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# Comparative Analysis for Atmospheric Oscillations

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## Abstract

In recent decades, studies on atmospheric circulations indicate that those patterns have influences on meteorological variables. This paper investigates the comparative statistical analysis of atmospheric oscillations with climatological elements. Based on analysis of the climate data obtained from observed values of meteorological station in Antalya, it was pointed that atmospheric elements such as meteorological variables were associated with atmospheric oscillations such as North Atlantic Oscillation, Arctic Oscillation, Antarctic Oscillation and Pacific-North American pattern. Spearman's rho and Kendall's tau statistics were employed to reveal the relations between atmospheric variables and atmospheric oscillations as statistically significant. Both coefficients were compared in interpreting the direction and strength of the relationships. It was seen that Spearman's rho coefficients presented more suitable values generally.

**Keywords:** Atmospheric oscillation, Meteorological variables, Spearman's rho, Kendall's tau

## Atmosferik Salınımlar için Karşılaştırmalı Analiz

## Öz

Son yıllarda, atmosferik salınımlar üzerine yapılan araştırmalar, bu modellerin iklim değişkenleri üzerinde etkili olduğunu göstermektedir. Bu makale, atmosferik salınımların klimatolojik unsurlarla karşılaştırmalı istatistiksel analizini incelemektedir. Antalya'daki meteoroloji istasyonunun gözlemlenen değerlerinden elde edilen iklim verilerinin analizine dayanarak, meteorolojik değişkenler gibi atmosferik unsurların Kuzey Atlantik Salınımı, Arktik Salınımı, Antarktika Salınımı ve Pasifik-Kuzey Amerika modeli gibi atmosferik salınımlarla ilişkili olduğuna işaret edilmiştir. Spearman's rho ve Kendall's tau istatistikleri, atmosferik değişkenler ve atmosferik salınımlar arasındaki ilişkileri istatistiksel olarak anlamlı olacak biçimde ortaya çıkarmak için kullanılmıştır. İlişkilerin yönü ve gücü yorumlanırken her iki katsayı karşılaştırılmıştır. Spearman's rho katsayılarının genel olarak daha uygun değerler verdiği görülmüştür.

**Anahtar Kelimeler:** Atmosferik salınım, Meteorolojik değişkenler, Spearman's rho, Kendall's tau

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# 1. INTRODUCTION

Climatic characteristics for any region have changed around the world over recent years. Any change climate especially affects the physical geography elements and the climate properties of urban areas. The consequences of climate change brought different effects on human life such as environmental, economic, social and health problems. The environmental deterioration such as drought that is occured in the lack of precipitation is one of the environmental problem as a result of climate change [1]. Climate change is taking the world by storm day by day and It has negative results in terms of agricultural product progress [2]. Drought due to climate change and the negative impact on agricultural areas will cause mandatory changes in land use in the coming years [3,4]. Excessive increase and decrease of temperatures negatively affect the life of living things. It will be difficult to find clean water in the future as the increase of temperatures will increase the evaporation level. Increasing or falling temperatures will cause climate change [5].

An analysis was done by Santos et. al. [6] about drought events and large-scale atmospheric circulations. The increment in the periodicity of excessive climatic occurrences that took place in late years is associated with the variations in atmospheric oscillations, wind cycles and large-scale pressures [7-10]. There has been strong relationship between precipitation and atmospheric circulation [11]. Andrade et. al. [12] revealed the relationships between precipitation and atmospheric circulation for winter. Xoplaki et. al. [13] studied on the Mediterranean precipitation variability and large scale dynamics for wet season. Zorita et. al. [14] investigated the interactions of atmospheric circulation, sea surface temperature and precipitation. In last decades, analysis of atmospheric oscillations were implemented by some researchers in various areas over the world [15-31].

The North Atlantic Oscillation (NAO) is one of the principal modes of atmospheric variability in Northern Hemisphere. NAO consists of variations in surface sea level pressure between subtropical anticyclone near Azores and subpolar cyclone near Iceland in North Atlantic [32]. North Atlantic Oscillation index (NAOi) is defined as the scale of that variation. The NAOi becomes negative or positive, respectively, depending on whether the low or high pressure value is dominant. NAOi affects especially precipitation over Turkey. For positive phase of NAOi, drier weather cases take place particularly in winter. Furthermore, in negative phase of NAOi, the systems which bring precipitation around North Atlantic have an influence on Turkey.

The Arctic Oscillation (AO) is a kind of atmospheric circulation pattern that occurs between mid and high latitudes of Northern Hemisphere. It is also known as Northern Annular Mode. The reflection of the AO's phase is the storm steering from North location to South location and the jet stream in the mid latitude. If AO index value becomes positive, it means that more drier and colder weather conditions occur in Mediterranean basin, whereas in negative value of AO index condition, more warmer and rainier weather conditions become in the Mediterranean basin [10].

The Antarctic Oscillation (AAO) is referred to as Southern Annular Mode (SAM). This pattern takes place over mid-latitudes to high latitudes in Southern Hemisphere. Its scale is defined as sea level pressure between the two latitudes mentioned above. In this region, over the extratropical Southern Hemisphere, precipitation and temperature are related closely to AAO index [33]. The Pacific-North American (PNA) pattern is another mode of atmospheric circulation around the North Pacific Ocean and near the continent North America [34]. Atmospheric oscillations, like arctic oscillation, are not only on the surface but also in the troposphere and even exist in the stratosphere [35].

Atmospheric oscillations may lead to zonal atmospheric variations and climatic conditions [36-51]. For example Arctic Oscillation led to precipitation increment [52]. Arctic Oscillation has also effect on and related to daily temperature [15]. Additionally, the interactions among atmospheric elements such as climate variables and air pollutants, as well as with each other, lead to variations in the urban climate and its characteristics [53-60]. Furthermore, some natural and anthropogenic sources enhance the air pollution level and cause the deterioration of the air quality of urbans that affect the climate charecteristics [59-63].

It has been shown that global atmospheric circulations have influenced on climate elements on recent studies [64-75]. Hence, it is important to examine the relations between climate elements and atmospheric circulations for decision makers and policy makers to manage the climate. There has also been some studies on investigating the influence of atmospheric circulations on climatic parameters for Turkey [9,10,76-81].

In present study, it was aimed to determine the difference of the two statistical methods if there exist. Climate elements were addressed over Antalya by using correlation approach, taking into account changes in the atmospheric oscillations.

## 2. MATERIAL AND METHOD

The methods Spearman's rho and Kendall's tau were employed for climate data to judge the more suitable technique for defining the relations between climate variables and atmospheric circulations. Daily atmospheric circulations data were provided by Climate Prediction Center [82] whereas daily climate data were obtained from meteorological station located in Antalya for 2011-2015 period.

The correlation coefficient is used to determine the relationship between two variables in two ways, direction and strength. Its value is in range between -1 and +1. Negative values define the negative correlation and vice versa. If the value of one of the variables increases while the other decreases, an inverse relationship is mentioned. If the sign of the correlation coefficient is positive, it means the same directional relationship. It shows that while one of the variables increases (decreases), the other increases (decreases). In the case of no relationship, correlation coefficient approaches zero, whereas in the case of strong relationship, it approaches 1 in absolute value. There has been a few correlation analysis methods used to determine the relations between the variables. In this study, Spearman's rho and Kendall's tau correlation techniques were preferred to explain the relations. The correlation coefficient is predicted for both methods to evaluate the strength of the relations between the climate elements and atmospheric circulation indices.

Before calculating the Spearman's rho correlation coefficient, observation values from large to small or small to large are sorted correctly and the sequence number is given according to this order (Sequences X and Y). Spearman's rho correlation coefficient is computed by Equation 1, as follows:

$$r_s = 1 - \frac{6\sum D_i^2}{n(n^2-1)} \quad (1)$$

where D is the difference between sequence numbers of X and Y, n is the number of observations.

Kendall's tau correlation coefficient is calculated as the difference between the number of concordant and discordant pairs divided by the geometric mean of the number of unequal pairs in series X and Y. This is shown in Equation 2.

$$\tau_b = \frac{P-Q}{\sqrt{(P+Q+T_x)(P+Q+T_y)}} \quad (2)$$

where P and Q denote the number of corcordant and discordant couples respectively, $T_x$ and $T_y$ are the number of unequal pairs in series X and Y respectively.

## 3. RESULTS AND DISCUSSION

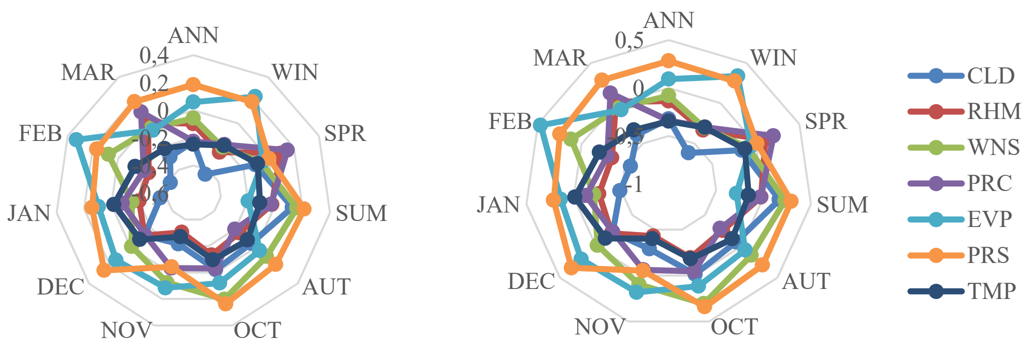
In present study, correlations of atmospheric circulation indices with seasonal (WIN, SPR, SUM, AUT) and annual (ANN) climate variables in Antalya were shown in Table 1-4 for 2011-2015 records. The 95% level of confidence is indicated with boldface characters. Climate variables such as cloud cover (CLD), relative humidity (RHM), wind speed (WNS), precipitation (PRC), evaporation (EVP), pressure (PRS), and air temperature (TMP) are denoted by their respective abbreviations. Also, the cooling period October to March (OCT, NOV, DEC, JAN, FEB, MAR) was evaluated for clarifying the relations in more detail. In addition, cross-correlations between atmospheric oscillations during different periods were presented in Table 5-6. The correlation coefficients of Kendall's tau and Spearman's rho were named as Kt_CC and Sr_CC, respectively.

**Table 1.** Correlations for North Atlantic Oscillation index

| PERIOD | STATISTIC | CLD | RHM | WNS | PRC | EVP | PRS | TMP |
|---|---|---|---|---|---|---|---|---|
| ANN | Kt_CC | **-,227(*)** | -0,097 | -0,057 | **-,225(*)** | 0,06 | **0,186** | **-,246(*)** |
| | Sr_CC | **-,323(*)** | -0,137 | -0,08 | **-,340(*)** | 0,092 | **,282(*)** | **-,347(*)** |
| WIN | Kt_CC | **-,439(**)** | **-,248(*)** | **-,206(*)** | **-0,182** | **,231(*)** | 0,187 | **-0,19** |
| | Sr_CC | **-,617(**)** | **-,335(*)** | **-,307(*)** | **-,298(*)** | **,336(*)** | 0,274 | **-,302(*)** |
| SPR | Kt_CC | -0,105 | 0,093 | -0,06 | 0,149 | -0,048 | 0,003 | -0,087 |
| | Sr_CC | -0,16 | 0,109 | -0,089 | 0,202 | -0,056 | 0,014 | -0,125 |
| SUM | Kt_CC | 0,125 | -0,025 | 0,158 | -0,032 | **-,198(*)** | **,211(*)** | -0,112 |
| | Sr_CC | 0,167 | -0,026 | 0,227 | -0,028 | **-0,284** | **,292(*)** | -0,157 |
| AUT | Kt_CC | -0,045 | -0,16 | 0,101 | **-,200(*)** | 0,036 | **0,19** | -0,081 |
| | Sr_CC | -0,071 | -0,255 | 0,141 | **-0,287** | 0,057 | **,297(*)** | -0,122 |
| OCT | Kt_CC | -0,021 | -0,132 | **,202(*)** | -0,03 | 0,079 | **,237(*)** | -0,096 |
| | Sr_CC | -0,015 | -0,194 | **,305(*)** | -0,046 | 0,114 | **,339(*)** | -0,183 |
| NOV | Kt_CC | **-,216(*)** | **-,304(**)** | 0,076 | -0,033 | 0,116 | -0,043 | **-,270(**)** |
| | Sr_CC | **-,291(*)** | **-,431(**)** | 0,096 | -0,063 | 0,182 | -0,054 | **-,401(**)** |
| DEC | Kt_CC | -0,133 | -0,132 | -0,009 | -0,137 | 0,141 | **,255(**)** | -0,087 |
| | Sr_CC | -0,229 | -0,211 | -0,018 | -0,23 | 0,205 | **,341(*)** | -0,129 |
| JAN | Kt_CC | **-,359(**)** | **-,204(*)** | -0,151 | -0,081 | 0,094 | 0,141 | -0,019 |
| | Sr_CC | **-,488(**)** | **-0,265** | -0,213 | -0,129 | 0,138 | 0,212 | -0,013 |
| FEB | Kt_CC | **-,418(**)** | **-,245(*)** | 0,076 | **-,206(*)** | **,331(**)** | 0,168 | -0,137 |
| | Sr_CC | **-,564(**)** | **-,349(*)** | 0,119 | **-,299(*)** | **,468(**)** | 0,247 | -0,207 |
| MAR | Kt_CC | **-,289(**)** | 0,008 | -0,039 | 0,099 | -0,059 | **0,187** | **-,216(*)** |
| | Sr_CC | **-,391(**)** | 0,016 | -0,056 | 0,123 | -0,083 | **,285(*)** | **-,332(*)** |

***. Correlation is significant at the 0.01 level (p<0.01) & *. Correlation is significant at the 0.05 level (p<0.05).*

According to Table 1, North Atlantic Oscillation index was associated with climate elements in low and medium degree. CLD, RHM, PRC and TMP were related to NAO as negatively whereas EVP, PRS as positively. WNS was related to NAO as negatively in WIN and positively in OCT. These relations were also shown in Figure 1.



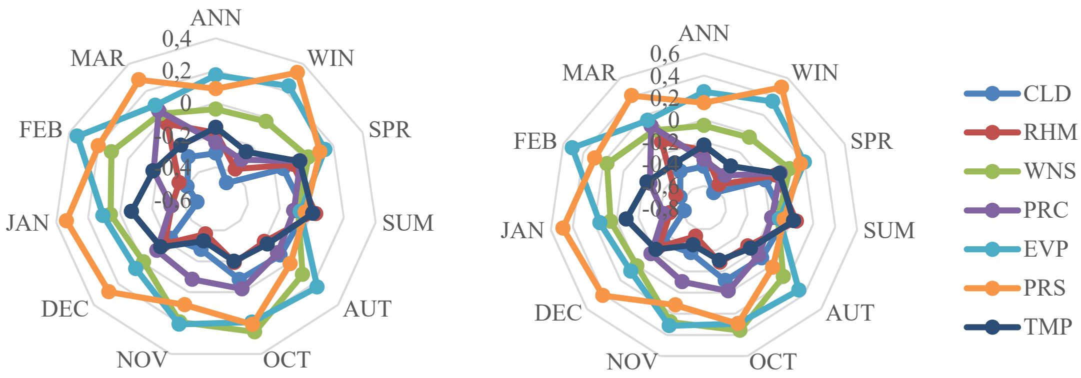

(a) (b)

**Figure 1.** Correlation coefficients for North Atlantic Oscillation index (a) Kt_CC (b) Sr_CC

**Table 2.** Correlations for Arctic Oscillation index

| PERIOD | STATISTIC | CLD | RHM | WNS | PRC | EVP | PRS | TMP |
|---|---|---|---|---|---|---|---|---|
| ANN | Kt_CC | **-,313(**)** | -0,186 | -0,04 | **-,247(*)** | 0,172 | 0,087 | -0,153 |
| | Sr_CC | **-,424(**)** | -0,276 | -0,053 | **-,360(*)** | 0,253 | 0,153 | -0,231 |
| WIN | Kt_CC | **-,478(**)** | **-,376(**)** | -0,025 | **-,307(**)** | **,237(*)** | **,336(**)** | **-,249(*)** |
| | Sr_CC | **-,637(**)** | **-,549(**)** | -0,04 | **-,450(**)** | **,348(*)** | **,500(**)** | **-,349(*)** |
| SPR | Kt_CC | -0,141 | -0,076 | 0,031 | -0,025 | 0,143 | 0,11 | -0,029 |
| | Sr_CC | -0,191 | -0,086 | 0,052 | -0,041 | 0,2 | 0,161 | -0,05 |
| SUM | Kt_CC | -0,042 | 0,026 | -0,086 | -0,112 | -0,071 | -0,04 | 0,007 |
| | Sr_CC | -0,065 | 0,046 | -0,124 | -0,181 | -0,11 | -0,068 | 0,02 |
| AUT | Kt_CC | -0,072 | **-,201(*)** | 0,111 | -0,093 | **,231(*)** | 0,01 | -0,177 |
| | Sr_CC | -0,108 | **-0,274** | 0,15 | -0,145 | **,336(*)** | 0,023 | -0,243 |
| OCT | Kt_CC | -0,082 | -0,191 | **,257(*)** | -0,021 | **0,194** | **,209(*)** | **-,200(*)** |
| | Sr_CC | -0,114 | -0,286 | **,357(*)** | -0,016 | **,293(*)** | **,293(*)** | **-,305(*)** |
| NOV | Kt_CC | **-,276(**)** | **-,376(**)** | 0,193 | -0,083 | **,208(*)** | 0,082 | **-,331(**)** |
| | Sr_CC | **-,377(**)** | **-,532(**)** | 0,277 | -0,103 | **,313(*)** | 0,117 | **-,451(**)** |
| DEC | Kt_CC | **-,230(*)** | -0,179 | -0,008 | -0,117 | 0,056 | **,276(**)** | -0,149 |
| | Sr_CC | **-,313(*)** | -0,262 | 0,002 | -0,166 | 0,076 | **,412(**)** | -0,225 |
| JAN | Kt_CC | **-,483(**)** | **-,323(**)** | 0,059 | **-,320(**)** | 0,106 | **,335(**)** | -0,072 |
| | Sr_CC | **-,620(**)** | **-,489(**)** | 0,053 | **-,432(**)** | 0,151 | **,489(**)** | -0,089 |
| FEB | Kt_CC | **-,405(**)** | **-,350(**)** | 0,111 | -0,175 | **,344(**)** | **,200(*)** | -0,173 |
| | Sr_CC | **-,563(**)** | **-,521(**)** | 0,165 | -0,263 | **,511(**)** | **,287(*)** | -0,234 |
| MAR | Kt_CC | **-,286(**)** | -0,042 | 0,033 | 0,055 | 0,094 | **,283(**)** | **-,201(*)** |
| | Sr_CC | **-,404(**)** | -0,089 | 0,038 | 0,083 | 0,143 | **,410(**)** | **-,316(*)** |

Similar to NAO, AO was associated with climate variables in low and medium degrees (Table 2, Figure 2). CLD was generally related to AO in low and medium degrees with a negative direction. In addition, RHM, PRC and TMP have similar behaviours with AO by relating in low and medium degrees as negatively. WNS and PRS have a positive relation with AO in low and medium scales.




(a) (b)

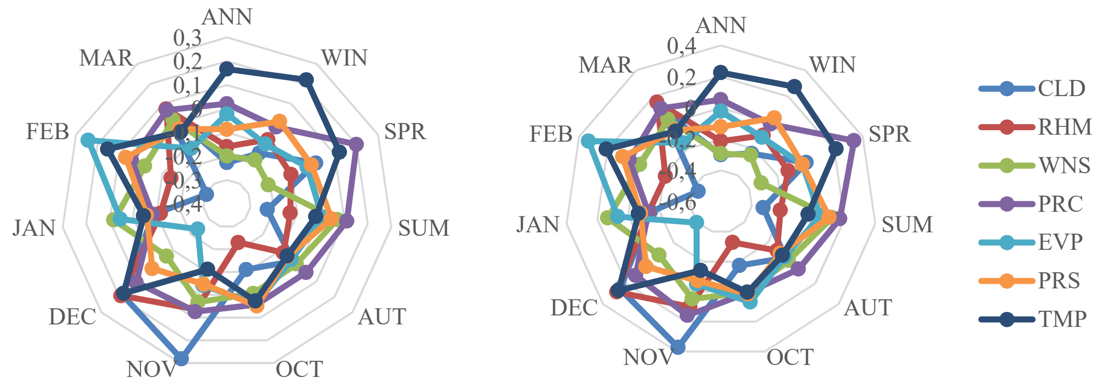
**Figure 2.** Correlation coefficients for Arctic Oscillation index (a) Kt_CC (b) Sr_CC

**Table 3.** Correlations for Antarctic Oscillation index

| PERIOD | STATISTIC | CLD | RHM | WNS | PRC | EVP | PRS | TMP |
|---|---|---|---|---|---|---|---|---|
| ANN | Kt_CC | -0,227 | -0,159 | -0,199 | 0,021 | -0,022 | -0,087 | 0,167 |
| | Sr_CC | -0,3 | -0,212 | -0,292 | 0,053 | -0,021 | -0,121 | 0,226 |
| WIN | Kt_CC | -0,147 | -0,079 | -0,181 | -0,016 | -0,101 | 0,012 | 0,22 |
| | Sr_CC | -0,234 | -0,095 | -0,245 | -0,01 | -0,111 | 0,037 | 0,275 |
| SPR | Kt_CC | 0,012 | -0,103 | -0,208 | 0,201 | -0,028 | -0,008 | 0,122 |
| | Sr_CC | 0,003 | -0,125 | -0,314 | 0,339 | -0,025 | -0,025 | 0,213 |
| SUM | Kt_CC | -0,228 | -0,13 | 0,07 | 0,111 | 0,006 | 0,045 | -0,021 |
| | Sr_CC | -0,325 | -0,214 | 0,12 | 0,171 | 0,043 | 0,102 | -0,034 |
| AUT | Kt_CC | -0,03 | -0,085 | -0,013 | 0,042 | -0,041 | -0,061 | -0,064 |
| | Sr_CC | -0,052 | -0,122 | -0,026 | 0,059 | -0,06 | -0,095 | -0,076 |
| OCT | Kt_CC | -0,111 | -0,23 | -0,006 | 0,043 | 0,039 | 0,049 | 0,027 |
| | Sr_CC | -0,174 | -0,328 | 0,004 | 0,007 | 0,07 | 0,015 | 0,005 |
| NOV | Kt_CC | **,281(*)** | 0,064 | 0,032 | 0,074 | -0,041 | -0,047 | -0,112 |
| | Sr_CC | **,372(*)** | 0,101 | 0,049 | 0,159 | -0,051 | -0,073 | -0,141 |
| DEC | Kt_CC | 0,184 | 0,191 | -0,063 | 0,106 | -0,237 | 0,017 | 0,176 |
| | Sr_CC | 0,254 | 0,282 | -0,077 | 0,122 | **-,395(*)** | 0,035 | 0,268 |
| JAN | Kt_CC | -0,088 | -0,117 | 0,082 | -0,083 | 0,054 | -0,058 | -0,045 |
| | Sr_CC | -0,145 | -0,133 | 0,132 | -0,129 | 0,068 | -0,081 | -0,067 |
| FEB | Kt_CC | **-,306(*)** | -0,141 | -0,019 | 0,042 | 0,243 | 0,069 | 0,153 |
| | Sr_CC | **-,441(*)** | -0,21 | -0,029 | 0,044 | 0,332 | 0,091 | 0,207 |
| MAR | Kt_CC | 0,073 | 0,074 | 0,019 | 0,069 | -0,123 | -0,026 | -0,04 |
| | Sr_CC | 0,099 | 0,156 | 0,027 | 0,11 | -0,153 | -0,058 | -0,064 |

***. Correlation is significant at the 0.01 level ($p<0.01$) & *. Correlation is significant at the 0.05 level ($p<0.05$).*

Table 3 and Figure 3 indicate the correlations between the Antartic Oscillation and climate elements. The relations for Antarctic Oscillation index have no statiscally significant results except the periods NOV, DEC and FEB. In NOV and FEB, CLD was related to NAO in low degree as positively and inversely, respectively. In DEC, EVP was ossociated with NAO negatively in low degree.




(a) (b)

**Figure 3.** Correlation coefficients for Antarctic Oscillation index (a) Kt_CC (b) Sr_CC

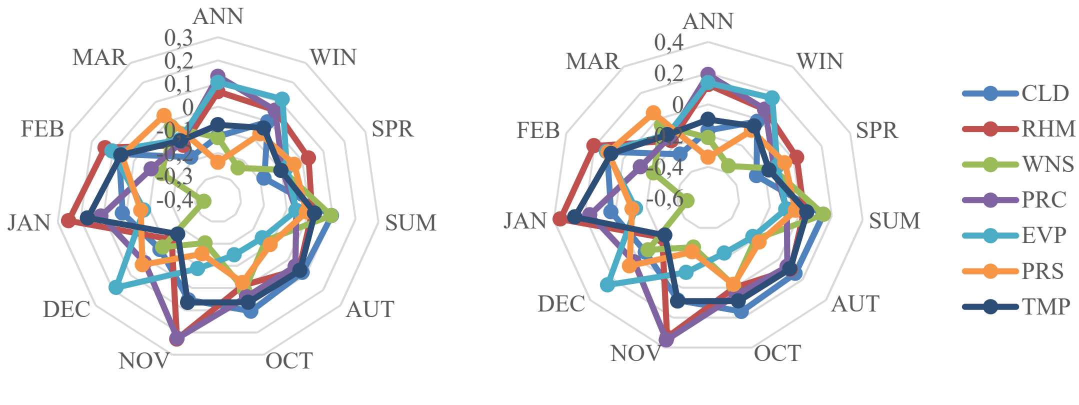
**Table 4.** Correlations for Pacific North American pattern

| PERIOD | STATISTIC | CLD | RHM | WNS | PRC | EVP | PRS | TMP |
|---|---|---|---|---|---|---|---|---|
| ANN | Kt_CC | -0,128 | 0,065 | -0,134 | 0,131 | 0,105 | **-,240(*)** | -0,078 |
| | Sr_CC | -0,167 | 0,126 | -0,214 | 0,19 | 0,138 | **-,340(*)** | -0,097 |
| WIN | Kt_CC | -0,002 | 0,057 | **-,239(*)** | 0,057 | 0,114 | -0,064 | -0,034 |
| | Sr_CC | -0,017 | 0,073 | **-,357(*)** | 0,075 | 0,161 | -0,086 | -0,053 |
| SPR | Kt_CC | -0,181 | 0,03 | -0,095 | -0,094 | -0,074 | -0,038 | -0,101 |
| | Sr_CC | -0,258 | 0,025 | -0,146 | -0,136 | -0,113 | -0,059 | -0,17 |
| SUM | Kt_CC | 0,096 | 0,01 | 0,094 | -0,058 | -0,059 | -0,014 | 0,022 |
| | Sr_CC | 0,146 | 0,021 | 0,148 | -0,09 | -0,096 | -0,034 | 0,04 |
| AUT | Kt_CC | 0,082 | 0,063 | -0,128 | 0,042 | -0,146 | -0,101 | 0,069 |
| | Sr_CC | 0,139 | 0,1 | -0,198 | 0,071 | -0,22 | -0,167 | 0,094 |
| OCT | Kt_CC | 0,104 | -0,013 | 0,009 | 0,039 | -0,15 | -0,025 | 0,064 |
| | Sr_CC | 0,159 | -0,001 | -0,013 | 0,046 | -0,231 | -0,021 | 0,089 |
| NOV | Kt_CC | 0,053 | **,230(*)** | **-,203(*)** | **,226(*)** | -0,088 | -0,154 | 0,065 |
| | Sr_CC | 0,084 | **,331(*)** | **-0,27** | **,349(*)** | -0,102 | -0,239 | 0,09 |
| DEC | Kt_CC | -0,069 | -0,135 | -0,084 | 0,019 | 0,182 | 0,032 | -0,17 |
| | Sr_CC | -0,069 | -0,212 | -0,091 | 0,027 | 0,252 | 0,066 | -0,234 |
| JAN | Kt_CC | 0,017 | **,252(*)** | **-,339(**)** | 0,111 | -0,076 | -0,063 | 0,169 |
| | Sr_CC | 0,029 | **,357(*)** | **-,465(**)** | 0,165 | -0,131 | -0,108 | 0,263 |
| FEB | Kt_CC | 0,07 | 0,136 | -0,133 | -0,083 | 0,103 | 0,057 | 0,061 |
| | Sr_CC | 0,112 | 0,203 | -0,216 | -0,123 | 0,116 | 0,105 | 0,083 |
| MAR | Kt_CC | -0,184 | -0,123 | -0,028 | -0,106 | -0,095 | 0,03 | -0,1 |
| | Sr_CC | -0,268 | -0,165 | -0,048 | -0,139 | -0,118 | 0,047 | -0,119 |

***. Correlation is significant at the 0.01 level ($p<0.01$) & *. Correlation is significant at the 0.05 level ($p<0.05$).*

As shown in Table 4, PNA has the correlation with RHM and PRC in positive direction and low strength as statistically significant. On the contrary, WNS and PRS have negative relation with PNA in low scale.

Furthermore, cross-correlations for atmospheric oscillation indices were estimated by statistical analysis and the results were presented in Table 5 and 6. Table 5 was arranged for annual and seasonal terms whereas Table 6 for cooling period. For annual and seasonal terms AAO has no significant correlation with other atmospheric circulations while it was apparently related to NAO and AO as positively and PNA as negatively in February during cooling period. All atmospheric circulations except AAO have significant correlations during all time periods in different scales. The direction of pairwises was generally obtained as positive for NAO-AO (shown in Figure 5) and negative for NAO-AAO, NAO-PNA, AO-AAO, AO-PNA, and AAO-PNA.




(a) (b)

**Figure 4.** Correlation coefficients for Pacific North American pattern (a) Kt_CC (b) Sr_CC

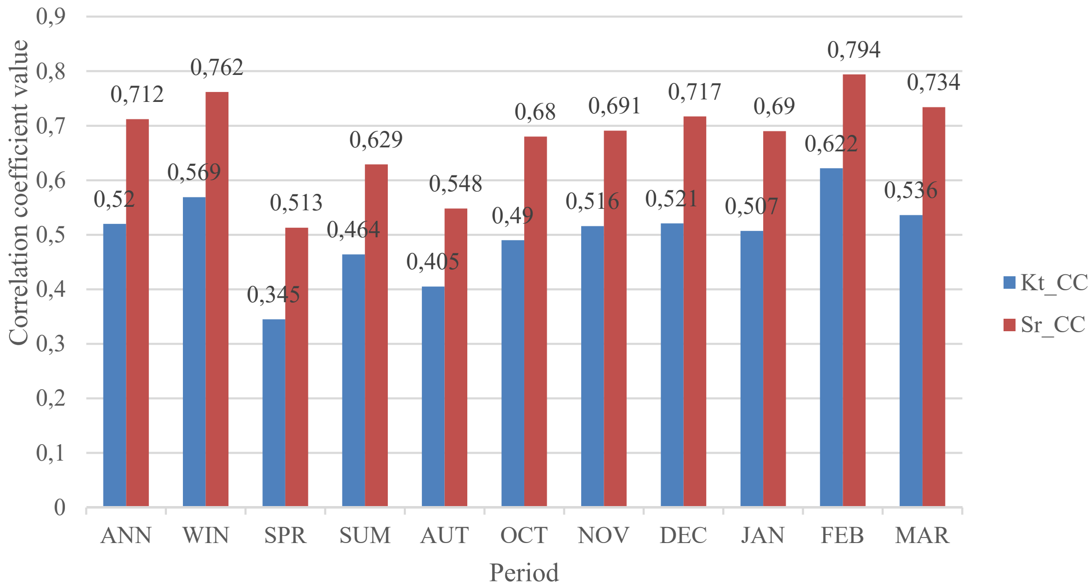



**Figure 5.** Correlations between North Atlantic Oscillation and Arctic Oscillation

**Table 5.** Cross-Correlations for atmospheric oscillations during different periods

| | | Kendall's tau | | | | Spearman's rho | | | |
|---|---|---|---|---|---|---|---|---|---|
| PERIOD | INDEX | NAO | AO | AAO | PNA | NAO | AO | AAO | PNA |
| ANN | NAO | 1 | **,520(**)** | -0,089 | -0,177 | 1 | **,712(**)** | -0,123 | -0,27 |
| | AO | | 1 | -0,032 | **-,221(*)** | | 1 | -0,048 | **-,297(*)** |
| | AAO | | | 1 | -0,026 | | | 1 | -0,042 |
| | PNA | | | | 1 | | | | 1 |
| WIN | NAO | 1 | **,569(**)** | -0,024 | 0,022 | 1 | **,762(**)** | -0,013 | 0,038 |
| | AO | | 1 | 0,117 | -0,158 | | 1 | 0,162 | -0,226 |
| | AAO | | | 1 | -0,087 | | | 1 | -0,137 |
| | PNA | | | | 1 | | | | 1 |
| SPR | NAO | 1 | **,345(**)** | -0,099 | -0,045 | 1 | **,513(**)** | -0,182 | -0,078 |
| | AO | | 1 | -0,093 | **-,387(**)** | | 1 | -0,15 | **-,552(**)** |
| | AAO | | | 1 | -0,121 | | | 1 | -0,203 |
| | PNA | | | | 1 | | | | 1 |
| SUM | NAO | 1 | **,464(**)** | -0,071 | 0,031 | 1 | **,629(**)** | -0,113 | 0,063 |
| | AO | | 1 | -0,028 | 0,131 | | 1 | -0,046 | 0,183 |
| | AAO | | | 1 | 0,212 | | | 1 | 0,343 |
| | PNA | | | | 1 | | | | 1 |
| AUT | NAO | 1 | **,405(**)** | 0,194 | 0,052 | 1 | **,548(**)** | 0,255 | 0,071 |
| | AO | | 1 | 0,161 | **-,190(*)** | | 1 | 0,219 | **-,280(*)** |
| | AAO | | | 1 | 0 | | | 1 | -0,015 |
| | PNA | | | | 1 | | | | 1 |

***. Correlation is significant at the 0.01 level (p<0.01) & *. Correlation is significant at the 0.05 level (p<0.05).*

**Table 6.** Cross-Correlations for atmospheric oscillations for cooling period

| | | Kendall's tau | | | | Spearman's rho | | | |
|---|---|---|---|---|---|---|---|---|---|
| PERIOD | INDEX | NAO | AO | AAO | PNA | NAO | AO | AAO | PNA |
| OCT | NAO | 1 | **,490(**)** | 0,242 | 0,051 | 1 | **,680(**)** | 0,348 | 0,08 |
| | AO | | 1 | 0,198 | -0,036 | | 1 | 0,308 | -0,041 |
| | AAO | | | 1 | 0,184 | | | 1 | 0,258 |
| | PNA | | | | 1 | | | | 1 |
| NOV | NAO | 1 | **,516(**)** | -0,052 | 0,002 | 1 | **,691(**)** | -0,081 | 0,007 |
| | AO | | 1 | 0,01 | **-,230(*)** | | 1 | 0,002 | **-,338(*)** |
| | AAO | | | 1 | 0,008 | | | 1 | -0,002 |
| | PNA | | | | 1 | | | | 1 |
| DEC | NAO | 1 | **,521(**)** | -0,03 | 0,094 | 1 | **,717(**)** | -0,013 | 0,116 |
| | AO | | 1 | -0,056 | -0,108 | | 1 | -0,059 | -0,162 |
| | AAO | | | 1 | 0,014 | | | 1 | 0,034 |
| | PNA | | | | 1 | | | | 1 |
| JAN | NAO | 1 | **,507(**)** | 0,067 | -0,034 | 1 | **,690(**)** | 0,036 | -0,057 |
| | AO | | 1 | 0,093 | -0,173 | | 1 | 0,124 | -0,238 |
| | AAO | | | 1 | -0,222 | | | 1 | -0,343 |
| | PNA | | | | 1 | | | | 1 |
| FEB | NAO | 1 | **,622(**)** | **,299(*)** | -0,026 | 1 | **,794(**)** | **,431(*)** | -0,053 |
| | AO | | 1 | **,349(**)** | -0,177 | | 1 | **,465(**)** | -0,269 |
| | AAO | | | 1 | **-,297(*)** | | | 1 | **-,416(*)** |
| | PNA | | | | 1 | | | | 1 |
| MAR | NAO | 1 | **,536(**)** | 0,145 | -0,046 | 1 | **,734(**)** | 0,225 | -0,069 |
| | AO | | 1 | 0,008 | **-,226(*)** | | 1 | 0,067 | **-,315(*)** |
| | AAO | | | 1 | -0,239 | | | 1 | -0,306 |
| | PNA | | | | 1 | | | | 1 |

***. Correlation is significant at the 0.01 level (p<0.01) & *. Correlation is significant at the 0.05 level (p<0.05).).*

According to the findings, Spearman's rho is the most suitable statistical method to explain the relations between climate elements and circulation indices. Statistically significant correlations were obtained between atmospheric circulation indices and precipitation over Mediterranean basin [68]. NAO has a significant role on climate elements but especially in winter precipitation variability, relative humidity and cloudiness. AO has effect on climate variables in all periods except spring and summer. AAO affected evaporation on December whereas cloudiness on November and February. PNA has influence on climatic variables such as wind speed, precipitation and relative humidity in November and January, additionally pressure in annual period

## 4. CONCLUSION

The relations between climate elements and atmospheric oscillations for 2011-2015 records in Antalya were investigated in the present study. One goal of this analysis was to present how climate elements were varying with atmospheric circulations. Those results were deduced from daily ground-based measurement records at meteorological station.

In this study, two statistical techniques were implemented to determine the statistical analysis. Spearman's rho and Kendall's tau correlation coefficients were used to determine the degree of relationship between variables. Both coefficients were compared in interpreting the direction and strength of the relationships. According to the results, Spearman's rho coefficients presented more suitable values generally. Looking at the literature, we see that Spearman's Rho and Kendall correlation tests are frequently used for the evaluation of climate parameters. Evaluation of climate parameters with such correlation tests will result in high accuracy of climate forecasts [83-86].

Climate change has put the world at risk as a result of increased carbon emissions and greenhouse gas emissions. The level of $CO_2$ reduces the protective use of the bard layer. As a result of this action, it produces unpredictable precipitation and severe temperature increases [87].

It has been shown that various global atmospheric circulations have influences on and related to climate elements [2,29,38,41,46,47,51,88]. It is presumably to affect the climate elements and extreme climatic events in the future. Hence, it is important to examine the relations between climate elements and atmospheric oscillations for stakeholders involved and policymakers to manage the climate.

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