

Article

Evaluating Climate Change Effects on Coastal Tourism over the Black Sea Region by Using the Summer Simmer Index

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Abstract: Climate change will have a tremendous effect on tourism activities. Tourism revenue plays a crucial role in the Turkish economy; therefore, it is vital to assess the impacts of climate change on tourism. This research aims to investigate the effects of climate change on seaside tourism on the Black Sea region in Türkiye. The summer simmer index (SSI) was utilized to determine the climatic comfort conditions in the summer months. Meteorological data, over 30 years, was used to observe the impact of climate change. Mann–Kendall trend analysis and Şen’s innovative trend analysis were applied to reveal the trends. As a result, SSI zones were computed as zones 1, 2, 3, and 4. Zone 4 was rarely observed. Thermal comfort conditions in the summer were found to not pose a health threat to tourists. Both trend methods determined an upward trend of SSI scores in Akçakoca, Samsun, Rize, and Hopa. These destinations are becoming more favorable in terms of seaside tourism due to climate change. The results of this study can be used for destination marketing. Tourism decision makers may benefit from these results for developing coastal tourism in this region.

Keywords: climate change; coastal tourism; summer simmer index; trend analysis; Black Sea region

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1. Introduction

Climate change is one of the biggest environmental problems that has the potential to seriously affect human life and ecosystems. Increasing air and sea surface temperatures, rising sea levels, changes in precipitation and wind patterns, heat waves, droughts, ocean acidification, and more frequent storms and flood events are adverse effects of a changing climate [1,2]. Almost all sectors are affected or will be affected by the detrimental impacts of climate change. Since tourism activities are highly dependent on weather and climate [3–5], it is obvious that tourism will suffer from climate change [6,7]. Türkiye is among the top destinations in the world. Tourism is one of the major contributors to the Turkish economy [8] and, therefore, it is quite important to investigate the impacts of climate change on the tourism sector. Turkish tourism highly depends on seaside tourism [9]. Sea-side tourism in Türkiye is well-developed on the southern and western coasts; on the other hand, tourism in the Black Sea region is less developed compared to the Aegean and the Mediterranean regions [7]. Climate change may create both threats and opportunities for tourism [10]. Rising sea levels, extreme weather events, and shoreline erosion due to climate change threaten coastal tourism [11]. On the other hand, coastal tourism may benefit from increasing air and sea surface temperatures [12,13]. Dumitrescu et al. (2021)

mentioned that in the short and medium term, seaside tourism in Romania may benefit from climate change and gain an economic advantage due to increasing temperatures [12]. Kostianaia and Kostianoy (2021) stated that climate change in the Black Sea will bring warming of seawater and climate in the short term, which may support the development of coastal tourism [13].

Many factors such as prices, distance, transportation, weather, and climatic conditions affect tourist decisions when selecting a destination [12]. Especially for coastal tourism activities, tourists prefer “good weather” (warm air and sea water temperature, sunny weather) [4,14]. The air temperature should range from 20 °C to 34 °C for a sun bath with an optimum range of 25–28 °C [15]. Similarly, sea water temperature should be between 18 and 28 °C, and the optimum range is 22–25 °C [15]. Moreover, sunny air without precipitation is required [15]. The negative impacts of climate change reduce the attractiveness of destinations and create dissatisfaction among tourists [6]. Changing thermal comfort conditions due to climate change create health risks for tourists. Thermal stress and heat strokes pose a health risk for tourists [2]. When tourists realize the risk, they tend to avoid traveling and stay home or consider alternative destinations [16]. As a result, a destination has to cope with fewer tourist arrivals, and accordingly, occupancy rates and tourism revenue will decline [2].

Bioclimatic (climatic or thermal) comfort is the measure of a person’s response to climatic factors (such as temperature, relative humidity, and wind speed) in a certain environment. It depends on clothing, body structure, personal conditions, age, gender, emotions, cultural influences, and past climate experiences [17]. In optimal bioclimatic conditions, a person demonstrates an adaptation to an environment by utilizing the least amount of energy and feels healthy and dynamic [18,19]. Bioclimatic comfort is an important parameter for regional planning and tourism development. To measure the impacts of climate on the tourism industry, bioclimatic comfort indices can be implemented [7,8]. Trend analysis methods are effective tools to estimate the impacts of climate change [1]. The Mann–Kendall (MK) test and Şen’s Innovative Trend Analysis (ITA) are widely used trend estimation methods for climate data. The MK test is one of the most common statistical tests to determine whether a trend exists in a time series or not [20,21]. In this study, we applied both the MK test and ITA for trend detection. Determination of bioclimatic comfort zones and revealing the impacts of climate change are vital for tourism development in the Black Sea region. This study is one of the rare studies analyzing the effects of climatic changes on tourism in the Black Sea coastal region of Türkiye. This paper aims to investigate the effects of climate change over the coastal zone of the Black Sea region. To evaluate the changes in tourism convenience, SSI has been calculated. The temperature and humidity values are obtained from reanalysis datasets. Trend analysis has been applied to reveal the impacts of climate change. The results of this study contribute to both climate change and tourism management fields.

2. Literature Review

The climate is a key component for the development of coastal tourism. Therefore, it is necessary to measure the convenience of the destination by employing climate indices. Also, the impacts of climate change can be measured with the help of climate indices. To evaluate the bioclimatic comfort condition of destinations, the Tourism Climate Index (TCI) was proposed by Mieczkowski in 1985 [22]. The TCI is the first method to quantitatively assess the bioclimatic comfort of destinations [23]. Due to the limitations of the TCI [24], many indices were developed for coastal tourism to overcome the shortcomings of previous indices [25]. Since coastal tourism requires high temperatures, a bioclimatic index should successfully measure heat-related stress. Zhu et al. (2019) classified the thermal comfort

indices into three main categories: high temperature, low temperature, and comprehensive indices [26]. Since we focused on coastal tourism in the summer season, a high-temperature index is required to measure thermal comfort. The Summer Simmer Index (SSI), Humidity Index (Humidex), Environmental Stress Index (ESI), Discomfort Index (DI), Wet-Bulb Globe Temperature (WBGT), and Heat Index (HI) are some of the indices used to measure heat stress [26,27]. Among these indices, the Summer Simmer Index (SSI) was developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers [28] and validated by Kansas State University [26].

The SSI has been implemented by many researchers in the literature [15,17,26,29–32]. Asghari et al. (2021) investigated thermal comfort conditions in Iran by using the SSI and reported that only a few stations were in the thermal comfort zone [29]. Ghalhari et al. (2022) compared the SSI with the WBGT index and Humidex and stated that SSI significantly correlated with both indices. They proposed the use of SSI due to its easier calculation instead of WBGT and Humidex [30]. In Türkiye, researchers implemented the SSI mainly to evaluate tourism regions. For example, Mansuroğlu et al. (2021) and Sancar and Güngör (2020) calculated SSI scores in Antalya [17,28]. Guclu (2016) evaluated the thermal comfort classes by means of SSI in the Goller (Lakes) region, located over the Antalya, Burdur, and Isparta provinces of Türkiye [31]. Some other papers examined the SSI over the Black Sea region in Türkiye. Cetin and Alrabiti (2022) implemented the SSI in Ordu province on the Black Sea coast of Türkiye to determine the climate comfort zones in the summer season [32]. Arıca (2020) computed SSI scores in Samsun province on the Black Sea coast of Türkiye [33]. Lastly, Güçlü (2010) applied SSI together with the TCI and Temperature Humidity Index (THI) for the region covering the Sinop, Samsun, and Ordu provinces [34]. The SSI is specifically designed to measure the health impacts of heat-related thermal stress [29,30]. It was used in many studies evaluating thermal comfort for summer tourism. For these reasons, the SSI is selected and used to measure the impacts of climate change in this study.

3. Materials and Methods

3.1. Study Area

The study area is composed of 11 provinces on the Black Sea coast of Türkiye. The Black Sea climate is observed in the coastal regions of the study area. Figure 1a depicts the location of the study area. Figure 1b represents 11 provinces (from west to east Düzce, Zonguldak, Bartın, Kastamonu, Sinop, Samsun, Ordu, Giresun, Trabzon, Rize, and Artvin). In some of these provinces (Düzce, Bartın, Kastamonu, and Artvin), the city center is located away from the seashore; therefore, the counties located near the Black Sea coast (Akçakoca, Amasra, Cide, İnebolu, and Hopa) are included in the SSI calculations. Apart from Düzce and Bartın, each province has an airport. Ordu and Giresun share Ordu–Giresun airport. Similarly, Rize and Artvin share the Rize–Artvin airport, which was established in 2022 [35,36]. Tourism-related statistics of the study area for the year 2022 are provided in Appendix A. Trabzon was the leading province in terms of tourist arrivals and average stay [37]. Sinop had the highest occupancy rates in 2022 [37]. Khan (2020) stated that Trabzon receives the highest number of tourists due to its developed infrastructure and transportation facilities [38]. Apak and Gürbüz (2023) mentioned that about one million domestic tourists journeyed to the eastern Black Sea region in 2021 [39]. There are only 21 blue flag beaches on the Black Sea coast, which constitute only 4% of the country's total. These beaches are located in the Düzce (1), Zonguldak (2), Bartın (3), Samsun (13), and Ordu (2) provinces [40]. Akçakoca and Amasra are important seaside destinations. Due to their closer locations to İstanbul and Ankara, they receive domestic tourists from these cities. Samsun is another destination with highly developed coastal tourism. Due to

geological formations and the existence of the Black Sea coastal road, there a fewer number of beaches in the eastern part of the study area [41,42].

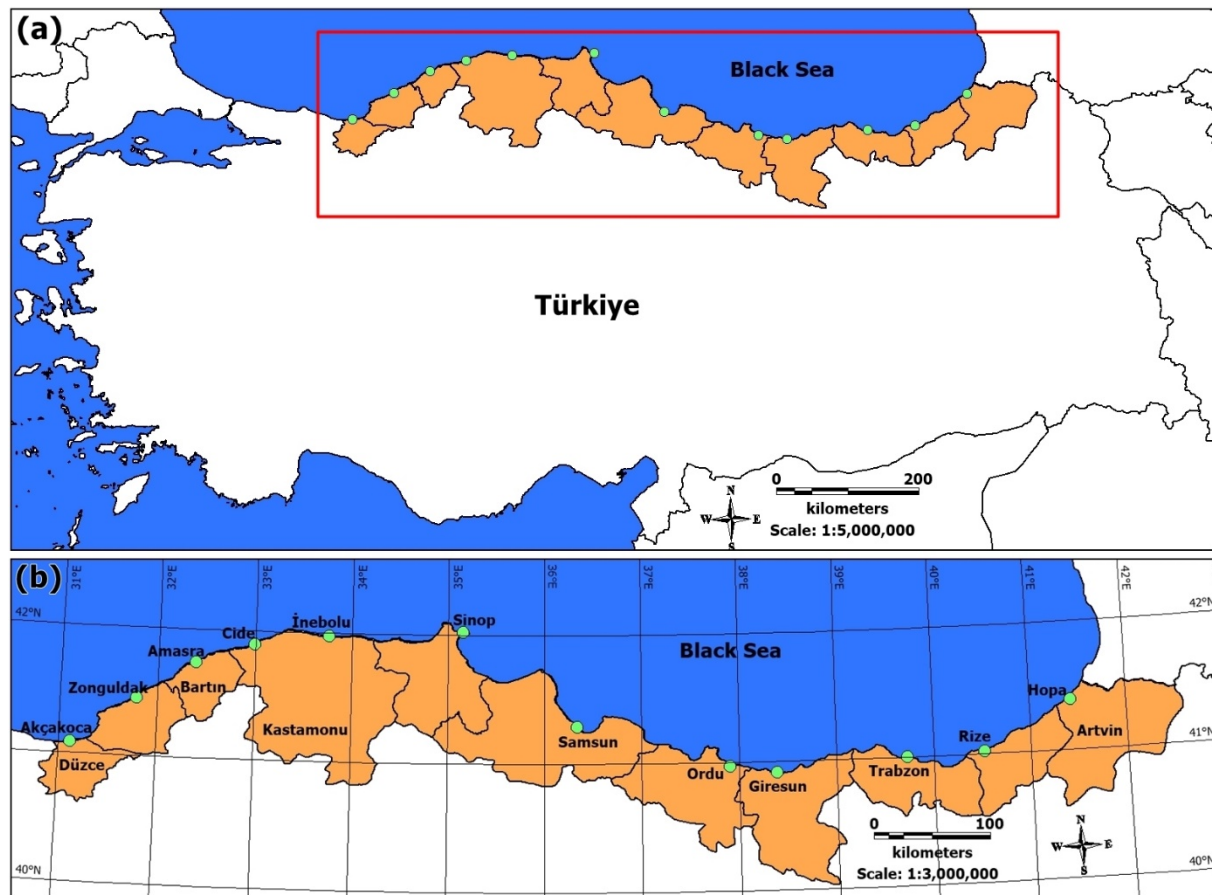


Figure 1. (a) Location of the study area; (b) Provinces in the study area. Green dots indicate province or county centers.

3.2. Data Acquisition

The traditional method of calculating the bioclimatic comfort index requires obtaining meteorological data recorded at the meteorological stations. Observational meteorological data may contain temporal and spatial gaps due to the lack of observations [43]. Reanalysis datasets can fill gaps by implementing model simulations using data assimilation techniques [44] and generating seamless and consistent maps [45]. Therefore, it provides temporally and spatially continuous and readily available data [46]. It is stated that daily and monthly reanalysis of mean temperatures demonstrated good agreement with station data [47]. National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data are employed to investigate the temperature changes due to climate change in the eastern part of the Black Sea for the period of 1950–2015 [48]. The precipitation and its relationship with other meteorological parameters are investigated by applying NCEP/NCAR reanalysis data in İzmir, Türkiye [49]. In another study, the effects of climate change over the western Black Sea region of Türkiye are analyzed by implementing the wind speed, wind direction, and sea surface temperature variables from the NCEP/NCAR reanalysis dataset from 1979 to 2018 [1]. Within the light of cited literature, the NCEP/NCAR reanalysis dataset was selected and implemented in this study.

To calculate the SSI, temperature and relative humidity values are required. The reanalysis data are obtained from the NCEP/NCAR. Climate Forecast System Reanalysis

(CFSR) data are used to acquire air temperature and relative humidity values. The temporal coverage of data is from 1993 to 2022 (30 years). Since NCEP/NCAR provides two separate reanalysis datasets for different periods, the following datasets are implemented:

- i. NCEP Climate Forecast System Reanalysis (CFSR) Selected Hourly Time-Series Products, January 1979 to December 2010 (ds093.1) (<https://rda.ucar.edu/datasets/d093001/> (accessed on 22 February 2023));
- ii. NCEP Climate Forecast System Version 2 (CFSv2) Selected Hourly Time-Series Products (ds094.1) (<https://rda.ucar.edu/datasets/d094001/> (accessed on 22 February 2023)). Version 2 provides data from January 2011.

Both datasets provide hourly temperature (at the ground or water surface) and relative humidity (at a height of 2 m above ground). The dataset ds093.1 has $0.5^\circ \times 0.5^\circ$ and $0.312^\circ \times 0.312^\circ$ spatial resolutions for relative humidity and temperature, respectively. The spatial resolutions of ds094.1 for relative humidity and temperature are $0.5^\circ \times 0.5^\circ$, $0.205^\circ \times 0.204^\circ$, respectively. The data are freely available to the public. The data are subsetted by choosing the nearest grid point to locations of concern (province and county centers).

3.3. Methodology

3.3.1. Summer Simmer Index (SSI)

Monthly averages of temperature and relative humidity are calculated via an aggregate function in R programming. Since only monthly means are required, no data cleaning or missing value imputation was implemented. SSI scores are computed for 12 locations for the summer season. The SSI was first introduced by Pepi (1987) [50]. The new version of the SSI, also called the New Millennium Index, was developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the results are proven by psychological experiments carried out at Kansas State University. This index was presented at the conference of the American Meteorological Association in 2000. The SSI measures thermal discomfort by considering the combined effect of relative humidity and temperature in the warm season [26,51]. Equation (1) is used to calculate the SSI. SSI values are computed for each month of the summer season (June, July, and August) since we investigate the impact of climate change on summer tourism.

$$SSI = 1.98 \times [T - (0.55 - 0.0055 \times RH) \times (T - 58)] - 56.83 \quad (1)$$

where

SSI: summer simmer index ($^\circ\text{F}$)

T: air temperature ($^\circ\text{F}$)

RH: relative humidity (%)

SSI classification and thermal zone classes are depicted in Table 1. SSI ranges from 70 to 150. There are 8 comfort zones, and heat stress increases as the zone number rises. The most comfortable zone is 2. In zone 1, some individuals feel a little cool. In zone 3, some individuals feel a little warm. Starting from zone 4, increasing temperature creates discomfort and adverse health effects become more frequent as the SSI zone increases [29,30].

Table 1. SSI classifications [29,30].

SSI (°F)	Zone	Thermal Comfort Class for Human
$70 \leq \text{SSI} < 77$	1	Most people are comfortable, but slightly cool
$77 \leq \text{SSI} < 83$	2	Nearly everyone feels quite comfortable
$83 \leq \text{SSI} < 91$	3	Most are comfortable, but slightly warm
$91 \leq \text{SSI} < 100$	4	Increasing discomfort is experienced (warm)
$100 \leq \text{SSI} < 112$	5	A caution of sunstroke and heat exhaustion exists for prolonged exposure and activity, along with significant discomfort (extremely warm)
$112 \leq \text{SSI} < 125$	6	Virtually everyone is uncomfortable, a danger of heatstroke and great discomfort exists (hot)
$125 \leq \text{SSI} < 150$	7	There is an extreme danger of heatstroke, especially for the weakened or elderly, and even young children, whose body metabolism demands cooler effective temperatures than most adults. Maximum discomfort exists in these conditions (extremely hot)
$\text{SSI} \geq 150$	8	Circulatory collapse is imminent for prolonged exposure

3.3.2. Mann–Kendall Test

The Mann–Kendall (MK) is a widely used statistical test for monotonic trend determination in hydrologic, meteorologic, or climatic time series. A study conducted in Serbia applied the MK test to analyze the changes in meteorological variables [52]. Another study implemented the MK test to reveal trends in precipitation and temperature [53]. Five bioclimatic indices were computed in ten big cities in Romania, and the MK test was implemented for trend detection [54]. In another study conducted in Iran, a trend analysis of Humidex values was performed by using the MK test [20]. The MK test is a non-parametric test, and the assumption of normality is not required [52,55]. Since the MK test measures the ranks of the observations rather than their actual values, it is less affected by the presence of outliers and data gaps [53,56]. The “x” variable is time, and the “y” variable is evaluated for trends. The null hypothesis (H_0) assumes the data have no trends, and the alternative hypothesis (H_1) assumes data have either upward or downward monotonic trends [57]. The MK test analyses the signs of the difference between later data and all earlier observed data. Each later data are compared to all previous data, which results in $n(n-1)/2$ possible data pairs (n is the number of observations) [56]. The test statistic, S , is computed by using Equation (2), where $\text{Sgn}(y_i - y_k)$ is equal to +1, 0, or −1 (Equation (3)). Then, Kendall’s Tau (τ) correlation coefficient is used to test the trend (Equation (4)) [57]. Tau ranges between −1 and +1 and is analogous to Pearson’s correlation coefficient in regression analysis. The null hypothesis is rejected if S and τ are significantly different from 0 (when the p -value is small). A positive S indicates an upward trend, whilst a negative S represents a downward trend [56,57]. The Kendall library is used in R programming to perform the MK test. S and τ values are determined via the *SeasonalMannKendall()* function in the Kendall library to eliminate any seasonality-related problems. τ values are tested for a 95% confidence interval ($p < 0.05$).

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{Sgn}(y_j - y_k) \quad (2)$$

$$\text{Sgn}(x_j - x_k) = \begin{cases} +1 & \text{if } (y_j - y_k) > 0 \\ 0 & \text{if } (y_j - y_k) = 0 \\ -1 & \text{if } (y_j - y_k) < 0 \end{cases} \quad (3)$$

$$\tau = \frac{S}{n(n-1)/2} \quad (4)$$

3.3.3. Şen's Innovative Trend Analysis (ITA)

The Innovative Trend Analysis (ITA) method has been proposed by Şen (2012) [58]. Since then, ITA has been widely used to detect a trend in hydroclimatic and hydrometeorological time series. For example, the sea surface temperature (SST) trend was evaluated around the Türkiye coasts [59]. Both the MK test and ITA were applied using monthly SST. In another study, the MK test and ITA were applied to investigate the spatiotemporal variations in TCI over Türkiye [60]. Similarly, the MK test and ITA were used to reveal the effects of climate change on the western Black Sea coast of Türkiye [1]. A study conducted in China implemented the MK test and ITA to detect the presence of trend in the flow of Yangtze River [61]. The ITA robust technique is a non-parametric approach and is not affected by length of time series or seasonality [61]. The classical trend analysis requires serial independence, homoscedasticity, and normal probability distribution assumptions [62,63]. ITA reveals the trend without any distribution assumptions [61,64,65]. The trend represented by ITA is linguistically qualitative and graphically objective [59]. To perform ITA, the time series dataset is equally divided into two segments: 1. half and 2. half. Then, both groups are ordered either ascending or descending. Next, a scatter plot graph, using 1. half on the x -axis and 2. half on the y -axis, is drawn on the Cartesian coordinate system. $Y = x$ straight line is shown on the graph. If data points fall on the $y = x$ line or are quite close to it, the dataset is trendless. If all data points exist above (below) the $y = x$ line, a monotonic increasing (decreasing) trend exists in the dataset [58]. If low-value data pairs are below (above) the 1:1 line and then other pairs are above (below) this line, there is a non-monotonic increasing (decreasing) trend [59]. In this research, we draw horizontal and vertical lines to represent SSI zones on Cartesian coordinates. We utilized Veusz scientific plotting software version 3.6.2 (<https://veusz.github.io>) to draw trend analysis graphs of the SSI at each destination.

4. Results

4.1. Evaluation of SSI Scores

Interannual averages of meteorological parameters and SSI scores are depicted in Table 2 for two different periods. For the initial period, the highest level of relative humidity (83.3%) is recorded in Hopa in July. Conversely, the lowest level of relative humidity (64.1%) is noted in Akçakoca during the same month. In August, Amasra experiences the highest mean temperature of 22.7 °C (72.8 °F), whereas in June, the lowest mean temperature of 15.7 °C (60.2 °F) is recorded in Rize and Hopa. For the first period, the highest SSI score (86.2 °F) is computed in Giresun, whilst the lowest SSI score (61.8 °F) is calculated in Rize. For June, SSI scores are less than 70 in İnebolu, Sinop, Samsun, Ordu, Giresun, Trabzon, Rize, and Hopa, which corresponds to cold summers, and these locations are not convenient places for seaside tourism. The rest of the SSI scores range in zones of 1, 2, or 3. Apart from colder locations in June, the majority of people in the study area feel comfortable. SSI values fall in the third zone in Amasra, Sinop, Ordu, and Giresun in August, which means some people feel warm. When the second period is examined, the highest relative humidity (83.6%) is recorded in Trabzon in June, while the lowest (69.7%) is seen in Akçakoca in June and July. The highest mean temperature (23.3 °C–73.9 °F) is

recorded in Amasra in August, whilst the lowest mean temperature (16.9 °C–62.4 °F) is seen in İnebolu in June. The maximum average SSI score (85.1 °F) is calculated in Giresun in August. Conversely, the minimum average SSI score (65.6 °F) is computed in İnebolu in June. Similarly to the former period, some locations (Cide, İnebolu, Sinop, Trabzon, Rize, and Hopa) have SSI scores less than 70 in June for the latter period. Cide was not on this list for the years 1993–2007, while this destination experienced colder summers from 2008 to 2022. On the other hand, Samsun was experiencing colder summers for the first period, whilst Samsun’s SSI score was computed as 71.6 (zone 1) for the second period. For the majority of locations (apart from Rize and Hopa), July and August months have SSI scores of either 2 or 3. Therefore, it can be concluded that these two months are the most convenient times for seaside tourism.

Table 2. Interannual averages of meteorological parameters and SSI scores.

Location	Month	1993–2007				2008–2022			
		Relative Humidity (%)	Temperature (°C and °F)	SSI (°F)	Zone	Relative Humidity (%)	Temperature (°C and °F)	SSI (°F)	Zone
Akçakoca	June	64.4	18.7–65.7	70.3	1	69.7	19.8–67.6	73.9	1
	July	64.1	21.5–70.7	78.1	2	69.7	22.0–71.6	80.5	2
	August	67.4	21.3–70.3	78.1	2	70.2	22.1–71.8	80.7	2
Zonguldak	June	66.9	19.5–67.1	72.6	1	71.8	20.0–68.0	74.8	1
	July	66.0	22.2–72.0	80.6	2	71.0	22.3–72.1	81.5	2
	August	68.7	22.0–71.6	80.3	2	70.8	22.2–72.0	81.3	2
Amasra	June	72.0	19.0–66.2	71.8	1	77.5	18.7–65.7	71.2	1
	July	71.1	22.2–72.0	81.2	2	75.7	22.3–72.1	82.2	2
	August	72.0	22.7–72.9	83.0	3	74.4	23.3–73.9	84.9	3
Cide	June	70.0	18.8–65.8	71.0	1	76.1	17.9–64.2	68.4	-
	July	68.5	22.0–71.6	80.4	2	74.7	21.5–70.7	79.5	2
	August	70.3	22.5–72.5	81.9	2	73.5	22.4–72.3	82.2	2
İnebolu	June	66.4	18.0–64.4	68.4	-	76.2	16.9–62.4	65.6	-
	July	64.6	21.1–70.0	77.2	2	74.8	20.5–68.9	76.5	1
	August	68.4	20.8–69.4	76.6	1	74.1	21.2–70.2	78.5	2
Sinop	June	73.3	18.3–64.9	69.8	-	78.1	17.7–63.9	68.0	-
	July	71.7	21.8–71.2	80.1	2	75.8	21.7–71.1	80.2	2
	August	72.4	23.0–73.4	83.9	3	74.8	22.9–73.2	83.8	3
Samsun	June	72.3	17.8–64.0	68.1	-	76.9	18.8–65.8	71.6	1
	July	69.5	21.1–70.0	77.7	2	73.2	21.8–71.2	80.3	2
	August	71.3	21.6–70.9	79.5	2	73.9	22.3–72.1	81.8	2
Ordu	June	77.2	18.5–65.3	70.6	1	80.1	18.5–65.3	71.0	1
	July	76.2	21.8–71.2	80.7	2	76.7	21.7–71.1	80.6	2
	August	75.4	23.0–73.4	84.5	3	77.8	21.9–71.4	81.3	2
Giresun	June	76.6	19.1–66.4	72.6	1	79.4	18.6–65.5	70.9	1
	July	76.1	22.3–72.1	82.4	2	77.2	22.2–72.0	82.1	2
	August	75.5	23.6–74.5	86.2	3	77.4	23.1–73.6	85.1	3
Trabzon	June	77.6	17.9–64.2	68.7	-	83.6	17.7–63.9	68.5	-
	July	77.8	21.0–69.8	78.6	2	81.2	20.4–68.7	77.0	2
	August	78.3	22.1–71.8	82.1	2	83.0	20.7–69.3	78.2	2
Rize	June	77.5	15.7–60.3	61.8	-	78.1	17.7–63.9	68.1	-
	July	79.0	18.4–65.1	70.6	1	80.3	19.5–67.1	74.0	1
	August	79.6	19.0–66.2	72.3	1	82.4	19.9–67.8	75.4	1
Hopla	June	81.3	15.7–60.3	61.9	-	81.4	17.7–63.9	68.3	-
	July	83.3	18.4–65.1	70.9	1	82.3	19.5–67.1	74.2	1
	August	83.1	19.0–66.2	72.6	1	83.0	19.9–67.8	75.5	1

Percentages of SSI scores are represented as a heatmap in Table 3. It should be noted that both periods have 45 different monthly mean SSI values. SSI scores less than 70 are represented as Cold. Table 3 provides a better comparison of the two periods and reveals how SSI scores change within two intervals. In Akçakoca, more than half of the SSI values were fall in zone 1 from 1993 to 2007. However, more SSI values moved to zone 2 in the period of 2008–2022. A small increase in zone 3 is observed in Zonguldak between two intervals. In Amasra, the highest percentage of SSI was in zone 2 for the former period, while in the second period, the percentage of zone 2 decreased and some of the SSI scores moved to zone 4. In Cide, SSI values in zone 2 decreased and these scores seemed to be distributed between zones 1 and 3 over the years. In İnebolu, the majority of SSI scores were in zone 1 previously, but they shifted to zones 2 and 3 in the second interval. The highest percentage of SSI values was in zone 2 between 1993 and 2007 in Sinop, whilst the highest percentage fell in zone 3 in the second period. A decrease in cold summers and an increase in zone 2 SSI scores are observed in Samsun when transitioning from 1st to 2nd period. In Ordu, zones 2 and 3 SSI values were dominant in the former interval, while SSI scores mainly fell in the zones 1 and 2 category between 2008 and 2022. In Giresun, most SSI scores were either in zones 1, 2, or 3 in the first period. On the other hand, some of the SSI scores shifted to colder and zone 4 for the second period. In Trabzon, SSI values become more frequent in zone 1 and less frequent in zone 3 when moving from the first to the second period. The most striking results emerged in Rize and Hopa. In both locations, the majority of SSI scores were in cold and first zones between 1993 and 2007, whereas half of the SSI scores were in zone 1, and there was an increase in zone 2 scores for the second period.

Table 3. Percentages of SSI scores for periods of 1993–2007 and 2008–2022.

Location	SSI Zones (1993–2007)					SSI Zones (2008–2022)				
	Cold	1	2	3	4	Cold	1	2	3	4
Akçakoca	11.1	51.1	33.3	4.4	0.0	4.4	33.3	46.7	15.6	0.0
Zonguldak	6.7	31.1	46.7	15.6	0.0	2.2	28.9	46.7	22.2	0.0
Amasra	8.9	24.4	42.2	24.4	0.0	13.3	20.0	31.1	26.7	8.9
Cide	15.6	20.0	48.9	15.6	0.0	15.6	35.6	22.2	26.7	0.0
İnebolu	24.4	48.9	24.4	2.2	0.0	24.4	33.3	33.3	8.9	0.0
Sinop	20.0	15.6	37.8	26.7	0.0	17.8	31.1	15.6	35.6	0.0
Samsun	24.4	26.7	37.8	11.1	0.0	11.1	28.9	44.4	15.6	0.0
Ordu	20.0	15.6	35.6	28.9	0.0	13.3	33.3	31.1	22.2	0.0
Giresun	4.4	28.9	26.7	40.0	0.0	11.1	26.7	22.2	35.6	4.4
Trabzon	24.4	20.0	37.8	17.8	0.0	20.0	40.0	35.6	4.4	0.0
Rize	57.8	40.0	2.2	0.0	0.0	26.7	51.1	22.2	0.0	0.0
Hopa	55.6	37.8	6.7	0.0	0.0	26.7	51.1	22.2	0.0	0.0

4.2. Trend Analysis Results

Table 4 depicts the MK test results of SSI values for the study region. S , τ , and 2-sided p -values are presented in this table. In Akçakoca, Samsun, Rize, and Hopa p -values are quite lower than 0.05. For these locations, S and τ values are positive. Therefore, an upward trend is identified in these destinations. By considering the MK test results (Table 4) and SSI percentages (Table 3), it can be concluded that thermal comfort conditions in the summer season become more favorable for seaside tourism activities in the aforementioned locations. For the rest of the locations, no trend is identified by MK analysis.

Table 4. Mann–Kendall test results of SSI values.

Location	S	τ	2-Sided <i>p</i> -Value	Trend
Akçakoca	955	0.238	<0.001	Upward trend
Zonguldak	491	0.123	0.088	No trend
Amasra	207	0.052	0.473	No trend
Cide	−103	−0.026	0.722	No trend
İnebolu	85	0.021	0.770	No trend
Sinop	53	0.013	0.856	No trend
Samsun	815	0.203	0.005	Upward trend
Ordu	−91	−0.023	0.754	No trend
Giresun	−89	−0.022	0.759	No trend
Trabzon	−287	−0.072	0.319	No trend
Rize	1219	0.304	<0.001	Upward trend
Hopa	1183	0.295	<0.001	Upward trend

The ITA graphs for the SSI at each destination are given in Figure 2. Red dots indicate data pairs, and the blue line represents the 1:1 line. Black dotted horizontal and vertical lines separate SSI zones. The $70 \leq \text{SSI} < 77$, $77 \leq \text{SSI} < 83$, and $83 \leq \text{SSI} < 91$ regions present SSI zones 1, 2, and 3, respectively. In the graphs, Monotonic increasing trends of the SSI are revealed in Akçakoca (Figure 2a) and Zonguldak (Figure 2b) except in two data pairs, and Samsun (Figure 2g), Rize (Figure 2k), and Hopa (Figure 2l) except one data pair. The exceptional data pairs in Zonguldak and Hopa are quite close to the $y = x$ line; therefore, we assume that they do not affect the monotonic trend. Except for Zonguldak, all four locations have shown an upward trend in MK analysis too. In Figure 2b, the SSI data pairs of Zonguldak are closer to the 1:1 line compared to the other four locations. This may be the reason for no trend in MK analysis in Zonguldak. In Rize and Hopa, there are many more data pairs in the $\text{SSI} < 70$ zones compared to other destinations. However, all these data pairs are above the 1:1 line. By considering the rising SSI trend in this region it can be concluded that for Rize and Hopa, the number of cold summers is decreasing. For the rest of the locations (Figure 2c–f,h–j), no monotonic trend exists, and similar plots are constructed.

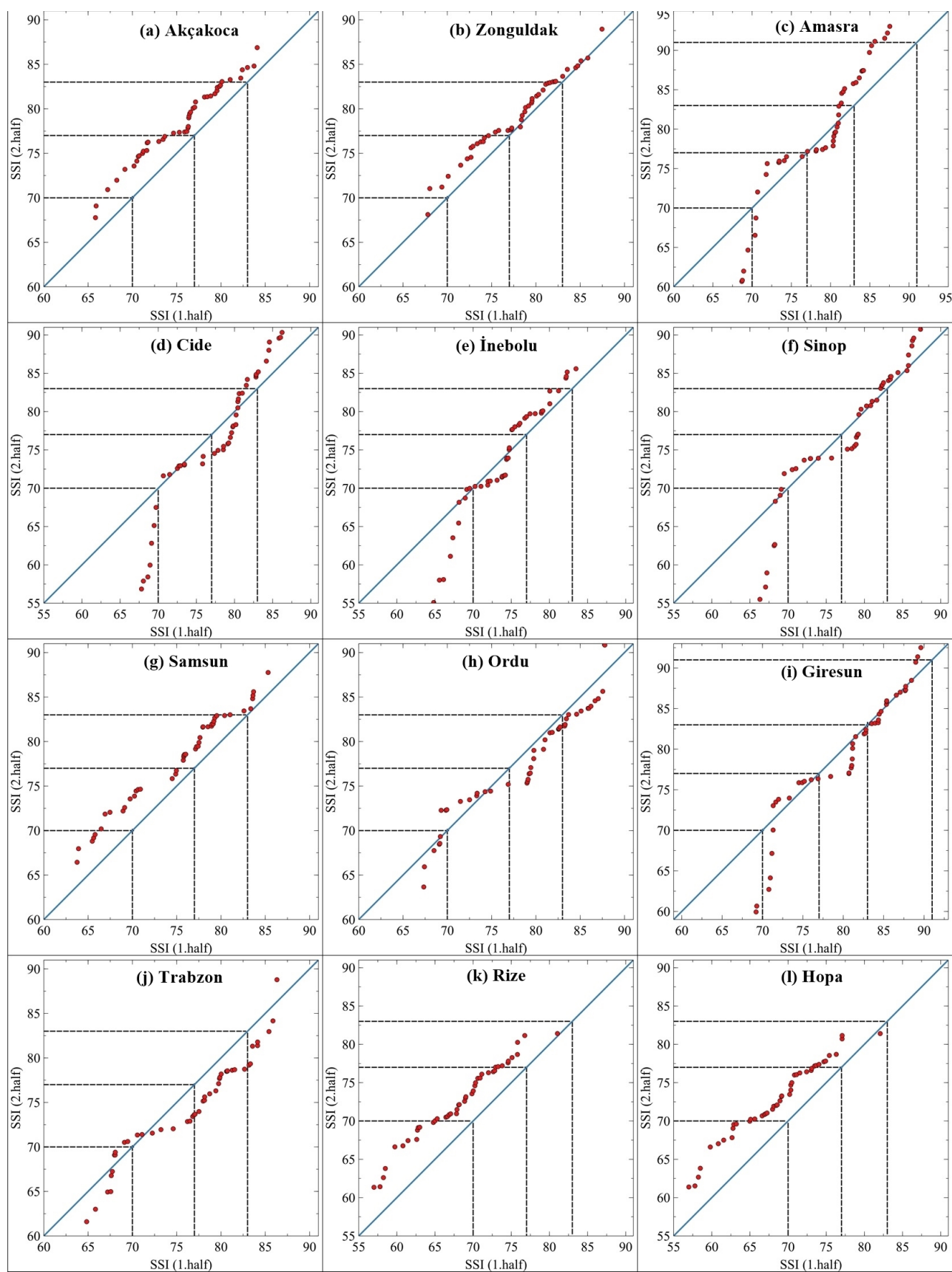


Figure 2. Şen's innovative trend analysis graphs of SSI (1993–2022 summer season) for 12 destinations in the study area.

5. Discussion

The results of SSI scores are similar to the studies conducted on the Black Sea coastline. For example, Ibret et al. (2013) used the meteorological data between 1984 and 2010 and calculated the SSI zones for Cide as 1, 2, and 3 [7]. Similarly, in our study, SSI values are found in zones 1, 2, and 3 for Cide. Another study was conducted in the Sinop, Samsun, and Ordu provinces and SSI classes were identified as 1, 2, and 3 on the coastlines for the summer season [34]. Our results are parallel to these findings. The same SSI classes are calculated in this present study. In another work, the thermal comfort conditions in Samsun were investigated by using meteorological data from 1929 to 2020 [33]. In June and July, three SSI classes (1, 2, and 3), and in August, four (1, 2, 3, and 4) SSI classes were reported in that study. In our study, we revealed only three classes for SSI values in Samsun. The different durations of meteorological data could have caused such a difference. Similar studies are also performed on the Mediterranean coast of Türkiye. Sancar and Güngör (2020) determined the thermal comfort in Antalya province, which is located on the Mediterranean coast of Türkiye [28]. For the summer, they found SSI zones 3, 4, and 5 along the coastline. Similarly, Mansuroğlu et al. (2021) reported that SSI classes range between 1 and 4 in June and 3 and 5 in July and August in Antalya [17]. Zone 4 is classified as warm, and zone 5 is classified as extremely warm. The risk of sunstroke exists in zone 5. In another study, Cinar et al. (2023) reported that climate conditions in Muğla province expose heat stress in the summer months [66]. In our work, most of the SSI scores are categorized as 1, 2, and 3 in the Black Sea region. Colder summers are becoming less frequent, and zone 4 in SSI scores is quite rare. Therefore, it can be concluded that the Black Sea coast of Türkiye has better thermal comfort conditions. Climate comfort in the study region does not pose a health risk for tourists in the summer months. Tourists who worry about heat strokes or sunburns may safely choose the Black Sea coasts of Türkiye in the summer season.

Few studies examined the bioclimatic comfort index trends in Türkiye. Efe and Gözet (2021) computed TCI trends for Samsun and stated that there was an upward trend in May and September (data period: 1990–2019) [67]. TCI trends in the summer season were statistically insignificant. On the other hand, Efe et al. (2022) determined the trend of TCI using 40-year data (1981–2020) in Türkiye and reported the downward TCI trends in the Black Sea coasts in the summer season [60]. Both studies were based on locally measured meteorological data. In this study, we calculated upward SSI trends in Akçakoca, Samsun, Rize, and Hopa for 1993–2022 using NCEP/NCAR reanalysis datasets. Differences in data sources, temporal coverages, and bioclimatic comfort indexes may cause such different results. It should be noted that the SSI is based on only temperature and humidity data, whilst TCI requires temperature, humidity, precipitation, sunshine duration, and wind speed as inputs.

Tourism revenue plays a key role in the Turkish economy. Therefore, estimating the impacts of climate change on tourism is quite important. For seaside tourism destinations, SSI scores can be continuously computed in the summer season, and early warning systems can be established to warn tourists in case of unhealthy thermal comfort conditions. The findings of this research are extremely valuable for the tourism industry in the Black Sea region. The Ministry of Culture and Tourism, tourism policymakers, tour operators, and managers of accommodation facilities may use this information for tourism marketing. Thermal climate conditions are more favorable compared to the Mediterranean Region. The Black Sea region may benefit from this result for sustainable tourism development. Tourism facilities and tour operators can make advertisements for warm and favorable destinations to attract tourists. The ministry may support new tourism establishments. Increasing the number of accommodation facilities and extending their capacities is crucial. Tourism infrastructure should also be supported. Beaches should be cleaned and services

such as lifeguards, showers, and cabins should be provided. Beach water quality should be improved. The number of blue flag beaches must be increased. These contribute to the Sustainable Development Goals (SDG) item 6 (clean water and sanitation) and item 14 (life below water). Moreover, these destinations should be more accessible. To accomplish this, new flight routes can be added for the airports in the Black Sea region to attract more tourists. While increasing the capacity of tourism, the carrying capacity should also be considered. Managing the number of tourists at a destination improves the life quality of locals (SDG item 11—sustainable cities and communities), promotes efficient use of natural resources (SDG item 12—responsible consumption and production), reduces the amount of carbon footprint (SDG item 13—climate action), and protects the ecosystems (SDG item 15—life on land). Social development should be provided, and local people and businesses should be included in tourism so that jobs and services created by tourism will contribute to SDG item 1 (no poverty) and item 8 (decent work and economic growth). All of these will pave the way for sustainable tourism development in the Black Sea region.

6. Conclusions

The impacts of climate change on seaside tourism have been investigated via computed SSI scores on the Black Sea coastal region of Türkiye. SSI zones are generally classified as zones 1, 2, and 3. Zone 4 is determined in the second period only at two locations. In Rize and Hopa, SSI zones are shifting from the colder side to zones 1 and 2. Furthermore, as a result of trend analysis, statistically significant upward trends in the SSI are determined in Akçakoca, Samsun, Rize, and Hopa. In addition to these four locations, ITA determined a monotonic rising SSI trend in Zonguldak. These five destinations are becoming more favorable in terms of seaside tourism due to climate change. Due to its convenient climate compared to the Mediterranean, the Black Sea coast of Türkiye can be a potential tourist destination for European tourists who avoid sunburn in the summer months.

This study has some limitations. Firstly, only 30 years of meteorological data are used. Therefore, the results are valid from 1993 through 2022. The findings are valid for only the Black Sea region shoreline of Türkiye. The results cannot be generalized for other destinations. In this study, we calculated SSI scores only for the summer months. Thermal comfort conditions of shoulder seasons can be evaluated in future studies. In future research, to foresee the future impacts of climate change on the region of investigation, climate change projections should be implemented, and thermal comfort index scores should be computed using forecasted meteorological variables. Moreover, similar research can be conducted for other tourism destinations (inside or outside Türkiye) using the same methodology. Using alternative meteorological datasets such as local measurements or Copernicus Climate Data will validate the results.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su17041490/su17041490/s1>, File S1: Data.

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Abbreviations

The following abbreviations are used in this manuscript:

SSI	Summer Simmer Index
NCEP/NCAR	National Centers for Environmental Prediction/National Center for Atmospheric Research
MK	Mann–Kendall
ITA	Şen’s innovative trend analysis
TCI	Tourism Climate Index
Humidex	Humidity Index
ESI	Environmental Stress Index
DI	Discomfort Index
WGBT	Wet-Bulb Globe Temperature
HI	Heat Index
THI	Temperature Humidity Index
CFSR	Climate Forecast System Reanalysis
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
SDG	Sustainable Development Goals

Appendix A

Table A1. Tourism-related statistics of the study area for the year 2022 [37].

Province	Accommodation Facilities	Room Capacity	Bed Capacity	Tourist Arrivals	Tourist Overnight Stays (Days)	Average Stay (Days)	Occupancy Rate (%)
Düzce	96	2282	4611	101,440	202,985	2.00	31.08
Zonguldak	52	1876	3808	177,291	284,377	1.60	36.13
Bartın	196	2217	4426	167,270	293,679	1.76	34.15
Kastamonu	100	2288	4567	163,885	238,537	1.46	26.84
Sinop	114	1529	3421	102,730	210,003	2.04	25.42
Samsun	150	3973	7998	425,968	653,387	1.53	34.82
Ordu	107	3137	6399	384,845	557,313	1.45	41.81
Giresun	75	1874	3763	139,791	230,874	1.65	31.96
Trabzon	246	9340	19,041	742,783	1,614,914	2.17	38.49
Rize	120	3102	6335	144,747	262,263	1.81	37.67
Artvin	136	2787	5585	102,092	163,102	1.60	34.31
Total study area	1392	34,405	69,954	2,652,842	4,711,434	1.78	33.88 *
Total Türkiye	20,690	921,560	1,907,917	70,242,410	185,902,110	2.65	54.15

*: average.

Appendix B

Table A2. Grid coordinates for relative humidity and temperature data for both datasets.

Location	Relative Humidity (ds093.1 and ds094.1)	Temperature (ds093.1)	Temperature (ds094.1)
Akçakoca	41.0000N–31.0000E	41.0581N–31.2500E	40.9881N–31.0909E
Zonguldak	41.5000N–32.0000E	41.3703N–31.8750E	41.3969N–31.9091E
Amasra	42.0000N–32.5000E	41.6825N–32.5000E	41.8058N–32.3182E
Cide	42.0000N–33.0000E	41.9948N–33.1250E	42.0102N–32.9318E
İnebolu	42.0000N–34.0000E	41.9948N–33.7500E	42.0102N–33.7500E
Sinop	42.0000N–35.0000E	41.9948N–35.0000E	42.0102N–34.9773E
Samsun	41.5000N–36.0000E	41.3703N–36.2500E	41.3969N–36.2045E
Ordu	41.0000N–38.0000E	41.0581N–37.8125E	40.9881N–37.8409E
Giresun	41.0000N–38.5000E	41.0581N–38.4375E	40.9881N–38.4545E
Trabzon	41.0000N–39.5000E	41.0581N–39.6875E	40.9881N–39.6818E
Rize	41.0000N–40.5000E	41.0581N–40.6250E	40.9881N–40.5000E
Hopa	41.5000N–41.5000E	41.3703N–41.2500E	41.3969N–41.3182E

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