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Statistical analysis of Sunspot and total solar irradiance effects on the climate in kirkuk area for three solar cycles (22,23,24)

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ABSTRACT

In this study Sunspot number(SSN) and Total solar irradiance(TSI wm^{-2}) observation were extracted from the Solar Influences Data analysis Center (SIDC) and Earth Radiation Budget Satellite (ERBS) for solar cycles 22,23 and 24 (1988-2017) and for the same cycles the parameters of climate were taken from the meteorological data recorded in Kirkuk station, which includes annual relative humidity(RH%),annual air temperature (c°)(T), annual Rainfall (mm)(p), and annual Sunshine duration(h/day)(SH).The statistical correlation between the adopted solar and climate parameters has been achieved by using Statistical program (SPSS) version (23). From this statistical analysis shows that there is a correlation between SH with both (SSN) and (TSI) less than 0.5 that is mean (SSN) and (TSI) have little effect on SH while the correlation is weak or missing between both (SSN) and solar (TSI) with RH% through the correlation coefficient values (0.05,0.032). The effect of (TSI) on the air temperature more than the impact of (SSN) but less than 0.5. The effect of (SSN) more than (TSI) on the amount of rainfall less than 0.5 according to the correlation coefficient value .this investigation shows that the climate in Kirkuk is clearly influenced by solar activity which includes SSN and TSI.

1. Introduction

Kirkuk Governorate of area about 9700 km² is located in northern Iraq. which lies between latitudes 35°28'north and longitudes 44°24' east as shown in Figure (1). For the priority of environment technological progress is studying of the relationship between solar activity and the climate parameters through the solar cycles .solar cycles considered an indicators of the instability of solar magnetic field and the activity of the Sun which is considered an unstable stare of spectral type G2 of main sequence stare. Sun is known to be far from a static state, the so-called "quiet" sun described by simple stellar-evolution theories, but instead goes through various nonstationary active processes . Such nonstationary and nonequilibrium (often eruptive) processes can be broadly regarded as solar activity .All these activity due to the nuclear fusion processing [1].

The extent to which changes in solar activity affect climate has been the subject of considerable investigation over many years and has often been the cause of speculation and controversy. As observational and modelling techniques were improve, and the understanding of the natural internal variability of the climate system advances, it is becoming more feasible both to detect solar signals in climate records and to investigate the mechanisms whereby the solar influence acts[2]. Total solar irradiance (TSI) is Earth's dominant energy input, exceeding the next largest energy source by nearly10^4 [3]. It has recently been suggested that the solar irradiance has varied in phase with the 80- to 90-year period represented by the envelope of the 11-year sunspot cycle and that this variation is causing a significant part of the changes in the global temperature[4].

Solar data have been used as parameters in a great number of studies concerning variations of the physical conditions in the Earth's upper atmosphere. The varying solar activity is distinctly represented by the 11-yr cycle in the number of sunspots[5]. The main objective of this study is to demonstrate that the solar activity affects climate change for the study area statistically. In this study, focus has been on the effect of increasing or decreasing the number of Sunspots and TSI(wm^{-2}) on the available climatic variables annual relative humidity (%),annual air temperature (c°), annual Rainfall (mm), and annual Sunshine duration(h/day) .

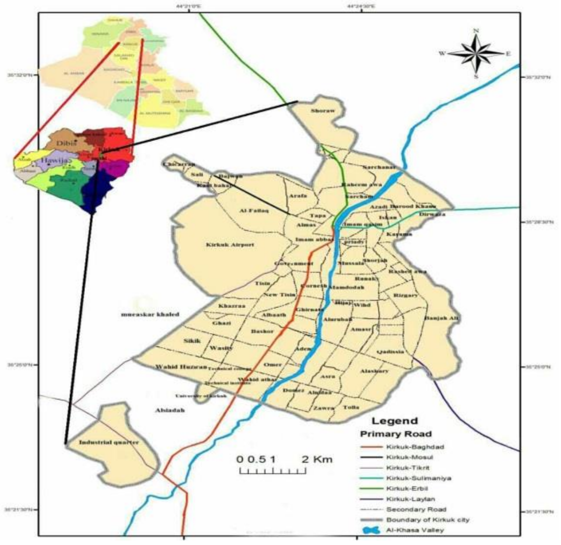

Figure 1. Location of study area

The climate on Earth is determined by the energy input that the Earth receives from the Sun in the form of total solar irradiance (TSI). Therefore, the TSI is an essential climate variable that needs to be monitored from space in order to quantify a possible solar influence on climate variability or climate change on Earth ,and sunspots number that were held from The Solar Influences Data analysis Center (SIDC) [6].

2. Observations and Data Handling

Table1. The Climate parameters, Sunspots(SSN) and Total Solar Irradiance TSI(wm^{-2})data for the period (1988-2017)[7][8][9].

years	*T(c°)*	*p(mm)*	*SH(h/day)*	*RH%*	*SSN*	*TSI(wm^{-2})*
1988	27.7	41.6	8.1	47.4	123	1360.64
1989	29.1	31.5	8.75	43	211.1	1360.78
1990	29.1	22.2	8.9	41.5	191.8	1361.12
1991	28.4	41.4	8.9	47.1	203.3	1361.64
1992	26.3	60.9	7.8	48.9	133	1361.55
1993	27.8	49.6	8.1	49.6	79.1	1361.52
1994	29.0	33.2	8	50.3	44.9	1361.31
1995	28.9	23.8	8.6	48.2	25.1	1360.94
1996	29.3	36.2	8.1	46.4	11.6	1360.74
1997	28.0	41.3	8.2	50	28.9	1360.73
1998	30.3	24.0	8.5	47.6	88.3	1360.68
1999	30.2	19.2	8.3	44.5	136.3	1360.81
2000	29.5	21.5	7.9	46.4	173.9	1361.18
2001	30.1	23.1	8.6	47.6	170.4	1361.48
2002	29.1	38.5	8.3	47.9	163.6	1361.66
2003	28.8	28.5	8.5	46.5	99.3	1361.57
2004	28.6	26.0	8.1	46.7	65.3	1361.63
2005	29.0	22.7	8.5	43.1	45.8	1361.13
2006	29.5	41.7	8.6	43.7	24.7	1360.92
2007	26.9	17.3	8.4	44.3	12.6	1360.7
2008	29.3	13.5	7.6	40.2	4.2	1360.86
2009	28.9	20.5	8.3	46.9	4.8	1360.6
2010	31.1	22.3	8.3	44.4	24.9	1360.61
2011	28.8	18.5	8	44.8	80.8	1360.61
2012	30.0	24.3	7.8	43.4	84.5	1360.79
2013	29.3	32.9	8.4	45.4	94	1361.07
2014	30.0	29.0	7.9	44.5	113.3	1361.19
2015	29.5	26.3	8.1	45.0	69.8	1361.26
2016	29.7	22.4	8.2	44.9	39.8	1361.39
2017	30	22	8.5	44.9	26.1	1360.63

3. Results and discussion

3.1 Classification of Climate

The climate classifications are intended the organize large amount of information to facilitate the rapid retrieval and communication, grouping items according to their similarities to provide an estimate of the climatic resources of a particular place or region, serving for various purposes. They simplify the climatic data of a place or region, provides a concise description of climate factors in terms of real assets (the which creates the local climate), provides a means by which the climatic regions can be accurately identified and can be used in global, local or micro scale, being the starting point for analyzing the causes of climate variations[10]. There are many classifications for climate complied and proposed by many scientists and researchers to find and determine the type of the climate. The classifications will be used to delineate type of climate in the study area using the annual dryness processing depending on the amount of rainfall and temperature as shown in Table 2 , according to the following equations[11]:

AI – 1 = (1.0 × p) / (11.525×T) …..(T not equal zero)

AI – 2 = 2 $\sqrt{p}$/ T

Where:

AI: Aridity index.

p: Total rainfall (mm).

T: Average Temperature (C°).

Table 2. The monthly averages of rainfall and temperature for the period (1988-2017)[9].

Months	*Rainfall (mm)*	*Temperatures (C°)*
Jan.	66	14.2
Fab.	59.2	16.1
Mar.	49.1	20.5
Apr.	37	27
May	13.5	34.2
Jun	0.1	40.3
July	0.3	43.6
Aug.	0.1	43.2
Sep.	0.7	38.2
Oct.	13.3	31.4
Nov.	46.4	22.7
Dec.	56.3	16.2
Average	28.5	28.96666667
Total	342	347.6

The value of (AI-1) represents the classification of the dominated climate, while the value of (AI-2) represents a modification of the latter classification as shown in Table 3. The values of AI-1 and AI-2 becomes as follows:

AI – 1 = (1 × 342) / (11.525 × 28.9) =1.05

AI – 2=$\frac{2*\sqrt{342}}{28.9}$ = 1.27

When comparing the values of (AI-1) and (AI-2) with the type of the climate reveals that the dominated climate in the area is Humid to moist- Sub arid.

Table 3. Climate classification depending on values of annual dryness treatment (A-I.1 and A-I.2)[11].

Type.1	*Evaluation*	*Type.2*	*Evaluation*
AI-1>1.0	Humid to moist	AI-2>4.5	Humid
		2.5 <AI-2< 4.0	Humid to moist
		1.85<AI-2<2.5	Moist
		1.5<AI-2<1.85	Moist to sub arid
AI-1<1.0	Sub arid to arid	1.0 ≤ AI-2<1.5	Sub arid
		AI-2<1.0	Arid

3.2 Statistical Analysis of the adopted solar activity and climate parameters

The statistical approaches are an important process to detect the correlations between Solar variability and Climate parameters. All data had been analyzed by means of the statistical software (SPSS) program to find out the correlations between Sunspots number ,TSI and each of the following climate parameters (annual Rainfall(mm), annual air temperature (c°), annual Sunshine (h/day) and annual Relative Humidity %) for the period (1988-2017). The correlation is estimated by correlation coefficient. It symbolizes R and Its value ranges (-1≤ R≤ 1).

a. The correlations between Sunspots number (SSN) and the climate parameters

In this study the annual rate of sunspots were used to find the relationship between them and each of the following climate parameters (The annual Rainfall (mm), annual temperature (c°), annual Sunshine(h/day), and annual Relative Humidity %).as shown in figure (2,3,4,5).

Table 4. The correlation coefficient values between the Sunspot number (SSN) and The Climate parameters for the period (1988-2017)

Dependent Variable	*In dependent Variable*	*Correlation coefficient (R)*
T(c°)	SSN	0.042
p(mm)		0.214
RH%		0.032
SH(h/day)		0.345

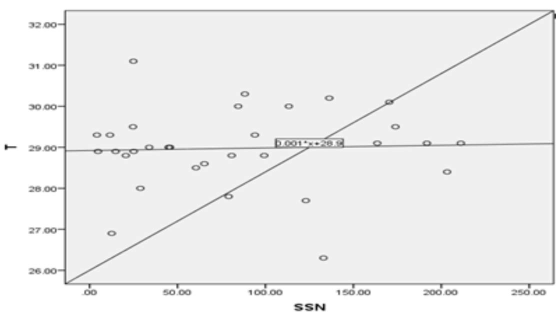

Figure 2. Scatter plot between the Sunspot number (SSN) and annual air temperature (C°) for the period (1988-2017).

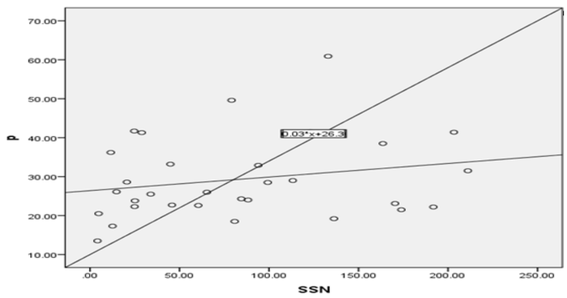

Figure 3. Scatter plot between the Sunspot number (SSN) and annual Rainfall(mm) for the period (1988-2017).

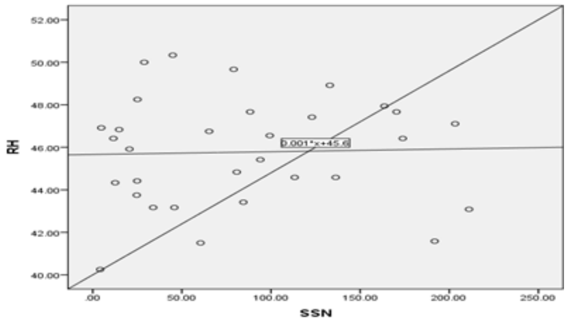

Figure 4. Scatter plot between the Sunspot number (SSN) and annual Relative Humidity % for the period (1988-2017).

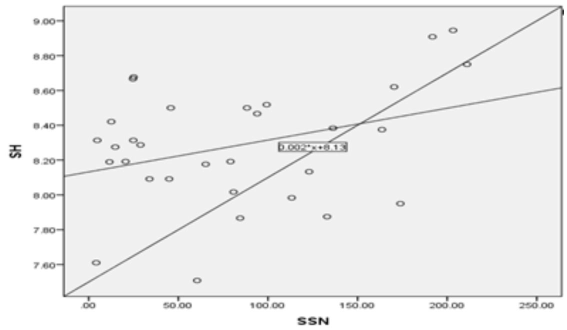

Figure 5. Scatter plot between the Sunspot number (SSN) and annual Sunshine(h/day) for the period (1988-2017).

b. The correlations between TSI(wm^{-2}) and the climate parameters

The annual rate of TSI(wm^{-2}) was used to find the statistical relationship with climate parameters(The annual Rainfall(mm), annual temperature(c°), annual Sunshine(h/day), and annual Relative Humidity %).as shown in figure (6,7,8,9).

Table 5. The correlation coefficient values between the Total Solar Irradiance TSI(wm^{-2}) and The Climate parameters for the period (1988-2017).

Dependent Variable	*Independent Variable*	*correlation coefficient (R)*
T(c°)	TSI(wm^{-2})	0.191
p(mm)		0.181
RH%		0.050
SH(h/day)		0.318

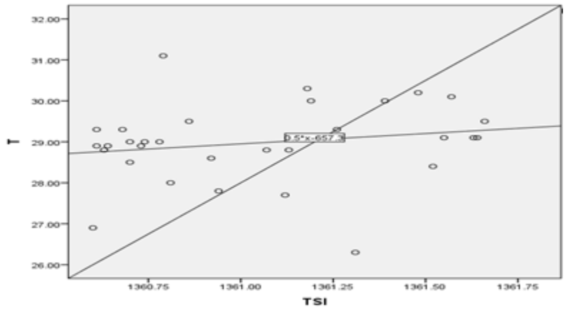

Figure 6. Scatter plot between TSI(wm^{-2}) and annual air temperature (C°) for the period (1988-2017).

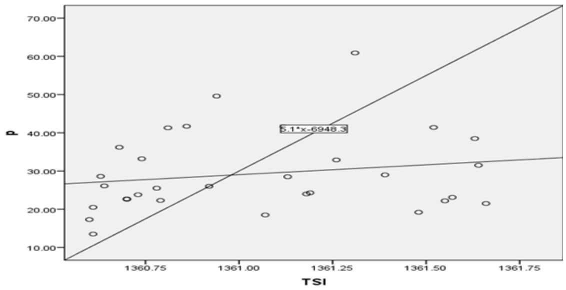

Figure 7. Scatter plot between TSI(wm^{-2}) and annual Rainfall(mm) for the period (1988-2017).

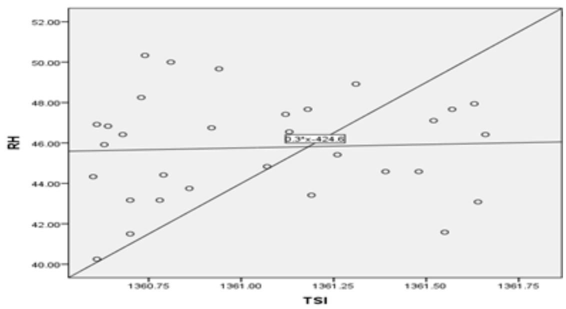

Figure 8. Scatter plot between TSI(wm^{-2}) and annual Relative Humidity % for the period (1988-2017).

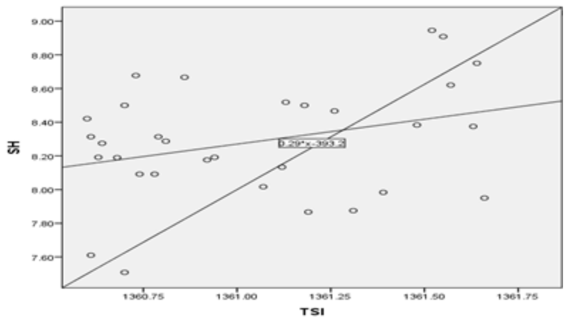

Figure 9. Scatter plot between TSI(wm^{-2}) and annual Sunshine(h/day) for the period (1988-2017).

3.3 Discussion

Figure 2 shows a scatter plot (using SPSS software vir.23) between (SSN) and the annual air temperature (C°) for the period (1988-2017) and the statistical equation is **Y=0.001X+28.921** that is mean (T=28.921 + 0.001SSN) .And as shown in **Figure 2** and **Table 4** that the correlation coefficient is a positive value and its absolute value is less than 0.5 (0.042) very small value this means that increased of (SSN) don't affect clearly in air temperature (C°) of study area . **Figure 3** shows a scatter plot between

(SSN) and the annual Rainfall(mm) for the period (1988-2017) and the statistical equation is **Y=0.03X+26.399** that is mean (R=26.399+0.035SSN). And as shown in **Figure 3** and **Table 4** that the correlation coefficient is a positive value and its absolute value is less than 0.5 (0.214) that is means a good correlation between (SSN) and R(mm).

Figure 4 shows a scatter plot between (SSN) and the annual Relative Humidity % for the period (1988-2017) and the statistical equation is **Y=0.001X+45.663** that is mean (RH=45.663+0.001SSN). **Figure 4** and **Table 4** shows that the correlation coefficient value is less than 0.5 (0.032) this value mean that is the relationship between SSN and RH is too small. **Figure 5** illustrates a scatter plot between (SSN) and the annual Sunshine(h/day) for the period (1988-2017) and the statistical equation is **Y=0.002X+8.132** that is mean (SH=8.132+0.002SSN) according to the principle equation of regression . And as shown in **Figure 5** and **Table 4** that the correlation coefficient value is (0.345) shows effect of SSN On increasing SH.

Figure 6 shows a Scatter plot(using SPSS software vir.23) between TSI(wm^{-2}) and the annual air temperature (C°) for the period (1988-2017) and the statistical equation **Y=0.504X- 657.38**. that is mean (T=-657.38+0.504 TSI) .And as shown in **Figure 6** and **Table 5** that the correlation coefficient is a positive value less than 0.5 (0.191) shows an increasing relationship between the two variables. **Figure 7** shows Scatter plot between TSI(wm^{-2}) and the annual Rainfall(mm) for the period (1988-2017) and the statistical equation is **Y=5.153X-6948.156**. that is mean the principle equation of regression is(R=-6984.15+5.15TSI).Also as shown in **Figure 7** and **Table 5** that the correlation coefficient is a positive value (0.181) Showing the effect of TSI on R. **Figure 8** shows Scatter plot between TSI(wm^{-2}) and the monthly average Relative Humidity % for the period (1988-2017) and the statistical equation is **Y=10X- 13566** that is mean the principle equation of regression is(RH=-424.6+0.346TSI). As shown in **Figure 8** and **Table 5** that the correlation coefficient is a positive value (0.05) very small value . This value shows that the relationship between the two variables is virtually non-existent. **Figure 9** shows Scatter plot between TSI(wm^{-2}) and the monthly average Sunshine(h) for the period (1988-2017) and the statistical equation is **Y=0.295X- 393.264** that is mean(SH=-393.246+0.295TSI) . As shown in **Figure 9** and **Table 5** that the correlation coefficient value is (0.318). This value shows the degree of correlation between TSI and SH.

4. Summary

In this research the data analysis of the present work leads us to conclude the following:

1) For the degree of correlation between SSN and air temperature (C°), The correlation coefficient shows that the SSN have no effect on increasing the air temperature of the study area .While the correlation between the TSI and the air temperature illustrate that correlation coefficient value between them (0.191) is greater than the correlation coefficient value between the SSN and the air temperature (0.042). This means that TSI impacts the air temperature of the study area over the long term.

2) The relationship between SSN and R is greater than the relationship between TSI and R .Where noted that the correlation coefficient value (0.214) between SSN and R is greater than the correlation coefficient value (0.181) between TSI and R . Ie, the SSN have a higher effect on the amount of rainfall for the study area than TSI .

3) By observing the statistical analysis . found the correlation between both SSN, TSI and RH% ,which shows that increased in SSN and TSI don't affect on the change in Relative Humidity % . Which is shown by its correlation coefficient, where the value of correlation coefficient between SSN and RH is (0.032) and value of correlation coefficient between TSI and RH is (0.05).

4) The value of the correlation coefficient between SSN and Sunshine (SH) is (0.345) is slightly similar to the value correlation coefficient between TSI and Sunshine (SH) (0.318). From these values we observe the effect of SSN and TSI on the percentage of the SH for study area.

5) From this study we also conclude that the change in TSI has a greater impact on climate parameters than the change in SSN.

In fact, all these statistical processes are the prediction of any solar variability that have a greater impact on the climate changes .

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التحليل الاحصائي لتأثير البقع الشمسية والاشعاع الشمسي على المناخ في منطقه كركوك لثلاث دورات شمسيه (22,23,24)

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الملخص

في هذه الدراسة تم رصد اعداد البقع الشمسية (SSN) والاشعاع الشمسي (TSI) في مركز تحليل بيانات التأثيرات الشمسية (SIDS) والقمر الصناعي (ERBS) للدورات الشمسية (22,23,24) للفترة (1988−2017). وبالنسبة لنفس الفترة تم اخذ بيانات الارصاد الجوية المسجلة في محطة كركوك لمعاملات المناخ والتي تتضمن(المعدل السنوي للرطوبة النسبية، المعدل السنوي لدرجة حرارة الهواء، المعدل السنوي للساقط المطري، المعدل السنوي للسطوع الشمسي) .حيث تم التحقق من الارتباط الاحصائي بين المعاملات الشمسية والمناخية باستخدام البرنامج الاحصائي (SPSS) للإصدار (23). من هذا التحليل الاحصائي تبين ان هناك ارتباط بين السطوع الشمسي مع كل من البقع الشمسية والاشعاع الشمسي اقل من 0.5 اي ان البقع الشمسية والاشعاع الشمسي يؤثر بشكل قليل على SH بينما الارتباط يكون ضعيف او معدوم بين كل من البقع الشمسية والاشعاع الشمسي مع الرطوبة النسبية من خلال قيمة معامل الارتباط (0.05,0.032). كما ان تأثير الاشعاع الشمسي على درجه حراره الهواء اكثر من تأثير البقع الشمسية ولكن بنسبه اقل من 0.5.وايظا يكون تأثير البقع الشمسية اكثر من الاشعاع الشمسي على كميه الساقط المطري بنسبه اقل من 0.5 حسب قيمة معامل الارتباط الاحصائي. يظهر هذا التحقيق ان المناخ في منطقه كركوك يتأثر بشكل قليل بالنشاط الشمسي الذي يشمل البقع الشمسية والاشعاع الشمسي.