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The Effects of North Sea Caspian Pattern Index on the Temperature and Precipitation Regime in the Aegean Region of Turkey

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***Abstract*—**North Sea Caspian Pattern Index (NCP) refers to an atmospheric teleconnection between the North Sea and North Caspian at the 500 hPa geopotential height level. The aim of this study is to search for effects of NCP on annual and seasonal mean temperature and also annual and seasonal precipitation totals in the Aegean region of Turkey. The study contains the data that consist of 46 years obtained from nine meteorological stations. To determine the relationship between NCP and the climatic parameters, firstly the Pearson correlation coefficient method was utilized. According to the results of the analysis, most of the stations in the region have a high negative correlation NCPI in all seasons, especially in the winter season in terms of annual and seasonal mean temperature (statistically at significant at the 90% level). Besides, high negative correlation values between NCPI and precipitation totals are observed during the winter season at the most of stations. Furthermore, the NCPI values were divided into two group as NCPI(-) and NCPI(+), and then mean temperature and precipitation total values, which are grouped according to the NCP(-) and NCP(+) phases, were determined as annual and seasonal. During the NCPI(-), higher mean temperature values are observed in all of seasons, particularly in the winter season compared to the mean temperature values under effect of NCP(+). Similarly, during the NCPI(-) in winter season precipitation total values have higher than the precipitation total values under the effect of NCP(+); however, in other seasons there no substantial changes were observed between the precipitation total values. As a result of this study, significant proof is obtained with regards to the influences of NCP on the temperature and precipitation regime in the Aegean region of Turkey.

***Keywords*—**Aegean Region, North Sea Caspian Pattern, precipitation, temperature.

I. Introduction

THE effects of atmospheric teleconnections on the climate of different parts of the world have been investigated for decades. Reference [1] scrutinized the liaison between climate parameters and atmospheric teleconnections such as North Atlantic Oscillation (NAO) and Southern Oscillation (SO). Reference [2] examined the relationship between temperatures and NAO, Arctic Oscillation (AO), El Niño Southern Oscillation (ENSO), and North Caspian Sea Pattern (NCP). Similarly, studies were carried out in order to examine the impacts of NAO, SO and NCP on climatic parameters in different regions of Turkey. In this context, it was searched for the linkage between monthly streamflows and El Niño and La Niña events and the results which varied from region to region were acquired by [3]. In another study which was performed by [4], the relationship between climatic parameters (streamflow, temperature, precipitation) and NAO and SO was revealed.

The influences of NCP on climate parameters were investigated by studies which were carried out around the world. The significant impacts of NCP on climate parameters such as temperature and precipitation were determined as a result of these studies. Reference [6] investigated the effects of NCP on Eastern Mediterranean which contains the various stations from some regions of Greece, Turkey and Israel. It was revealed that mean temperature values under the effect of NCPI(-) are higher than the mean temperatures values under the effect of NCPI(+) in all regions for the studied period from October to April; however, in terms of rainfall, it was pointed out that precipitation amounts under the effect of NCPI(-) and NCPI(+) varied in regions of countries, which were mentioned above, that is there is no clear indication for precipitation regime [6]. In another study carried out by [7], the remarkable differences between mean temperature values under the effect of NCPI(-) and NCPI(+), respectively, were observed in continental central Turkey. However, it was pointed out that the effects of NCPI on precipitation totals in same region were not as strongly observed as the effects of NCPI on mean temperature [7]. Reference [8] demonstrated that NCPI is highly negatively correlated with the winter temperature values in Iran. Reference [9] found high negative correlations between NCPI and surface air temperatures for all seasons, especially during the winter season in Greece. Furthermore, it was also expressed that temperatures under the effect of NCPI(-) are higher than the temperatures under the effect of NCPI(+) during the winter season [9].

In this study, the effects of NCPI on monthly mean temperatures and the total precipitation regime in the Aegean Region of Turkey were studied. For this purpose, firstly, the correlation coefficients were determined. Next, the mean temperatures and precipitation totals data were assessed according to the NCP(-) and NCP(+) phases.

II. Data and Methodology

In this study, the monthly mean temperature and monthly precipitation total data which cover the period from 1960 to 2005, were acquired from Turkish State Meteorological Service for nine stations (İzmir, Aydın, Manisa, Kütahya,

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Uşak, Dikili, Denizli, Bodrum, Muğla) in the Aegean region of Turkey. The data were classified as annual and the seasons of winter (December, January, February), spring (March, April, May,) summer (June, July, August), and autumn (September, October, November). As indicated in Fig. 1, the Aegean region is located in west part of Turkey. Moreover, the information as regards to the stations were given in Table I, and the statistical data concerning annual and seasonal mean temperatures and precipitation totals are shown in Tables II and III, respectively. The NCPI data were obtained from [10].

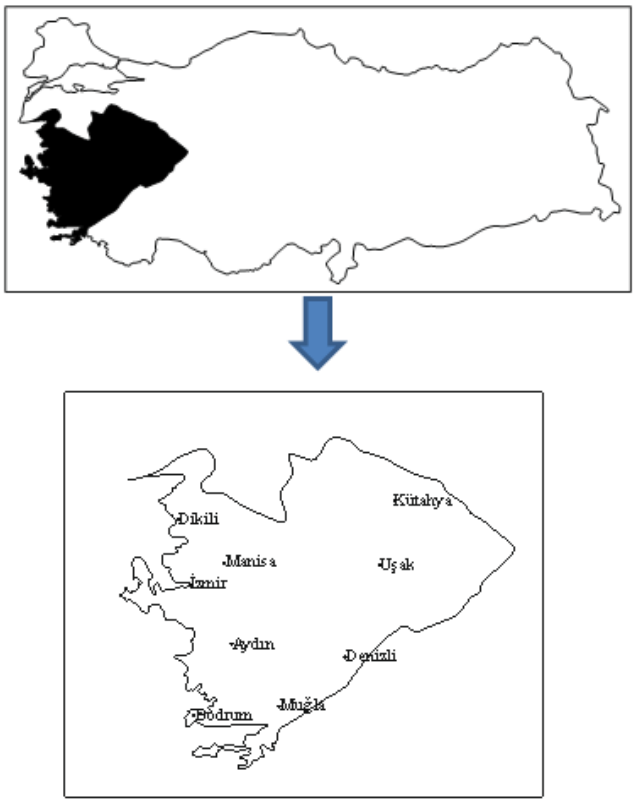

Fig. 1 Aegean Region in Turkey

Firstly, the Pearson correlation coefficients between the climatic data and NCPI values were calculated. The formula of correlation coefficient is shown in (1) [11].

$$r_{X,Y} = \frac{\sum\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)}{N s_x s_y} \quad (1)$$

In (1), x_i shows the annual and seasonal climatic data which belongs to the year of i, $\bar{x}$ is the mean of annual and seasonal climatic data; y_i indicates annual and seasonal NCPI which belongs to the year of i,; $\bar{y}$ is the mean of annual and seasonal NCPI, in addition, N is the number of data, s_x and s_y refers to the standard deviations for climatic data and NCPI, respectively.

Secondly, NCPI values were divided into two phases as NCPI (-) and NCPI (+), thus the effect of either phases on the climatic parameters, as mentioned above, were detected and compared. The NCP index was expressed by [5], as indicated in (2):

$$NCPI = \overline{gpm}\left(0^{\circ}, 55^{\circ}N; 10^{\circ}E, 55^{\circ}N\right) - \overline{gpm}\left(50^{\circ}E, 45^{\circ}N; 60^{\circ}E, 45^{\circ}N\right) \quad (2)$$

$\overline{gpm}$ refers the geopotential height which is between two grid points. Thus, the monthly NCPI values can be calculated thanks to (2). In addition, standardization of monthly data of NCPI is demonstrated in (3):

$$z_i = \left(NCPI_i - \overline{NCPI}\right)/\sigma \quad (3)$$

$NCPI_i$ refers the monthly data of NCPI for year i, $\overline{NCPI}$ is the monthly average of NCPI, and σ is the standard deviation of it [5]. According to the study [5], it was also pointed out that if $z_i \leq$-0.5, that means the negative phase of NCPI (NCPI(-)). Besides, once $z_i \geq 0.5$, that means the positive phase of NCPI (NCPI(+)).

TABLE I
FEATURES OF STATIONS

Station No	Station	Time Period	Height (m)	Lat.(N)	Long.(E)
17155	Kütahya	1960-2005	969	39.4171	29.9891
17180	Dikili	1960-2005	3	39.0737	26.8880
17186	Manisa	1960-2005	71	38.6153	27.4049
17188	Uşak	1960-2005	919	38.6712	29.4040
17234	Aydın	1960-2005	56	37.8402	27.8379
17220	İzmir	1960-2005	29	38.3949	27.0819
17237	Denizli	1960-2005	425	37.7620	29.0921
17292	Muğla	1960-2005	646	37.2095	28.3668
17290	Bodrum	1960-2005	26	37.0328	27.4398

III. RESULTS

A. The Effects of NCPI on Annual and Seasonal Mean Temperature

Firstly, the correlation coefficients between NCPI and annual and seasonal mean temperature values were calculated and the results which are evaluated according to the Student's t-test with significance levels α=0.01, α=0.05, and α=0.10 were shown in Table IV. According to Table IV, high negative correlation coefficients were observed to be statically significant at α= 0.01 between NCPI and annual mean temperature, as well as the seasonal mean temperature especially for winter season at all the studied monitoring stations in the Aegean region. It can be understood that only the correlation coefficients for summer season can be interpreted as low for five out of nine stations (İzmir, Aydın,

Manisa, Dikili, and Bodrum), when the significance levels are taken into consideration compared to other seasons.

Thus, the high negative correlation coefficients which were presented in Table IV, indicate the strong relationship between the NCPI and annual and seasonal mean temperature statistically for general of Aegean region. In addition, the annual and seasonal temperature values under the effect of NCPI (-) and NCPI (+) were demonstrated in Table V.

TABLE II
STATISTICAL DATA CONCERNING ANNUAL AND SEASONAL MEAN TEMPERATURE

Stations	Winter			Spring			Summer			Autumn			Annual		
	Mean Tem. (°C)	Std.Dev.(°C)	Max. Tem. (°C)	Mean Tem. (°C)	Std.Dev.(°C)	Max. Tem. (°C)	Mean Tem. (°C)	Std.Dev. (°C)	Max. Tem. (°C)	Mean Tem. (°C)	Std.Dev. (°C)	Max. Tem. (°C)	Mean Tem. (°C)	Std.Dev. (°C)	Max. Tem (°C)
Kütahya	1.49	1.59	4.20	9.81	0.93	12.3	19.66	0.82	21.57	11.59	0.90	14.00	10.66	0.67	12.08
Dikili	8.65	1.05	10.77	14.69	0.81	16.47	24.95	0.63	26.13	17.43	0.80	19.33	16.44	0.51	17.54
Manisa	7.69	1.16	10.40	15.38	0.89	17.27	26.97	0.87	28.80	17.75	0.81	19.67	16.97	0.54	18.22
Uşak	3.13	1.12	5.00	10.89	0.90	13.37	22.22	0.90	24.40	13.37	0.80	15.10	12.42	0.56	13.79
İzmir	9.51	1.01	11.33	16.05	0.86	18.23	26.90	0.79	28.37	18.77	0.80	20.50	17.82	0.55	19.18
Aydın	8.93	1.01	10.93	16.08	0.84	18.10	27.07	0.75	28.70	18.27	0.82	20.03	17.60	0.55	18.96
Denizli	6.64	1.23	8.63	14.63	0.93	16.87	26.00	1.06	28.40	16.68	0.91	18.53	16.01	0.70	17.73
Muğla	6.13	0.91	7.77	12.81	0.93	14.80	24.86	0.81	26.77	16.00	0.78	17.63	14.97	0.54	16.24
Bodrum	11.81	0.86	13.40	16.75	0.76	18.5	27.07	0.70	28.67	20.21	0.75	22.23	18.97	0.50	20.09

TABLE III
STATISTICAL DATA CONCERNING ANNUAL AND SEASONAL PRECIPITATION TOTALS

Stations	Winter			Spring			Summer			Autumn			Annual		
	Mean Pre. (mm)	Std.Dev. (mm)	Max. Pre. (mm)	Mean Pre. (mm)	Std.Dev. (mm)	Max.Pre. (mm)	Mean Pre. (mm)	Std.Dev. (mm)	Max. Pre. (mm)	Mean Pre. (mm)	Std.Dev.(mm)	Max. Pre. (mm)	Mean Pre. (mm)	Std.Dev. (mm)	Max. Pre. (mm)
Kütahya	216.1	80.5	422.8	170.6	49.1	321.1	68.4	34.9	154.1	112.9	41.1	190.1	567.9	106.5	844.3
Dikili	317.0	111.5	571.6	136.4	51.4	279.8	13.5	12.1	43.2	135.1	65.8	372.2	602.0	146.2	1114.6
Manisa	377.0	132.9	657.3	179.7	59.1	343.9	25.9	23.2	83.6	151.0	60.5	308.5	733.6	167.5	1123.1
Uşak	214.9	77.6	413.0	162.0	51.5	298.8	50.9	30.4	141.2	113.6	39.2	195.5	541.4	95.7	794.4
İzmir	371.6	116.6	636.1	148.7	59.2	302.2	11.8	13.8	52.0	150.4	74.9	395.2	682.5	158.8	1136.0
Aydın	315.7	110.4	552.8	161.7	62.2	370.7	19.1	21.9	98	130.2	60.0	345.4	626.7	143.8	923.7
Denizli	250.2	94.1	424.2	160.5	50.9	298.3	45.9	38.8	188.6	103.5	41.3	198.9	560.0	115.0	755.6
Muğla	682.0	219.7	1142	242.9	92.0	469.5	37.3	31.1	106.4	224.0	77.8	428.5	1186	260.3	1612
Bodrum	417.7	145.0	727.6	129.6	63.0	263.2	6.3	9.0	40.7	149.6	70.9	305.4	703.2	157.0	1026

TABLE IV
CORRELATION COEFFICIENTS BETWEEN NCPI AND ANNUAL AND SEASONAL MEAN TEMPERATURE

Stations	Annual	Winter	Spring	Summer	Autumn
İzmir	-0.51***	-0.77***	-0.36**	-0.24	-0.45***
Aydın	-0.43***	-0.73***	-0.31**	-0.23	-0.39***
Manisa	-0.56***	-0.76***	-0.39***	-0.24	-0.41***
Kütahya	-0.63***	-0.74***	-0.46***	-0.37**	-0.55***
Uşak	-0.52***	-0.68***	-0.34**	-0.41***	-0.44***
Dikili	-0.57***	-0.77***	-0.49***	-0.14	-0.50***
Denizli	-0.42***	-0.72***	-0.27*	-0.29*	-0.48***
Bodrum	-0.48***	-0.69***	-0.34**	-0.23	-0.42***
Muğla	-0.48***	-0.71***	-0.26*	-0.41***	-0.39***

*** For α= 0.01 significance level ** For α=0.05 significance level * For α=0.10 significance level

As seen in Table V, the temperature values under the effect of NCPI(-) are higher than the temperature values under the effect of NCPI(+). In this context, significant temperature differences were obtained in terms of either annual or seasonal mean temperature. Besides, the most remarkable differences between temperature values under the effect of NCPI(-) and NCPI(+) were observed for winter season. To illustrate, in winter season, the maximum difference is 3.22 °C for Kütahya station, while the minimum difference is 1.64 °C for Bodrum station.

B. The Effects of NCPI on Annual and Seasonal Precipitation Totals

The same procedure which was utilized for annual and seasonal mean temperature, was also carried out for annual and seasonal precipitation totals. In this context, firstly correlation coefficients between NCPI and annual and seasonal precipitation totals were determined and results were assessed according to the Student's t test with significance levels α=0.01, α=0.05, and α=0.1. According to Table VI, it can be understood that significant negatively correlations were observed in winter season for almost all of the stations. On the other hand, statistically significant positive correlation coefficients were acquired in summer season for Manisa, Uşak, Denizli and Muğla stations, whereas significant negatively correlations were seen in terms of annual for some stations such as İzmir, Aydın and Manisa.

TABLE V
THE SEASONAL AND ANNUAL MEAN TEMPERATURE VALUES (°C) OF UNDER THE EFFECT OF NCPI(-) AND NCPI(+)

	Winter		Spring		Summer		Autumn		Annual	
Stations	NCP(-)	NCP(+)	NCP(-)	NCP(+)	NCP(-)	NCP(+)	NCP(-)	NCP(+)	NCP(-)	NCP(+)
Kütahya	2.97	-0.25	10.59	9.20	20.17	19.20	12.46	11.19	11.71	9.91
Dikili	9.68	7.25	15.41	14.15	24.93	24.77	18.16	17.20	17.17	15.94
Manisa	8.85	6.36	16.10	15.00	27.07	26.57	18.35	17.49	17.67	16.46
Uşak	4.03	1.95	11.55	10.63	22.86	21.69	13.98	13.11	12.88	11.90
İzmir	10.52	8.31	16.74	15.70	27.01	26.55	19.49	18.58	18.33	17.35
Aydın	9.85	7.80	16.70	15.83	27.22	26.79	18.91	18.13	17.93	17.23
Denizli	7.73	5.21	15.23	14.40	26.23	25.45	17.50	16.34	16.33	15.54
Muğla	6.87	5.16	13.49	12.62	25.28	24.44	16.61	15.83	15.37	14.58
Bodrum	12.54	10.90	17.40	16.51	27.18	26.83	20.84	19.97	19.42	18.66

TABLE VI
CORRELATION COEFFICIENTS BETWEEN NCPI AND ANNUAL AND SEASONAL PRECIPITATION TOTALS

Stations	Annual	Winter	Spring	Summer	Autumn
İzmir	-0.33**	-0.45***	0.07	0.22	-0.28*
Aydın	-0.35**	-0.47***	0.14	0.21	-0.15
Manisa	-0.37**	-0.51***	-0.05	0.38***	-0.01
Kütahya	-0.27*	-0.45***	-0.05	0.28*	0.17
Uşak	-0.19	-0.50***	0.23	0.41***	0.07
Dikili	-0.17	-0.27*	0.13	0.11	-0.30**
Denizli	-0.28*	-0.45***	0.09	0.37**	0.26*
Bodrum	-0.21	-0.38***	0.21	0.18	-0.07
Muğla	-0.27*	-0.35**	0.07	0.32**	-0.01

*** For α= 0.01 significance level ** For α=0.05 significance level * For α=0.1 significance level

TABLE VII
THE SEASONAL AND ANNUAL PRECIPITATION TOTAL VALUES (MM) OF UNDER THE EFFECT OF NCPI(-) AND NCPI(+)

	Winter		Spring		Summer		Autumn		Annual	
Stations	NCP(-)	NCP(+)	NCP(-)	NCP(+)	NCP(-)	NCP(+)	NCP(-)	NCP(+)	NCP(-)	NCP(+)
Kütahya	237.85	168.14	163.41	161.97	49.75	77.89	97.96	123.18	591.51	549.26
Dikili	350.80	285.44	120.18	140.78	12.26	13.98	147.29	127.67	604.28	586.86
Manisa	431.36	290.89	172.70	176.09	15.88	35.65	131.57	159.15	769.60	694.77
Uşak	240.62	171.76	138.83	173.99	31.69	63.14	110.25	121.98	545.90	541.74
İzmir	419.71	318.51	131.85	143.64	6.64	14.12	162.28	140.83	714.06	645.00
Aydın	353.64	258.91	147.94	157.40	16.58	25.05	134.15	128.47	671.53	585.79
Denizli	279.95	195.93	143.75	158.33	31.13	55.76	92.29	111.49	575.66	538.10
Muğla	741.66	593.59	221.99	229.49	23.40	51.52	218.14	218.50	1230.85	1129.59
Bodrum	467.05	357.09	102.46	127.05	4.40	8.44	153.42	145.92	727.04	674.04

Secondly, the annual and seasonal precipitation totals under the effect of NCPI (-) and the annual and seasonal precipitation totals under the effect of NCPI (+) were determined as indicated in Table VII. As seen in Table VII, the relationship between precipitation totals and NCPI has various situations. The precipitation total values under the effect of NCPI(-) are higher than the precipitation total values under the effect of NCPI(+) as annual and in winter season; however, reverse situation is valid for summer season. When the correlation coefficients which were presented in Table VI are taken into account, these results are consistent. Furthermore, when the effects of NCPI on annual and seasonal mean temperature are taken into consideration, it can be observed that precipitation totals under the effect of NCPI(-) and NCPI (+), are not very different from each other except for especially winter season an annual.

IV. CONCLUSIONS

The impacts of NCP on mean temperature and precipitation totals in Aegean were examined by means of calculating the correlation coefficients and then, evaluating the temperature and precipitation data with regard to NCPI (-) and NCPI (+) phases. In the light of the findings above, NCPI has remarkable effects on the annual and seasonal mean temperature. The annual and seasonal mean temperature and NCPI have highly negative correlations for either annual or seasonal except for summer season for almost all stations. In addition, the differences between mean temperature values under the NCPI (-) and NCPI (+) were calculated as annual and seasonal. It was observed that the mean temperature values under the effect of NCPI (-) are higher than the mean temperature values under the effect of NCPI (+) in terms of annual and seasonal. However, the effect of NCP on the mean temperature is very significant in spring, summer and autumn periods, the most important differences were acquired in winter season. Secondly, the same process was utilized so as

to determine the relationship between NCPI and precipitation totals. Although high correlation coefficients were observed as negatively or positively for annual data and the periods of summer and autumn in a few stations, the most remarkable negative correlation coefficients were calculated in winter season. Moreover, it was detected that the precipitation total values under the effect of NCPI(-) are higher than the precipitation total values under the effect of NCPI(+) for annual and winter periods. On the contrary, the precipitation total value under the effect of NCPI(+) are higher than the precipitation total value under the effect of NCPI(-) for summer period. When the positive correlation coefficients which were obtained in summer season, are taken into consideration, the results can be evaluated as consistent. In conclusion, NCP have crucial effects on the temperature and precipitation, particularly for winter season and annually in the Aegean region of Turkey.

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