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Correlation of Winter Temperature at Tripoli City, Shahāt, Sebhā and Al-Kufra Sites (Libya) and Large Scale Tele-Connection Indices

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Abstract

The impact of two winter atmospheric large scale tele-connection indices; North Atlantic Oscillation (NAO) and Arctic Oscillation (AO), on winter temperature at four different locations in Libya is presented. Winter temperature data series for 31 years (1980-2010) were analyzed using two different correlation analysis techniques. One is parametric (Pearson Correlation method) and the other is non-parametric (Spearman Correlation method). A scatter plot display along with the magnitude comparison between Pearson's and Spearman's coefficients showed that the relationship is linear. Winter temperature at all sites is negatively correlated to both NAO and AO. It is evident that the calculated Pearson's correlation coefficients is large and highly significant compared to Spearman's coefficients which are less in magnitude and low in significance, particularly for the correlation with AO. The results indicate that the inverse relationship of NAO and AO with the winter temperatures is stronger in the southern than in the northern regions. Mediterranean seawater could have played an important role in the modulation of coastal regions' winter temperatures. According to the obtained results, NAO and AO should certainly be considered as important factors in determining winter temperature variability in Libya although other factors (beyond the scope of this study) might have some role.

Keywords: North Atlantic Oscillation; Arctic Oscillation; Winter temperature; Tele-connection indices; Correlation coefficient

المستخلص

يعد التأثير الناتج عن مؤشري التذبذب الشتوي واسع النطاق في الغلاف الجوي، وهما مؤشر تذبذب شمال الأطلسي و مؤشر تذبذب القطب الشمالي، على درجة الحرارة الشتوية في أربع مواقع مختلفة في ليبيا. والذي تم عرضه في هذه الدراسة باستخدام معاملين مختلفين للإرتباط (معامل بيرسون ومعامل سبيرمان) بين درجات الحرارة الشتوية ومؤشري التذبذب المذكورين للفترة (1980 – 2010). بتوظيف المخطط المبعثر وبمقارنة قيم كلا المعاملين إتضح العلاقة بين درجات

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الحرارة الشتوية و مؤشري التذبذب في كل مواقع الدراسة كانت خطية والإرتباط سلبياً. تدل نتائج الدراسة أن معامل إرتباط بيرسون كان أكبر و ذو درجة معنوية أعلى مقارنةً بمعامل سبيرمان وهو ما يؤكد خطية العلاقة. أوضحت الدراسة أيضاً أن مقدار الإرتباط السلبي بالنسبة لمدينتي سبها والكفرة أكبر منه بالنسبة لمدينتي طرابلس و شحات وهو ما يقود إلى الإعتقاد بأن التأثير السلبي على درجات الحرارة الشتوية بسبب المؤشرين أكبر في المناطق الجنوبية منه في المناطق الشمالية وبالأخص على الساحل الليبي. السبب ربما يرد إلى الدور الذي تلعبه مياه البحر المتوسط في تعديل أو تلطيف درجات الحرارة الشتوية للمناطق الساحلية وغياب هذا الدور في الجنوب مما يترتب عليه تبريد أكبر وبالتالي زيادة في قوة الإرتباط بين مؤشري التذبذب و درجات الحرارة الشتوية الجنوبية. عطفاً على ما سبق، تبين أن مؤشر تذبذب شمال الأطلسي و مؤشر تذبذب القطب الشمالي بالإمكان اعتبارهما عاملان مهمان في تغير درجة الحرارة الشتوية في ليبيا.

Introduction

In the lower tropospheric layer between the earth's surface and an altitude of five kilometers, the North Atlantic Oscillation (NAO) is typically regarded as the primary regional teleconnection and is linked to observed climatological and oceanographic variability (Van Loon and Rogers, 1978; Lamb and Peppler; 1987; Mann and Drinkwater, 1994; Hurrell, 1995; Mitchell and Blier, 1997). The NAO is the most important pattern of atmospheric circulation variability and is the only atmospheric mode that can be clearly noticed during the whole year in the northern hemisphere (Hurrel et al., 2003). It is responsible for inter-annual climate variability in major parts of the northern hemisphere including the Mediterranean and North Africa, particularly during winter season (Hurrel and Deser, 2009; Visente-Serrano et al., 2011).

NAO reflects fluctuations in atmospheric pressure at sea-level between the Icelandic Low pressure and the Azores High pressure. The sea level atmospheric pressure difference between two chosen points so that one is in Gibraltar and the other one lies in the southwest of Iceland is called NAO index (Jones et al., 1997). A positive NAO index implies relatively strong westerly winds across the mid-latitudes of the Atlantic to Europe, resulting in cool, wet summers and mild, wet winters in Europe and to cold and dry winters in Greenland. In contrast, when the NAO is negative, European winters will be cold, while Greenland will have milder winter temperatures. The NAO is associated with many meteorological variations in North Atlantic region, affecting wind speed and direction and differences in temperature and rainfall (Hurrell, 1995 and Hurrel et al., 2003).

The Arctic Oscillation (AO) climatic index is shown to be correlated with inter-annual climate variability in the Northern Hemisphere. The AO is a dominatant mode of atmospheric mean-monthly sea level pressure variability over the Northern Hemisphere with an out-of-phase relation between the sea level pressure over the Arctic base and at the mid-latitudes (Thompson and Wallace, 1998). AO is characterized by a meridional dipole in sea level atmospheric pressure between Polar Regions and mid-latitudes. It could be interpreted as the surface signature of modulations in the strength of the polar vortex aloft. When the AO index is positive (characterized by a strengthening of the polar vortex), surface pressure is low in the polar region, and the opposite occurs when the index is negative. Relationships between the

AO index and Surface Air Temperature (SAT), are extensively documented over different parts of the globe (Thompson et al., 2000; Wettstein and Mearns, 2002; Burrmann et al., 2003).

In the past 15 years, several studies have indicated that variations in monthly and seasonal temperature over a large part of the northern hemisphere are controlled by various teleconnection patterns such as the NAO and AO (Del Rio et al., 2013). In the Mediterranean Basin, various studies have been conducted regarding the type of the relationship between large scale Tele-connection indices and winter temperature variability. Bozyurt and Ozdemir (2014) noticed that across Turkey there is a significant negative correlation between average winter temperature values and NAO. However, the response of the sites toward NAO and degree of significance weakens eastward. Interestingly, the results revealed that the effect of NAO on temperature (the strength of correlation) is larger for inland continental sites than the coastal ones. Regionally, Hasanean (2004) conducted a correlation analysis between number of atmospheric circulation indices and winter temperature in Egypt and revealed a statistically significant negative relationship with NAO, in particular.

Despite the fact that the teleconnection between oceanic-atmospheric indices (NAO, AO) and air temperature was presented by some studies as a prime responsible for the inter annual as well as seasonal temperature variability over different regions in the globe, the relationships between regional air temperature in Libya, particularly winter temperatures and such indices have not yet been comprehensively examined. The aim of this study is to carry out a detailed correlation analysis between winter temperatures and the two atmospheric circulation indices, NAO and AO over the period 1980-2010. The type of relationship, strength of correlation and a brief comparison between the targeted sites will be examined.

Data and Methodology

Data Source

Data series of winter temperature were obtained from the NCEP/NCAR (National Centre for Environmental Prediction/National centre for Atmospheric research) Updated 40-Year Re-analysis Project (Kalany et al., 1996). The NCEP and NCAR are cooperating in a project denoted reanalysis, in which a numerous amount of global climatic data; e.g. air temperature, precipitation etc, are available for the needs of the research and climate monitoring communities. Data are obtained from land surface, ships, aircrafts, satellite, and other sources and have been well treated in terms of homogeneity and quality. The data length covers the period (1980-2010) for the targeted sites in Libya namely; Tripoli, Shahāt, Sebha and Al-Kufra (Fig. 1). NAO indices and AO indices have been compiled from Climate Data Guide (Hurrel, 2020) and National Climatic Data Center (NCDC) in the National Oceanic and Atmospheric Administration (NCDC and NOAA, 2020), respectively. The initial available formats of the data were monthly series compatible with other regional climatological studies. The three common months (December, January and February) were used to represent winter season. Therefore, the mean value of the above 3 months concerning any variable (Temperature, NAO and AO) is simply corresponding to the winter season value.

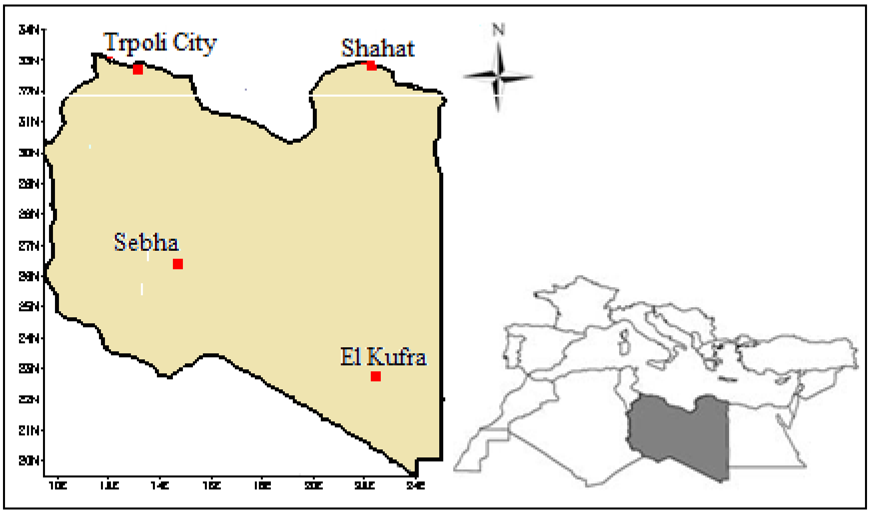

Fig. 1. The geographical location of the study sites (Tripoli, Shahāt, Sebhā, Al Kufra) on the map of Libya.

Data Standardization

Standardization is a crucial approach for multivariate analysis of climate data for the following two reasons:

1. Climatic elements (e.g. Temperature and Precipitation) have different units and scales (e.g. degrees Celsius and millimeters), so the standardization process cancels the units of the different variables and make them unit-less.
2. When data standardized, the mean value of any variable or element is equal to zero which makes climate analysis (e.g. comparison, spatial coverage etc.) between different variables easy to conduct.

In standardization process, the 1st step is that the (1961-1990) reference period mean for each winter variable (Temperature, NAO, AO) is subtracted from the winter season values over the targeted study period (1980-2010). The 2nd step is the division of the outcomes from 1st step by the standard deviations of the same reference period. The resultant values are then called the standardized anomalies which fluctuate between positive (above normal) and negative (below normal) and the normal or the mean is valued zero (see Bhutiyani, 2007).

Correlation Coefficient

As the main objective of this study is to examine the strength of the relationship (correlation) between winter temperature variability at study sites in Libya and large-scale Tele-connection indices, it was appropriate to use Pearson Correlation Coefficient (r). As Pearson test is a measure of a linear relationship between two variables and in our study the presence of such linearity might not exist due to the randomness variation of the variables that have been utilized, it was crucial to deploy another test that measures the monotonic or the nonlinearity relationship between random variables. The perfect and closest test in this case is the Spearman Correlation Coefficient (ρ). Moreover, comparison between two different correlation coefficients gives clear idea about the type of relationship between any two targeted variables. Therefore the calculation of both coefficients and comparison between their values is indeed needed. It has been suggested that if $\rho > r$, the correlation is monotonic and hence the relationship between the variables is nonlinear. On the other hand, the relationship is linear if $r > \rho$ (Thiele, 2017).

Usually in these situations, plotting the data on a scatter plot diagram as a starting point, demonstrates schematically the expected type of relationship. If data points are clustering symmetrically around the regression line, the relationship is trusted to be linear (Fig. 2). Correlation coefficient is a measure of association between two variables, and it ranges between –1 and 1. If the two variables are in perfect linear relationship, the correlation coefficient will be either 1 or –1. Fig. 2, shows that for the negative correlation, if the independent variable increases the dependent variable decreases and vice versa. Considering the positive correlation, any increase in the idependent variable is associated with an increase in dependent variable and vice versa. If the independent variable increases and the dependent variable neither increase nor decrease, there is No correlation.

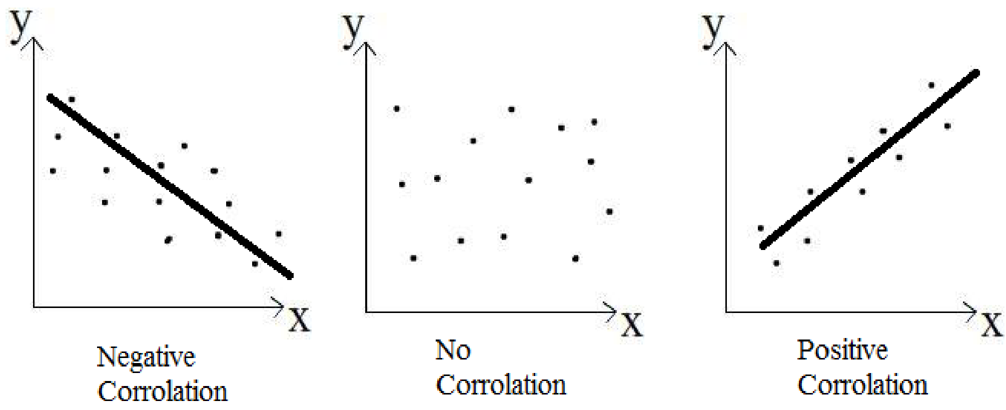

Fig. 2. Types of correlation between two variables, x and y.

Calculation of Pearson Correlation Coefficient (r)

Given paired measurements $(x_1,y_1), (x_2,y_2), \ldots, (x_n, y_n)$, the Pearson correlation coefficient is calculated by means of the following equation;

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \ \sum_i (y_i - \bar{y})^2}} ------(1)$$

Where,

x_i = values of the *x*-variable

$\bar{x}$ = mean of the values of *x*-variable

y_i = values of the *x*-variable
$\bar{y}$ = mean of the values of *y*-variable

The calculation of Pearson's correlation coefficient and subsequent significance testing of it requires the following data assumptions to hold: interval or ratio level; linearly related; bivariate normally distributed.

Correlation is an effect size and therefore the strength of the correlation can be described verbally using the guide presented below for the absolute value of r :

1. .00 - .19 " very weak "
2. .20 - .39 " weak "
3. .40 - .59 " moderate "
4. .60 - .79 " strong "
5. .80 – 1.0 " very strong "

Calculation of Spearman's Correlation Coefficient (ρ)

The Spearman rank correlation coefficient is based on the rank relationship between variables. It is denoted by the symbol r_s but very often by the Greek letter ρ. In Spearman test, data of the two variables are ranked into two columns either in ascending or descending order. The formula for Spearman rank correlation coefficient (ρ) when there are no tied ranks is:

$$\rho = 1 - \frac{6\sum d_i^{\,2}}{n(n^2 - 1)} - - - - - - - - (2)$$

Where,
d_i is the difference between the paired ranks or the ranked columns,
n is the length of each column or data size
When there are tied ranks (two observations or more in a column have the same rank) as it is the case in this study, equation (2) can still be used with a condition of slight modification in data ranking process. Ranks for tied observations are averaged and the resultant average number is assigned to the tied observations. So if there two tied observations in column X and their ranks are 3 and 4, the new rank for each observation is 3.5.
The returned value of Spearman's coefficient (ρ) ranges from -1 to +1 where,
+1 = a perfect positive correlation between ranks
-1 = a perfect negative correlation between ranks
0 = no correlation between ranks

Determination of Significance of Pearson's and Spearman's Correlation Coefficients

To test whether the calculated correlation coefficients for Pearson (r) and for Spearman (ρ) are significantly different from zero, two separate tables of critical values for (Zar, 1972, 1984). Firstly, the calculated values of r and ρ from equations (1) and (2), respectively were compared with their critical values in the tables taking into account the data length (n) and subsequently the degree of freedom (df). Therefore, if the calculated r or ρ is equal to or greater than its critical value under the (0.05) level of confidence (α), it would be considered as "significant" whereas it is "highly significant" if it was equal to or greater than the critical value under the (0.01) level of confidence (α).

Results and Discussion

In order to examine the relationship between the large scale teleconnection indices (NAO, AO) and winter temperatures at the targeted sites, a scatter plot display was used (Figs. 3 and ,4) respectively. It is clear (Fig. 3) that data points are clustering around the regression line and close to it which indicate that the association between the NAO and winter temperatures is linear and negative, although the strength of such relationship differs from one site to the other. An important characteristic of scatter plot diagrams is that the larger the slope of the line on the x-axis, the greater the association (positive or negative) between the considered variables and vice versa. All the panels (Fig. 2) show that winter temperature is related inversely to NAO indices but not all sites have the same magnitude of response. In Table 1, the largest correlation coefficients between winter temperature and NAO was found at the southern sites, Sebhā (-0.76) and Al Kufra (-0.72) followed by Tripoli (-0.64) then Shahāt (-0.46). The probability values (P-values) in Table 1, determine whether a specific coefficient is significant or not and also the level or strength of significance. The calculated Pearson Correlation Coefficients at all studied sited were highly significant.

Similar scenario has been obtained when winter temperatures were related to the AO. The temperature response to AO variability at every site acted in a very similar manner to the response to NAO (Fig. 4). In addition, the patterns of the relationship in every panel (site) are almost the same. The only exception is that the values of r are somewhat smaller than those associated with NAO except for Al Kufra which showed a marginal increase from - 0.72 with NAO to - 0.73 with AO (see Table 1).

When the Spearman Correlation test was applied, Table 2, the calculated correlation coefficients (ρ) between winter temperature and NAO at all sites were clearly negative and range between marginally strong at Al Kufra and Sebhā with values of -0.62 and -0.60 respectively, moderate at Tripoli with -0.49 and weak at Shahā with -0.30. However, only the latter site showed insignificant correlation.

The fact that the four study sites are located at the northwest (Tripoli), northeast (Shahāt), south west (Sebhā) and south east (Al Kufra) of Libya and the winter temperature in each site has shown a negative correlation to both the NAO and AO, it could be argued that in general, Libya's winter temperature is inversely related to the winter large scale Tele-connection indices (NAO and AO). This simply means that during the years of positive NAO and positive AO, winter temperatures at different sites in Libya are expected to be cooler than normal. On the other hand, when NAO and AO are notably negative, winter temperatures are dominantly warmer than normal. For Tripoli, the three consecutive coldest winters during the study period were 1991 (-1.5C˚), 1992 (-1.7C˚) and 1993 (-1.2C˚). The recorded NAO and AO values for the same consecutive winters were (+1.0,+0.5), (+1.3,+1.1), (+2.1,+1.2) respectively. On

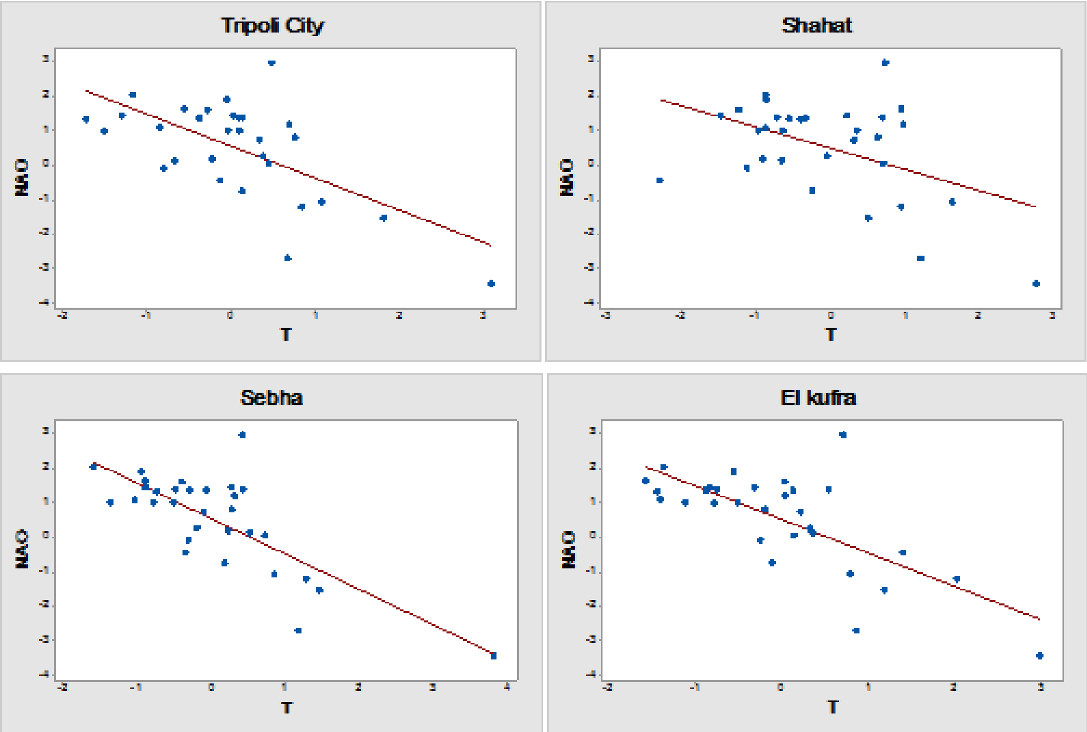

Fig. 3. Scatter plot of the relationship between NAO and winter temperature for (Tripoli, Shahāt, Sebhā, Al Kufra).

contrary, the values of (NAO, AO) for the two warmest winters 2009 (+1.8C˚) and 2010 (+3.1C˚) were (-1.5,-1.1) and (-3.4,-3.2) respectively. Similar behavior and response has been achieved with respect to the southern sites. Considering Al Kufra, which is situated on the far southeastern region, the three above normal and hottest winter temperatures 1985 (+2.0 C˚), 2009 (+1.2 C˚), 2010 (+3.0 C˚) have occurred when NAO and AO showed clear negative phases (-1.2,-2.1), (-1.5,-1.1) and (-3.4,-3.2) respectively. In contrast, the cold winters 1989 (-1.6 C˚), 1992 (-1.5 C˚), 1993 (-1.4 C˚) have occurred during the positive phases of (NAO,AO) with indices (+1.6,+1.9), (+1.3,+1.1), (+2.1,+1.2) respectively.

These results which clearly demonstrate the inverse relationship between NAO and AO indices and winter temperature at the chosen study sites are consistent with the findings of some regional studies that have been carried out on the response of winter temperature variability to the same season variability of NAO and AO (e.g. Hasanean 2004 in Egypt; Luterbacher and Xoplaki, 2003 in major part of the Mediterranean region). The probable explanation for the latter result is related to the positioning of the subtropical Azores High Pressure system, one of the two pressure centers which determine the value and sign of large scale indices. When NAO and AO indices are positive (usually > +1.0), the Azores High pressure strengths and shifts further northward instead of its natural position which is normally over the eastern Atlantic and to the west of Africa. This situation allows the polar northerly and northwesterly winds to penetrate southward towards the mid-southern

Mediterranean region and therefore winter temperatures in Libya suffer remarkable decreases as a result of that.

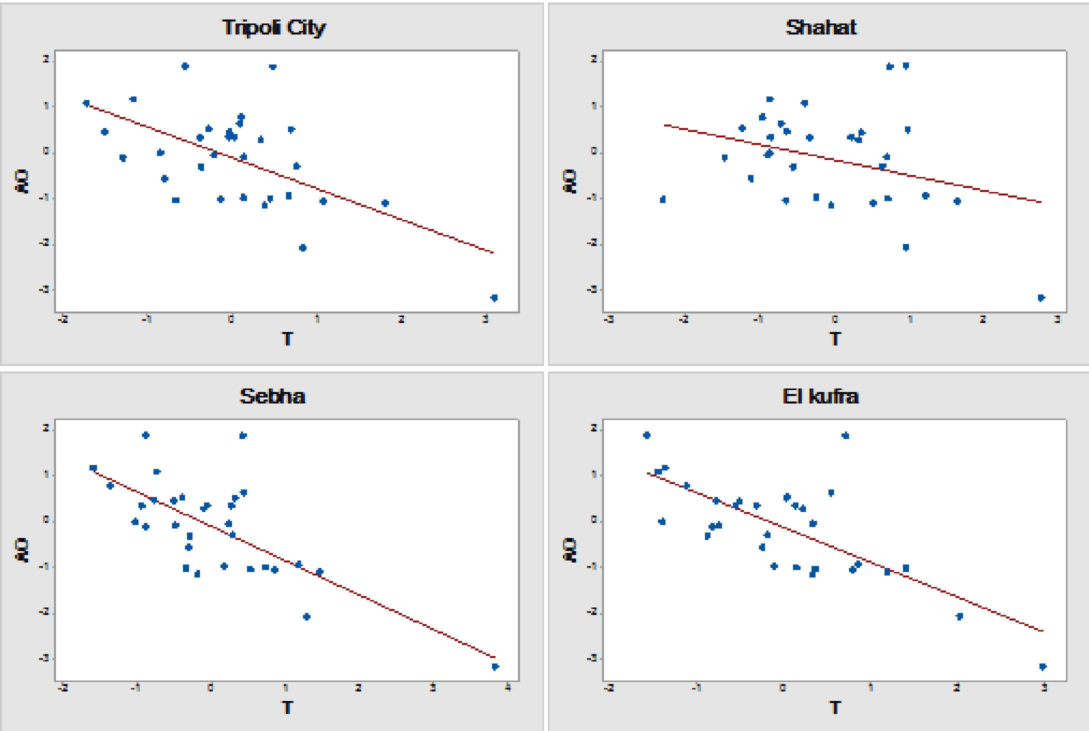

Fig. 4. Scatter plot of the relationship between AO and winter temperature for Tripoli, Shahāt, Sebhā and Al Kufra.

Table. 1. Pearson correlation coefficients between winter temperature and large–scale indices (NAO, AO) for the 4 shown sites. Numbers correspond to P-values in the table are the calculated probability values for each correlation coefficient. The asterisks close to Spearman values denote the strength of significance of the correlation coefficient so that ** is highly significant and * is significant and no stars means not significant.

Station / Index	Tripoli City	Sebha	Shahat	El Kufra
NAO	-0.64 **	-0.76 **	-0.46**	-0.72**
P-value	0.000	0.000	0.009	0.000
AO	-0.60**	-0.72**	-0.32	-0.73 **
P-value	0.000	0.000	0.075	0.000

In contrast, when NAO and AO indices are negative enough (< -1.0), the Azores High pressure system weakens and retreats southward. The consequence of this retreating is that the characteristics associated with positive NAO and AO would be reversed. Hence, most regions in Libya receive southerly and south-easterly winds which usually raises the normal temperatures during this cold season to become above-normal.

Interestingly, the inverse (negative) correlation between winter temperature and NAO and AO in the southern sites of Libya appeared to be stronger than those closer to the coastal line; see the values of both r and ρ in Tables 1 and 2, for the comparison between, e.g. the southern site (Al Kufra) and the northern site (Tripoli). This might be attributed to the temperature modulation effect of the Mediterranean sea waters.

Table. 2. Spearman correlation coefficients between winter temperature and large–scale indices (NAO, AO) for the 4 shown sites. Numbers correspond to P-values in the table are the calculated probability values for each correlation coefficient. The asterisks close to Spearman values denote the strength of significance of the correlation coefficient so that ** is highly significant and * is significant and no stars means not significant.

Station / Index	Tripoli City	Sebha	Shahat	El Kufra
NAO	-0.49 **	-0.60 **	-0.30	-0.62 **
P-value	0.005	0.000	0.099	0.000
AO	-0.47 **	-0.58 **	-0.23	-0.61 **
P-value	0.008	0.001	0.214	0.000

During winter time when NAO is in its regarded positive phase, the northerly and/or northwesterly winds usually grab a very cold and dry air mass deep into the southern regions of Libya which results in a remarkable lowering of the winter temperatures in these regions. Closer to the northern coastal region, however, the sea surface temperatures are slightly warmer than the nearby land and with the presence of humidity in the air, coastal regions experience mild temperatures compared to southern regions.

When NAO is perfectly negative, major parts of Libya are affected by the easterly or south-easterly prevailing winds. The ultimate impact of such winds is a clear rise of winter temperatures in all regions but at the coastal regions, the warming would be less due to the modulation role of the sea waters as explained previously.

Finally, the results of this study showed that both decline and increase of winter temperatures in Libya are evidently related to the positive and negative phases of NAO and AO respectively. This inverse relationship is however, stronger in the southern sites than in the northern coastal sites of Libya which is expressed in terms of the higher values of both Pearson's and Spearman's correlation coefficients. Moreover, despite the fact that other factors, either globally or locally, could indeed play important roles in winter temperature variability over the diverse sites and the correlation between any two variables is not a definitive cause and effect relationship, the impact of NAO and AO is undoubtedly crucial in determining winter temperature variability in Libya.

Conclusions

In this study a detailed correlation analysis has been performed between winter atmospheric circulation indices (NAO and AO) and winter temperatures in chosen locations in Libya over the period 1980-2010. Using a trusty and high quality winter temperature and NAO and AO data series, remarkable results have been obtained which might be summarized in the following conclusions: Firstly, a scatter plot analysis showed a clear linear relationship among all sites between winter temperature and both NAO and AO indices. Secondly, the employment of two different correlation analyses (one is parametric and the other is non-parametric) confirmed the inverse relationship and clearly demonstrated that winter temperatures are negatively correlated to NAO and AO. Thirdly, the calculated Pearson's correlation coefficients between NAO and winter temperatures were statistically highly significant at all sites, whereas it was insignificant for Shahāt site when the correlation was with AO instead of NAO. Fourthly, except for Shahāt, other sites showed high significant Spearman's correlation coefficients between NAO and AO indices and winter temperatures. The reason behind weak and insignificant correlation coefficients in Shahāt site could be attributed to the diminishing effect of the Icelandic Low Pressure centre towards the northeastern part of Libya as it plays a key role in the establishment of AO phenomena. Finally, it is revealed that the -ve correlation between NAO and AO with winter temperature in the southern sites is stronger than that in the northern sites of Libya. In this aspect, the temperature modulation of the nearby land by the sea waters during the winter season might be the prime reason for the slight rise of winter temperatures on coastal sites and hence lowering correlation strength.

References

Bhutiyani, M. R., Vishwas, S. K. and Pawar, N. J. (2007). Long-term trends in maximum, minimum and mean annual air temperatures across the Northwestern Himalaya during the twentieth century. Climatic Change **85**, 159–177

Bozyurt, O. and Ozdemir, M. A. (2014). The relations between north Atlantic Oscillation and minimum temperature in Turkey. Procedia-Social and Behavioral Sciences, **120**, 532-537.

Buermann, W., Anderson, B., Tucker, C. J., Dickinson, R. E., Lucht, W., Potter, C. S. and Myneni, R. B. (2003). Interannual covariability in Northern Hemisphere air temperatures and greenness associated with El Nin˜o-Southern Oscillation and the Arctic Oscillation, J. Geophys. Res., **108** (D13), 4396, doi:10.1029/2002JD002630.

Del Rio, S., Anjum Iqbal, M., Cano-Ortiz, A., Herrero, L., Hassand, A. and Penasa, A. (2013). Recent mean temperature trends in Pakistan and links with teleconnection patterns. Int. J. Climatol., **33**, 277–290.

Hasanean, H. M. (2004). Wintertime Surface Temperature in Egypt In relation To the associated atmospheric circulation, Int. J. Climato. **24**, 985-999

Hurrell, J. W. (1995). Decadal trends in the North Atlantic Oscillation regional temperatures and precipitation. Science, **269**, 676-679.

Hurrell, J. W., Kushnir, Y., Ottersen, G. and Visbeck, M. (2003). An overview of the North Atlantic Oscillation, Geophysical Monograph, **134**, 1-35

Hurrell, J. W. and Deser, C. (2009). North Atlantic climate variability: The role of the North Atlantic Oscillation. J. Mar. Syst. **78**, 28–41.

Hurrell, J. W. and National Center for Atmospheric Research Staff. (2020). "The Climate Data Guide: Hurrel North Atlantic Oscillation (NAO) Index (station-based)." Retrieved from https://climatedataguide.ucar.edu/climate-data/hurrell-north-atlantic-oscillation-nao-index-station-based.

Jones, P. D., Josson, T. and Wheeler, D. (1997). Extension to the North Atlantic Oscillation using early instrumental pressure observations from Gibraltar and South-West Iceland. Int J Climatol. **17**, 1433–1450

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., Iredell, M., Saha, S., White, G., Woollen, J., Zhu, Y., Leetmaa, A., Reynolds, R., Chelliah, M., Ebisuzaki, W., Higgins, W., Janowiak, J., Mo, K. C., Ropelewski, C., Wang, J., Jenne, R. and Joseph, D. (1996). The NCEP/NCAR 40-Year Reanalysis Project. Bull. Am. Meteor. Soc. **77**, 437–471

Lamb, P. J. and Peppler, R. A. (1987). North Atlantic Oscillation: Concept and an application. Bull. Amer. Meteor. Soc., **68**, 1218-1225.

Luterbacher, J. and Xoplaki, E. (2003). 500-year Winter Temperature and Precipitation Variability over the Mediterranean Area and its Connection to the Large-scale Atmospheric Circulation. In: Bolle HJ. (eds) Mediterranean Climate. Regional Climate Studies. Springer, Berlin, Heidelberg, 133-153

Mann, K. H. and Drinkwater, K. F. (1994). Environmental influences on fish and shellfish production in the northwest Atlantic. Environ. Rev., **2**, 16-32.

Mitchell, T. P. and Blier, W. (1997). The variability of wintertime precipitation in the region of California. J. of Climate, **10**, 2261-2276.

NCDC (National Climatic Data Center) and NOAA(National Oceanic and Atmospheric Administration). (2020). Arctic Oscillation station based data, https://www.ncdc.noaa.gov/teleconnections/ao.

Thiele, J. (2017). How to choose between Pearson and Spearman correlation?, URL (version: 2017-12-09): https://stats.stackexchange.com/q/14963.

Thompson, D. W. J. and Wallace, J. W. (1998). The Arctic Oscillation signature in the wintertime geopotential height and temperature fields, Geophys. Res. Lett., **25**, 1297–1300.

Thompson, D. W. J., Wallace, J. W. and Hegerl, G. C. (2000). Annular modes in the extratropical circulation. Part II Trends. J Climate **13**, 1018–1036.

Van Loon, H. and Rogers, J. C. (1978). The seasaw in winter temperatures between Greenland and north Europe. Part I: General description. Mon. Wea. Rev., **106**, 296-310.

Vicente-Serrano, S. M., Trigo, R. M., López-Moreno, J. I., Liberato, M. L. R. and Lorenzo-Lacruz, J. (2011). Extreme winter precipitation in the Iberian Peninsula in 2010: anomalies, driving mechanisms and future projections. Clim. Res. **46**, 51–65.

Wettstein, J. J. and Mearns, L. (2002). The Influence of the North Atlantic-Arctic Oscillation on Mean, Variance, and Extremes of Temperature in the Northeastern United States and Canada. J. Climate, **15**, 3586-3600.

Zar, J. H. (1972). Significance testing of Spearman rank correlation coefficient. Journal of the American Statistical Association, **67**, 578-580.

Zar, J. H. (1984). Biostatistical analysis, 2nd ed., Prentice Hall, Englewood Cliffs, NJ.

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