Time Series Analysis of Southern Oscillation Index and Temperature over Iraq

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Abstract

El Nino Southern Oscillation is believed to be responsible for some climate change in the world. The aim of this work is to investigate the relationship between the Southern Oscillation Index (SOI) and the monthly mean temperature over Iraq. Time series of SOI and temperature for the period of 1900 to 2008 were analyzed. Pearson, Spearman, and Mann-Kendall non-parametric tests were carried to see how the SOI and temperature time series are correlated. The results showed the correlation coefficients were slight for all the locations suggesting that there is no relationship between SOI and temperature over Iraq.

Key words: 1- Air temperature 2- Southern Oscillation Index 3- Climate 4- Mann-Kendall, Pearson, Spearman 5- Correlation

تحليل السلاسل الزمنية لمؤشر التذبذب الجنوبي ودرجة الحرارة في العراق

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مستخلص

يعتقد بان ظاهرة النينو مسؤولة عن بعض التغيرات المناخية في العالم. يهدف البحث إلى دراسة العلاقة بين مؤشر التذبذب الجنوبي (SOI) و المعدلات الشهرية لدرجة الحرارة في العراق. تم تحليل بيانات السلاسل الزمنية بين مؤشر التذبذب الجنوبي (SOI) ودرجة الحرارة للفترة من 1900-2008 تم استخدام الاختبارات الإحصائية التالية (بيرسن، سبيرمان، مان-كاندل) لاختبار العلاقة بين (SOI) ودرجة الحرارة.

أظهرت النتائج أن معاملات الارتباط ضعيفة لجميع مناطق الدراسة مما يؤشر على عدم تأثير ظاهرة النينو على درجة الحرارة في العراق.

كلمات مفتاحية: 1- درجة حرارة الهواء 2- مؤشر التذبذب الجنوبي 3- المناخ 4- مان-كاندل، بيرسن، سبيرمان 5- الارتباط

Introduction

El Nino Southern Oscillation (ENSO) has been linked to many climate anomalies throughout the world. The changes in the phases of the Southern Oscillation (SO) are considered as the most notable signals in inter-annual climate variations [1]. In last four decades, the extreme phases of the SO (namely, ElNino and La Nina events) and their influences on climate and other earth systems processes have always intrigued researchers to make an investigation from aregional scale. Cullen and deManocal [2] and Kutiel et al.,[3] found no clear correlation between the hydroclimatological variables in Turkey and SO indicators. Karabörk et al.,[4] analysed teleconnection between the extreme phases of the SO and Turkish temperature patterns and noted that a cold signal season associated with El Nino events was significantly detectable in western Turkey. Karabörk et al., [5] have studied the links between the categorised southern oscillation indicators and climate and hydrologic variables in Turkey. Hassan and Zaki [6] investigated the correlation between La Nina with meteorological variables over Middle East region. Jaffer [7] investigated teleconnections including El Nino. The aim of this work is to analyze the time series of the Southern Oscillation Index (SOI), and the mean temperature for three selected station in Iraq, and the explore the relationship between the SOI and the temperature for these locations.

El-Nino-Southern Oscillation (ENSO)

The El Nino–Southern Oscillation (ENSO) is atropical Pacific atmosphere-ocean phenomenon but its influence on climate can be seen globally [8]. The detailed mechanisms driving these changes are unclear but large-scale changes in global circulations are involved. During La Nina events, the zonal circulation of theWalker Circulation is enhanced and becomes pronounced, withwell-defined and vigorous rising and sinking branches. In contrast, during El Nino events, there is an increase in meridional Hadley cell circulation and subtropical highs intensify, although the relationship betweenthe enhanced regional Hadley cell and warm phase ENSO cycle circulation anomalies is not always straight forward [9]. A more vigorous overturning of the Hadley Cell circulation leads to an increase in heat transfer from tropical to higher latitudes in both hemispheres Oort and Yienger [10], and Bhaskaran and Mullan [9]found that during La Nina conditions the Hadley cell in bothhemispheres weakens. The anomalies in the strength of theHadley Cell Circulation are also stronglyand inverselycorrelated with the anomalies in the strength in the Walker Circulation. As meridional circulation increases during El Nino events, there are teleconnections globally [11]. It seems clear, therefore, that theENSO signal is correlated with climate variation, which inturn is reflected in mean global temperature. The extent towhich ENSO is related to the latter may be a key to successful extended climate forecasts [12].The El Nino-Southern Oscillation (ENSO) phenomena can be captured by the Southern Oscillation Index (SOI) by computation of the sea surface pressure differences between Tahiti in the eastern tropical Pacific basin and at Darwin, Australia in the western Pacific. While negative values of the SOI is generally indicative of El Nino, positive values demonstrate La Nina conditions in the tropical Pacific Ocean.This study uses the monthly SOI reported by the Australian Bureau of Meteorology, known as the Troup SOI [13] and is calculated as follows:

$$SOI = \frac{[P_{diff} - P_{diffav}]}{SD(P_{diff})} * 10 \quad (1)$$

where:

$$P_{diff} = P_{Tahiti} - P_{Darwin} \quad (2)$$

where:

P_{Tahiti}: average Tahiti Mean Sea Level Pressure for the month.
P_{Darwin}: average Darwin Mean Sea Level Pressure for the month.
P_{diffav}: long term average of P_{diff} for the month in question.
$SD(P_{diff})$: long term standard deviation of P_{diff} for the month in question.

Data and Methodology

Monthly data of SOI for the period of 1900 to 2008 were obtained from [13] The monthly mean of air temperature for the same above period were obtained from the University of Delaware. Three geographical locations in Iraq were chosen for analyzing the temperature time series. These are Mosul, Baghdad, and Basra which represent the northern, central, and southern parts of the country.Table (1) Shows the geographical parameters for the selected locations.

Table (1): The geographical parameters for selected locations

Location	Longitude (ºE)	Latitude (ºN)	Elevation (m)
Mosul	43.15	36.32	223
Baghdad	33.23	44.23	34
Basra	30.57	47.78	2

MATLAB programs were written for the analysis of the SOI and temperature 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 SOI and temperature 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:

$$r = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{(X_i-\bar{X})^2\,(Y_i-\bar{Y})^2}} \tag{3}$$

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:

$$r = \frac{1}{n-1}\sum_{i=1}^{n}\frac{(X_i-\bar{X})}{s_X}\frac{(Y_i-\bar{Y})}{s_Y} \tag{4}$$

where:

$\frac{(X_i-\bar{X})}{s_X}$ is stander scores, $\bar{X}$ is a sample mean, and s_X 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:

$$T = \sum_{j<i} \mathrm{sgn}(Z_i - Z_j) \quad (5)$$

$$\mathrm{sgn}(x) = \begin{cases} 1, \ldots \text{if} \ldots x > 0 \\ 0, \ldots \text{if} \ldots x = 0 \\ -1, \ldots \text{if} \ldots x < 0 \end{cases} \quad (6)$$

If there is not any relationship between variables and the series has not trend, thus It would have [14]:

$$E(T) = 0 \quad (7)$$

$$\text{and } Var(T) = n(n-1)(2n+5)/18 \quad (8)$$

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:

$$D = 1 - \frac{6\sum_{i=1}^{n}[R(X_i)-i]^2}{n(n^2-1)} \quad (9)$$

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 [15]:

$$E(D)=0 \quad (10)$$

$$\text{and } V(D)= 1/n-1 \quad (11)$$

Results and Discussion

Figure (1) shows the results of analysis for the SOI 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 SOI 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 SOI 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 auto correlated close together because of inertia or carryover process in the physical system.
Figures (2), (3), and (4) illustrates the results of analysis of the monthly mean temperature time series for the cities of Mosul, Baghdad, and Basrarespectively. It is seen that the data for all three stations looks stationary and does not appear to be showing a trend. The correlograms exhibit the same damped oscillation behavior that the SOI correlogram did. However the amplitudesare smaller, indicating a small overall auto correlation 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.

To study the relationship between SOI and the monthly mean temperature time series of the three cities, Pearson correlation coefficient, Spearman's rank correlation coefficient, and Kendalls's (tau) rank correlation coefficient were computed. The results are given in Table (2). It is evident that the values of the three correlation coefficients are comparable and are less than 0.2 for all cases except for the month of July for Baghdad and Basra where the Pearson and Spearman correlation coefficients were slightly greater than 0.2. This slight correlation suggests that there is almost no correlation between SOI and the monthly mean temperature in Iraq.

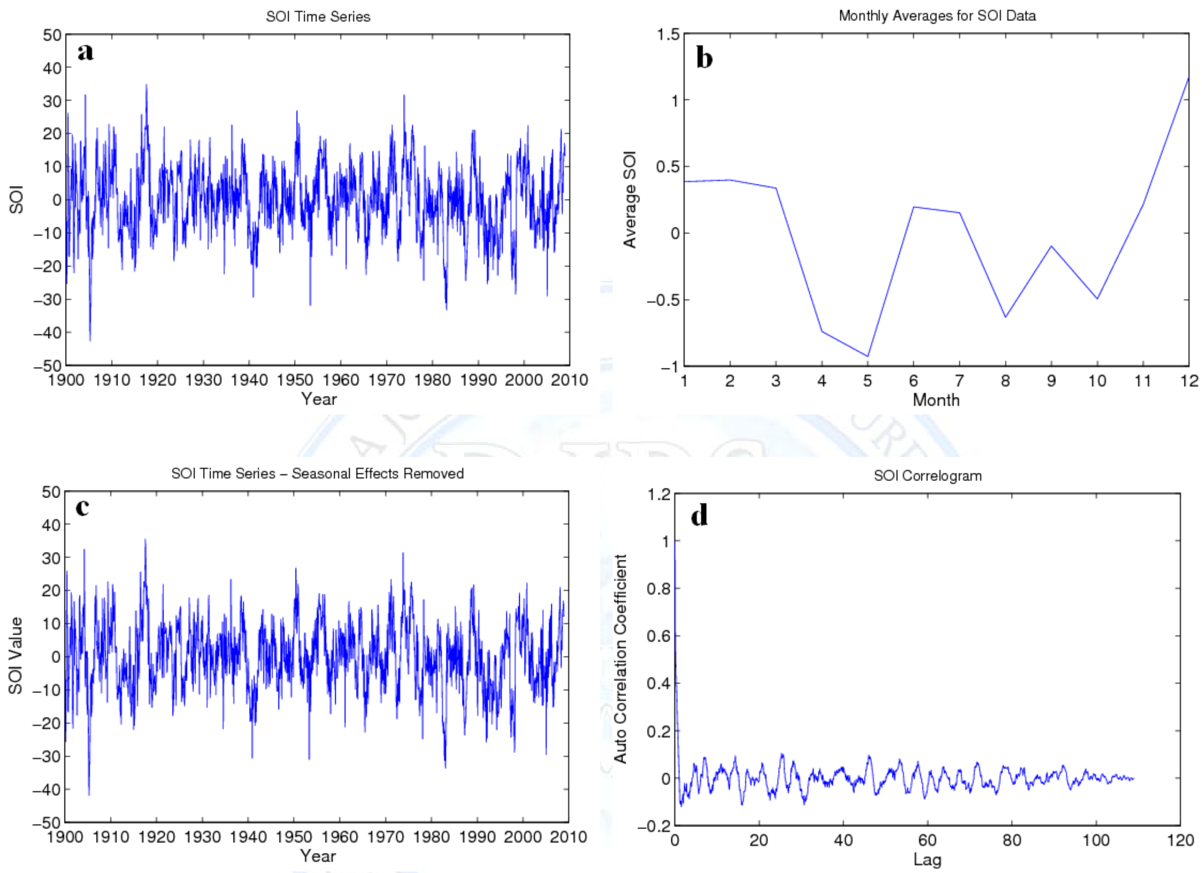

Figure 1. Analysis of SOI data. (a) SOI Time Series, (b) Monthly Averages for SOI Data, (c) SOI Time Series- Seasonal Effects Removed, (d) SOI Correlogram.

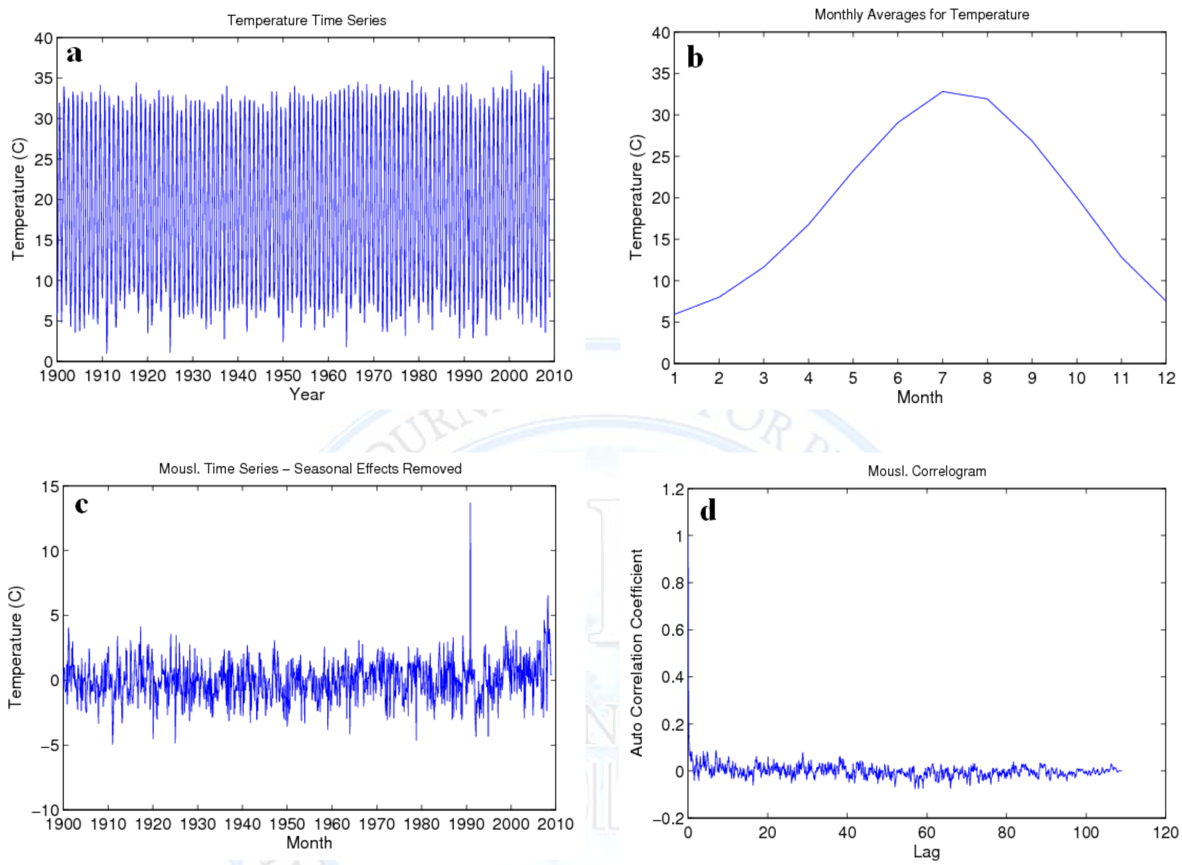

Figure 2. Analysis of Monthly Mean Temperature data for Mosul. (a) Temperature Time Series, (b) Monthly Averages for Temperature, (c) Mosul Time Series-Seasonal Effects Removed, (d) Mosul Correlogram.

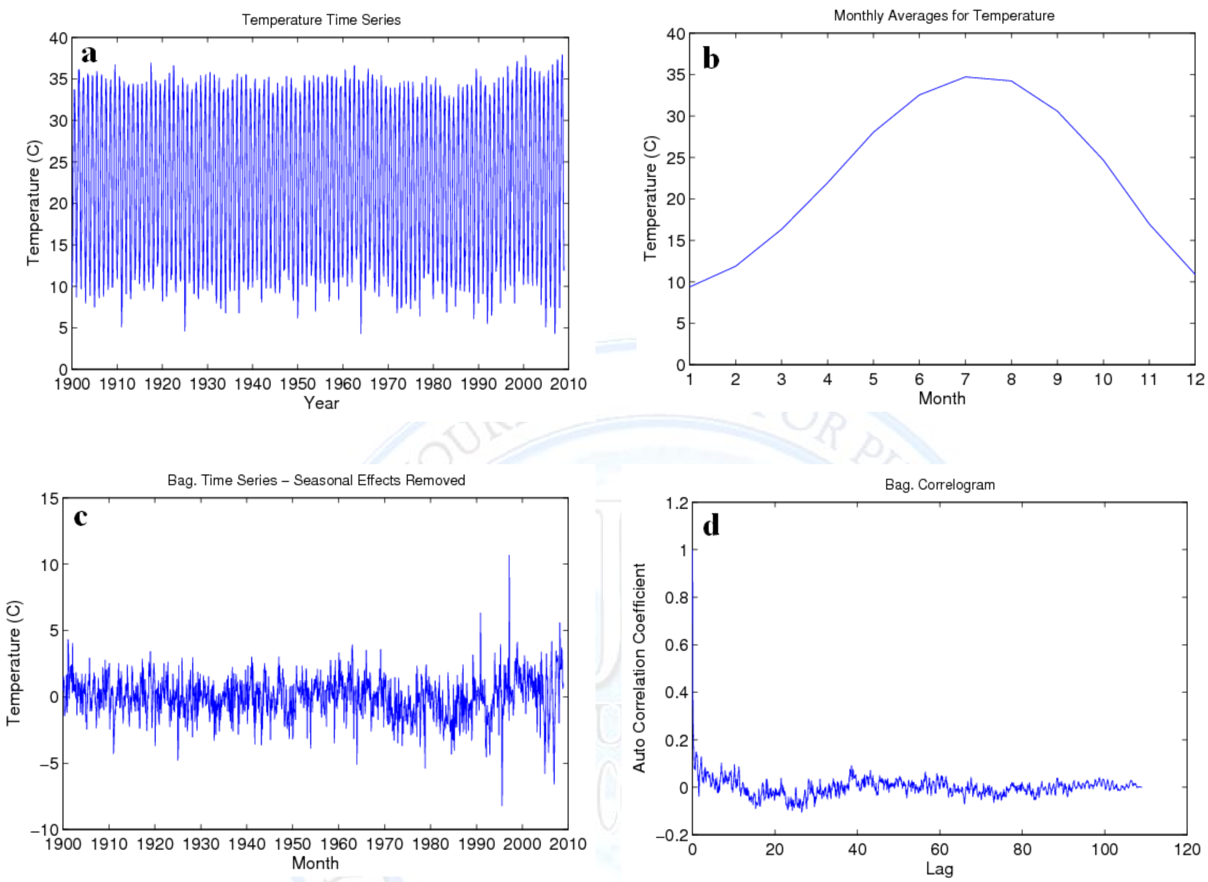

Figure 3.Analysis of Monthly Mean Temperature data for Baghdad. (a) Temperature Time Series, (b) Monthly Averages for Temperature, (c) Bag. Time Series-Seasonal Effects Removed, (d) Bag. Correlogram

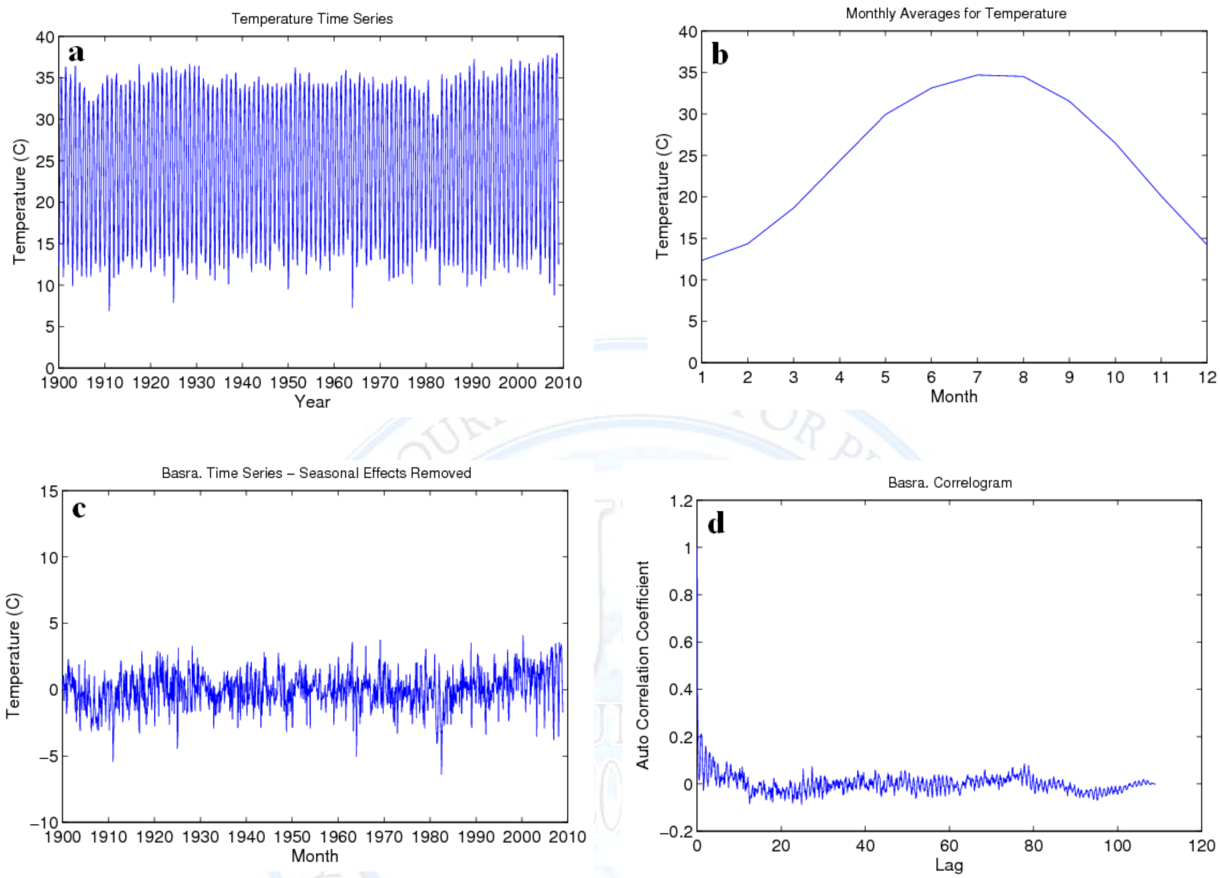

Figure 4. Analysis of Monthly Mean Temperature data for Basra. (a) Temperature Time Series, (b) Monthly Averages for Temperature, (c) Basra Time Series-Seasonal Effects Removed, (d) Basra Correlogram.

Table (2): Pearson, Spearman and Mann-Kendall correlation coefficients of SOI and for Mosul, Baghdad and Basra.

Mosul

Month	Pearson	Spearman	Mann-Kendall
Jan	-0.0125	-0.0293	-0.0131
Feb	-0.0842	-0.1292	-0.0939
Mar	0.1902	0.1230	0.0871
Apr	0.0733	0.0254	0.0277
May	0.0468	0.0395	0.0243
June	0.0146	0.0547	0.0401
July	0.1198	0.1646	0.1067
Aug	0.0190	0.0027	0.0017
Sep	0.0736	0.0413	0.0284
Oct	0.0548	0.0335	0.0222
Nov	0.0894	0.0793	0.0553
Dec	0.0970	0.1423	0.0960

Baghdad

Month	Pearson	Spearman	Mann-Kendall
Jan	0.0011	-0.0691	-0.0421
Feb	-0.0609	-0.1232	-0.0874
Mar	0.0690	0.0293	0.0209
Apr	0.0029	-0.0096	-0.0078
May	-0.0282	-0.0678	-0.0468
June	0.0337	0.0475	0.0288
July	0.2563	0.2657	0.1836
Aug	0.0395	0.0427	0.0321
Sep	-0.0597	-0.0793	-0.0443
Oct	-0.0415	-0.0572	-0.0434
Nov	0.1133	0.1189	0.0804
Dec	0.0956	0.0799	0.0575

Basra

Month	Pearson	Spearman	Mann-Kendall
Jan	-0.0031	-0.0299	-0.0136
Feb	-0.1688	-0.1989	-0.1335

Mar	0.1369	0.0592	0.0409
Apr	0.0198	0.0023	0.0002
May	-0.0364	-0.0934	-0.0621
June	0.0460	0.0385	0.0290
July	0.2047	0.1933	0.1366
Aug	0.0253	-0.0327	-0.0153
Sep	0.0523	0.0351	0.0257
Oct	-0.1150	-0.1142	-0.0891
Nov	0.0471	0.0436	0.0296
Dec	-0.0077	-0.0098	-0.0088

Conclusion

Monthly data of SOI and monthly mean temperature for three selected locations in Iraq for the period of 1900 to 2008 were analyzed. The results indicated that the time series of SOI and temperature do not appear to show any trend. The slight correlation coefficients suggested there is almost no correlation between SOI and the monthly mean temperature in Iraq.

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