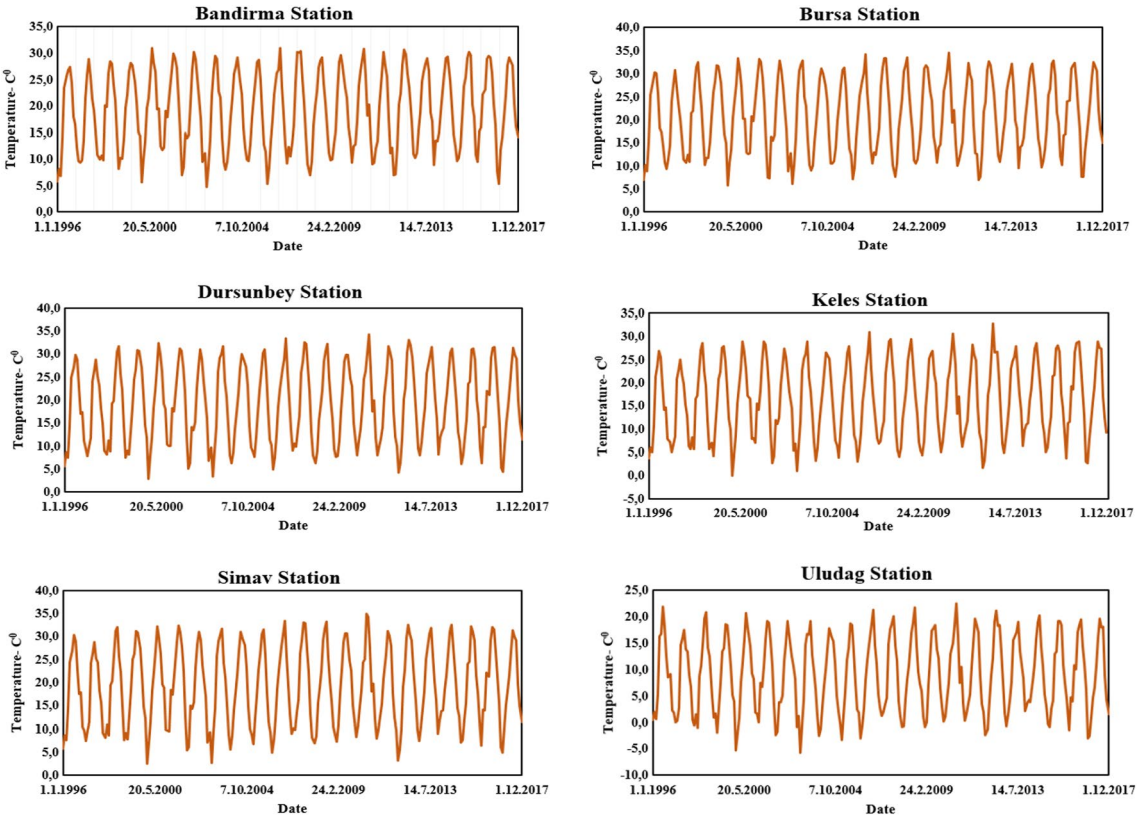

Fig. 2 Course line of monthly average temperature data of observation stations

and shows analysis result by dividing it into four regions. Figure 4 shows hypothetical Trend polygon Star Concept Method (Sen 2021).

As seen in Fig. 4, the graphic area consists of four parts. Each arrow in figure is drawn from the point 0:0 (Origin). These arrows are drawn according to transition line between two months. The greater the length of arrow line, the greater transition between two months. On coordinate axis, X-axis represents the first half of data set and Y-axis represents second half of data set. The values on vertical and horizontal axes of arrows showing transition between two months show change of first half in data set compared to second half. If direction of an arrow line is in I region, it results in an increasing trend in both axes. If direction of arrow line is in III region, it indicates that there is a decreasing trend in both axes. If direction of an arrow line is in II or IV region, change between both axes of data set appears as increasing or decreasing.

Results and discussion

In this study, IPTA and Trend Polygon Star Concept Methods were applied to monthly average temperature data. These analysis methods were applied separately for both arithmetic mean data and standard deviation data. Figure 5 shows the arithmetic mean results analyzed by IPTA method.

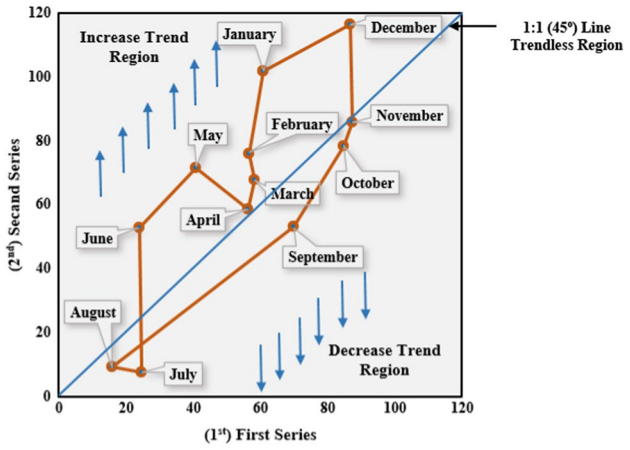

Fig. 3 Hypothetical innovative polygon trend analysis method for monthly data

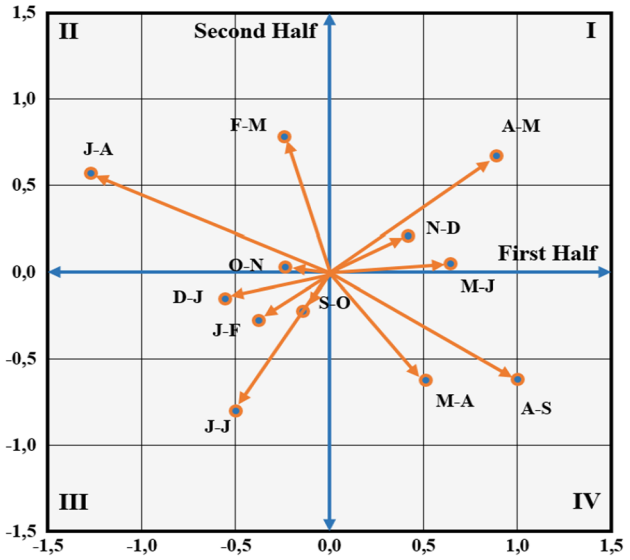

Fig. 4 Hypothetical trend polygon star concept method for monthly data

Table 2 contains the information of the results shown in Fig. 5.

The evaluation of the results given in both Fig. 5 and Table 2 can be summarized as follows:

1. Since not a single polygon is form in each station in Fig. 5, monthly average temperature data are not homogeneous.
2. The red arrows in Table 2 indicate that second monthly data set has higher temperatures than the first data set. The black arrows show that monthly data set is same as second data set.
3. There is no trend for Bandirma station in October, but there are increasing trends in other months.
4. There is no trend for Bursa station in four months, but there are increasing trends in other months.
5. For Dursunbey, Keles, Simav and Uludag stations, there is no trend in five months, while there are increasing trends in other months.
6. When all results for each station are generally examined, there is no trend in January, May, October and November, but an increasing trend is observed in other months. This situation can be considered as a result of climate change.

Figure 6 shows the standard deviation results analyzed by IPTA method.

Table 3 contains the information of the results shown in Fig. 6.

The evaluation of the results given in both Fig. 6 and Table 3 can be summarized as follows:

1. In Fig. 6 is seen that more complex polygons emerge of standard deviation graphs compared to arithmetic mean graphs.
2. For Bandirma station, while there are increasing trends in four months and decreasing trends in four months. There is no trend in other months.
3. For Bursa station, while there are increasing trends in six months and decreasing trends in three months. There is no trend in other months.
4. For Dursunbey station, while there are increasing trends in three months and decreasing trends in five months. There is no trend in other months.
5. For Keles station, while there are increasing trends in four months and decreasing trends in five months. There is no trend in other months.
6. For Simav station, while there are increasing trends in four months and decreasing trends in six months. There is no trend in other months.
7. For Keles station, while there are increasing trends in three months and decreasing trends in eight months. There is no trend in October.

Table 4 contains statistical values for six station analyzed by IPTA method.

The values shown in bold in Table 4 show maximum transition between two months. For example, when statistical results of Uludag station are examined, it shows that maximum length is between April and May for arithmetic average and between August and September for standard deviation. The maximum slope shows that arithmetic average is between January and February and for standard deviation between February and March.

Trend Polygon Star Concept Method graphics of arithmetic mean analysis results are given in Fig. 7.

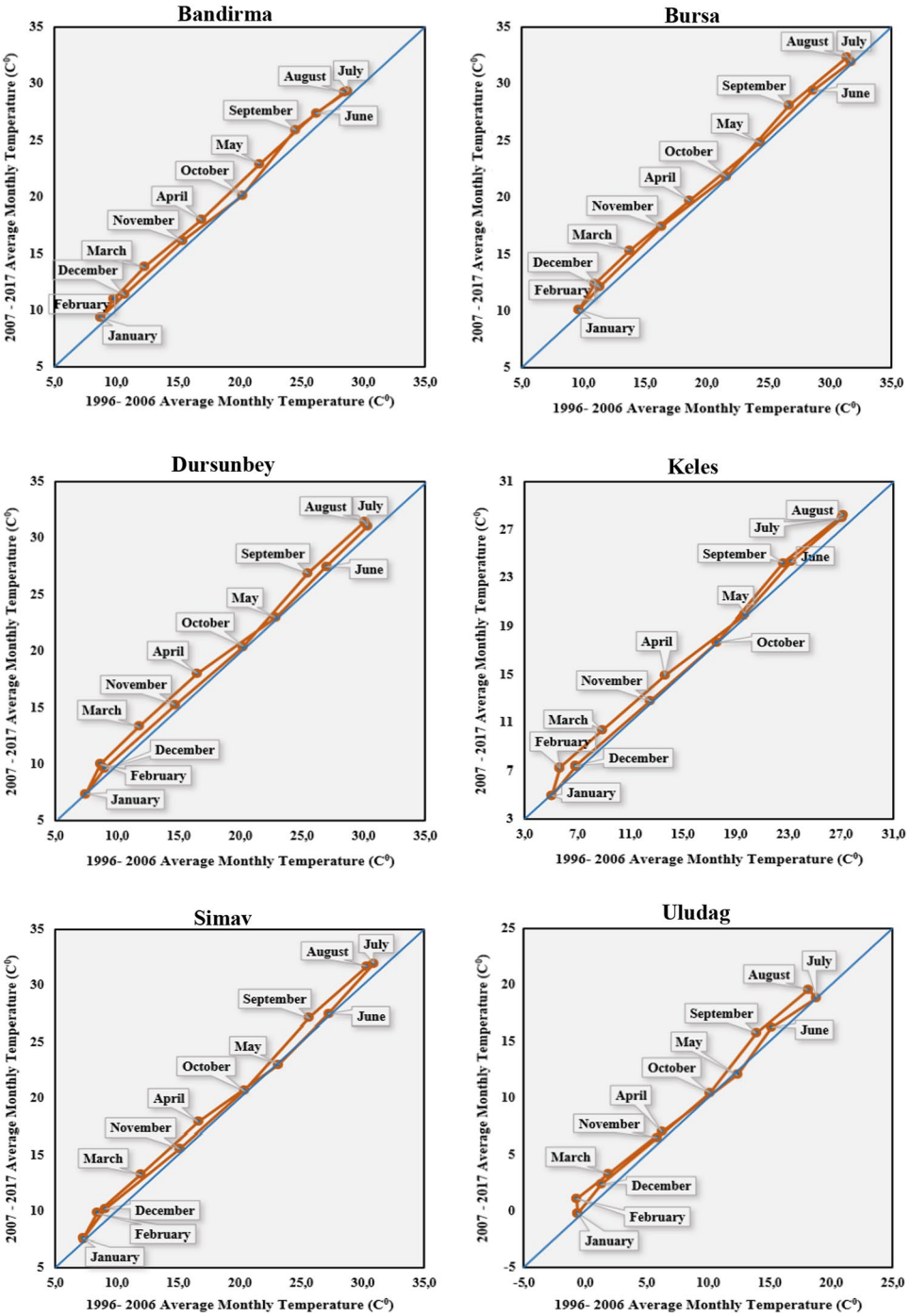

Fig. 5 Innovative polygon trend analysis method graphics of arithmetic mean analysis results for each station

Table 2 Evaluation of arithmetic mean analysis results for each station

Stations	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Bandirma	↗	↗	↗	↗	↗	↗	↗	↗	↗	→	↗	↗
Bursa	→	↗	↗	↗	→	↗	→	↗	↗	→	↗	↗
Dursunbey	→	↗	↗	↗	→	↗	↗	↗	↗	→	→	→
Keles	→	↗	↗	↗	→	↗	↗	↗	↗	→	→	→
Simav	→	↗	↗	↗	→	→	↗	↗	↗	→	→	↗
Uludag	→	↗	↗	↗	→	↗	→	↗	↗	→	→	↗

→ : No Trend ↗ : Increasing Trend

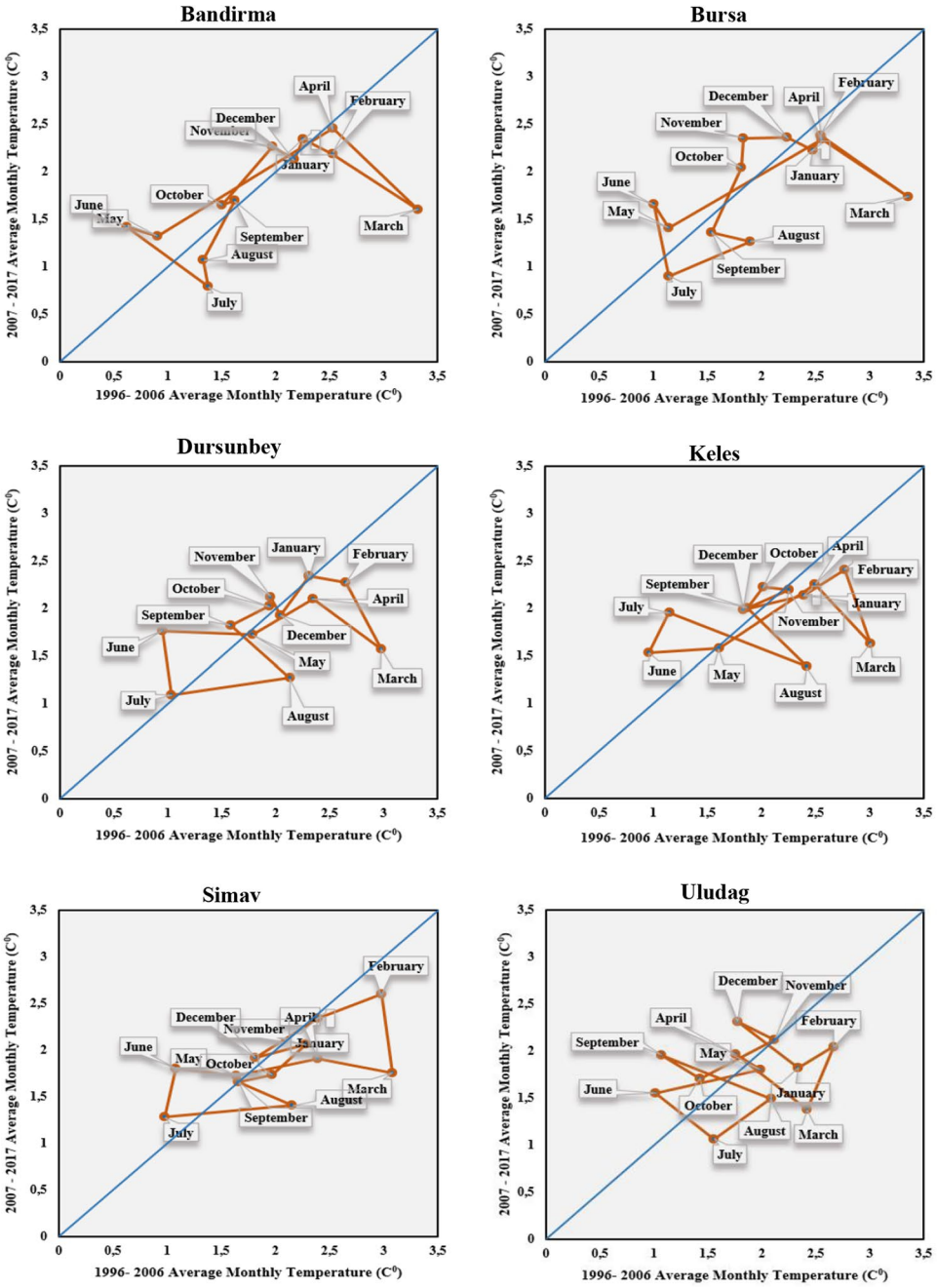

Fig. 6 Innovative polygon trend analysis method graphics of standard deviation analysis results for each station

Table 3 Evaluation of standard deviation analysis results for each station

Stations	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Bandirma	→	↘	↘	→	↗	↗	↘	↘	→	↗	↗	→
Bursa	→	↗	↘	↗	↗	↗	↘	↘	→	↗	↗	↗
Dursunbey	→	↘	↘	↘	→	↗	→	↘	↗	→	↗	↘
Keles	↘	↘	↘	↘	→	↗	↗	↘	↗	↗	→	↗
Simav	→	↘	↘	↘	↗	↗	↗	↘	→	↘	↘	↗
Uludag	↘	↘	↘	↘	↘	↗	↘	↘	↗	→	↘	↗

→ : No Trend ↗ : Increasing Trend ↘ : Decreasing Trend

Table 4 Statistical values for six station of innovative polygon trend analysis method

Bandirma		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Trend Length (mm)	1.96	3.73	6.22	6.82	6.35	3.26	0.28	5.16	7.22	6.30	6.67	2.78
	Trend Slope	1.51	1.15	0.91	1.03	0.98	0.78	0.34	0.84	1.36	0.82	1.01	1.04
Standard Deviation	Trend Length (mm)	0.31	0.99	1.16	1.98	0.30	0.99	0.28	0.69	0.13	0.77	0.24	0.22
	Trend Slope	-0.54	-0.74	-1.07	0.70	-0.34	-0.82	-5.76	2.19	0.44	1.31	-0.65	2.63
Bursa		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Trend Length (mm)	2.61	4.10	6.52	7.71	6.24	4.03	0.52	6.29	8.06	6.88	7.33	2.64
	Trend Slope	1.72	1.04	0.91	0.89	1.07	0.82	-1.10	0.89	1.24	0.84	1.06	1.19
Standard Deviation	Trend Length (mm)	0.18	1.04	1.00	1.70	0.28	0.76	0.84	0.37	0.74	0.31	0.41	0.27
	Trend Slope	2.14	-0.79	-0.75	0.66	-1.86	-5.67	0.48	-0.25	2.43	21.35	0.02	-0.58
Dursunbey		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Trend Length (mm)	2.88	4.63	6.61	8.08	6.05	4.90	0.45	6.47	8.38	7.56	8.02	2.73
	Trend Slope	2.17	1.05	0.98	0.80	1.08	1.07	-1.93	0.97	1.25	0.93	0.98	1.41
Standard Deviation	Trend Length (mm)	0.35	0.78	0.83	0.67	0.83	0.67	1.11	0.78	0.41	0.10	0.21	0.49
	Trend Slope	-0.19	-2.12	-0.83	0.66	-0.04	-8.22	0.16	-1.00	0.55	6.47	-2.23	1.53
Keles		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Trend Length (mm)	2.36	4.47	6.58	7.87	5.62	5.37	0.23	6.04	8.25	7.03	7.86	2.99
	Trend Slope	3.78	0.94	0.98	0.83	1.24	0.95	11.27	0.88	1.31	0.96	0.95	1.34
Standard Deviation	Trend Length (mm)	0.47	0.82	0.81	1.11	0.65	0.46	1.39	0.83	0.26	0.24	0.47	0.58
	Trend Slope	0.73	-3.27	-1.21	0.76	0.08	2.31	-0.45	-1.13	1.54	-0.13	0.50	0.27
Simav		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Trend Length (mm)	2.51	4.94	6.63	8.23	6.08	5.73	0.60	6.52	8.35	7.32	8.10	3.16
	Trend Slope	2.03	0.97	1.00	0.77	1.10	1.21	0.47	0.98	1.21	0.97	0.88	1.51
Standard Deviation	Trend Length (mm)	0.64	0.85	0.71	0.78	0.56	0.53	1.18	0.56	0.32	0.45	0.50	0.72
	Trend Slope	0.44	-7.87	-0.22	0.24	-0.13	5.17	0.11	-0.50	0.26	1.03	0.31	0.74
Uludag		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Trend Length (mm)	1.27	3.43	5.76	7.93	5.03	4.46	0.96	5.69	6.51	5.85	6.11	3.19
	Trend Slope	-9.84	0.85	0.86	0.81	1.52	0.71	-1.05	0.89	1.39	0.96	0.89	1.32
Standard Deviation	Trend Length (mm)	0.40	0.71	0.88	0.28	1.00	0.73	0.68	1.11	0.43	0.80	0.40	0.75
	Trend Slope	0.70	2.72	-0.89	-0.74	0.25	-0.90	0.82	-0.45	-0.69	0.59	-0.55	-0.86

When Fig. 7 is examined, arrows showing transition between both months for six stations (Bandirma, Bursa, Dursunbey, Keles, Simav and Uludag) are in I and III region. Arrows showing transitions between the first six months (J-F, F-M, M-A, A-M, M-J and J-J) are in region III. Arrows showing transitions between other six months (J-A, A-S, S–O, O-N, N-D and D-J) are in I region. While months in I region show an increasing trend, months in III region show a decreasing trend. Trend Polygon Star Concept Method graphics of standard deviation analysis results are given in Fig. 8.

When Fig. 8 is examined, following results have emerged;

1. For Bandirma and Bursa Stations, arrows showing transition between both months are in four regions. The longest of arrows indicating transition between two months is arrow indicating transition between A-M

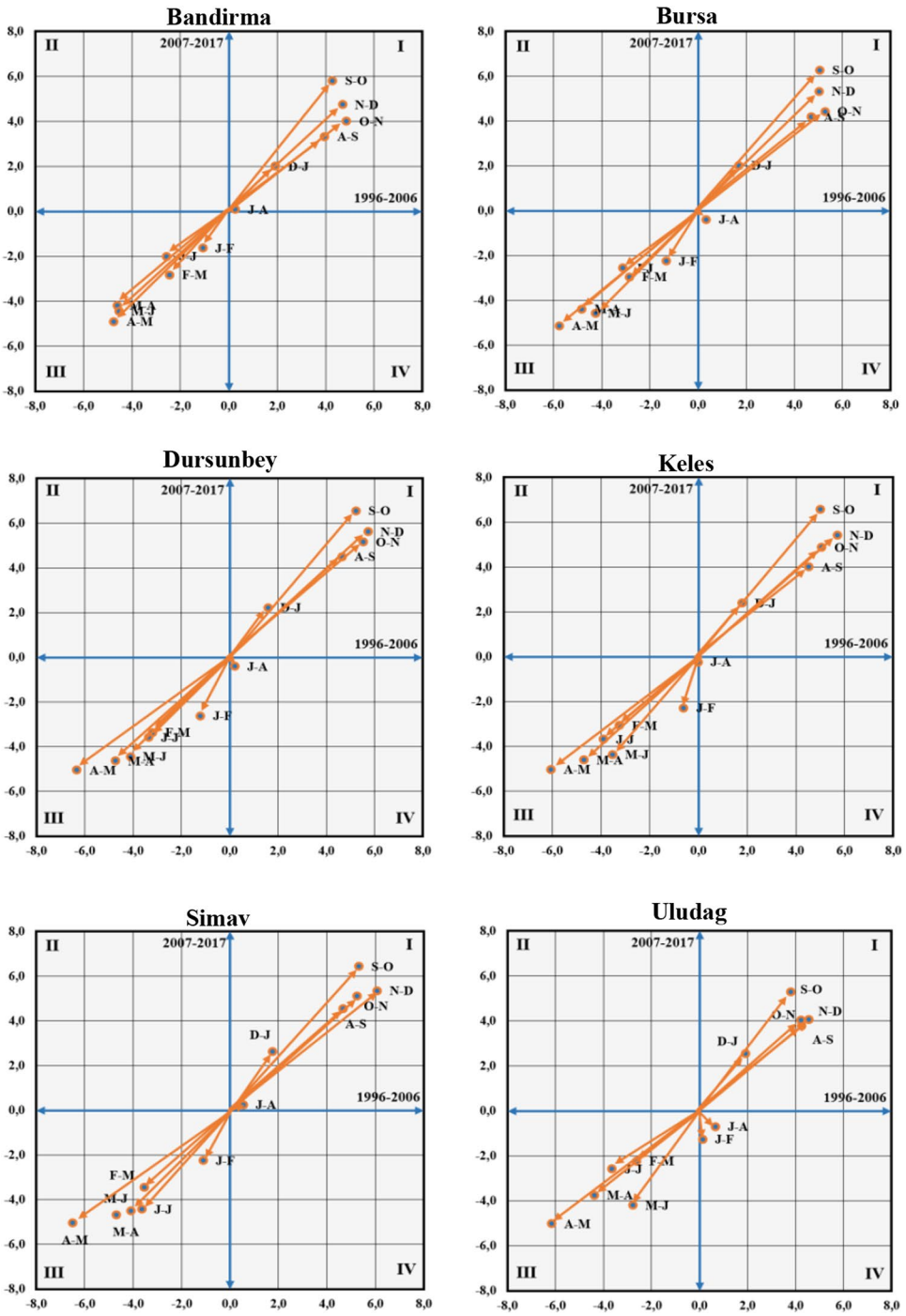

Fig. 7 Trend polygon star concept method graphics of arithmetic mean analysis results for each station

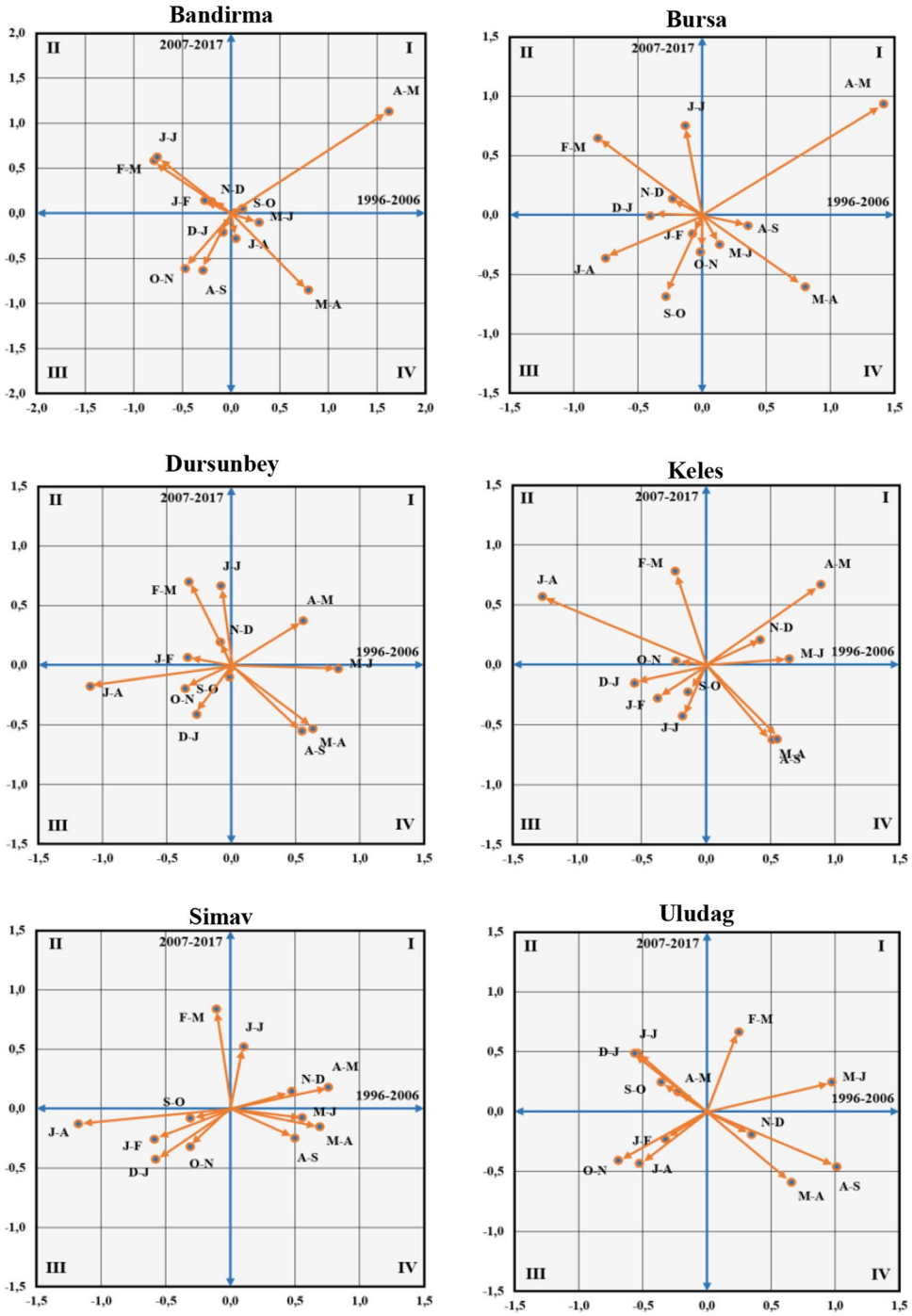

Fig. 8 Trend polygon star concept method graphics of standard deviation analysis results for each station

(April and May). This size turns out to be a highly increasing trend in transition between two months.

2. For Dursunbey and Simav Stations, arrows showing transition between both months are in four regions. The longest of arrows indicating transition between two months is arrow indicating transition between J-A (July and August). This size turns out to be a highly decreasing trend in transition between two months.
3. For Keles Station, arrows showing transition between both months are in four regions. The longest of arrows indicating transition between two months is arrow indicating transition between J-A (July and August). When this size is examined, second data set shows an increasing trend compared to first data set.
4. For Uludag Station, arrows showing transition between both months are in four regions. The longest of arrows

indicating transition between two months is arrow indicating transition between A-S (August and September). When this size is examined, second data set shows a decreasing trend compared to first data set.

Statistical values for six station of Trend Polygon Star Concept Method are given in Table 5.

The values shown in bold in Table 5 show maximum transition between two months. For example, when statistical results of Bandirma station are examined, it shows that maximum horizontal is between October and November for arithmetic average and between April and May for standard deviation. The maximum vertical shows that it is between April and May for both the arithmetic mean and the standard deviation.

When IPTA Method results are compared with results of scientific study analysis conducted by Turkes and Sumer (2004), the following results are obtained:

1. While in Bandirma station is generally observed an increasing trend, in study conducted by Turkes and Sumer is generally observed decreasing trends.
2. In Dursunbey station is observed increasing trends in seven months (Feb, Mar, Apr, June, July, Aug and Sep), but no trend was observed in five months (Jan, May, Oct, Nov and Dec). In study conducted by Turkes and Sumer is observed no trends in 12 months in general for Balıkesir station.
3. While in Bursa, Keles and Uludag stations are generally observed an increasing trend, in study conducted by Turkes and Sumer is seen decreasing trends.
4. In Simav station is generally observed an increasing trend. In study by Turkes and Sumer is generally seen increasing trends. Therefore, analysis results of both studies give similar results.

When IPTA results are compared separately for common stations with results of scientific study analysis conducted by Ceribasi and Ceyhunlu (2019), the following results are obtained:

1. Comparing the results of both meteorological (Precipitation and Temperature) analyses for Bandirma station, a decreasing trend is seen in September as a result of arithmetic mean analysis of precipitation parameter, while arithmetic average analysis of temperature parameter indicates an increasing trend for September. In standard deviation analysis results for precipitation and temperature parameters, the biggest change is seen in July, August and October.
2. When the results of both meteorological (Precipitation and Temperature) analysis for Dursunbey station are compared, it is seen that there is generally an increasing trend as a result of arithmetic average analysis of precipitation parameter, while temperature parameter is not a trend as a result of arithmetic mean analysis. In standard deviation analysis results for precipitation and temperature parameters, the greatest change is observed in March, April, August, November and December.
3. When the results of both meteorological (Precipitation and Temperature) analysis for Keles station are compared, a decreasing trend is seen in February, March and September as a result of arithmetic average analysis of precipitation parameter, while arithmetic average analysis of temperature parameter does not show an increasing trend in these months. In standard deviation analysis results for the precipitation and temperature parameters, the biggest change is seen in January, March, August and October.
4. Comparing the results of both meteorological (Precipitation and Temperature) analyzes for Simav station, a decreasing trend is observed in February, March, September and December as a result of arithmetic average analysis of precipitation parameter, while arithmetic average analysis of temperature parameter does not show an increasing trend in these months. In standard deviation analysis results for precipitation and temperature parameters, the biggest change is seen in May, August and December.
5. When the results of both meteorological (Precipitation and Temperature) analysis for Uludag station are compared, a decreasing trend is observed in March as a result of arithmetic average analysis of precipitation parameter, while arithmetic average analysis of temperature parameter does not show an increasing trend in this month. In standard deviation analysis results for precipitation and temperature parameters, the biggest change is seen in January, February, March, April, May and September.

Conclusion

IPTA and Trend Polygon Star Concept Methods were applied to monthly average temperature data of Susurluk Basin. As a result of study, IPTA and Trend Polygon Star Concept graphics created. Moreover, trend slopes and lengths of temperature data were calculated. On the other hand, horizontal and vertical of monthly average temperature data for each station of Trend Polygon Star Concept Method were calculated.

After these analyzes, following evaluations were made:

1. Since there was not a regular polygon in IPTA graphics of each station, it was seen that monthly average tem-

Table 5 Statistical values for six station of trend polygon star concept method

Bandirma		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Horizontal (mm)	-1,1	-2,4	-4,6	-4,7	-4,5	-2,6	0,3	4,0	4,3	4,9	4,7	1,9
	Vertical (mm)	-1,6	-2,8	-4,2	-4,9	-4,4	-2,0	0,1	3,3	5,8	4,0	4,7	2,0
Standard Deviation	Horizontal (mm)	-0,3	-0,8	0,8	1,6	0,3	-0,8	0,0	-0,3	0,1	-0,5	-0,2	-0,1
	Vertical (mm)	0,1	0,6	-0,9	1,1	-0,1	0,6	-0,3	-0,6	0,1	-0,6	0,1	-0,2
Bursa		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Horizontal (mm)	-1,3	-2,8	-4,8	-5,8	-4,3	-3,1	0,3	4,7	5,1	5,3	5,0	1,7
	Vertical (mm)	-2,3	-3,0	-4,4	-5,1	-4,6	-2,6	-0,4	4,2	6,3	4,4	5,3	2,0
Standard Deviation	Horizontal (mm)	-0,1	-0,8	0,8	1,4	0,1	-0,1	-0,8	0,4	-0,3	0,0	-0,4	-0,2
	Vertical (mm)	-0,2	0,6	-0,6	0,9	-0,2	0,8	-0,4	-0,1	-0,7	-0,3	0,0	0,1
Dursunbey		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Horizontal (mm)	-1,2	-3,2	-4,7	-6,3	-4,1	-3,4	0,2	4,6	5,2	5,5	5,7	1,6
	Vertical (mm)	-2,6	-3,4	-4,6	-5,0	-4,4	-3,6	-0,4	4,5	6,5	5,2	5,6	2,2
Standard Deviation	Horizontal (mm)	-0,3	-0,3	0,6	0,6	0,8	-0,1	-1,1	0,5	-0,4	0,0	-0,1	-0,3
	Vertical (mm)	0,1	0,7	-0,5	0,4	0,0	0,7	-0,2	-0,6	-0,2	-0,1	0,2	-0,4
Keles		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Horizontal (mm)	-0,6	-3,2	-4,7	-6,1	-3,5	-3,9	0,0	4,5	5,0	5,1	5,7	1,8
	Vertical (mm)	-2,3	-3,1	-4,6	-5,0	-4,4	-3,7	-0,2	4,0	6,6	4,9	5,4	2,4
Standard Deviation	Horizontal (mm)	-0,4	-0,2	0,5	0,9	0,6	-0,2	-1,3	0,6	-0,1	-0,2	0,4	-0,6
	Vertical (mm)	-0,3	0,8	-0,6	0,7	0,1	-0,4	0,6	-0,6	-0,2	0,0	0,2	-0,2
Simav		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Horizontal (mm)	-1,1	-3,5	-4,7	-6,5	-4,1	-3,6	0,5	4,7	5,3	5,2	6,1	1,7
	Vertical (mm)	-2,3	-3,4	-4,7	-5,0	-4,5	-4,4	0,3	4,6	6,4	5,1	5,4	2,6
Standard Deviation	Horizontal (mm)	-0,6	-0,1	0,7	0,8	0,6	0,1	-1,2	0,5	-0,3	-0,3	0,5	-0,6
	Vertical (mm)	-0,3	0,8	-0,2	0,2	-0,1	0,5	-0,1	-0,2	-0,1	-0,3	0,1	-0,4
Uludag		Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
Arithmetic Mean	Horizontal (mm)	0,1	-2,6	-4,4	-6,2	-2,8	-3,6	0,7	4,2	3,8	4,2	4,6	1,9
	Vertical (mm)	-1,3	-2,2	-3,7	-5,0	-4,2	-2,6	-0,7	3,8	5,3	4,0	4,1	2,5
Standard Deviation	Horizontal (mm)	-0,3	0,2	0,7	-0,2	1,0	-0,5	-0,5	1,0	-0,4	-0,7	0,3	-0,6
	Vertical (mm)	-0,2	0,7	-0,6	0,2	0,2	0,5	-0,4	-0,5	0,2	-0,4	-0,2	0,5

perature varies by years. While this change was seen increasingly in most months of each station in arithmetic mean graphs, in standard deviation graphs, in months of each station were seen as both increasing and decreasing.

2. When Trend Polygon Star Concept graphics of each station were examined, arrows showing transition between two months for each station in arithmetic mean analysis results were located in I and III region. Arrows showing transition between two months for each station occurring in results of standard deviation analysis were also located in four regions.

As a result, analyzing a hydro-meteorological (such as Precipitation, Humidity, Snow) parameter with both methods used in this study will reveal a more detailed trend result for this parameter. Moreover, the result of this trend will be very important in many engineering applications such as water supply, water resources, hydroelectric power generation, agricultural activities and irrigation practices.

Author contribution Ahmet Iyad Ceyhunlu implemented calculations. Gokmen Ceribasi and Naveed Ahmed wrote manuscript.

Funding The authors did not receive support from any organization for the submitted work.

Data availability Data availability

Declarations

Consent to participate and publication The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethics approval Ethics violation has not been done in the study.

References

Aksay CS, Ketenoglu O, Kurt L (2005) Global warming and climatic change. Selcuk Univ J Sci Faculty 1:29–42

Aktas B (2020) Possible changes in some climate parameters and climate types in Konya depending on global warming. Kastamonu University. Institute of Science. Department of Sustainable Agriculture and Natural Plant Resources. Kastamonu. Turkey.

Altunay A (2016) Investigation of climatological data in Turkey by Mann-Kendall-Sen Trend method. Canakkale On Sekiz Mart University. Institute of Social Sciences. Department of Geography. Canakkale. Turkey.

Ceribasi G (2018) Analysis of meteorological and hydrological data of iznik lake basin by using innovative sen method. J of Env Prot and Eco 19:15–24

Ceribasi G (2019) Analyzing rainfall datas' of eastern black sea basin by using sen method and trend methods. J of the Ins of Sci and Tech 9:254–264

Ceribasi G, Ceyhunlu AI (2020) Analysis of total monthly precipitation of Susurluk Basin in Turkey using innovative polygon trend analysis method. Journal of Water and Climate Change. (In Press).

Coban E (2013) Investigation into the effects of climate change on trends of precipitation in Turkey. Suleyman Demirel University. Institute of Science. Department of Civil Engineering. Isparta, Turkey

Dabanli I, Sen Z, Yelegen MO, Sisman E, Selek B, Guclu YS (2016) Trend assessment by the innovative-Şen method. Water Resour Manage 30:5193–5203

Demircan M, Demir O, Atay H, Eskioglu O, Yazici B, Gurkan H, Tuvan A, Akcakaya A (2014) Climate change projections in Turkey's river basin with new scenarios. TUCAUM - VIII. Geography Symposium. Ankara. Turkey.

Guclu YS (2018) Fundamentals and applications of comparative innovative trend analysis. J Nat Hazards Environ 4:182–191

Gungor S (2020) Comparison of Some Morphological Features of Squalius Species in the North Aegean, Susurluk and Gediz Basins. Eskisehir Osmangazi University. Institute of Science. Department of Biology. Eskisehir, Turkey

Han J, Singh VP (2020) Forecasting of droughts and tree mortality under global warming: a review of causative mechanisms and modeling methods. J Water Clim Change 11:600–632

Jones JR, Schwartz JS, Ellis KN, Hathaway JM, Jawdy CM (2015) Temporal variability of precipitation in the Upper Tennessee Valley. J Hydrol Reg Stud 3:125–138

Karmeshu N (2012) Trend detection in annual temperature & precipitation using the Mann Kendall test – a case study to assess climate change on select states in the northeastern United States. University of Pennsylvania. Department of Earth and Environmental Science. Pennsylvania, USA

Li T, Zhou Z, Fu Q, Liu D, Li M, Hou R, Pei W, Li L (2020) Analysis of precipitation changes and its possible reasons in Songhua River Basin of China. J Water Clim Change 11:839–864

Nikakhtar M, Rahmati SH, Bavani ARM (2020) Impact of climate change on the future quality of surface waters: case study of the Ardak River, northeast of Iran. J Water Clim Change 11:685–702

Ozkoca T (2015) Trend analysis of hydrometeorological parameters at middle Blacksea region coast band. Ondokuz Mayis University. Institute of Science. Department of Civil Engineering. Samsun, Turkey

Saris F, Hannah DM, Eastwood WJ (2010) Spatial variability of precipitation regimes over Turkey. Hydrol Sci J –j Des Sci Hydrol 55:234–249

Sen Z (2021) Conceptual monthly trend polygon methodology and climate change assessments. Hydrol Sci J 66:503–512

Sen Z, Sisman E, Dabanli I (2019) Innovative polygon trend analysis (IPTA) and applications. J of Hydro 575:202–210

Sezen C (2018) Effects of global atmospheric indexes on temperature and precipitation data in Turkey. Ondokuz Mayis University. Institute of Science. Department of Civil Engineering. Samsun, Turkey

Tabari H, Taye MT, Onyutha C, Willems P (2017) Decadal analysis of river flow extremes using quantile-based approaches. Water Resour Manage 31:3371–3387

Tokgoz S, Partal T (2020) Trend analysis with innovative sen and mann-kendall methods of annual precipitation and temperature data in the black sea region. J Inst Sci Technol 10:1107–1118

Topuz M, Feidas H, Karabulut M (2021) Trend analysis of precipitation data in Turkey and relations to atmospheric circulation: (1955–2013). Ital J Agrometeorol 2:91–107

Turkes M, Sümer UM (2004) Spatial and temporal patterns of trends and variability in diurnal temperature ranges of Turkey. Theoret Appl Climatol 77:195–227

Yang XL, Xu LR, Liu KK, Li CH (2012) Trends in temperature and precipitation in the Zhangweinan river basin during the last 53 years. Procedia Environ Sci 13:1966–1974

Yildirim A (2015) Trend analysis methods: Middle Firat region application. Istanbul Technical University. Institute of Energy. Department of Energy Science and Technology. Istanbul. Turkey.

Zeybekoglu U, Partal T (2018) Evaluated of monthly total annual mean and rainfall intensity series of standard duration of sinop by different trend analysis methods. Clim Change Environ 3:1–8

Zhang A, Zheng C, Wang S, Yao Y (2015) Analysis of streamflow variations in the Heihe River Basin, northwest China: trends, abrupt changes, driving factors and ecological influences. J Hydrol Reg Stud 3:106–124