A Study of the Effect of the North Atlantic Oscillations with Temperature and Precipitation in Baghdad City

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Abstract

The aim of this research is to study the effects of the North Atlantic Oscillation (NAO) on the temperature and precipitation patterns in Baghdad city. Data of the monthly means of the NAO index,the monthlymeans of temperature, and the monthly total of precipitation were analyzed for the period 1900-2008. Non-parametric tests were used to investigate the correlations between these variables. The time series of temperature and precipitation showed no trends. The results indicated that is a slight correlation between the NAO and temperature and precipitation suggesting that NAO has no major effects on the temperature and precipitation patterns in Baghdad city.

Key words: North Atlantic Oscillation Air temperature Precipitation Climate Mann-Kendall Pearson Spearman Correlation.

Introduction

The North Atlantic Oscillation (NAO) is a climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea level between the Icelandic low and the Azores high. Through east-west oscillation motions of the Icelandic low and the Azores high, it controls the strength and direction of westerly winds and storm tracks across the North Atlantic. It is part of the Arctic oscillation, and varies over time with no particular periodicity [1] .The NAO has been the concern of numerous and a wide range climatological researchers. One of the main issues of research is the extent of the influence on climate produced by NAO [2] .It is one of the well-known atmospheric circulation patterns, that control the weather and climate conditions and the extremes in the regions of the Atlantic and the Mediterranean basin [3] .NAO is considered as teleconnection between weather conditions in one area and those occurring elsewhere [4].Fowler and Kilsby ,2003 [5] found that variation of Northern England precipitation was linked significantly with NAOand prominent relationships were found between NAO and precipitation. The signs and magnitude were different between the windward, leeward and the NAO (positive and negative) index . Similar results between NAO and rainfall were found over Iberian Peninsula, though much weaker than over Northern England]6.[Bednorz ,2002 [7] studied connection between the durationof snow cover in western Poland and the fluctuation of NOA, a strong relationship between snow cover in Poland and NOA index was found. The NAO have the greatest influence on snow melt extent on the Greenland [8] .Box ,2002 [9] concluded that most of the observed variability of Greenland temperatures is shown to be linked to NOA .Bader and Latif,2005 [10] $D = 1 - \frac{6\sum_{i=1}^{n}[R(X_i)-i]^2}{n(n^2-1)}$ $D = 1 - \frac{6\sum_{i=1}^{n}[R(X_i)-i]^2}{n(n^2-1)}$ used coupled ocean-atmosphere model and found that a warm Indian Ocean produces a stronger NAO and a cold Indian Ocean produced a weaker NAO pattern .El-Kadi ,2007 [11] has discussed the variability, trends and the characteristics of Palestine temperature to detect the effects of the global warming.The aim of this work is to analyze the time series of the North Atlantic Oscillation (NAO), the mean temperature and precipitation for Baghdad station in Iraq, and the explore the relationship between the NAO and the temperature and between NAO and precipitation for this location .The aim of this research is to explore the connection of the NAO with temperature and precipitation for Baghdad city.

Calculations of the NAO Index

The dipole pattern of variation of the North Atlantic versus the central Atlantic and Western Europe is generally classified as a mode of atmospheric circulation known as the North Atlantic Oscillation (NAO), it is the only mid-tropospheric teleconnection to show up in all months of the year [8].

NAO is a redistribution of atmospheric mass between the North Atlantic subtropical high (Azores high) and Polar low (Icelandic Low). It is a dominant cause of winter variability in the Northern Hemisphere from North America to Europe and a large portion of Asia [12].The monthly NOA indexestimated as the difference of normalized sea-level pressure between Ponta Delagada, the Azores, and Stykkishomur/Reykjavic, Iceland [13].

For the southern station, *A* (which could be Lisbon, Gibraltar, Ponta Delgada etc.) and the northern station, *B* (which could be Reykjavik, SW Iceland etc.) [14]:

The mean and the standard deviation are computed separately for each month of the year, and for *A* and *B* separately, using values only from the reference period. Phil Jones often uses 1951-1980 as the reference period, others sometimes use 1961-1990.

Mean is:

$$\overline{A_m} = \sum_{y=1951}^{y=1980} A_{m,y} \quad (1)$$

Standard deviation is:

$$\sigma_{A_m} = \sqrt{\frac{1}{n-1}\sum\left(A_{m,y} - \overline{A_m}\right)^2} \quad (2)$$

And similarly for S.B where :
$A_{m,y}$ is sea level pressure (SLP) in month *m* (1..12) and year *y* at station *A*.
$B_{m,y}$ is SLP in month *m* (1..12) and year *y* at station *B*.
and similarly for station *B*. Each monthly station SLP series is then "normalized" by subtracting the mean for the appropriate month, and dividing by the standard deviation for the appropriate month.

$$A'_{m,y} = \frac{A_{m,y} - \overline{A_m}}{\sigma_{A_m}} \quad (3)$$

and similarly for station B. The monthly NAO index is then computed by differencing the two normalized series:

$$NAO_{m,y} = A'_{m,y} - B'_{m,y} \quad (4)$$

Seasonal means of the NAO index are computed simply by taking an average of the Monthly NAO index values (i.e., it is not necessary to compute seasonal means of theOriginal SLP series and go through the entire process again).
Because the normalization is applied to the individual station records prior to differencing them, the NAO index itself does not have a standard deviation of one. When the monthlyNAO index values are averaged into seasonal means, again no further normalization isdone and so the seasonal NAO index also does not have a standard deviation of one. [14]

Data and Methodology

Monthly data of NAO for the period of 1900 to 2008 were obtained from [15][16]. The monthly mean of air Temperature and monthly total of precipitation for the same above period were obtained from the University of Delaware. The geographical parameters for Baghdad city is longitude44.39 ^{o}E, latitude 33.33^{o}N and elevation 34m.MATLAB programs were written for the analysis of the NAO, temperatureand precipitation time series. The analysis includes plotting the original data, the monthly averages, the corrected data (i.e. removing the seasonal effects) and the autocorrelation coefficient. An autocorrelation coefficient tells how similar the time series is to itself. If it is highly autocorrelated, past values can be used to forecast future ones. An auto correlation coefficient close to zero indicates low correlation, and a coefficient far from zero indicates high correlation.

Pearson, Spearman, and Mann-Kendall non-parametric tests were carried to see how the NAO, temperature and precipitation time series are correlated.

Pearson's correlation coefficient when applied to a sample is commonly represented by the letter r and may be referred to as the sample correlation coefficient or the sample Pearson correlation coefficient. That formula for r is:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{(X_i - \bar{X})^2\,(Y_i - \bar{Y})^2}} \quad (5)$$

An equivalent expression gives the correlation coefficient as the mean of the products of the stander scores. Based on a sample of paired data (X_i, Y_i), the sample Pearson correlation coefficient is:

$$r = \frac{1}{n-1}\sum_{i=1}^{n}\frac{(X_i - \bar{X})}{s_X}\frac{(Y_i - \bar{Y})}{s_Y} \quad (6)$$

where:
is stander scores, is a sample mean, and is a sample standard deviation.
A single variable statistics of Mann–Kendall is defined for a special time series (Z_kK=1,2,…,n) by following relation:

$$\mathrm{T} = \sum_{j<i}\mathrm{sgn}(\mathrm{Z_i} - \mathrm{Z_j}) \quad (7)$$

$$\mathrm{sgn}(x) = \begin{cases} 1, \ldots.\text{if}\ldots.x > 0 \\ 0, \ldots.\text{if}\ldots.x = 0 \\ -1, \ldots\text{if}\ldots x < 0 \end{cases} \qquad (8)$$

If there is not any relationship between variables and the series has not trend, thus It would have [17]:

$$E(T) = 0 \qquad (9)$$

$$\text{and } Var(T) = n(n-1)(2n+5)/18 \qquad (10)$$

Spearman's rho test is a sequential non–parametric test. For data sets of $\{X_i, i=1,2,\ldots,n\}$ the null hypothesis is assumed that all X_i are independent and have the same distribution. But H_o hypothesis is assumed that X_i decrease or increase corresponding to i and it means there is a trend in the data series. Test statistics of D is defined as:

$$D = 1 - \frac{6\sum_{i=1}^{n}[R(X_i)-i]^2}{n(n^2-1)} \qquad (11)$$

Where, $R(X_i)$ is i the order of X_i observed data an n is sample size regard to null hypothesis, D has normal distribution symmetrically and its average and variance are [18]:

$$E(D) = 0 \qquad (12)$$

$$\text{and } V(D) = 1/n-1 \qquad (13)$$

Table 1 gives the degree of correlation and interpretation for the coefficients [19].

Results and Discussion

Figure (1) shows the results of analysis for the NAO time series. Parts (a), (b), (c), and (d) of this figure show the original data, the monthly average values, the corrected data i.e. seasonal effects are removed, and the autocorrelation coefficient (corrleogram) respectively. It can be seen that the NAO data does not show a trend and the time series is stationary. This is evidenced by the fact that the corrected data looks very similar to the uncorrected data, and the whole series simply oscillates back and forth around zero. The correlogram shows these coefficients plotted for different time separations between measurements (lags). It is seen that for this data set, the coefficients decrease from one at zero lag time to near zero at large lag times, exhibiting a damped oscillation. This indicates that the NAO values tend to be highly correlated with those measured a short time later, and less correlated with those measured a long time later. This is typical for earth science data sets, which are frequently autocorrelated close together because of inertia or carryover process in the physical system.

Figure (2) illustrates the results of analysis of the monthly mean temperature time series for Baghdad city. It is seen that the data for Baghdad station look stationary and does not appear to be showing a trend. The correlogram exhibits the same damped oscillation behavior that the NAO correlogram did. However, the amplitudes is smaller, indicating a small over autocorrelation of temperature variance. In other words, if the temperature is abnormally high or low one month the chances are not very high it will be abnormally high or low the next month.

Figures (3) shows the results of analysis of the monthly total of precipitation time series forBaghdad city. It can be noticed that there is no trend in the data and the correlogram indicates that there is a damping behavior similar to that of the NAO and temperature correlograms but a much smaller amplitudes. This result is expected since precipitation is more variable than temperature

To study the relationship between NAO, the monthly mean temperature and precipitation time seriesof Baghdad city, Pearson correlation coefficient, Spearman's rank correlation coefficient, and Kendall's (tau) rank correlation coefficient werecomputed. The results are given in Table (2) and Table (3). Table (2) shows that the values of the three correlation coefficientsbetween NAO and the monthly mean temperaturetime series are comparable and are less than 0.2 for the months from Apr to Oct and the three correlation coefficients are slightly greater than 0.2 for the months of Jan, Feb, Mar, Nov, and Dec. This slight correlation suggests that there is low correlation between NAO and the monthly mean temperature in Iraq. The results in Table (3) shows that the values of the three correlation coefficients for the NAO and monthly mean precipitation time series are comparable and are less than 0.2 for all cases. This slight correlation suggests that there is almost no correlation between NAO and the monthly mean precipitation in Iraq.

Conclusion

Monthly data of NAO and monthly mean temperature and precipitation for Baghdad city, Iraq for the period of 1900 to 2008 were analyzed. The results indicated that the time series of NAO and temperature do not show a high trend. The slight correlation coefficients suggested there is low correlation between NAO and the monthly mean temperature in Iraq. The results for the NAO and precipitation time series indicated that there is no trend. The slight correlation coefficients suggested there is almost no correlation between NAO and the monthly mean precipitation in Iraq. From these results, one can conclude that the NAO has almost no effects on the temperature and precipitation patterns in Baghdad city.

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Table No. (1): The degree of correlation and interpretation of the test Coefficients

Interpretation	Correlation	Coefficient
Almost no relationship	Slight correlation	Less than 0.2
Small relationship	Low correlation	0.2 to 0.4
Substantial relationship	Moderate correlation	0.4 to 0.7
Marked relationship	High correlation	0.7 to 0.9
Solid relationship	Very high correlation	0.9 and above

Table No.(2): Pearson, Spearman and Mann-Kendall correlation coefficients of NAOand temperature for Baghdad.

Baghdad

Mann-Kendall	Spearman	Pearson	Month
-0.3330	-0.4856	-0.4486	Jan
-0.3176	-0.4564	-0.4636	Feb
-0.2793	-0.4096	-0.2770	Mar
-0.0968	-0.1406	-0.1569	Apr
-0.0825	-0.1301	-0.1303	May
-0.0813	-0.1122	-0.1074	June
-0.0307	-0.0538	-0.0870	July
-0.0437	-0.0678	-0.0931	Aug
-0.0408	-0.0782	-0.0640	Sep
-0.0093	-0.0124	-0.0297	Oct
-0.2161	-0.3184	-0.3832	Nov
-0.2524	-0.3624	-0.3389	Dec

Table No.(3): Pearson, Spearman and Mann-Kendall correlation coefficients of NAO and precipitation for Baghdad.

Baghdad

Mann-Kendall	Spearman	Pearson	Month
-0.0010	0.0036	0.0082	Jan
0.0583	0.0866	0.0540	Feb
0.0028	0.0085	0.0265	Mar
0.0947	0.1463	0.0397	Apr
-0.0216	-0.0302	0.0035	May
-0.0082	-0.0109	-0.0466	June
0.0022	0.0033	-0.0130	July
0.1355	0.1663	0.1578	Aug
-0.1470	-0.1863	-0.1411	Sep
-0.0054	-0.0062	-0.0819	Oct
-0.0265	-0.0381	-0.0307	Nov
-0.0311	-0.0440	-0.0471	Dec

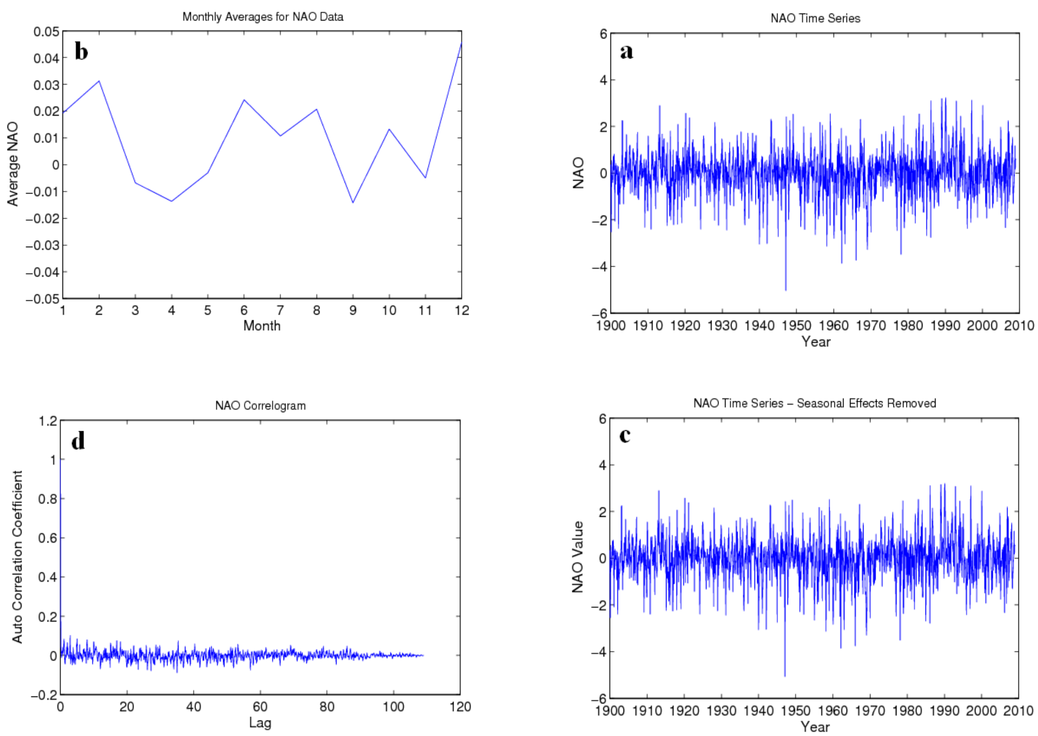

Figure No. (1) Analysis of NAO data. (a) NAO Time Series, (b) Monthly Averages for NAO Data, (c) NAO Time Series- Seasonal Effects Removed, (d) NAO Correlogram

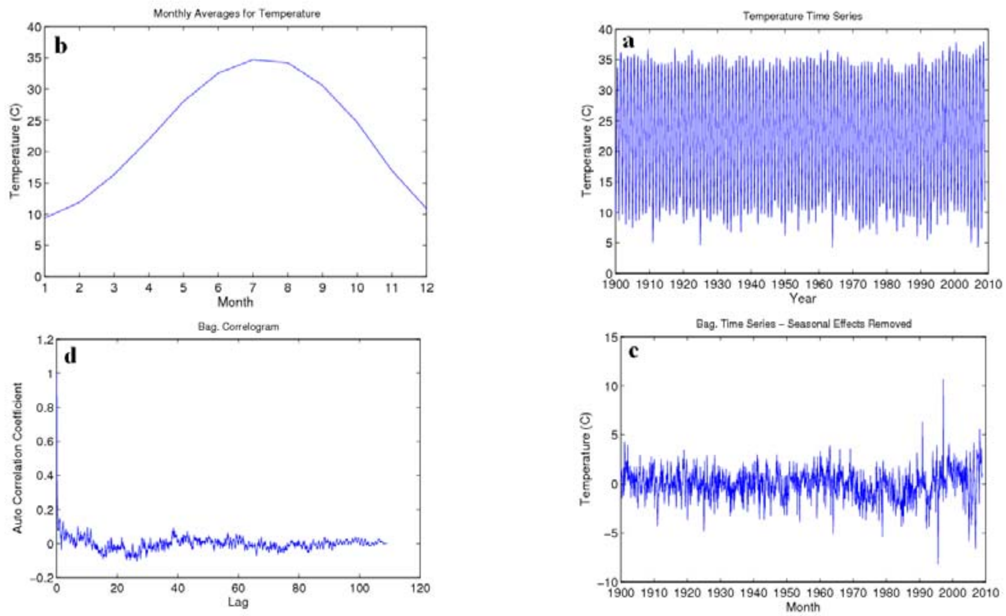

Figure No.(2):Analysis of Monthly Mean Temperature data for Baghdad. (a) Temperature Time Series, (b) Monthly Averages for Temperature, (c) Bag. Time Series-Seasonal Effects Removed, (d) Bag. Correlogram

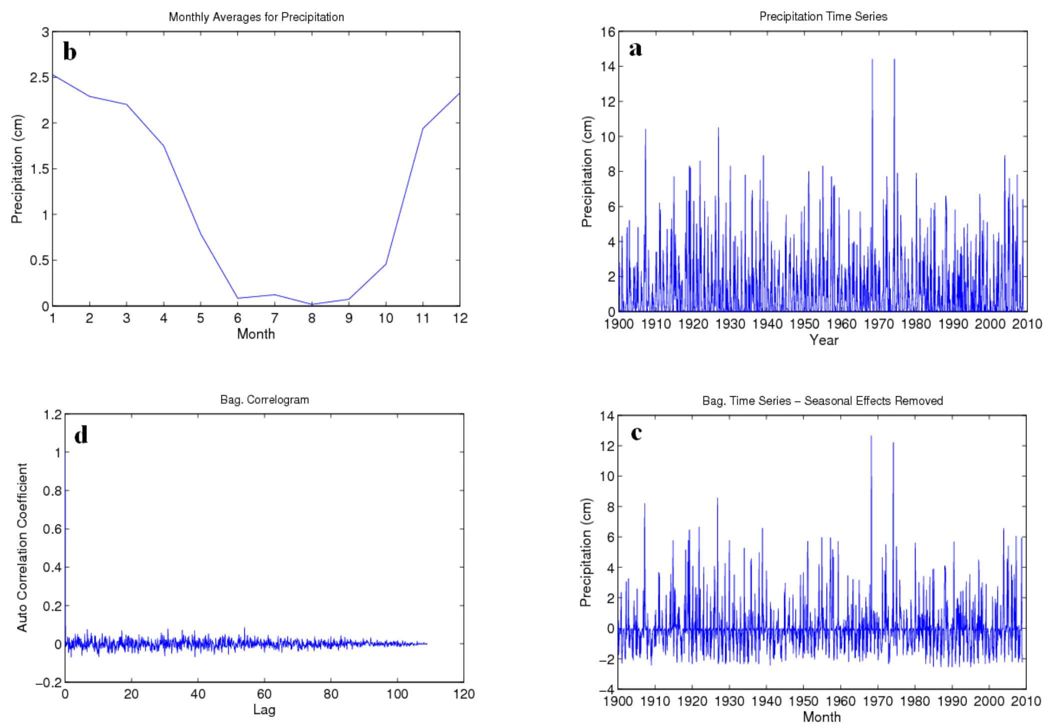

Figure No.(3):Analysis of Monthly Mean Precipitation data for Baghdad. (a) Precipitation Time Series, (b) Monthly Averages for Precipitation, (c) Bag. Time Series-Seasonal Effects Removed, (d) Bag. Correlogram.

دراسة تأثير ذبذبة شمال الأطلسي في أنماط درجة الحرارة والهطول لمدينة بغداد

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الخلاصة

يهدف هذا البحث الى دراسة تأثيرات ذبذبة شمال الأطلسي في أنماط درجة الحرارة والهطول لمدينة بغداد .تم تحليل بيانات المعدلات الشهرية لمؤشر ذبذبة شمال الأطلسي , ودرجة الحرارة والمجموع الشهري للهطول لمدينة بغداد للمده 1900الى .2008 اسلتعملت الاختبارات الإحصائية) مان-كاندال و بيرسون و سبيرمان (لفحص العلاقات بين المتغيرات أعلاه .لم تدل السلاسل الزمنية لدرجة الحرارة والهطول على وجود أي سلوك .بينت النتائج وجود علاقة طفيفة بين مؤشر ذبذبة شمال الأطلسي مع درجة الحرارة والهطول مما يدل على عدم وجود تأثيرات كبيرة لمؤشر ذبذبة شمال الأطلسي في أنماط درجة الحرارة والهطول لمدينة بغداد.

الكلمات المفتاحية:ذبذبة شمال الاطلسي درجة حرارة الهواء الهطول المناخ مان كاندال و بيرسون و سبيرمان