Journal of Coastal Conservation (2021) 25: 50
https://doi.org/10.1007/s11852-021-00839-y

Climate change analysis by using sen's innovative and trend analysis methods for western black sea coastal region of turkey

Ahmet Iyad Ceyhunlu[1] · Gokmen Ceribasi[1] · Naveed Ahmed[2,3] · Hassan Al-Najjar[4]

Received: 9 March 2021 / Revised: 7 September 2021 / Accepted: 4 October 2021 / Published online: 15 October 2021

Abstract

Climate change are investigated by tracking temporal variation in meteorological parameters and oceanic records. The southern coast of Western Black Sea of Turkey is experienced evidential changing trend in climatic features due to the impact of global warming that significantly alter ambient temperature and wind circulations along the coast. It is extremely important to investigate the effect of climate change that causes this change for Western Black Sea Coast of Turkey. Therefore, this study aims to investigate climate change caused by global warming in sea surface temperatures and wind speeds of Western Black Sea Coast of Turkey. Coastal regions of Duzce, Zonguldak, Bartin, Kastamonu, and Sinop provinces in Western Black Sea are determined as main points. Wind speed, wind direction, and sea temperature data at those main points are used in study. Data are obtained from National Centers for Environmental Prediction. The length of data is 40 years (1979–2018). Analysis of these data is investigated with Sen's Innovative and Trend Analysis Methods (Mann–Kendall and Spearman Rho). Graphs created with Sen's Innovative method are classified into three regions (Low, Medium and High). Trend analysis methods are classified as increasing and decreasing. As a result of study was observed increasing trends at high level of wind speeds (15–25 m/s), in medium levels of wind direction (120–160 Deg.) and at high levels of Sea Surface Temperature (15–27 ℃) with Sen's Innovative Method. Decreasing trends were observed in daily analyzes of wind speed with trend analysis methods. Sea surface temperature daily and annual analyzes were observed increasing trends. These increasing trends are expected to change both marine life, fish population, precipitation regime and tourism habits for the study area.

Keywords Climate change · Sen's innovative method · Trend analysis · Western black sea · Turkey

Introduction

Climate change has many adverse effects such as glaciers melting, temperature changing, wind circulation alternating and sea water level rising (Vigo et al. 2005; Poulos et al. 2009; Poupkou et al. 2011; Mohorji et al. 2017; Ceribasi 2018). Global warming trends to decrease ice cover return decreases albedo of the globe and leads to more warming and temperature rising (Wu and Qian 2017; Ceribasi 2019).

The coastlines are home to about half of the planet population. However, climate change consequences threat seriously sustainability of life within 150 km from the beaches due to increasing in sea water level (Kummu 2016). Therefore, climate change integrations along the coastlines are a crucial issue in terms of seawater level, circulation patterns and salty water variation.

Over the next 60 years, a rising of about 0.5 m is expected to be recorded in sea water level in conjunction with increasing in temperature and wind speed as well as disturbing in atmospheric pressure which in result raise occurrence of hurricanes and coastal flooding events (Gregory and Lowe 2000; Tsimplis et al. 2004; Levermann et al. 2005). On the other hand, a study has also an average increase of more than 44 cm is expected in seas by 2080 (Fisk 1997). Apart from rising sea levels, sea surface warming and increases in wind speeds can create major disasters from coastal areas.

✉ 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

[4] Department of Civil Engineering, Institute of Natural Sciences, Sakarya University, Sakarya, Turkey

For example, as temperature increases on a shore, pressure increases. This situation causes an increase in wind speeds depending on distance. The fact that tornado events, which are known recently as open sea events, are seen in closed seas is an indicator of this. Evaluating wind speed as a hurricane is evaluated as wind speed being over 33 m/s. 523 pieces of tornado formed between 1979–2019 in Turkey (European Severe Weather Database (ESWD) 2020). Approximate 25% of these weather events that occurred in Turkey (130 Pieces) occurred in study area.

Trend analysis methods are used effectively in researching climate change results. (Allenbach et al. 2015; Dabanli et al. 2016; Elouissi et al. 2016; Sen 2017; Dabanli and Sen 2018; Guclu 2018; Ceribasi and Caliskan 2019; Li et al. 2019; Pörtner et al. 2019; Sen et al. 2019; Ceribasi and Aytulun 2020; Ceribasi and Ceyhunlu 2020; Guclu et al. 2020; Sisman 2021). Dadaser-Celik and Cengiz analyzed the trends of wind speed and direction data gathered from 206 weather stations over the period of 1975–2006 in Turkey (Dadaser-Celik and Cengiz 2014). Erismis used sea water temperature data from 22 stations to detect trends in sea water temperatures in Turkey. When monthly, annual and seasonal trend values of these stations are examined, it is stated that there is an increasing trend in most of the stations (Erismis 2019). Dabanli et al. (2021) applied Innovative Trend Analysis (ITA) method on the coasts of Turkey by considering five categories (Hot, Warm-Hot, Warm, Cold and Very Cold) for sea surface temperature data. On the other hand, they compared ITA analysis results with Mann–Kendall Trend Test analysis results. As a result of the study, they stated that climate change has noticeable effects on sea surface temperature data on Turkish coast (Dabanli et al. 2021).

Therefore, in this study, the effects of climate change, which emerged as a result of global warming, on Western Black Sea Coast in Turkey is investigated. Data examined in Western Black Sea Coast are determined as sea surface temperatures, wind directions and wind speeds. Furthermore, analyzes are carried out daily-monthly-annual for wind speed, hourly-annual for wind direction and daily-monthly-annual for sea surface temperature. Coastal regions of Duzce, Zonguldak, Bartin, Kastamonu, and Sinop provinces in Western Black Sea are determined as main points. Wind speed, wind direction, and sea temperature data at those main points are used in study. Data are obtained from National Centers for Environmental Prediction. The length of data is 40 years (1979–2018). On the other hand, the analysis results of this study will be beneficial for many studies in areas such as evapotranspiration, humidity, temperature, hydrology, hydrometeorology and hydroclimatology. Moreover, the results of analysis will be extremely important for every living thing in this region.

Material and method

Study area

The Study area consists of Duzce, Zonguldak, Bartin, Kastamonu, and Sinop provinces that located on the coast of Western Black Sea in Turkey where occurrence of hurricanes and storms is a very common weather event. Geographical locations of these provinces are given in Table 1. In addition, location of provinces on map is given in Fig. 1.

Data of these coordinates were obtained from NCEP as hourly data (National Centers for Environmental Prediction (NCEP) 2020). Data (Wind Speeds, Wind Directions and Sea Surface Temperature Data) used in study represent period of 1979–2018. The monthly temporal variations in wind speed (m/s) and sea surface temperature (℃) were respectively presented in Fig. 2 and Fig. 3.

Sen's innovative method

The analysis methods that try to predict future data movements based on current data are called Trend Analysis Methods. Tests such as Mann–Kendall Test, Spearman's Rho Test and Sen's Test are used in trend analysis. Sen's Innovative Method, which is one of new trend analysis methods in recent years and has reliability to investigate climate change is created by Sen (2012). Data is divided into two parts from middle in Sen's Innovative Method. These two series are listed from small to large. First data series (X_i) is placed on

Table 1 Location Coordinates of Provinces

Provinces		Duzce	Zonguldak	Bartin	Kastamonu	Sinop
Coordinate	Latitude	41.3475	41.6335	42.3010	42.6138	42.6949
	Longitude	30.9987	31.3771	32.3189	33.6325	35.2769
Altitude (m)		160.00	13.00	25.00	780.00	28.00
Survey (km^2)		3,641.00	3,341.00	2,120.00	1,834.00	5,862.00

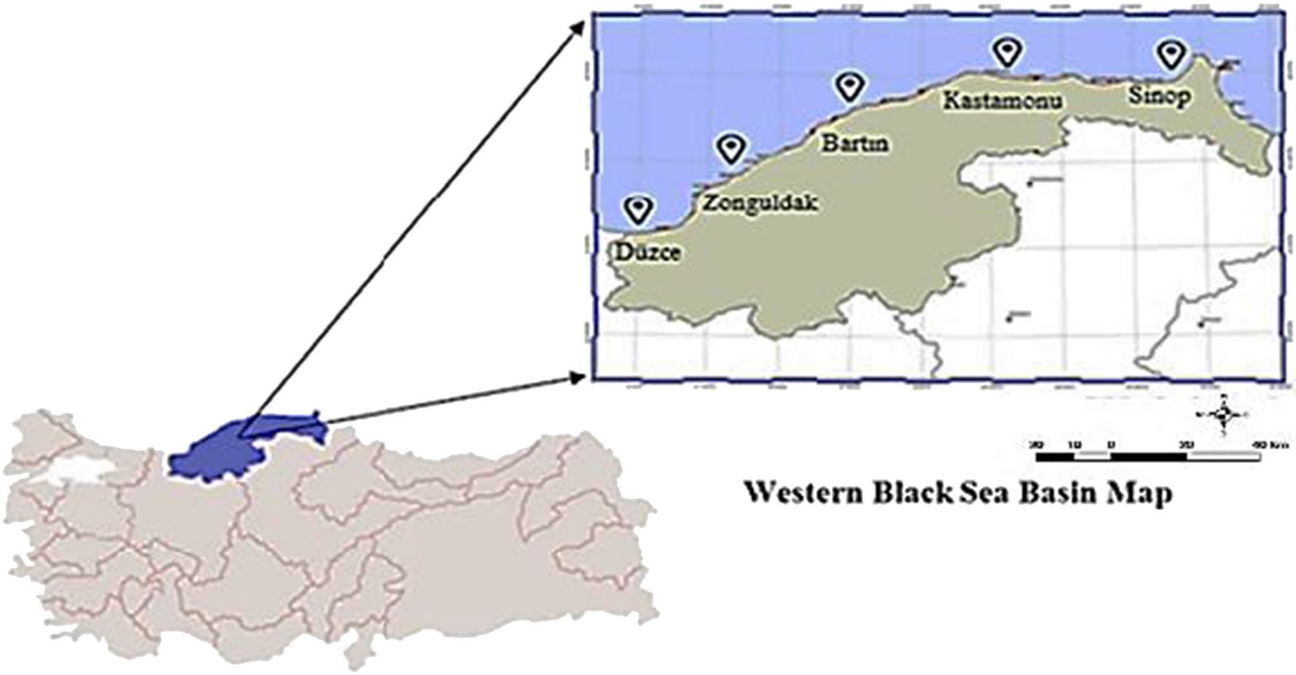


Fig. 1 Location of study area on turkey basins map

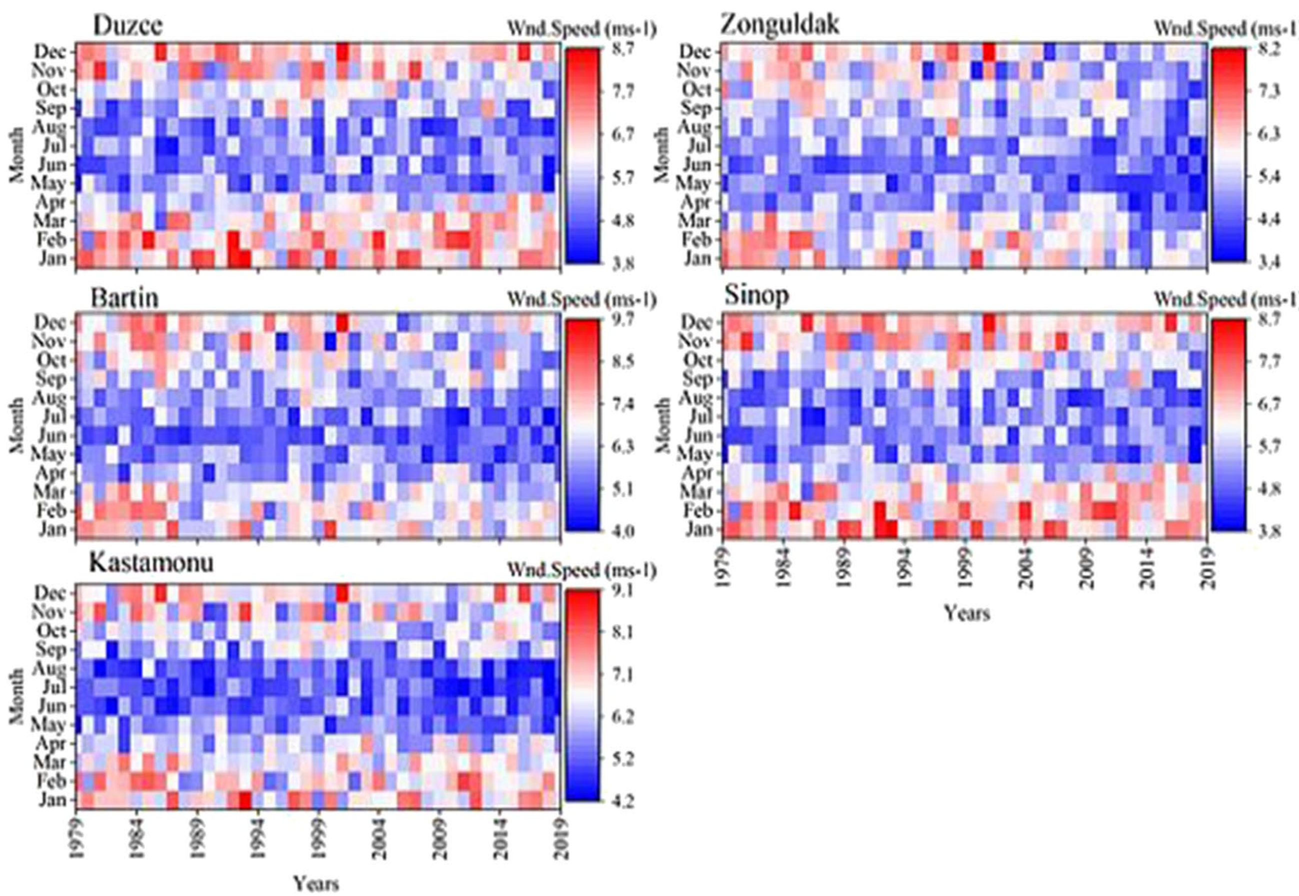


Fig. 2 Monthly variations in wind speed (m/s) along course line graphs of provinces during 1979–2019

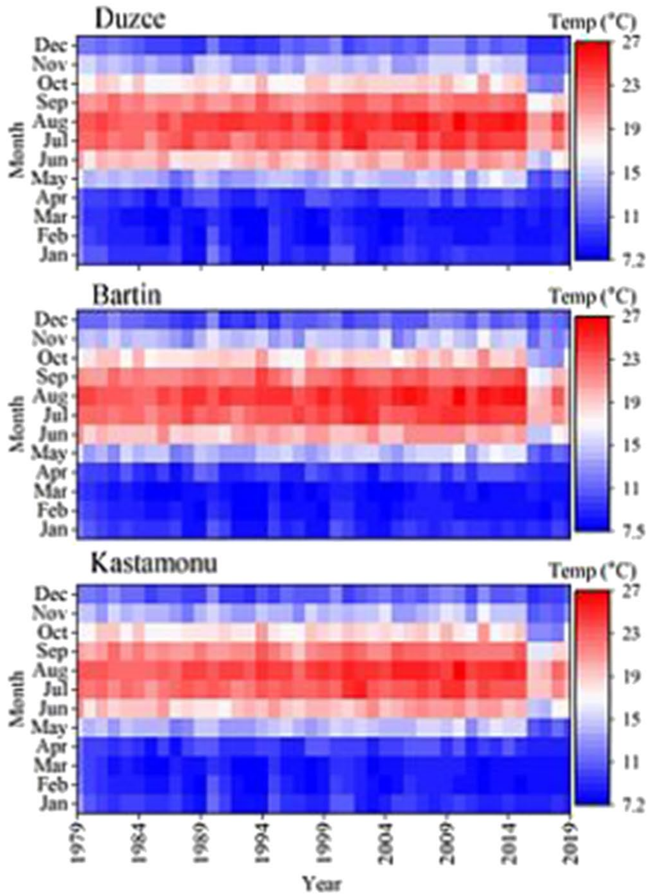


Fig. 3 Monthly variations in sea surface temperature (°C) along course line graphs of provinces during 1979–2019

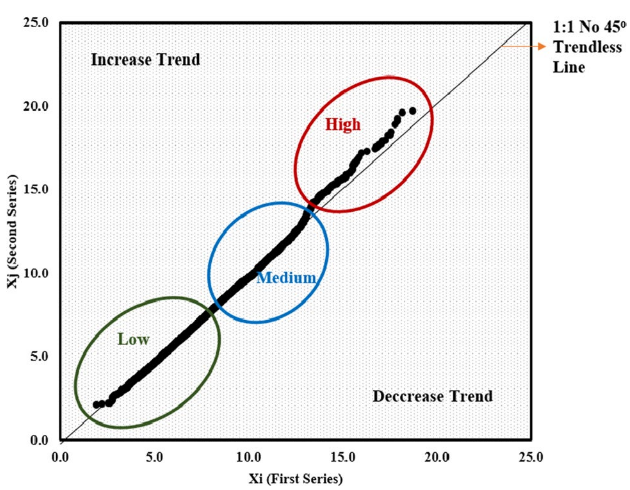


Fig. 4 Illustration of sen's innovative method

the horizontal axis, and second data series (Xj) is placed on vertical axis on cartesian coordinate system (Fig. 4).

If the distribution points in the graph are located in the upper triangle, it is concluded that there is a decreasing trend if the increasing trend is in the lower triangle. Moreover, the points of distribution are divided into approximately three equal parts. High part shows an increasing/decreasing trend at the high level. Middle part shows an increasing/decreasing trend at the middle level. Low part shows an increasing/decreasing trend at the lower level. If data remains above 1:1 (45°) curve, it is concluded that no trend has occurred in data set (Sen 2012, 2013). The data distribution divided into these three parts is independent for the study area.

Mann–kendall method

The presence of a trend in a time series with this test is checked with hypothesis "H_0: No Trend". In the time series which the test will be applied, the data is divided into two groups as x_i and x_j pairs. The number of pairs $x_i < x_j$ is denoted by P, while the number of pairs $x_i > x_j$ is denoted by M. Test statistic (S) is calculated by the following relation:

$$S = P - M \tag{1}$$

Kendall correlation coefficient:

$$\tau = \frac{S}{[n(n-1)/2]} \tag{2}$$

for $n \geq 10$

$$\sigma_s = \sqrt{n(n-1)(2n+5)/18} \tag{3}$$

$$Z = \begin{matrix} (S-1)/\sigma_s \,;\, S > 0 \\ 0 \quad ;\, S = 0 \\ (S+1)/\sigma_s \,;\, S < 0 \end{matrix} \tag{4}$$

If Z value is greater than $Z_{\alpha/2}$ value (1.96), which is identified from standard normal distribution tables at α significance level, H_0 hypothesis is rejected and it is concluded that a certain trend is present (Mann 1945; Kendall 1975).

Spearman rho method

This method is a test used to determine whether there is a correlation between two sets of observations. The rank statistic (R_{xi}) is determined by sorting the data in ascending or descending order. Spearman's Rho test statistic (r_s) is calculated according to the following equation.

$$r_s = 1 - 6\frac{\sum_{i=1}^{n}(R_{xi} - i)^2}{(n^3 - n)} \tag{5}$$

Since r_s distribution will proximate to normal for $n > 30$, normal distribution tables are used. For this, test statistic (Z) of r_s

$$Z = r_s\sqrt{n-1} \tag{6}$$

If Z value is greater than $Z_{\alpha/2}$ value (1.96), which is identified from standard normal distribution tables at α significance level, H_0 hypothesis is rejected and it is concluded that a certain trend is present (Kahya and Kalayci 2004).

Results and discussion

Wind speeds, wind directions, and sea surface temperature data of Duzce, Zonguldak, Bartin, Kastamonu and Sinop provinces were analyzed with the Sen's Innovative Method. Wind speed analysis results were given in Fig. 5.

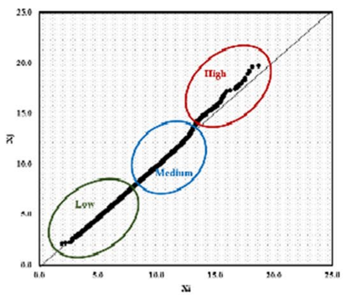
General evaluation of Sen's Innovative Method analysis results for each province in Fig. 5 was given in Table 2.

The results of Fig. 5 and Table 2 illustrate no trend in low and medium level in extreme daily wind speed analysis of Duzce province, whereas there is an increasing trend in a high level at 13–19 m/s. There is no trend in low level in monthly extreme analyses, whereas there is an increasing trend in medium and high level at 13–16 m/s and at 16–19 m/s. In annual extreme analyzes, there is an increasing trend in low, medium and high levels between 13–19 m/s. In extreme daily wind speed analysis of Zonguldak province, it is seen that there is no trend in low and medium levels, whereas there is an increasing trend in a high level at 16–23 m/s. In monthly extreme analyzes, there is a decreasing trend in low level at 9–13 m/s, and there is no trend in medium level, and an increasing trend is seen in high level at 16–23 m/s. There is an increasing trend in annual extreme analyses in low, medium and high levels between 16–23 m/s. In extreme daily wind speed analysis of province of Bartin, it is seen that there is no trend in low and medium levels, while in high level, there is an increasing trend at speeds of 16–21 m/s and a decreasing trend is formed at speeds at 21–24 m/s. In monthly extreme analysis, there is a decreasing trend in low level at 9–13 m/s, whereas there is an increasing trend between 16–21 in medium level and a decreasing trend in high levels at 21–24 m/s. In annual extreme analyses, there is an increasing trend in low level at 16–21 m/s, and a decreasing trend in medium level at 21–23 m/s, and there is an increasing trend in high level between 21–25 m/s. In extreme daily wind speed analysis of the province of Kastamonu, it is seen that there is no trend in low and medium levels and an increasing trend in high levels at 17–23 m/s. In the monthly extreme daily wind speed analysis, there is no trend in low level, whereas there is an increasing trend in medium and high levels between 17–21 m/s and 21–23 m/s. There is an increasing trend in annual analysis in low, medium, and high levels between 17–23 m/s. In extreme daily wind speed analysis of Sinop province, it is seen that there is no trend in low and medium levels and an increasing trend in high levels at 17–24 m/s. There is a decreasing trend in low level at 9–15 m/s in monthly analysis, whereas there is an increasing trend in medium and high levels between 17–20 m/s and 20–24 m/s. In annual analysis, there is an increasing trend in low, medium and high levels between 17–24 m/s.

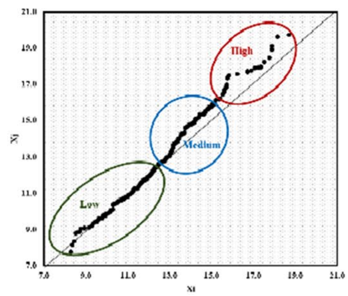
In evaluating wind direction analysis results, increasing or decreasing trend indicates prevailing wind direction in the current direction. Wind direction analysis of Duzce, Zonguldak, Bartin, Kastamonu, and Sinop provinces was applied hourly and annually, and results were given in Fig. 6.

General evaluation of Sen's Innovative Method analysis results for each province in Fig. 6 was given in Table 2.

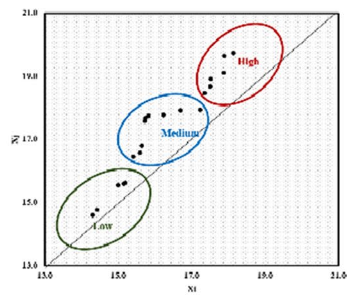
When results of Fig. 6 and Table 2 are analyzed, it is seen that there is no trend in low and high levels, in hourly wind direction analysis of Duzce province, whereas there is an increasing trend in medium level at winds coming from Southeast 120°-150° direction. Annually, there is an increasing trend in low and medium levels at winds coming



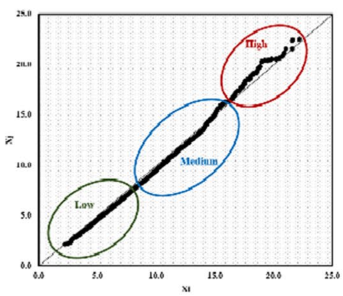
Duzce (Daily)



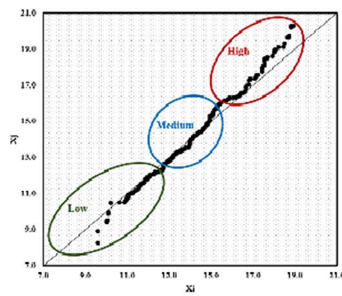
Duzce (Monthly)



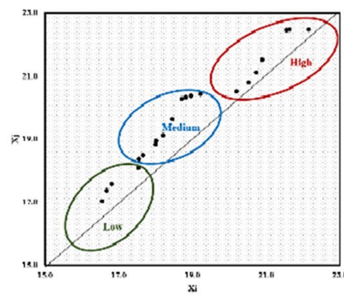
Duzce (Annual)



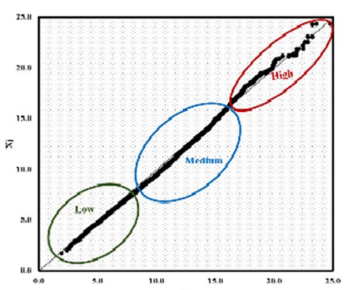
Zonguldak (Daily)



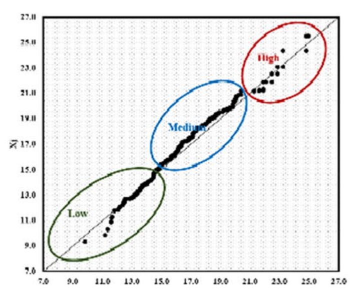
Zonguldak (Monthly)



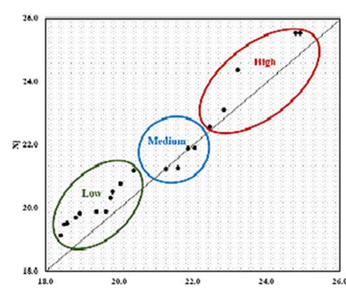
Zonguldak (Annual)



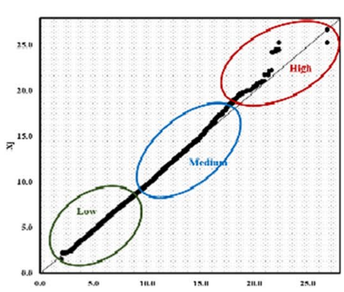
Bartin (Daily)



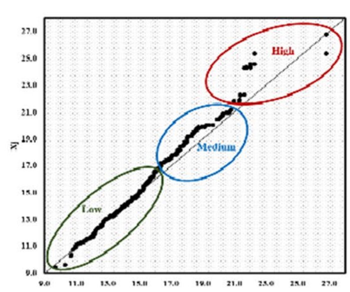
Bartin (Monthly)



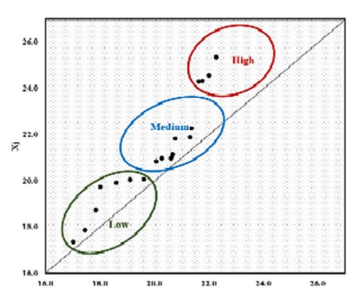
Bartin (Annual)



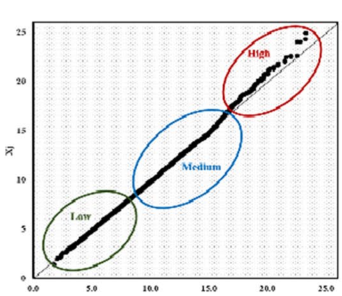
Kastamonu (Daily)



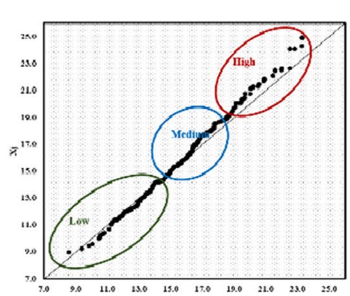
Kastamonu (Monthly)



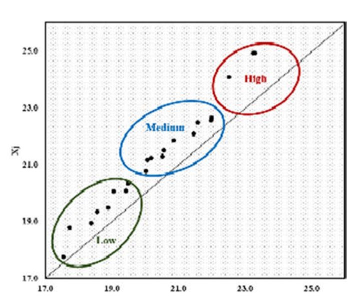
Kastamonu (Annual)



Sinop (Daily)



Sinop (Monthly)



Sinop (Annual)

◂**Fig. 5** Graphics of wind speed (m/s) analysis results for each province

from Southeast 120°-135 ° and 135°-150° direction, while there is a decreasing trend in high level at 150°-160°. In hourly wind direction analysis of Zonguldak province, it is seen that there is no trend in low and high levels, whereas there is an increasing trend in medium level at winds coming from Southeast 115°-150° direction. There is an increasing trend in annual analysis in low and medium levels at winds coming from the Southeast 115°-130° and 130°-150° direction, while there is a decreasing trend in a high level at 150°-160°. In hourly wind direction analysis of Bartin province, it is seen that there is an increasing trend in low level at winds coming from Northeast 30°-60° direction, and there is an increasing trend in medium level at winds coming from Southeast 110°-170° direction, while there is a decreasing trend in high a level at winds coming from Northwest 290°-340° direction. Annually, there is an increasing trend in low and medium levels at winds coming from Southeast 120°-140° and 140°-165° direction, while there is a decreasing trend in high level at 165°-170°. In hourly wind direction analysis of the province of Kastamonu, it is seen that there is no trend in low and high levels, whereas there is an increasing trend in medium level at winds coming from Southeast 120°-230° direction. On annual basis, there is an increasing trend in low and medium levels at winds coming from Southeast 140°-160° and South 160°-175° direction, while there is a decreasing trend in high level at 180°-190°. In hourly wind direction analysis of Sinop province, it is seen that there is an increasing trend in low level at winds coming from the east 60°-90° direction, and there is an increasing trend in medium level at winds coming from Southeast-South and Southwest 160°-230° directions, while there is a decreasing trend in a high level at winds coming from Northwest 300°-340° direction. On annual scale, there is an increasing trend in low and medium levels at winds coming from South 165°-185° and 185°-195° direction, while there is a decreasing trend in high level at 195° -205°.

Results of sea surface temperature analysis of Duzce, Zonguldak, Bartin, Kastamonu and Sinop provinces were given in Fig. 7 on a daily, monthly and annual basis.

General evaluation of Sen's Innovative Method analysis results for each province in Fig. 7 was given in Table 2.

Considering the results of Fig. 7 and Table 2, extreme daily sea surface temperature analysis of Duzce province shows an increasing trend in low and medium and high levels between 7–26 ℃. Monthly trends show an increasing trend in low, medium, and high levels at 7–26 ℃. Similarly, annual trend analysis also shows an increasing trend in low, medium, and high levels at 24–26 ℃. In extreme daily sea surface temperature analysis of Zonguldak province, it is seen that there is no trend in low level and there is an increasing trend in medium and high levels between 11–17 ℃ and 17–26 ℃. On monthly basis, the extreme analysis shows there is an increasing trend in low, medium, and high levels between 7–15 ℃, 15–21 ℃, and 21–26 ℃. Similarly, annual trends show an increasing trend in low, medium, and high levels between 24–26 ℃. In extreme daily sea surface temperature analysis of Bartin province, it is seen that there is no trend in low and medium levels, and there is an increasing trend in high level at 20–27 ℃. The monthly extreme analysis shows an increasing trend in low, medium, and high levels between 7–15 ℃, 15–20 ℃ and 20–27 ℃. Similarly, annual trends show an increasing trend in low, medium, and high levels between 24–27 ℃. In extreme daily sea surface temperature analysis of Kastamonu province, it is seen there is no trend in low and medium levels, whereas there is an increasing trend in high level at 19–27 ℃. The monthly extreme analysis shows no trend in low level, and there is an increasing trend in medium and high levels at 17–21 ℃ and 20–27 ℃. Annual extreme analysis of temperature shows that there is an increasing trend in low, medium, and high levels between 24–27 ℃. In extreme daily sea surface temperature analysis of Sinop province, there is no trend at low and medium levels, whereas there is an increasing trend in high level at 17–26 ℃. The monthly extreme analysis shows no trend in low level, and there is an increasing trend in medium and high levels at 15–20 ℃ and 20–27 ℃. The annual extreme analysis shows an increasing trend in low, medium, and high levels between 24–26 ℃.

Wind speeds, wind directions, and sea surface temperature data of Duzce, Zonguldak, Bartin, Kastamonu and Sinop provinces were analyzed with Mann–Kendall and Spearman Rho Methods. Wind speed, wind direction and sea surface temperature analysis results are given in Table 3.

When the analysis results in Table 3 were examined, the following results were obtained.

1. While a decreasing trend was observed in both methods in daily wind speed analysis results of Duzce province, no trend was observed in monthly and annual analysis results. When wind direction analysis results are examined, there is no trend for Mann–Kendall method, while an increasing trend is seen for Spearman Rho method. When sea surface temperature daily, monthly and annual analysis results are examined, increasing trends are seen in both methods.

Table 2 General evaluation of wind speed, wind direction and sea surface temperature analysis results for each province

	Provinces	Daily			Monthly			Annual		
		Low	Medium	High	Low	Medium	High	Low	Medium	High
Wind Speed	Duzce	→	→	↗	→	↗	↗	↗	↗	↗
	Zonguldak	→	→	↗	↘	→	↗	↗	↗	↗
	Bartin	→	→	↗	↘	↗	↗	↗	↘	↗
	Kastamonu	→	→	↗	→	↗	↗	↗	↗	↗
	Sinop	→	→	↗	↘	↗	↗	↗	↗	↗

	Provinces	Hourly			Annual		
		Low	Medium	High	Low	Medium	High
Wind Direction	Duzce	→	↗	→	↗	↗	↘
	Zonguldak	→	↗	→	↗	↗	↘
	Bartin	↗	↗	↘	↗	↗	↘
	Kastamonu	→	↗	→	↗	↗	↘
	Sinop	↗	↗	↘	↗	↗	↘

	Provinces	Daily			Monthly			Annual		
		Low	Medium	High	Low	Medium	High	Low	Medium	High
Sea Surface Temperature	Duzce	↗	↗	↗	↗	↗	↗	↗	↗	↗
	Zonguldak	→	↗	↗	↗	↗	↗	↗	↗	↗
	Bartin	→	→	↗	↗	↗	↗	↗	↗	↗
	Kastamonu	→	→	↗	→	↗	↗	↗	↗	↗
	Sinop	→	→	↗	→	↗	↗	↗	↗	↗

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

2. While a decreasing trend was observed in both methods in daily wind speed analysis results of Zonguldak and Bartin provinces, no trend was observed in monthly and annual analysis results. When wind direction analysis results are examined, no trend is seen in both methods. When sea surface temperature daily and annual analysis results are examined, increasing trends are seen in both methods, while no trend is seen in monthly analysis results.
3. While a decreasing trend was observed in both methods in daily wind speed analysis results of Kastamonu province, no trend was observed in monthly and annual analysis results. When wind direction analysis results are examined, no trend is seen in both methods. When sea

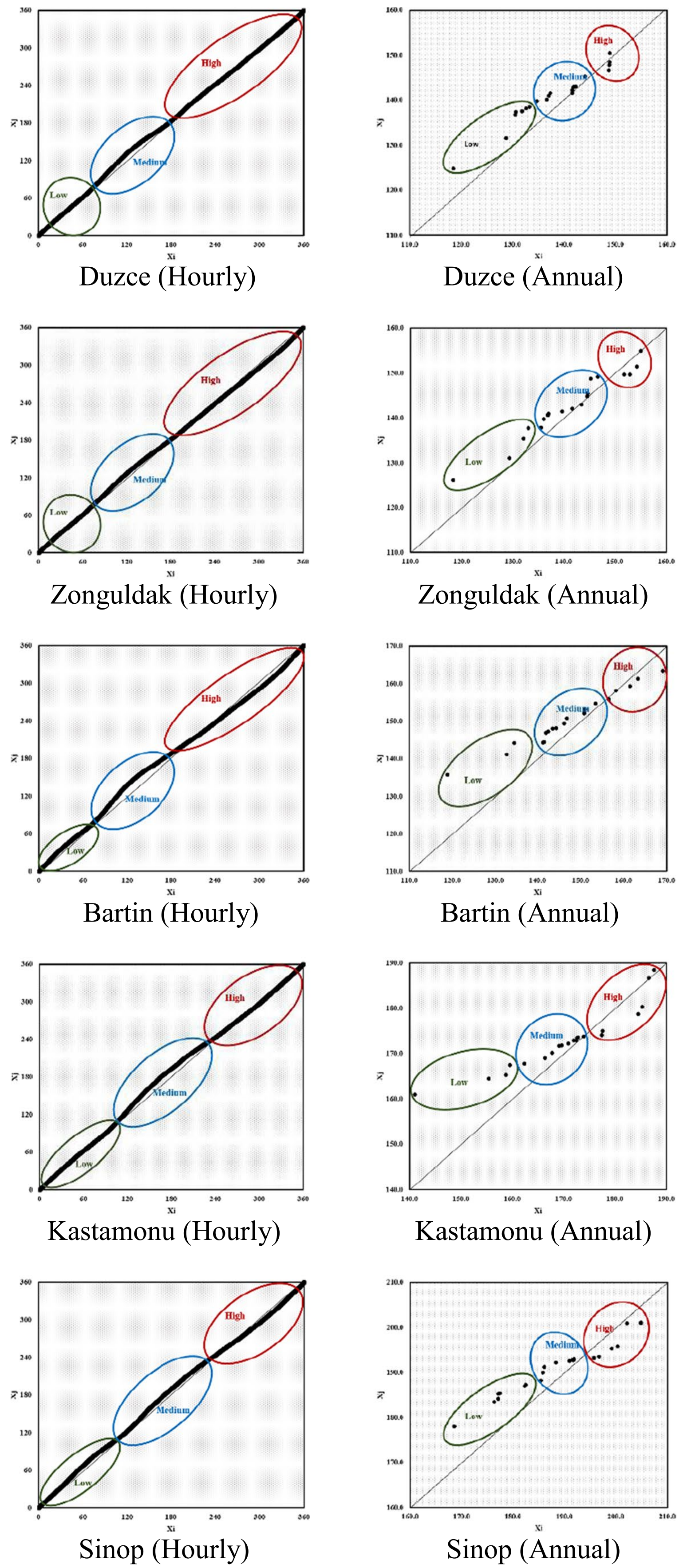
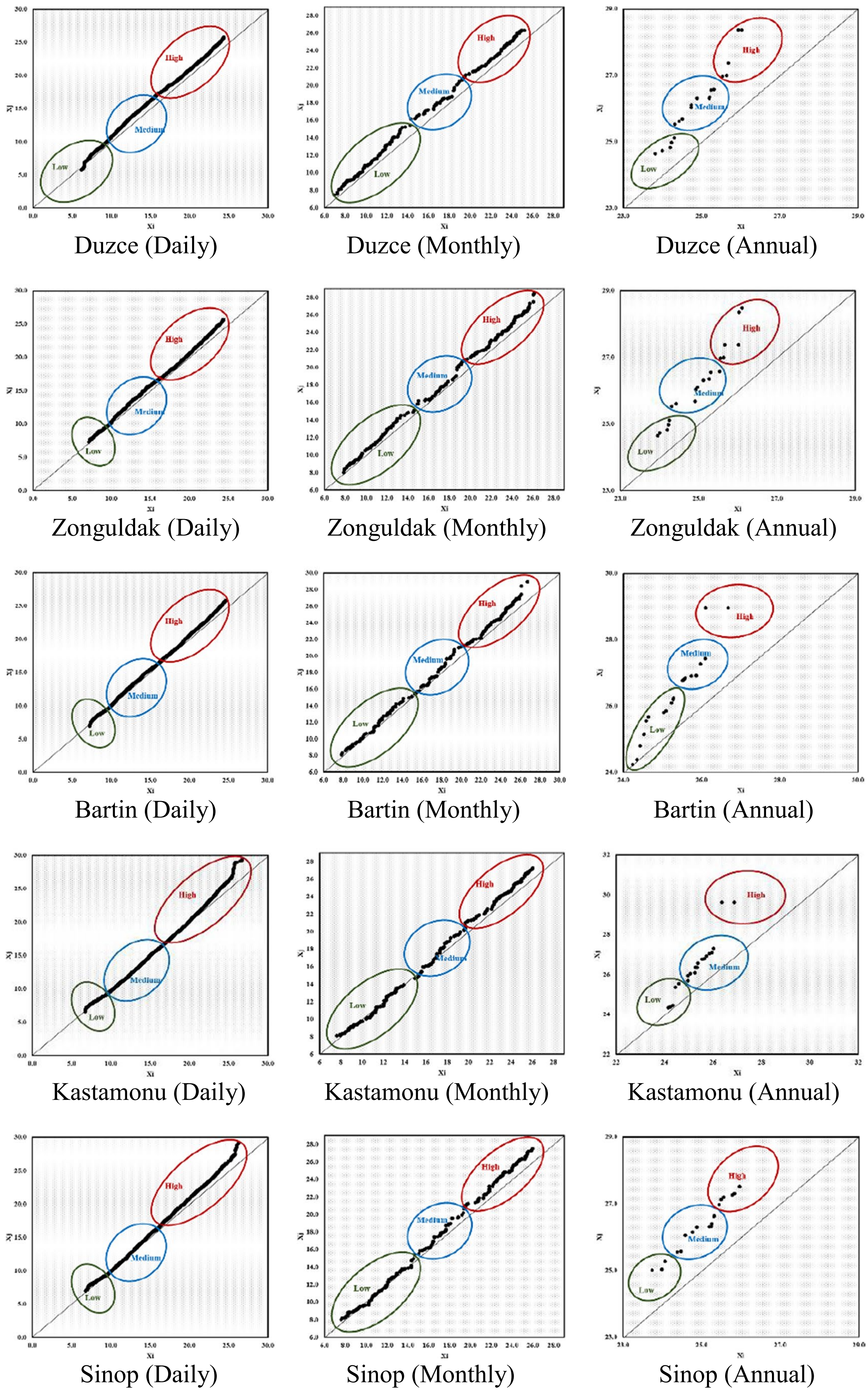


Fig. 6 Graphics of wind direction (deg.) analysis results for each province


Duzce (Daily)
Duzce (Monthly)
Duzce (Annual)
Zonguldak (Daily)
Zonguldak (Monthly)
Zonguldak (Annual)
Bartin (Daily)
Bartin (Monthly)
Bartin (Annual)
Kastamonu (Daily)
Kastamonu (Monthly)
Kastamonu (Annual)
Sinop (Daily)
Sinop (Monthly)
Sinop (Annual)
High
Medium
Low
Xi
Xj

◂**Fig. 7** Graphics of sea surface temperature (°C) analysis results for each province

surface temperature daily analysis results are examined, decreasing trends are observed in both methods, while no trend is observed in monthly and annual analysis results.

4. While no trend was observed in both methods in daily, monthly and annual wind speed analysis results of Sinop province. When wind direction analysis results are examined, no trend is seen in both methods. When sea surface temperature daily and monthly analysis results are examined, no trend is observed in both methods, while an increasing trend is observed in annual analysis results.

When the analysis results of Sen's Innovative Method and Trend Analysis Methods (Mann–Kendall and Spearman Rho Methods) were compared, it was observed that all provinces (Duzce, Zonguldak, Bartin, Kastamonu and Sinop) gave highly similar results. When the analysis results of this study are compared with the analysis results of similar studies, the following results are obtained.

- When the analysis results of Sinop and Kastamonu provinces are examined, generally increasing trends are observed for all three hydrometeorological parameters. When the result of this analysis is compared with the scientific study conducted by Dabanli et al., It is observed that it gave similar results (Dabanli et al. 2021).
- When the analysis results of Bartin province are examined, it is observed that sea water temperatures generally increase. When the result of this analysis is compared with the scientific study conducted by Güçlü, it is observed that it gave similar results (Guclu 2013).
- When the analysis results are examined for other two provinces, it is observed that sea water temperatures are generally increasing. When the result of this analysis is compared with the scientific study conducted by Ozdemir and Yetemen, it is seen that it gave similar results (Ozdemir and Yetemen 2019).

Hence, this study will be beneficial for many studies in areas such as evapotranspiration, humidity, temperature, hydrology, hydrometeorology and hydroclimatology. On the other hand, this study will guide all the planning for the western black sea region.

Conclusion

In this study, the effects of climate change on Western Black Sea Coast in Turkey were investigated on data between 1979 and 2018 (40 Years). According to analysis results; an increasing trend was observed at high levels of wind speeds (15–25 m/s), an increasing trend was observed in medium levels of wind direction (120°-160°), and an increasing trend was observed at high levels of Sea Surface Temperature (15–27 °C) with Sen's Innovative Method. On the other hand, decreasing trends were observed in daily analyzes of wind speed with Trend Analysis Methods (Mann–Kendall and Spearman Rho). Sea surface temperature daily and annual analyzes were observed increasing trends. Based on these results, the adverse effects expected in Western Black Sea Coast in coming years are listed below.

- As a result of increases in wind speeds and sea temperatures, hurricanes, and similar formations in study region will increase.
- The sufficient winds expected to be seen in the future will create more destructive waves in Western Black Sea Coast region.
- As a result of changes in sea water levels, coastal floods will be more common.
- It will mix into freshwater aquifers with saltwater waters.
- Decreases at low wind speeds will negatively affect biodiversity, and changes will occur in plants and species in study region.
- These increasing trends will change marine life
- Also, these trends will change both fish population, precipitation regime and tourism habits for the study area.

Funding and competing interests The authors did not receive support from any organization for the submitted work. The authors have no conflicts of interest to declare that are relevant to the content of this article.

Data Availability All the data used in this publication are publicly available in the NCEP data portal (https://www.cpc.ncep.noaa.gov).

Table 3 Wind speed, wind direction and sea surface temperature analysis results for each province

	Provinces	Daily				Monthly				Annual			
		Mann–Kendall		**Spearman Rho**		**Mann–Kendall**		**Spearman Rho**		**Mann–Kendall**		**Spearman Rho**	
		τ	**Z**	**r_s**	**Z**	**τ**	**Z**	**r_s**	**Z**	**τ**	**Z**	**r_s**	**Z**
Wind Speed	**Duzce**	-0.05	**-9.87**	-0.08	**-9.93**	0.003	0.09	0.01	0.17	0.17	1.58	0.27	1.73
	Zonguldak	-0.07	**-12.20**	-0.10	**-12.20**	-0.02	-0.69	-0.03	-0.66	0.07	0.63	0.11	0.68
	Bartin	-0.05	**-8.20**	-0.07	**-8.19**	0.01	0.45	0.02	0.48	-0.05	-0.47	-0.08	-0.51
	Kastamonu	-0.02	**-3.00**	-0.03	**-2.99**	0.05	1.50	0.07	1.43	0.10	0.90	0.15	0.93
	Sinop	-0.01	-1.82	-0.02	-1.86	0.03	0.94	0.04	0.93	0.08	0.76	0.13	0.84
Wind Direction	**Provinces**	**Annual**											
		Mann–Kendall		**Spearman Rho**									
		τ	**Z**	**r_s**	**Z**								
	Duzce	0.21	1.92	0.33	**2.08**								
	Zonguldak	0.10	0.90	0.15	0.95								
	Bartin	0.16	1.50	0.23	1.47								
	Kastamonu	0.17	1.55	0.24	1.54								
	Sinop	0.16	1.50	0.25	1.58								
Sea Surface Temperature	**Provinces**	**Daily**				**Monthly**				**Annual**			
		Mann–Kendall		**Spearman Rho**		**Mann–Kendall**		**Spearman Rho**		**Mann–Kendall**		**Spearman Rho**	
		τ	**Z**	**r_s**	**Z**	**τ**	**Z**	**r_s**	**Z**	**τ**	**Z**	**r_s**	**Z**
	Duzce	0.05	**9.27**	0.08	**9.34**	0.07	**2.20**	0.10	**2.17**	0.51	**4.66**	0.67	**4.24**
	Zonguldak	0.03	**5.55**	0.05	**5.76**	0.05	1.62	0.07	1.60	0.47	**4.25**	0.58	**3.66**
	Bartin	0.01	**2.39**	0.02	**2.66**	0.03	1.07	0.05	1.04	0.45	**4.07**	0.56	**3.51**
	Kastamonu	-0.02	**-3.31**	-0.03	**-3.16**	-0.02	-0.51	-0.02	-0.50	0.11	0.99	0.13	0.83
	Sinop	0.01	1.59	0.02	1.80	0.03	1.02	0.05	1.04	0.54	**4.91**	0.72	**4.54**

References

Allenbach K, Garonna I, Herold C, Monioudi IN, Giuliani G, Lehmann A, Velegrakis AF (2015) Black sea beaches vulnerability to sea level rise. Environ Sci Policy 46:95–109. https://doi.org/10.1016/j.envsci.2014.07.014

Ceribasi G (2018) Analysis of rainfall datas of the west black sea basin by innovative sen method. Aca Plat J Eng Sci 6:168–173. https://doi.org/10.21541/apjes.431965

Ceribasi G (2019) Analyzing rainfall datas' of eastern black sea basin by using sen method and trend methods. J Ins Sci Tech 9:254–264. https://doi.org/10.21597/jist.439569

Ceribasi G, Caliskan M (2019) Short- and long-term prediction of energy to be produced in hydroelectric energy plants of sakarya basin in Turkey. ES Part A: Rec Util Env Effects. https://doi.org/10.1080/15567036.2019.1665756

Ceribasi G, Aytulun U (2020) Investigation of the effect of climate change on precipitation and temperature data of Susurluk basin and Van Lake closed basin. Int J G Warm 22:54–71. https://doi.org/10.1504/IJGW.2020.110212

Ceribasi G, Ceyhunlu AI (2020) Generation of 1d and 2d flood maps of sakarya river passing through geyve district of sakarya city in Turkey. Nat Hazards 105:631–642. https://doi.org/10.1007/s11069-020-04327-8

Dabanli I, Sen Z, Yelegen MO, Sisman E, Selek B, Guclu YS (2016) Trend assessment by the innovative-sen method. Water Res Man 30:5193–5203. https://doi.org/10.1007/s11269-016-1478-4

Dabanli I, Sen Z (2018) Classical and Innovative-Şen trend assessment under climate change perspective. Int J G Warm 15:19–37. https://doi.org/10.1504/IJGW.2018.091951

Dabanli I, Sisman E, Guclu YS, Birpinar ME, Sen Z (2021) Climate change impacts on sea surface temperature (SST) trend around Turkey seashores. Acta Geophys 69:295–305. https://doi.org/10.1007/s11600-021-00544-2

Dadaser-Celik F, Cengiz E (2014) Wind speed trends over Turkey from 1975 to 2006. Int J Clim 34:1913–1927. https://doi.org/10.1002/joc.3810

Elouissi A, Sen Z, Habi M (2016) Algerian rainfall innovative trend analysis and its implications to Macta watershed. Arab J Geo 9:1–12. https://doi.org/10.1007/s12517-016-2325-x

Erismis M (2019) Trends in sea surface temperatures in Turkey. M.S. thesis. Cankiri: Cankiri Karatekin University, Institute of Social Sciences

European Severe Weather Database (ESWD) (2020) https://www.eswd.eu, (accessed 10 Jan 2020)

Fisk D (1997) Climate change and its impacts: A global perspective. Documentation. Crown Copyright

Gregory JM, Lowe JA (2000) Predictions of global and regional sea-level rise using AOGCMs with and without flux adjustment. Geophys Res Lett 27:3069–3072. https://doi.org/10.1029/1999GL011228

Guclu Y (2013) Sea surface temperature anomalies along the Black Sea Region coast of Turkey (1971–2010 period). J Hum Sci 10:863–896

Guclu YS (2018) Multiple Şen-Innovative trend analyses and partial mann-kendall test. J Hyd 566:685–704. https://doi.org/10.1016/j.jhydrol.2018.09.034

Guclu YS, Sisman E, Dabanli I (2020) Innovative triangular trend analysis. Arab J Geo 13:1–8. https://doi.org/10.1007/s12517-019-5048-y

Kahya E, Kalayci S (2004) Trend analysis of streamflow in Turkey. J Hydrol 289:128–144

Kendall MG (1975) Rank correlation methods. London: Charles Griffin, p 135

Kummu M (2016) Over the hills and further away from coast: global geospatial patterns of human and environment over the 20th-21st centuries. Environ Res Letters 11:1–15. https://doi.org/10.1088/1748-9326/11/3/034010

Levermann A, Griesel A, Hofmann M, Montoya M, Rahmstorf S (2005) Dynamic sea level changes following changes in the thermohaline circulation. Climate Dyn 24:347–354. https://doi.org/10.1007/s00382-004-0505-y

Li J, Wu W, Ye X, Jiang H, Gan R, Wu H, Jiang Y (2019) Innovative trend analysis of main agriculture natural hazards in China during 1989–2014. Nat Hazards 95:677–720. https://doi.org/10.1007/s11069-018-3514-6

Mann HB (1945) Non-parametric tests against trend. Econometrica 13:245–259

Mohorji AM, Sen Z, Almazroui M (2017) Trend analyses revision and global monthly temperature innovative multi-duration analysis. Earth Syst Environ 1:1–13. https://doi.org/10.1007/s41748-017-0014-x

National Centers for Environmental Prediction (NCEP) (2020) Wind speed, wind direction and sea surface temperature data acquisition. https://www.cpc.ncep.noaa.gov/ (accessed 30 Jun 2020)

Ozdemir ET, Yetemen O (2019) Meteorological Analysis of Lake Enhanced Snow in Istanbul, On February 17–19, 2015. J Anatolian Environ Anim Sci 2:105–121. https://doi.org/10.35229/jaes.574817

Poulos SE, Ghionis G, Maroukian H (2009) Sea-level rise trends in the Attico-Cycladic region (Aegean Sea) during the last 5000 years. Geomorphology 107:10–17. https://doi.org/10.1016/j.geomorph.2007.05.022

Poupkou A, Zanis P, Nastos P, Papanastasiou D, Melas D, Tourpali K, Zerefos C (2011) Present climate trend analysis of the etesian winds in the Aegean Sea. Theo App Clim 106:459–472. https://doi.org/10.1007/s00704-011-0443-7

Pörtner HO, Roberts DC, Masson-Delmotte V, Zhai P, Tignor M, Poloczanska E, Mintenbeck K, Alegría A, Nicolai M, Okem A, Petzold J, Rama B, Weyer NM (2019) Summary for policymakers. in: IPCC special report on the ocean and cryosphere in a changing climate. In press

Sen Z (2012) Innovative trend analysis methodology. J Hyd Eng 17:1042–1046. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000556

Sen Z (2013) Trend identification simulation and application. J Hyd Eng 19:635–642. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000811

Sen Z (2017) Innovative trend significance test and applications. Theo App Clim 127:939–947. https://doi.org/10.1007/s00704-015-1681-x

Sen Z, Sisman E, Dabanli I (2019) Innovative polygon trend analysis (IPTA) and applications. J Hyd 575:202–210. https://doi.org/10.1016/j.jhydrol.2019.05.028

Sisman E (2021) Power law characteristics of trend analysis in Turkey. Theor Appl Climatol 143:1529–1541. https://doi.org/10.1007/s00704-020-03408-9

Tsimplis MN, Josey SA, Rixen M, Stanev EV (2004) On the forcing of sea level in the black sea. J Geo Res 109:1–13. https://doi.org/10.1029/2003JC002185

Vigo I, Garcia D, Chao BF (2005) Change of sea level trend in the mediterranean and black seas. J Mar Res 63:1085–1100. https://doi.org/10.1357/002224005775247607

Wu H, Qian H (2017) Innovative trend analysis of annual and seasonal rainfall and extreme values in Shaanxi, China, since the 1950s. Int J Clim 37:2582–2592. https://doi.org/10.1002/joc.4866