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RESEARCH

The effect of air quality parameters on new COVID-19 cases between two different climatic and geographical regions in Turkey

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Abstract

Different health management strategies may need to be implemented in different regions to cope with diseases. The current work aims to evaluate the relationship between air quality parameters and the number of new COVID-19 cases in two different geographical locations, namely Western Anatolia and Western Black Sea in Turkey. Principal component analysis (PCA) and regression model were utilized to describe the effect of environmental parameters (air quality and meteorological parameters) on the number of new COVID-19 cases. A big difference in the mean values for all air quality parameters has appeared between the two areas. Two regression models were developed and showed a significant relationship between the number of new cases and the selected environmental parameters. The results showed that wind speed, SO_2, CO, NO_X, and O_3 are not influential variable and does not affect the number of new cases of COVID-19 in the Western Black Sea area, while only wind speed, SO_2, CO, NO_X, and O_3 are influential parameters on the number of new cases in Western Anatolia. Although the environmental parameters behave differently in each region, these results revealed that the relationship between the air quality parameters and the number of new cases is significant.

1 Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), an extremely transmissible and pathogenic coronavirus, caused the novel coronavirus disease (COVID-19), a highly pathogenic, infectious, and invasive pneumococcal disease. Two highly transmissible and pathogenic viruses known as severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV) emerged in humans at the beginning of the twenty-first century. COVID-19, a pandemic of acute respiratory disease, threatens human health and public safety (Cui et al., 2019; Hu et al., 2021).

The novel coronavirus disease (COVID-19) outbreak spread rapidly to Europe, the Middle East, the USA, and other places of the world in a short time, just after it started as an epidemic in Wuhan, China, in late December 2019. As a result of this event, World Health Organization announced on March 11, 2020, that: "We expect to see the number of cases, the number of deaths, and the number of affected countries climb even higher. We are deeply concerned both by the alarming levels of spread and severity and by the alarming levels of inaction. We have therefore made the assessment that COVID-19 can be characterized as a pandemic."

The first COVID-19 case was reported on 11 March 2020, and the first death from COVID-19 was announced on 17 March 2020 in Turkey. Therefore, Turkey took emergency measures to combat the epidemic as quickly as possible. January 10, 2020, a science council was established to evaluate and manage all COVID-19 cases over the country. Passengers were checked for COVID-19 at important points such as the airport before entering the country, and a quarantine period was applied. On 3 February 2020, in Turkey, all flights from China stopped temporarily. After Iran approved its first case,

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the borders between the two countries were closed. Hygiene, physical distancing, using a mask, and staying at home were advised by the government to reduce or stop transmission of the virus. Some restrictive measures such as education from home and preventing people over 65 from leaving their homes were taken. In addition, the curfew on weekends and official and religious holidays continues throughout the country, especially in metropolitan cities such as Istanbul, Ankara, and Konya. Despite drastic measures, the number of confirmed cases continued to increase (Aydın et al., 2021; Şahin, 2020).

Air pollution has been identified as the largest environmental problem and cause of premature death in the world. Because the body's immunity is affected by air pollution, humans remain more vulnerable to pathogens (Copat et al., 2020). World Health Organization estimates that around 7 million premature death happens every year caused by exposure to polluted air, due to exposure to highly polluted air by 9 out of 10 people all over the World (WHO, 2018). Epidemiological and toxicological studies show a link between urban air pollutants that can induce airway inflammation and airway hyperresponsiveness and the increasing rate and/or severity of respiratory and cardiovascular diseases (Koren, 1995; Madureira et al., 2019; Schwela, 2000; Zoran et al., 2020).

There are many studies to investigate the relationship between the epidemiological factors and the concentration of air pollutants and meteorological factors. In the study by Yao et al., 2020, a positive relationship was found between $PM_{2.5}$ and PM_{10} concentrations and the case fatality rate (CFR) of COVID-19 in Wuhan (Yao et al., 2020). It has been observed that when $PM_{2.5}$ and PM_{10} increase by 10 µg/m^3, CFR of COVID-19 increases by 0.86% (0.50%–1.22%) and 0.83% (0.49%–1.17%), respectively. According to the result of the review study (Mehmood et al., 2020), both short- and long-term exposure to $PM_{2.5}$ support the higher incidence of the lethality of COVID-19. In another study by Zoran et al., 2020, analysis results showed a negative correlation between COVID-19 and relative air humidity, and the high impact of the daily air quality index (AQI) on the COVID-19 cases outbreak in Milan (Zoran et al., 2020). In the study conducted by Li et al., 2020, it was stated that AQI had an important role in COVID-19 transmission as it was found that there was a statistically significant and positive correlation between AQI and the number of daily COVID-19 incidence in both Wuhan and Xiaogan (Li et al., 2020). NO_2, $PM_{2.5}$, and CO showed a statistically significant and positive correlation with the daily incidence of COVID-19, while temperature and daily sunshine duration correlated negatively. In the study by Biktasheva, 2020, it was determined that local air humidity was statistically negatively correlated with the COVID-19 mortality rate in the German Federal States (Biktasheva, 2020). The study by Bashir et al., 2020 is noted that $PM_{2.5}$, O_3, and NO_2 are significantly associated with total cases, recovered cases, active cases, and deaths from COVID-19. There was also a statistically significant correlation between temperature and total incidence, recovery, and deaths (Bashir et al., 2020). Finally, PM_{10}, humidity, and EQI were only significantly associated with active cases from the COVID-19 pandemic in Germany. These results reveal that while air pollutants such as $PM_{2.5}$, NO_2, and O_3 are the main determinants of COVID-19 in Germany, temperature is the only climate indicator. The study by Hendryx and Luo, 2020, showed that a higher risk of COVID-19 may be associated with higher diesel exhaust concentrations, as significant correlations with diesel PM, COVID-19 prevalence, and mortality have been detected (Hendryx and Luo, 2020). However, more studies are needed to confirm these relationships. Another study by Iqbal et al., 2020, showed a correlation between average daylight hours, total COVID-19 cases, average high temperatures, total COVID-19 cases, and deaths (Iqbal et al., 2020). These results are expected to support organizations such as WHO and local governments in their fight against the spread of COVID-19. The study by Srivastava, 2020, comprehensively reveals that SARS-CoV-2 viruses are associated with aerosols from sneezing, coughing, and speech (Srivastava, 2021). In addition, the study revealed that the aerosol containing SARS-CoV-2 produced by sneezing and coughing was the main source of the spread of the virus, particulate matter and gaseous pollutants caused more COVID-19 cases and deaths, and increased temperature/humidity decreased the number of cases. In a study conducted by Şahin in Turkey, COVID-19 cases and air pollutants were associated only; meteorological factors have not been evaluated (Şahin, 2020). It was found that SO_2 had a statistically significant positive correlation with the number of COVID-19 cases, O_3 had a high effect on the number of COVID-19, NO, NO_2, and NOx had a negative effect, and there was a correlation between PM_{10} and the number of COVID-19 cases. The study by Zhu et al., 2020, in eight regions of South American countries, exhibited a statistically highly significant negative correlation between daily incubate cases and absolute humidity throughout the selected regions (Zhu et al., 2020).

COVID-19 is known to be transmitted from human to human person through close contact (about 2 m) by aerosol containing SARS-CoV-2 produced by sneezing and coughing respiratory droplets smaller than 5 µm in diameter. Therefore, it has been one of the important issues investigated the role of environmental factors in transmission, as particulate matter and gaseous pollutants can cause more COVID-19 cases and deaths (Copat et al., 2020; Li et al., 2020; Srivastava, 2021; WHO, 2018). In addition, due to the effects of air pollution on the immune system, the relationship between air quality parameters and epidemiological factors should be examined. Since this issue concerns the whole society, it has serious importance in terms of public health management.

In this study, the air quality parameters in two different climatic and geographical areas were statistically evaluated and compared. The relationship between the air quality parameters and the new COVID-19 cases was conducted and discussed. Two regression models for the effect of air quality parameters on new cases were developed and discussed.

2 Material and methods

2.1 Study area

The study consists of two regions from turkey, which are the Western Black Sea and Western Anatolia. The Western Black Sea Region lay down along the Black Sea at the middle north boundary of Turkey (See Fig. 1). This area consists of 10 districts, which are Amasya, Çankırı, Kastamonu, Samsun, Tokat, Zonguldak, Karabük, Sinop, Bartın, and Çorum. The total area is 73,914.95 km^2. This area considers a low-density population area in Turkey 61 km^2. The population in the area is 4,493,559 people (2014).

The Western Anatolia region is located in the internal part of Turkey (See Fig. 1). This area consists of three big districts, which are Ankara, Konya, and Karaman. The total area of this region is 75,096.90 km^2. This

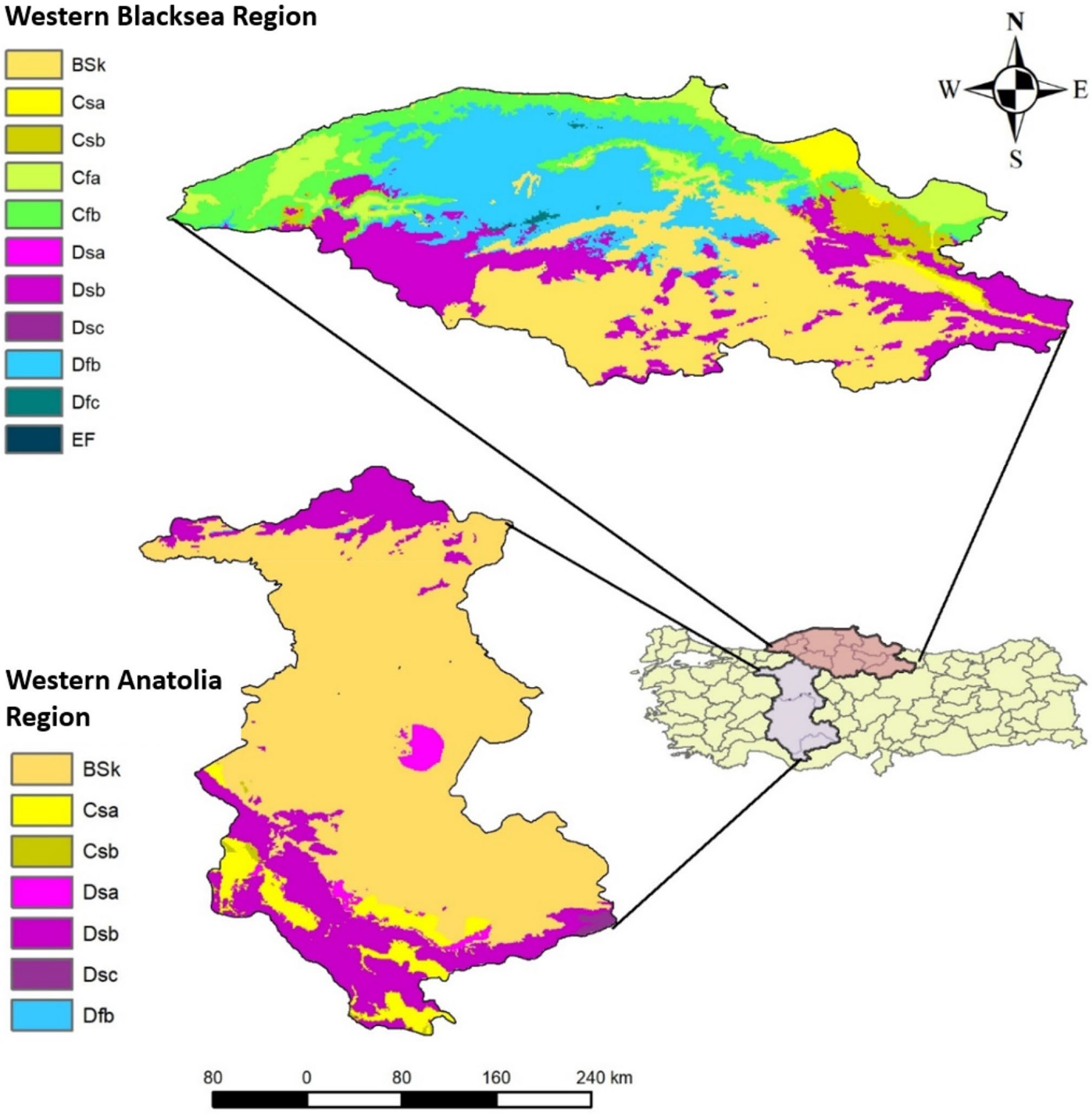


Fig. 1 The location of Western Anatolia and Western Black Sea regions. The map consisting the Köppen-Geiger climate classification (Öztürk et al., 2017)

area considers a low-density population area in Turkey 100 km^2. The population in the area is 7,499,242 people (2014).

To find the differences between the Western Anatolia and Western Black Sea regions, these areas were evaluated based on the Köppen-Geiger climate classification. The Köppen-Geiger climate classes represent a reflection of topography structure and vegetation characteristics. Considering vegetation as visible climate, different regions in a similar class share common vegetation characteristics. The Köppen-Geiger system separates climate into five major classes and 30 sub-types. The classification is based on threshold values and seasonality of monthly precipitation and air temperature patterns. The five major classes are A (tropical), B (dry), C (moderate), D (continental), and E (polar) (Öztürk et al. 2017). The study area is mainly consisting three main groups out of the five groups; these three classes are B (dry), C (moderate), and D (continental).

2.2 Group B: dry climates

This region is characterized by an increased rate of evaporation and transpiration than the annual rate of rain, making its plants of the type that tolerate heat and drought. One of the sub-classifications within the study area that appeared within this group is the cold semi-arid climate (BSk).

2.3 Group C: moderate climates

This region predominates in areas with moderate temperatures. The average temperature in the coldest months of the year in winter is less than 18 °C and not less than 3 °C below zero. Within the study area, there are the following sub-classifications found within this group: Csa has a Mediterranean climate characterized by hot and dry summer; Csb has a Mediterranean climate characterized by warm and dry summer; Cfa has a humid subtropical climate characterized by hot summers and no dry season; and Cfb has a temperate oceanic climate characterized by warm summers and no dry season.

2.4 Group D: continental climates

This climatic region is characterized by frozen soil in winter and the persistence of snow cover for several months of the year, and its average temperature in the coldest months of the year is less than 3 °C below zero, and its average exceeds 10 °C in the warmest of those months. Within the study area, the following sub-regions and sub-classifications appeared within this group:

Dsa: hot, summer, humid continental climate influenced by the Mediterranean region. The coldest month has an average of less than 0 °C, the average temperature of the warmest month is above 22 °C, and at least 4 months have an average

Table 1 Showing descriptive statistics for the selected environmental variables

Variable	Region	Mean	StDev	Minimum	Maximum
Pressure (Pa)	Western Black Sea	91998	388	91047	92988
	Western Anatolia	88415.85	350.37	87606.1	89207.13
Specific humidity (kg/kg)	Western Black Sea	0.007953	0.002042	0.003109	0.011899
	Western Anatolia	0.006373632	0.001478264	0.003005146	0.009562141
Temperature (°C)	Western Black Sea	17.339	5.374	1.673	24.625
	Western Anatolia	19.306	6.738	1.250	27.917
Wind speed (m/s)	Western Black Sea	2.0211	0.4850	1.0079	3.4977
	Western Anatolia	7.109	3.317	1.000	19.300
PM_{10} (µg/m^3)	Western Black Sea	47.79	16.23	23.61	103.98
	Western Anatolia	53.99	30.32	17.39	155.85
SO_2 (µg/m^3)	Western Black Sea	10.231	3.219	4.783	22.784
	Western Anatolia	6.168	1.837	3.360	12.484
CO (µg/m^3)	Western Black Sea	506.02	120.72	277.94	842.13
	Western Anatolia	529.0	289.3	245.4	2613.8
NO_2 (µg/m^3)	Western Black Sea	30.555	7.709	18.339	53.517
	Western Anatolia	40.20	14.77	14.65	74.48
NO_X (µg/m^3)	Western Black Sea	57.34	16.82	34.94	106.37
	Western Anatolia	71.64	42.59	19.75	206.95
O_3 (µg/m^3)	Western Black Sea	31.461	8.246	14.538	49.542
	Western Anatolia	45.86	13.97	20.84	72.86

of 10 °C. Precipitation comes in the winter months, and the summer months are dry, with the driest month in the summer receiving less than 30 mm.

Dsb: a continental climate with warm, humid summers influenced by the Mediterranean region. The coldest month has an average of less than 0 °C, the average temperature of the warmest month is less than 22 °C, and at least 4 months have an average above 10 °C. The precipitation comes during the winter months, and the summer months are the driest. The driest month in the summer receives less than 30 mm of precipitation.

Dsc: subarctic climate influenced by the Mediterranean region. The coldest months average below 0 °C and 1–3 months average above 10 °C. The precipitation is coming in the winter months, while the driest months are coming during the summer. The driest month in summer receives less than 30 mm of precipitation.

Dfb: warm-summer humid continental climate. The coldest months average less than −0 °C, all months have average temperatures below 22 °C, and at least 4 months average 10 °C. There is not much difference in precipitation between seasons.

Dfc: arctic climate. The coldest months average below 0 °C and 1–3 months average above 10 °C. There is no significant difference in precipitation between seasons.

The Western Anatolia region comprises (See Fig. 1) the sub-classes such as B (dry) BSk, C (moderate) Csa, Csb, and D (continental) Dsa, Dsb, Dsc, Dfb. Around 70.06% (52,615.16 km^2) from the Western Anatolia region appeared in the B dry group, 23.36% (17,545.09 km^2) appeared in the D (continental) group, while only 6.57% (4936.64 km^2)

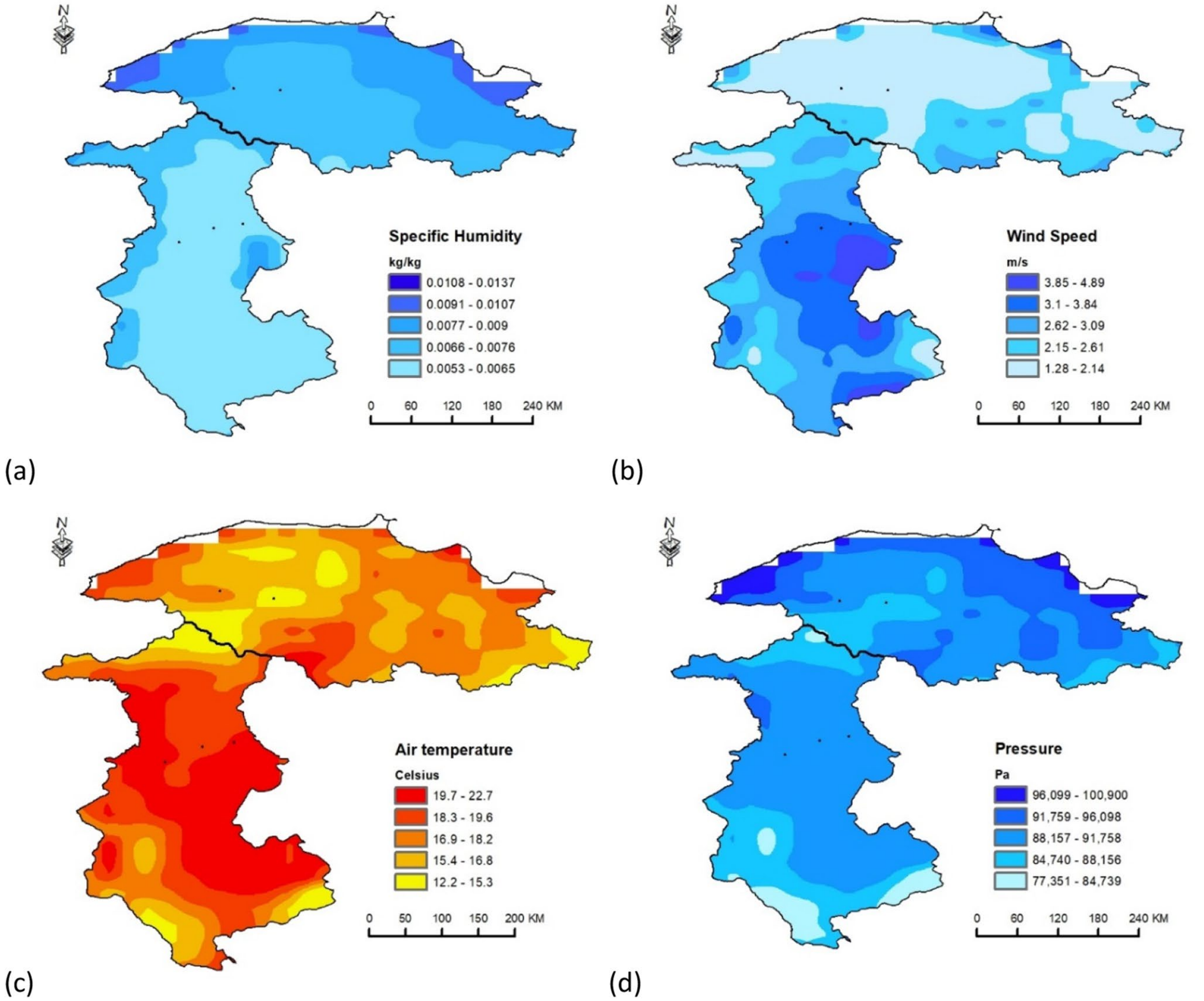


Fig. 2 The distribution of meteorological parameters **a** specific humidity, **b** wind speed, **c** air temperature, and **d** pressure in the two study areas

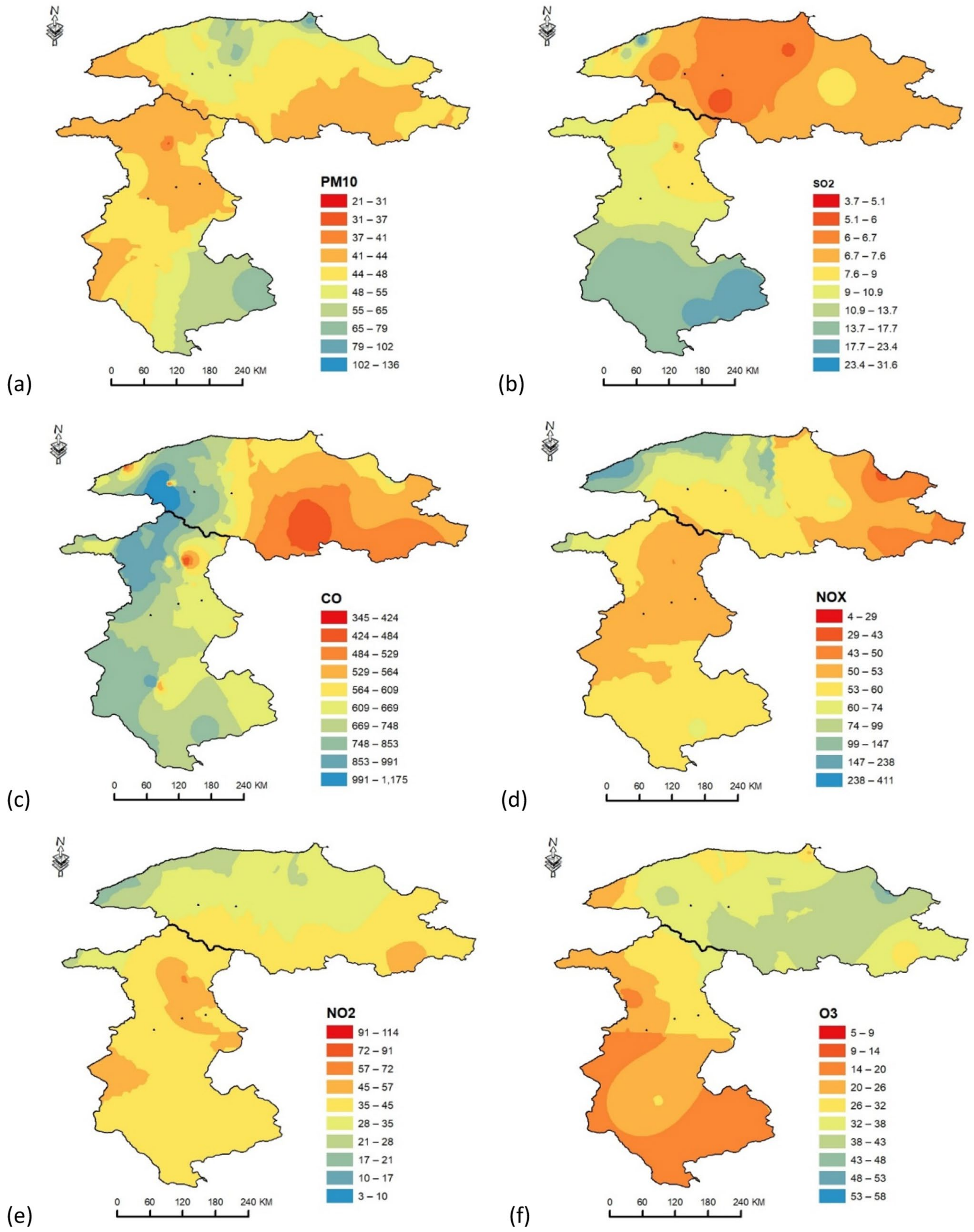
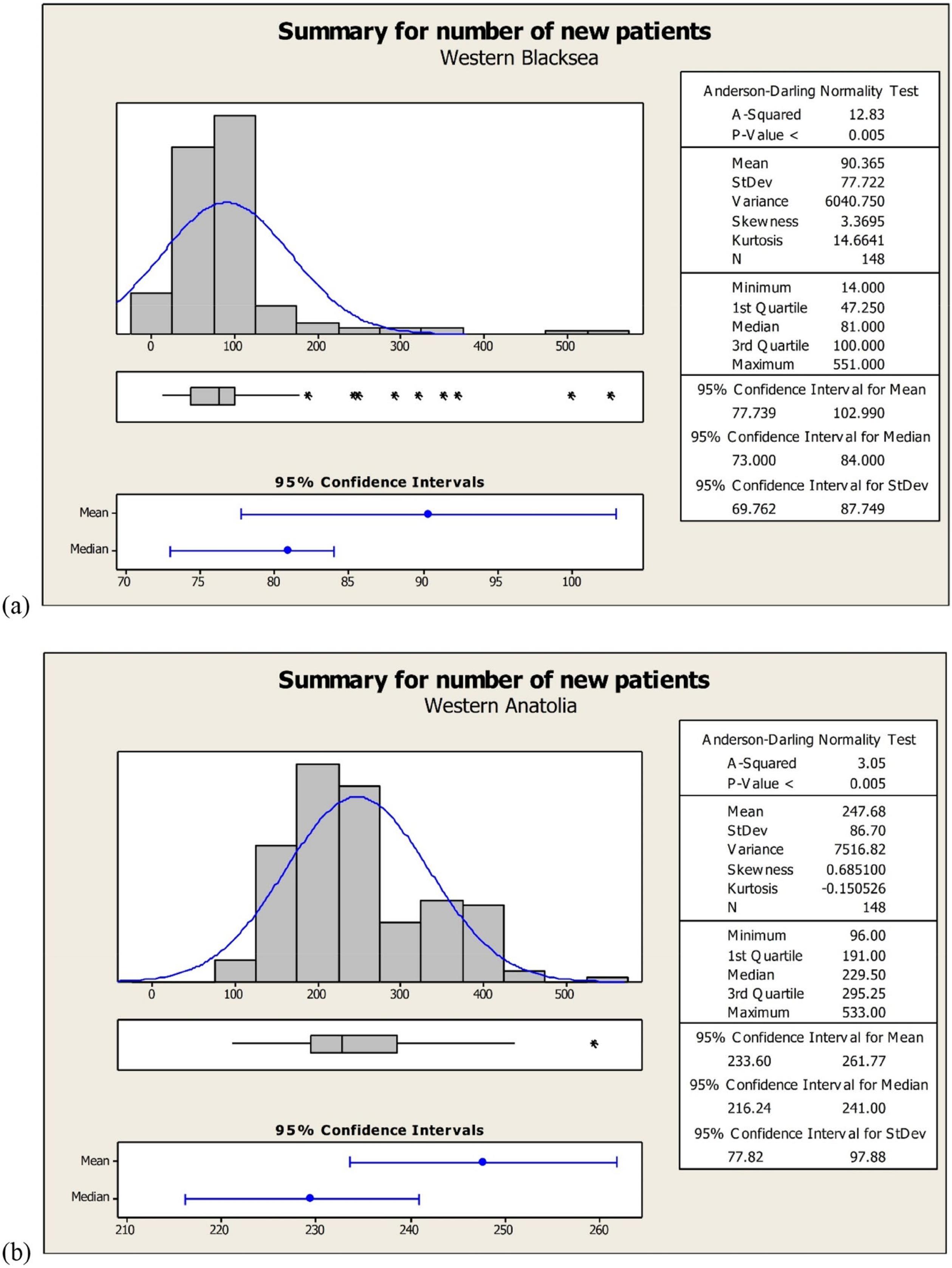


Fig. 3 The distribution of air pollutant parameters (μg/m^3) **a** PM$_{10}$, **b** SO$_2$, **c** CO, **d** NO$_2$, **e**)NO$_X$, and **f** O$_3$ in the two study areas



Anderson-Darling Normality Test	(a) Western Blacksea	(b) Western Anatolia
A-Squared	12.83	3.05
P-Value <	0.005	0.005
Mean	90.365	247.68
StDev	77.722	86.70
Variance	6040.750	7516.82
Skewness	3.3695	0.685100
Kurtosis	14.6641	-0.150526
N	148	148
Minimum	14.000	96.00
1st Quartile	47.250	191.00
Median	81.000	229.50
3rd Quartile	100.000	295.25
Maximum	551.000	533.00
95% Confidence Interval for Mean	77.739 102.990	233.60 261.77
95% Confidence Interval for Median	73.000 84.000	216.24 241.00
95% Confidence Interval for StDev	69.762 87.749	77.82 97.88

Fig. 4 Graphical summary for the new number of cases in the two regions **a** Western Black Sea and **b** Western Anatolia

Table 2 Showing the extracted components including eigenvalues, percentage, and cumulative variance explained by each component

Component	Extraction sums of squared loadings		
	Total	% of variance	Cumulative %
1	4.334	43.344	43.344
2	3.217	32.173	75.516
3	1.027	10.274	85.791

Table 3 Showing the loadings for the loading for the extracted components

	Component		
	P1	**P2**	**P3**
Pressure (P2)	.372	**−.912**	.061
Humidity (P2)	−.251	**.877**	−.351
Temperature (P3)	−.660	−.045	**.711**
Wind (P1)	**−.730**	.506	−.225
PM_{10} (P1)	**.686**	.449	.419
SO_2 (P1)	**.757**	−.403	−.099
CO (P1)	**.713**	.371	−.096
NO_2 (P2)	.613	**.678**	.267
NO_X (P1)	**.780**	.564	.114
O_3 (P1)	**−.793**	.281	.256

Values in bold indicate significant relation

from the area appeared C (moderate) group. On the other hand, The Western Black Sea region (See Fig. 1) contains the same climate groups (B (dry), C (moderate), and D (continental)), but consisting of different sub-classes such as BSk, Csa, Csb, Cfa, Cfb, Dsb, Dsc, Dfb, and Dfc. Approximately, 31.56% (23,332.30 km^2) from the Western Black Sea Region appeared in the B dry climate group, 26.26% (19,410.84 km^2) from the area appeared in the C (moderate) climate group, and 42.17 % (31,170.42 km^2) from the region appeared in the D (continental) climate group.

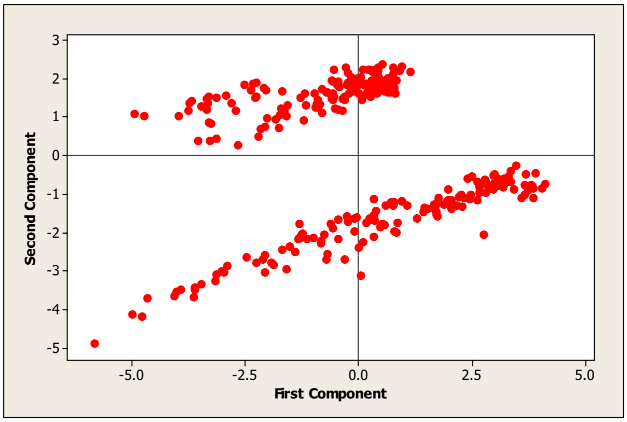


Fig. 5 The first and second components

In addition, the internal location of the Western Anatolia region and located in the shadow area of the continentals worked as a barrier against air movement. Thus, the air contamination is assumed to be different from the Western Black Sea Region. The Western Black Sea Region is generally located in the face of the air source coming from the Black Sea.

2.5 Data collection

Meteorological data such as net short wave radiation flux, temperature, relative humidity, wind speed, and pressure were gathered from the Global Land Data Assimilation System (GLDAS). The GLDAS meteorological data is hosted in Google Earth Engine (GEE) platform (Rodell et al., 2004). The climatological data were downloaded using Javascript language from the gridded images for the study of the Western Anatolia and Western Black Sea regions.

The data on air quality parameters were acquired from the Ministry of Environment and Urbanization (Ministry of Environment and Urbanization, 2021). Air quality parameters such as particulate matter (PM_{10}) having an aerodynamic diameter of less than or equal to 10 m (PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NOx), and ground-level ozone pollution (O_3). The data on confirmed cases and new hospitalizations on COVID-19 were obtained from the COVID-19 information page of the Republic of Turkey Ministry of Health on December 12, 2020 (https://covid19.saglik.gov.tr/). The daily data were collected from June 29, 2020, to November 23, 2020, for the meteorological data and air quality parameters which are equal to the available data on the number of COVID-19 cases

2.6 Statistical analysis

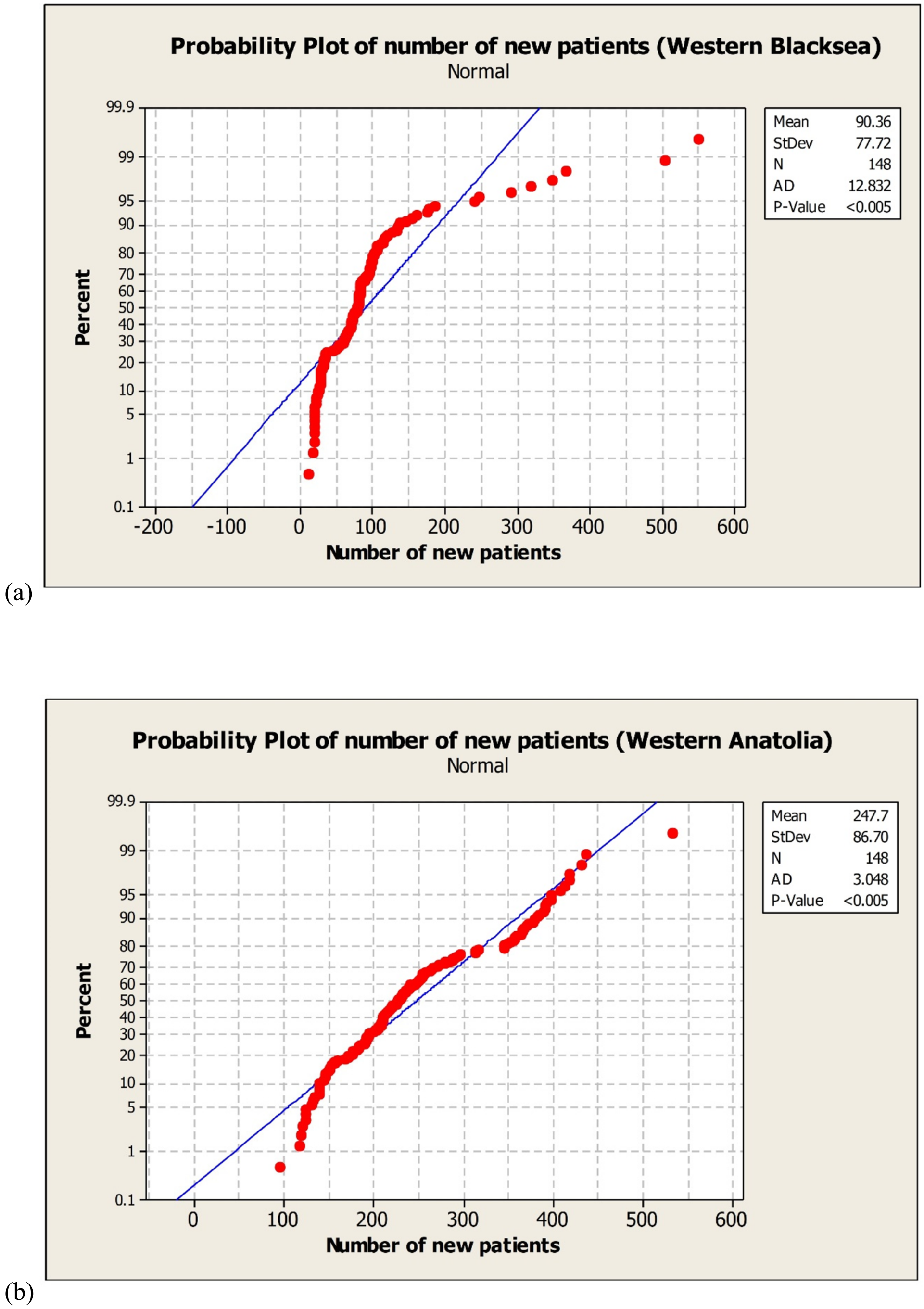
The data for the two regions regarding selected environmental parameters and the number of new cases of COVID-19 were analyzed using descriptive statistics and graphical presentation (Alkarkhi and Low, 2012). Two more techniques were used to find the effect of environmental parameters on the new cases of COVID-19; the two techniques are principal component analysis and regression model to describe the effect of environmental parameters on the number of new cases (Al-Karkhi and Alqaraghuli, 2020).

3 Result and discussion

3.1 Descriptive statistics

Descriptive statistics for the environmental variables in the two selected regions are presented in Table 1. The difference between the average values, standard deviation, and

Fig. 6 Probability plot for normality assumption test for number of new cases **a** Western Black Sea and **b** Western Anatolia



minimum and maximum values is high which is reflected by the values of standard deviation for most of the selected parameters which indicates that the level of the selected parameters has highly fluctuated. The distribution of meteorological and air pollutant parameters in the two study areas is visualized in Fig. 2 and Fig. 3, respectively. The collected data for the number of new COVID-19 cases in the two regions, Western Black Sea and Western Anatolia, are presented as a graphical summary in Fig. 4, including the mean, standard deviation, skewness kurtosis, minimum, maximum, first and third quartile, median, confidence interval, and histogram with the normal curve. The mean value for the Western Black Sea is less than Western Anatolia (90.365 < 247.68), while the skewness value for Western Black Sea is higher than Western Anatolia (3.3695 > 0.6851), both groups of data are skewed. The high variation is attributed to the difference between the two geographical and topographical locations, as Western

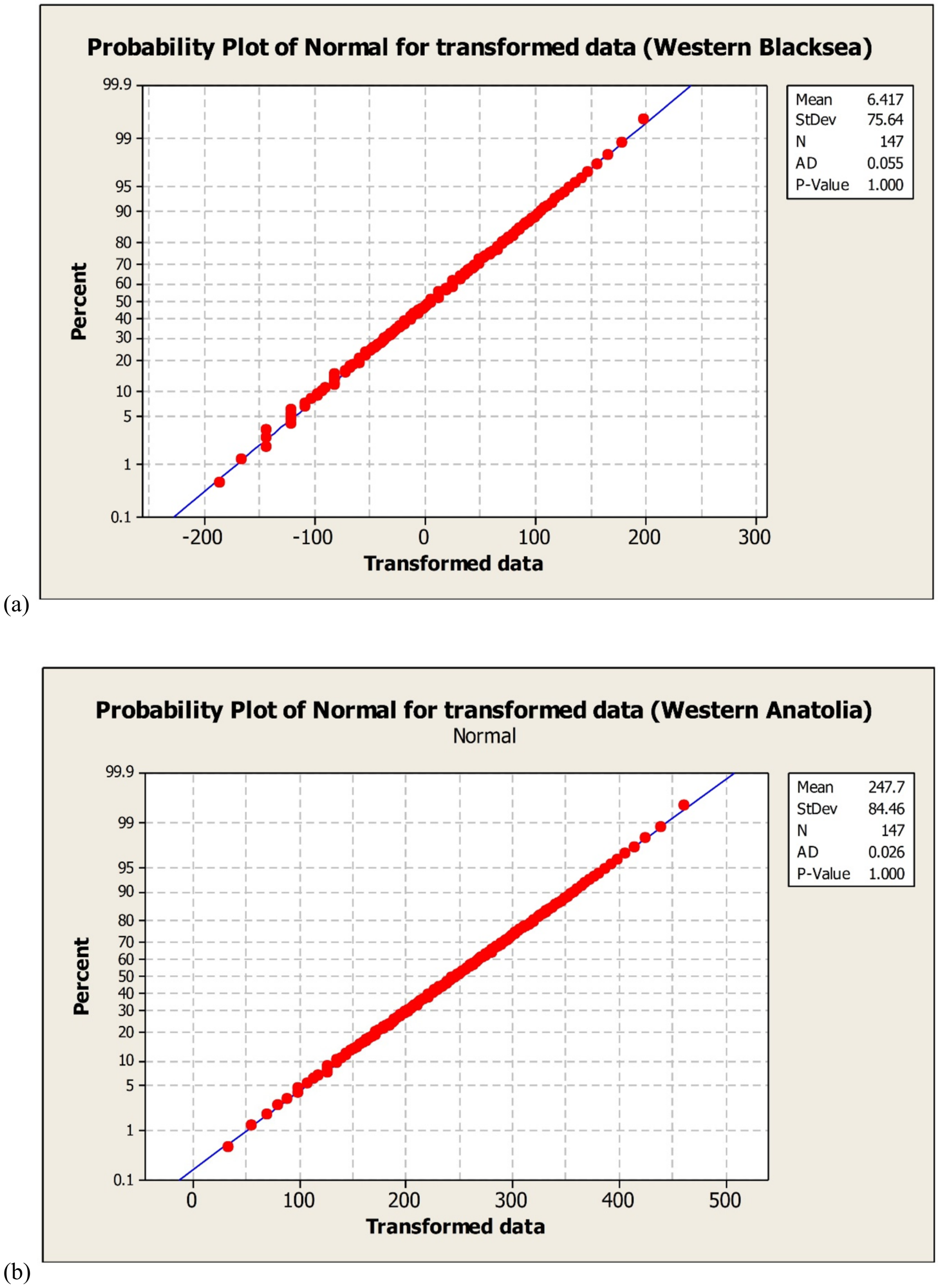


Fig. 7 Probability plot for transformed data (normality assumption test) **a** Western Black Sea and **b** Western Anatolia

Anatolia is a continental area and the Western Black Sea is a coastal area.

3.2 Principal component regression

Principal component regression was used to extract new variables from environmental parameters to be used as independent variables and the number of new cases of COVID-19 in the two selected regions as a dependent variable. Ten environmental variables were used to extract the independent variables that influence the number of new COVID-19 cases and model the relationship in terms of regression model. Three components were extracted with an eigenvalue of more than 1 explaining more than 85% of the total variance (Table 2 shows the contribution (percentage) of each component). The loading of each environmental variable with each component is measured by the coefficient associated with the variable (Table 3), loadings take values from −1 to 1, the high value of loading close to −1 or 1 gives an indication that the selected variable has a strong influence on the component, while close to 0 indicates that the variable has a weak influence on the component. The values of the first and second principal components are presented in Fig. 5, clearly showing the

Table 4 *t*-test for regression coefficient for Black Sea and Anatolia

Black Sea[a]				
Predictor	Coef SE	Coef	T	P
Constant	269.89	40.24	6.71	0.000
X_1	1.81	14.68	0.12	0.902
X_2	191.42	37.97	5.04	0.000
Anatolia[b]				
Predictor	Coef SE	Coef	T	P
Constant	318.74	43.03	7.41	0.000
X_1	49.79	18.34	2.71	0.007
X_2	−55.83	39.54	−1.41	0.160
X_3	6.717	5.380	1.25	0.214

[a] R-Sq = 59.3% R-Sq (adj) = 58.4%

[b] R-Sq = 13.7% R-Sq (adj) = 11.9%

difference between the two regions. The values of each component represent an independent variable; thus, three independent variables can be used based on the number of components. Based on the graphical summary of the number of new cases of COVID-19 (Fig. 4a, b), the variable is skewed, thus normality testing should be carried out. The result of the normality assumption for the number of new cases is presented in Fig. 6a, b, showing that the data did not meet the normality assumption as presented by the value of the Anderson-Darling (AD) 12.832 and 3.048 for Western Black Sea and Western Anatolia with P-value < 0.005. Transformation of the number of new cases was carried out in two steps, the first step is to transform the original data into fractional rank and the second step is to use inverse DF and IDF normal; the result of the transformed data is presented in Fig. 7a, b, showing the transformed data are normally distributed as appeared by the small value of AD, 0.055 and 0.026 for Western Black Sea and Western Anatolia respectively.

The relationship between the number of new cases (transformed variable) as dependent variable and the three variables that resulted from principal component analysis (each component produced one variable), X_1, X_2, and X_3 are given in Eqs. 1 and 2 for Western Black Sea and Western Anatolia respectively.

$$\text{New cases Western Black Sea} = 270 + 1.8\,X_1 + 191\,X_2 - 71.8\,X_3 \tag{1}$$

$$\text{New cases Western Anatolia} = 319 + 49.8\,X_1 - 55.8\,X_2 + 6.72\,X_3 \tag{2}$$

Where X_1 represents the effective values for the parameters: wind speed, PM_{10}, SO_2, CO, NO_X, and O_3, X_2 represents the effective values for pressure, humidity, and NO_2, and X_3 represents the effective value for temperature.

The results of the analysis showed that the model in Eqs. 1 and 2 is significant which indicates the existence of relationship between the number of new cases and the selected environmental parameters. Furthermore, testing of individual variable showed that the variable X_1 which represents the values of the first components (wind speed, SO_2, CO, NO_X, and O_3) is not an influential variable in the Western Black Sea area (Table 4); this indicates that the parameters represented in X_1 are not influential parameters and does not affect the number of new cases of COVID-19, while X_1 and X_2 are influential variables. On the other hand, the variables X_2 and X_3 are not influential variables in Western Anatolia (Table 4); this indicates that only wind speed, SO_2, CO, NO_X, and O_3 which represent X_1 are influential parameters and affect the number of new cases in Western Anatolia. Accordingly, the number of new cases is affected by different parameters and based on the region which indicates the difference in the number of new COVID-19 cases. The model in Eq. 1 explains only 59.3% of the total variance in the number of new cases while the model in Eq. 2 explains only 13.7% of the total variance.

The data for the number of new cases of COVID-19 were further analyzed using *t*-test. The results of the analysis showed that the number of new cases of COVID-19 is different in the two regions as the *t*-test statistic is −16.58 and P-value $<$ 0.0001. These results confirmed that the environmental parameters behave differently in each region. This could be due to the difference in the climate classes that are explained in section 2.1.

4 Conclusion

Evaluation of the effect of air quality parameters on new COVID-19 cases between two different climatic and geographical regions is expected to contribute to the determination of appropriate health management strategies. Based on the abovementioned findings and discussion, it can be concluded that the number of new cases of COVID-19 and the selected air quality parameters in both areas (continental and coastal areas) has a significant relationship. Furthermore, more than 85% of the total variation in the data was explained by only three components which represent the new variables in regression analysis. The Tow regression model that describes the relationship between the new independent variables (X_1, X_2, and X_3) and the number of new cases of COVID-19 (response variable) was significant. In the continental area, wind speed, SO_2, CO, NO_X, and O_3 which represent X_1 are influential parameters and affect the number of new cases. The model in Eq. 1 explains only 59.3% of the total variance in the number of new cases, while the model in Eq. 2 explains only 13.7% of the total variance. The results of the analysis of variance for regression analysis showed a strong significant effect on the number of new cases (P-value < 0.0001). Furthermore, X_1 showed a negative effect on the number of cases, while X_2 and X_3 showed a positive effect on the number of new COVID-19 cases.

Author's contribution S.D. and K.U. collected the data and prepared for analysis. A.F.M.A. conducted the statistical analysis. S.S.A.A. wrote the main manuscript text. S.K.M.A. prepared the methodology part and figures. All authors reviewed the manuscript.

Data availability Data are available from the corresponding author on reasonable request.

Code availability Not applicable

Declarations

Ethics approval Not applicable

Consent to participate Not applicable

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References

Alkarkhi AFM, Low HC (2012) Elementary statistics for technologist, 1st edn. Pulau Pinang, Universiti Sains Malaysia, Penerbit, USM, pp 300

Al-Karkhi AFM, Alqaraghuli WAA (2019) Applied statistics for environmental science with R. Elsevier

Aydın S, Nakiyingi BA, Esmen C, Güneysu S, Ejjada M (2021) Environmental impact of coronavirus (COVID-19) from Turkish perceptive. Environ. Dev. Sustain 23:7573–7580

Bashir MF, Jiang B, Komal B, Bashir MA, Farooq TH, Iqbal N, Bashir M (2020) Correlation between environmental pollution indicators and COVID-19 pandemic: a brief study in Californian context. Environ. Res 187:109652. https://doi.org/10.1016/j.envres.2020.109652

Biktasheva IV (2020) Role of a habitat's air humidity in Covid-19 mortality. Sci. Total Environ 736:138763

Copat C, Cristaldi A, Fiore M, Grasso A, Zuccarello P, Santo Signorelli S, Conti GO, Ferrante M (2020) The role of air pollution (PM and NO2) in COVID-19 spread and lethality: a systematic review. Environ. Res 191:110129

Cui J, Li F, Shi Z-L (2019) Origin and evolution of pathogenic coronaviruses. Nat. Rev. Microbiol 17:181–192

Hendryx M, Luo J (2020) COVID-19 prevalence and fatality rates in association with air pollution emission concentrations and emission sources. Environ. Pollut 265:115126

Hu B, Guo H, Zhou P, Shi Z-L (2021) Characteristics of SARS-CoV-2 and COVID-19. Nat. Rev. Microbiol 19:141–154

Iqbal MM, Abid I, Hussain S, Shahzad N, Waqas MS, Iqbal MJ (2020) The effects of regional climatic condition on the spread of COVID-19 at global scale. Sci. Total Environ 739:140101. https://doi.org/10.1016/j.scitotenv.2020.140101

Koren HS (1995) Associations between criteria air pollutants and asthma. Environ. Health Perspect 103:235–242

Li H, Xu X-L, Dai D-W, Huang Z-Y, Ma Z, Guan Y-J (2020) Air pollution and temperature are associated with increased COVID-19 incidence: a time series study. Int. J. Infect. Dis 97:278–282

Madureira J, Brancher EA, Costa C, de Pinho RA, Teixeira JP (2019) Cardio-respiratory health effects of exposure to traffic-related air pollutants while exercising outdoors: a systematic review. Environ. Res 178:108647. https://doi.org/10.1016/j.envres.2019.108647

Mehmood K, Saifullah MI, Abrar MM (2020) Can exposure to PM2. 5 particles increase the incidence of coronavirus disease 2019 (COVID-19)? Sci. Total Environ 741:140441

Ministry of Environment and Urbanization, N.A.Q.M.N 2021. Air quality data [WWW Document]. URL https://sim.csb.gov.tr/Services/AirQuality

Öztürk M, Çetinkaya G, Aydın S (2017) Climate types of Turkey according to Köppen-Geiger climate classification. Istanbul Univ J Geogr 2017:17–27. https://doi.org/10.26650/JGEOG330955

Rodell M, Houser PR, Jambor UEA, Gottschalck J, Mitchell K, Meng C-J, Arsenault K, Cosgrove B, Radakovich J, Bosilovich M (2004) The global land data assimilation system. Bull. Am. Meteorol. Soc 85:381–394

Şahin M (2020) The association between air quality parameters and COVID-19 in Turkey. Pharm. Biomed. Res 6:49–58

Schwela D (2000) Air pollution and health in urban areas. Rev. Environ. Health 15:13–42

Srivastava A (2021) COVID-19 and air pollution and meteorology-an intricate relationship: a review. Chemosphere 263:128297. https://doi.org/10.1016/j.chemosphere.2020.128297

WHO, 2018. 9 out of 10 people worldwide breathe polluted air, but more countries are taking action [WWW Document]. URL https://www.who.int/news/item/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action (accessed 9.30.21).

Yao Y, Pan J, Liu Z, Meng X, Wang W, Kan H, Wang W (2020) Temporal association between particulate matter pollution and case fatality rate of COVID-19 in Wuhan. Environ. Res 189:109941. https://doi.org/10.1016/j.envres.2020.109941

Zhu L, Liu X, Huang H, Avellán-Llaguno RD, Lazo MML, Gaggero A, Soto-Rifo R, Patiño L, Valencia-Avellan M, Diringer B (2020) Meteorological impact on the COVID-19 pandemic: a study across eight severely affected regions in South America. Sci. Total Environ 744:140881. https://doi.org/10.1016/j.scitotenv.2020.140881

Zoran MA, Savastru RS, Savastru DM, Tautan MN (2020) Assessing the relationship between surface levels of PM2. 5 and PM10 particulate matter impact on COVID-19 in Milan, Italy. Sci. Total Environ 738:139825. https://doi.org/10.1016/j.scitotenv.2020.139825