INVESTIGATION OF THE IMPACT OF SUNSPOTS ON EARTH'S CLIMATE

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World history of the effect of climate change on humanity is enough witness to attest to its lethal effects. Various researches have delved into the investigation of the probable causes of variation in earth's climatic condition, with majority of such researches concentrating more on the impact of the changes in the reflectivity of earth's atmosphere, surface and increase in the emission of greenhouse gases into the atmosphere chiefly propelled by human inducement, while little has been done to investigate the impact of the temporary phenomena on the photosphere of the Sun that appears visibly as dark spots compared to surrounding regions (Sunspots). Using Global sunspots and annual temperature anomalies data of 1900 - 2014, attempt has been made in this research to investigate temporal variation of the trend of sunspots and their impact on earth's climate since temperature is one of the basic indices that define climate while the sun is the fundamental source of energy that drives our climate system. The result shows that the earth is getting warmer over the years as increase in years lead to increase in annual temperature anomaly. A very weak correlation was observed between the global mean sunspot number and the annual temperature anomaly while there is a positive correlation between the global mean sunspot number and the Earth's temperature though very weak and statistically insignificant. It is thus concluded that the direct impact of sunspots on Earth's anomaly is very weak, minimal and at best, indirect.

Keywords: Climate, Temperature anomalies, Sunspot, Photosphere, greenhouse emission, global warming, sun irradiance.

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INTRODUCTION

Climate is the average weather in a place over more than thirty years. It is any long-term significant change in the “average weather” that a given region experiences. Average weather may include average temperature, precipitation and wind patterns. It involves changes in the variability or average state of the atmosphere over durations ranging from decades to millions of years. These changes can be caused by dynamic processes on Earth, external forces including variations in sunlight intensity, and more recently by human.

Our planet's climate is influenced by so many factors some of which include volcanic eruptions, wind, solar radiations and ocean currents to man-made emissions of greenhouse gases. Nearly all the energy impacting Earth's climate comes from the sun, even if it is sometimes indirectly (www.wikibooks.org). The sun can be described as a thermonuclear engine which emits energy that is released by the fusion of hydrogen atoms within the sun’s core. It supplies the energy needed for life on Earth. It is a constant star when compared with many others in the galaxy. Some stars pulsate dramatically, varying wildly in size and brightness and even exploding. In comparison, the sun varies in the amount of light it emits by only 0.1 percent over the course of a relatively stable 11-year-long pattern known as the solar cycle (Charles, 2013). The solar activity which consists of Solar wind, coronal mass ejections (CME), solar flares, sunspots, etc is a major influencer of earth’s temperature.

Sunspot, which is one of the major solar activities can be described as the temporal phenomena on the photosphere of the Sun which appears visibly as dark spots compared to surrounding regions. They form on the surface of the Sun due to strong magnetic field lines coming up from within the Sun through the solar surface. They correspond to concentrations of magnetic field flux that inhibit convection and result in reduced surface temperature compared to the surrounding photosphere (en.wikipedia.org). They are cooler than the surrounding photosphere, typically by about 1500K (thus, they are still at a temperature of about 4500K, but this is cool compared to the rest of the photosphere which could be as high as 6,500K). They could be as large as 50,000 miles in diameter, move across the surface of the sun, contracting and expanding as they go. These sunspots can sometimes become many times bigger than the earth are always dark because they are much cooler than the surrounding surface of the Sun itself. Sunspots are predominantly present during solar maximum (Solar max is the period of greatest solar activity in the solar cycle of the sun, where one solar cycle lasts about 11 years) while only very few or even no sunspot appears during solar minimum (www.spaceweatherlive.com). Sunspot consists of two parts namely: The umbra (dark part) and the Penumbra (Lighter part around the dark part).

REVIEW OF RELATED LITERATURES

Global climate change including long-term periods of global cold, rainfall, drought, and other weather shifts are also perceived to be influenced by solar cycle activity, based on historical evidence as documented by quite a number of researchers some of which are herein presented in this subsection:

Some parts of the solar spectrum, especially ultraviolet, increase a great deal during sunspot activity. Even though ultraviolet radiation makes very little contribution to the total energy that comes from the sun, changes in this type of radiation can have a large effect on the earth's atmosphere, especially the energy balance and chemistry of the outer atmosphere (Wilson, 2014). One of the first notably documented researches on the impact of sunspots and climate change was conducted by Eddy (1976). The research looked at the record of the globally averaged sea surface temperature (SST) and noticed an obvious similarity between this and the variation of solar activity represented by the 11 year cycle sunspot number. He observed that a period of unusually low sunspot activity from 1645-1715, called the Maunder Minimum, coincided with a period of long cold winters and severe cold temperatures." Temperatures dropped by 1.8 to 2.7 degrees Fahrenheit in Western Europe and North America, often called the "Little Ice Age." In 1991, this relationship was further examined using the length of the sunspot cycle as a parameter which varies from cycle to cycle. It had been demonstrated that the length of the sunspot cycle is usually shorter during strong activity cycles than during low activity cycles. A comparison with the Northern Hemisphere land temperature during the last 130 years did show a remarkably good correlation with the smoothed curve of the varying solar cycle length indicating that this parameter was possibly a better indicator of solar activity variations that could affect the Earth's climate (Friis-Christensen and Lassen, 1991).

The recent investigations of possible effects of solar variations on the earth's temperature and on the height of constant pressure levels in the stratosphere were reviewed by Labitzke and Van-Loon (1993). The research found that the correlations between solar activity and climate parameters for the stratosphere on a decadal scale have a specific spatial distribution over the globe, and that they have the highest values between 20° N and 45° N in the Pacific-Atlantic area during most of the year but especially high and statistically significant during summer. But during winter the correlations are not statistical significant. This research also submitted that the solar radiation circulation is a major factor controlling the spatial distribution of the atmosphere's response to solar variability and that the average temperature difference between solar maximum and solar minimum years is largest just below the tropopause.

Lassen (1995) re-examined the solar total and UV irradiances since 1610. The result of the research validated the results gotten earlier by Friis- Christensen (1995) which confirmed that the correlation between the total solar irradiance and the Northern Hemisphere surface temperature from year 1610 to 1800 is 0.86, which suggests a predominant solar influence. By inference, there is an indication that solar forcing may have contributed to about half of the 0.5°C surface warming since the year 1860. Douglas and Kenneth (1997), in the book titled "The Role of the Sun in Climate Change" examined different sampling methods and their problems; they studied data of solar variation with climate in the early centuries and found that the correlation is remarkably parallel. They also summarized several ideas on the recent century results, finding it controversial since the surface temperature of the earth is increasing steady with increased sunspot number.

Friis-Christensen and Henrik (1997), discovered that the relationship between sunspots and the earth's climate is complex as a result of large radioactive effect of clouds, which could be the missing link between solar activity variations and climate changes. Nine (9) cycles of changes in solar brightness were tracked by Kevin and Kevin (2002) and correlated the solar brightness with the climate of the earth. Their findings observed that the period of low sunspots within the period of their investigation corresponds with the Maunder Minimum, a period of extreme cold in Europe. Scientists from NASA Earth Observatory (2005) confirmed after studying the total solar irradiance (TSI) at different points and time that the amount of radiation arriving from the Sun is not constant. It varies from the average value of the TSI-1,368W/m^2 on a daily basis. They concluded that the number of sunspots on the Sun's surface is roughly proportional to total solar irradiance.

The Intergovernmental Panel on Climate Changes (IPCC) of Cambridge in 2007 made use of calculations of Total Solar Irradiance (TSI) data of various cycles till 2007 and found out that the sunspots number has been increasing steadily at the time when the earth has been getting warmer during the past periods. This implies that the increase in the number of sunspots corresponds to the increase in the warmness of the earth, even though, the past two cycles indicate that the sun and the climate are moving in opposite directions.

Jennifer (2008) presented that changes in sunspot cycles do change the amount of solar radiation given off by the sun, but by a little bit. Using the solar irradiance and daytime high temperatures relationship, Soon and Briggs (2012) argued that the sun warms the earth and more effects are experienced in the regions of cloudless skies. This findings was also supported by Harry Van Loon and Gerald Meehl (2009). Gerald (2009) presented persuasive evidence that solar variability is leaving an imprint on climate, especially in the Pacific. According to the report, when researchers look at sea surface temperature data during sunspot peak years, the tropical Pacific shows a pronounced La Nina-like pattern, with a cooling of almost 1^{o}C in the equatorial eastern Pacific. In addition, "there are signs of enhanced precipitation in the Pacific Inter-Tropical Convergence Zone (ITCZ) and South Pacific Convergence Zone (SPCZ) as well as above-normal sea-level pressure in the mid-latitude North and South Pacific," correlated with peaks in the sunspot cycle. Of course, this was expected since the Sun warms the equator more than the poles, climate varies with latitude.

According to NASA's Marshall Space Flight Center in July 22, 2009, sunspots play a role in climate change, but at very minimal value. They suggest that maybe if carbon emissions are reduced, we will be able to detect the impact of sunspots and other natural influences on earth's climate. Recent research (Lane et al, 1994) indicates that the combined effects of sunspot-induced changes in solar irradiance and increases in atmospheric greenhouse gases offer the best explanation yet for the observed rise in average global temperature over the last century (Geerts and Linacre, 1997). Charles (2013b) opined that even small changes in solar activity can impact Earth's climate in significant and surprisingly complex ways, though it may have more of a regional effect than a global one. Scientists from the American Institute of Physics in 2014 proposed that before 20^{th} century, irregular variations in solar surface activity were connected with earth's climate shifts but from 20^{th} century till date, the variations in solar surface activity with earth's climate is minor.

Study Area

The earth is the only astronomical object in the solar system known to harbor life. It is one of the planets of the solar system contained in the milky-way galaxy. It gravitationally interacts with other objects in space, especially the Sun and the Moon. It rotates about its own axis 366.26 times, creating 365.26 solar days or one sidereal year during its one orbit around the Sun. The earth's only permanent natural satellite is the Moon. The earth's gravitational interaction with its only natural satellite gradually slows earth's rotational rate, stabilizes the orientation of earth's rotational axis and causes ocean tides. The shape of the earth approximates an oblate spheroid (a sphere flattened at the axis from pole to pole creating a bulge around the equator).

According to evidences from radiometric dating and other sources, the earth was formed about 4.54 billion years ago.

MATERIALS AND METHODS

Global sunspots and annual temperature anomalies data of 1900 – 2014 were used for this investigation. The sunspot data was extracted from the online data repository of WDC-SILSO (Sunspot Index and Long-term Solar Observations), Royal Observatory of Belgium, Brussels (http://www.sidc.be/silso/datafiles). The global temperature anomaly data set was extracted from the online data repository of National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (http://data.giss.nasa.gov/gistemp/). Both land and satellite based measurements were used to source for these data. All data used can be classified as secondary data.

From the monthly temperature anomaly data, annual temperature anomaly was computed for each of the years from 1900 to 2014 to reduce data complexity for effective data management. Also, yearly mean total number of sunspots were computed for each of the obtained sunspot data. These computed or extracted data were thus arranged in fields and tuples within Microsoft excel worksheet environment which was the software environment where the result was processed using the analyse-it add-in statistical software. Both regression and correlation analysis were adopted to establish the existence of statistically significant relationship (association and dependency) between the variables of the dataset.

RESULTS

- Table 1.0a and b shows the result of the Correlation analysis expressing the relationship between the annual mean temperature anomaly and the years and the result of the regression analysis establishing a dependency relationship between annual mean temperature anomaly and the years of study respectively.
- Figure 1.0a is a scattered diagram superimposed on the histogram showing the correlation between annual mean temperature anomaly and the years while Figure 1.0b presents the scattered diagram showing the association between annual mean temperature anomaly and the years from regression analysis. Figure 1.0c presents the residuals of the regression analysis showing: (a) the relationship between standardized residuals and frequency, (b) standardized residual and observation and (c) standardized residual and Normal theoretical quantile of the annual mean temperature anomaly and the years. The residual plots allow visual assessment of the distance of each observation from the fitted line, while the

histogram of the residuals allows visual assessment of the assumption that the measurement errors in the response variable are normally distributed.

- Table 2.0a contains the result of the Correlation analysis showing the relationship between the Yearly Mean Total Sunspot Number and the years while Table 2.0b shows the results of the regression analysis establishing a dependency relationship between Yearly Mean Sunspot Number and the years of study.
- Figure 2.0a presents a scattered diagram superimposed on the histogram showing the correlation between Yearly Mean Total Sunspot Number and the years while Figure 2.0b is the scattered diagram showing the association between Yearly Mean Sunspot number and the years from regression analysis. Figure 2.0c is the scattered diagram showing the association between standardized residuals and the years from regression analysis while Figure 2.0d: Residuals of the regression analysis showing: (a) the relationship between standardized residuals and frequency, (b) standardized residual and observation and (c) standardized residual and Normal theoretical quantile of the yearly mean number of sunspots and the years.
- Table 3.0a shows the result of the Correlation analysis showing the relationship between the annual mean temperature anomaly and the yearly mean sunspot numbers while Table 3.0b shows the results of the regression analysis establishing a dependency relationship between Yearly Mean Sunspot Number and the annual temperature anomaly.
- Figure 3.0a presents a scattered diagram superimposed on a histogram showing the correlation between Yearly Mean Total Sunspot Number and the annual temperature anomaly, Figure 3.0b is the scattered plot showing the association between Yearly Mean Sunspot number and the annual temperature anomaly from regression analysis. Figure 3.0c presents the scattered diagram showing the association between standardized residuals and the annual temperature anomaly from regression analysis while Figure 3.0d Residuals of the regression analysis showing: (a) the relationship between standardized residuals and frequency, (b) standardized residual and observation and (c) the standardized residual and Normal theoretical quantile of the yearly mean number of sunspots and the annual temperature anomaly.

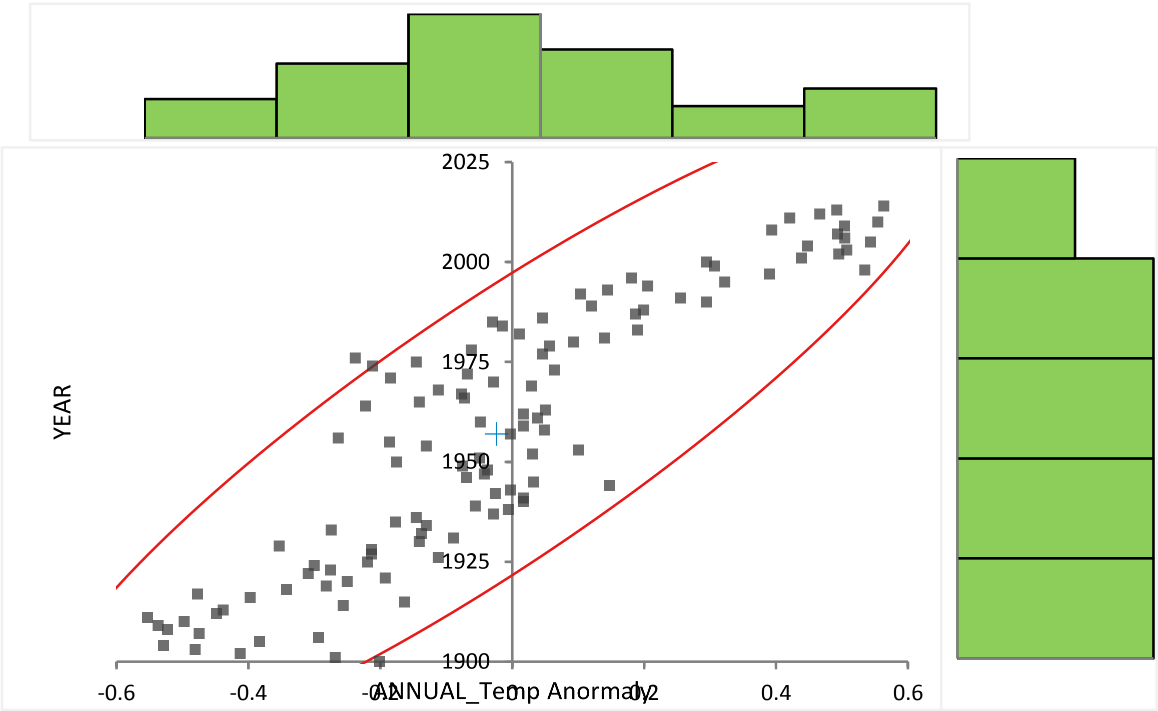


Figure 1.0a: Scattered diagram superimposed on histogram showing the correlation between annual mean temperature anomaly and the years.

Table 1.0: Result of the Correlation analysis showing the relationship between the annual mean temperature anomaly and the years.

N	115	
Pearson's r	0.889	
Fisher 95% CI	0.843	to 0.922
Hypothesized value	0	
t approximation	20.64	
DF	113	
p-value	<0.0001	

H0: $\rho = 0$, The correlation coefficient ρ of the bi-variable population is equal to 0.
H1: $\rho \neq 0$, The correlation coefficient ρ of the bi-variable population is not equal to 0.

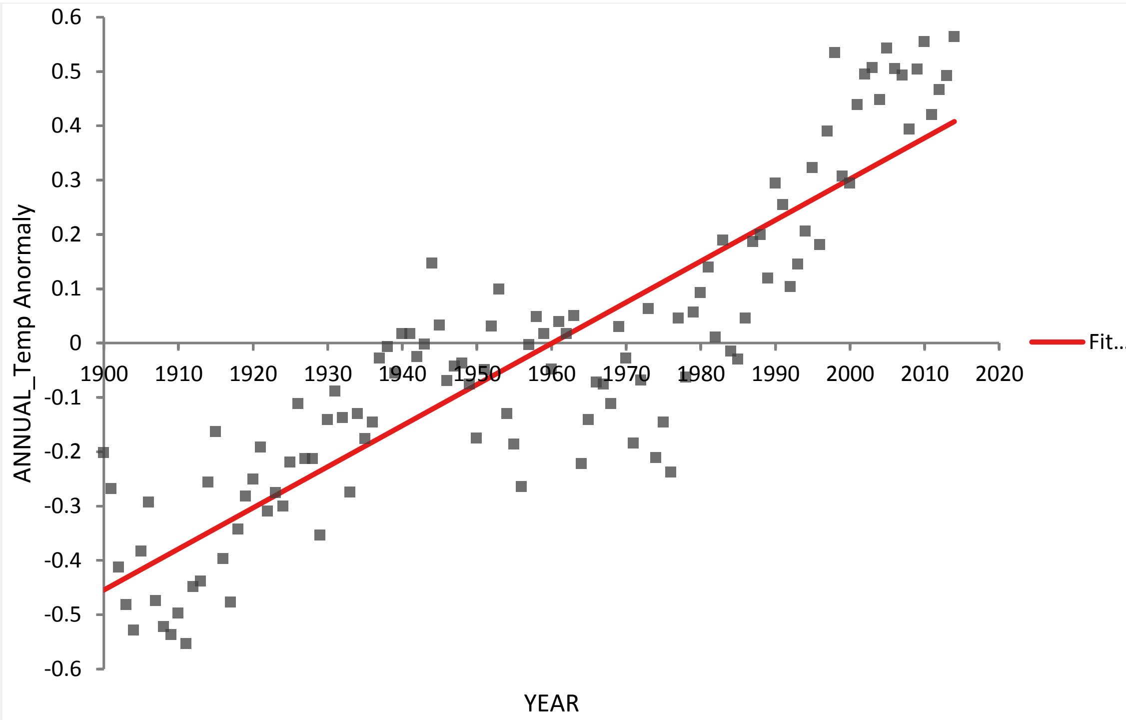


Figure 1.0b: Scattered diagram showing the association between annual mean temperature anomaly and the years from regression analysis.

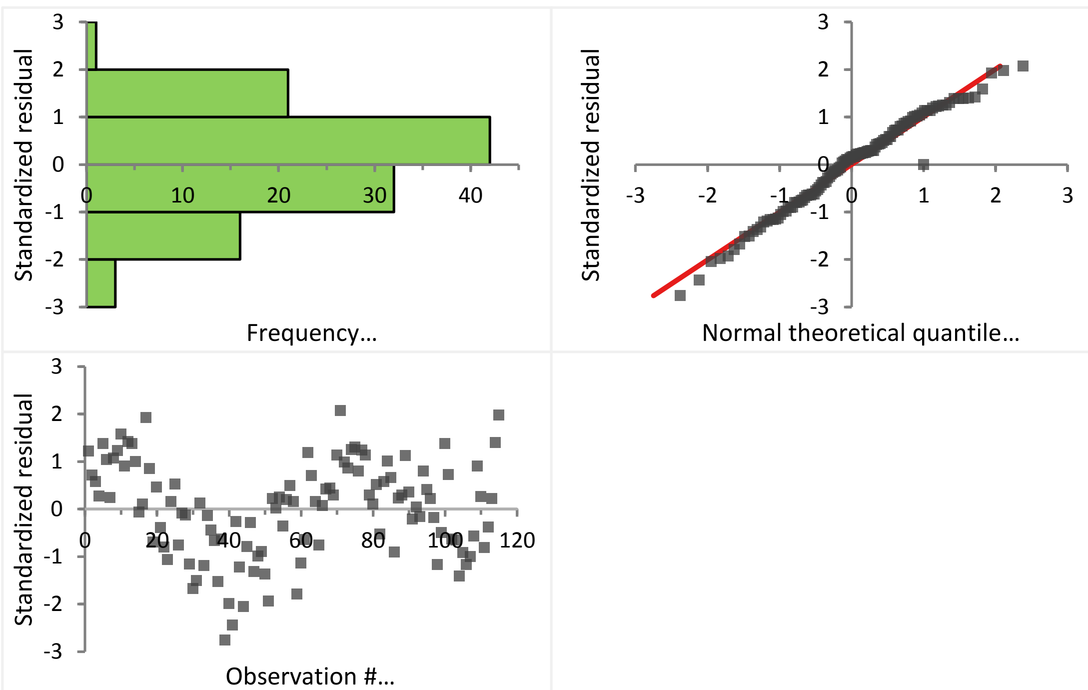


Figure 1.0c: Residuals of the regression analysis showing: (a) the relationship between standardized residuals and frequency, (b) standardized residual and observation and (c) standardized residual and Normal theoretical quantile of the annual mean temperature anomaly and the years.

FIT					
N	115				
Variable	Mean	SD	Minimum	Median	Maximum
YEAR	1957.0	33.3	1900	1957.0	2014
ANNUAL_Temp Anomaly	-0.0236	0.2837	-0.553	-0.0420	0.564
Equation	ANNUAL_Temp Anomaly = -14.83 + 0.007565 YEAR				
R^2	0.790				
R^2 adjusted	0.789				
SE of fit (RMSE)	0.13046				
Parameter	Estimate	95% CI		SE	p-value
Constant	-14.83	-16.25	to -13.41	0.71729	<0.0001
YEAR	0.007565	0.006839	to 0.008291	3.6647 E-04	<0.0001
H0: $\beta = 0$, The parameter is equal to 0. H1: $\beta \neq 0$, The parameter is not equal to 0.					
EFFECT OF MODEL					
Source	SS	DF	MS	F	p-value
Difference	7.2530	1	7.2530	426.14	<0.0001
Error	1.9233	113	0.0170		
Null model	9.1763	114	0.0805		
H0: $E(Y\|X=x) = \mu$, The model is no better than a null model $Y=\mu$. H1: $E(Y\|X=x) = \alpha + \beta x$, The model is better than the null model.					
EFFECT OF TERMS					
Term	SS	DF	MS	F	p-value
YEAR	7.2530	1	7.2530	426.14	<0.0001
H0: $\beta_{Term} = 0$, The term does not contribute to the model. H1: $\beta_{Term} \neq 0$, The term contributes to the model.					

Table 1.0b: Results of the regression analysis establishing a dependency relationship between annual mean temperature anomaly and the years of study.

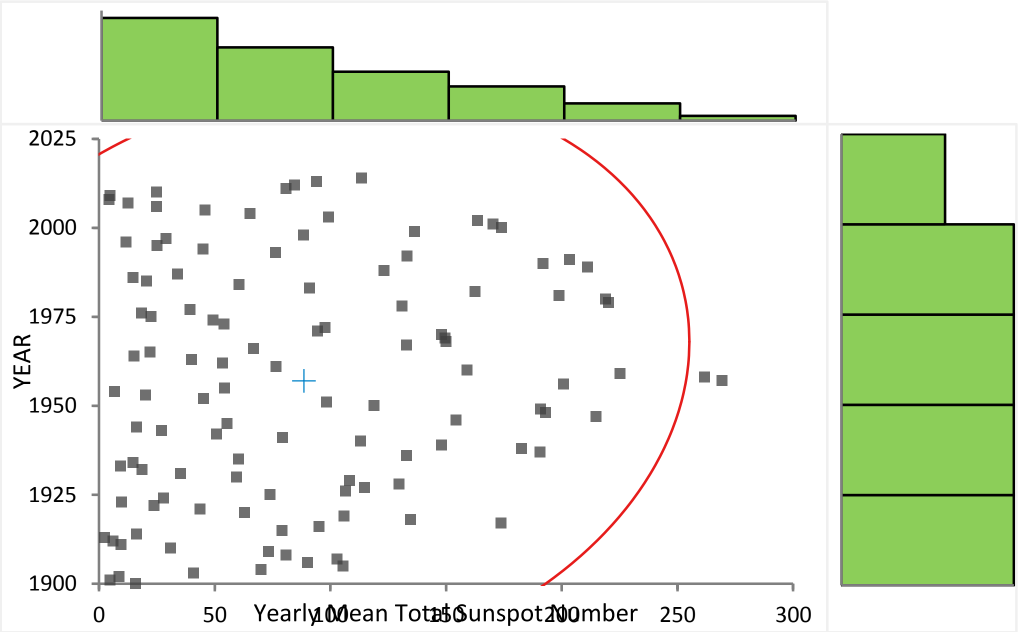


Figure 2.0a: Scattered diagram superimposed on histogram showing the correlation between Yearly Mean Total Sunspot Number and the years.

Table 2.0a: Result of the Correlation analysis showing the relationship between the Yearly Mean Total Sunspot Number and the years.

N	115	
Pearson's r	0.133	
Fisher 95% CI	-0.051	to 0.308
Hypothesized value	0	
t approximation	1.43	
DF	113	
p-value	0.1569	

H0: ρ = 0, The correlation coefficient ρ of the bi-variable population is equal to 0.
H1: ρ ≠ 0, The correlation coefficient ρ of the bi-variable population is not equal to 0.

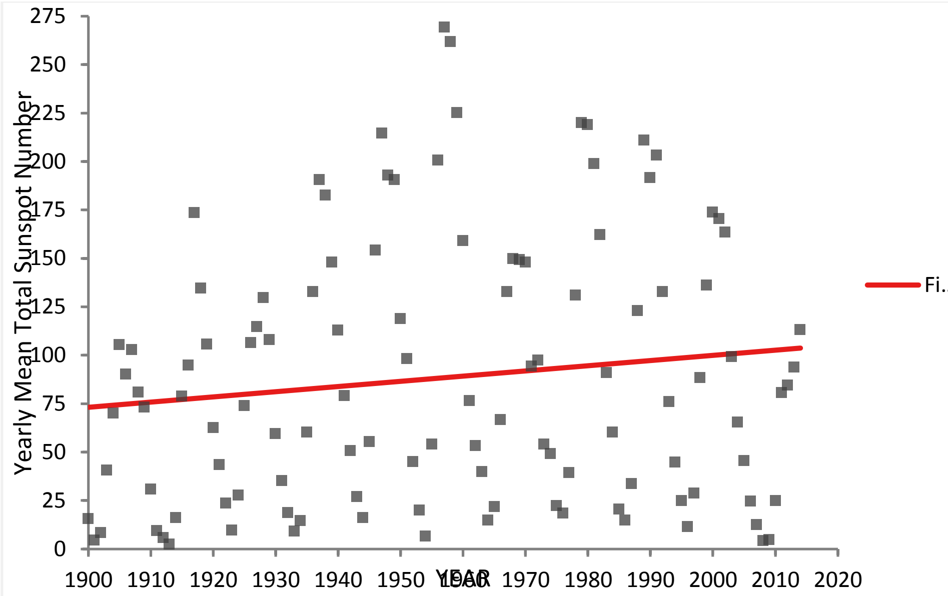


Figure 2.0b: Scattered diagram showing the association between Yearly Mean Sunspot number and the years from regression analysis.

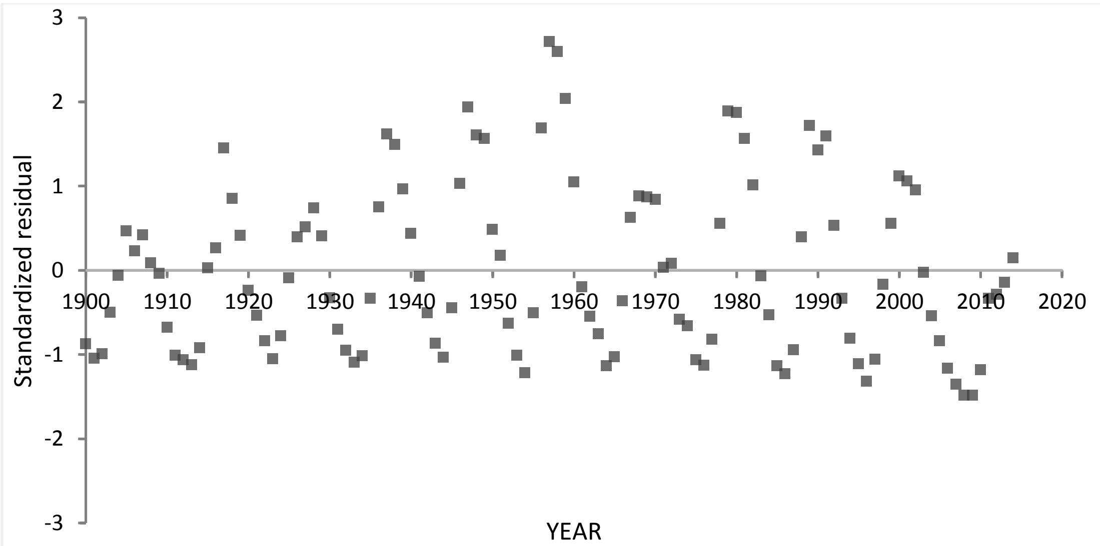
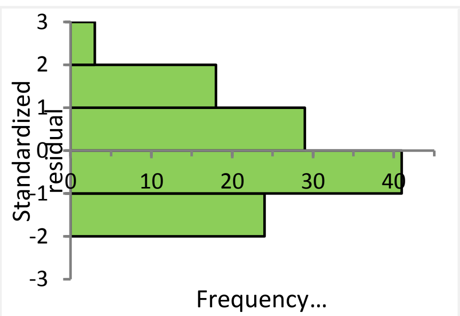
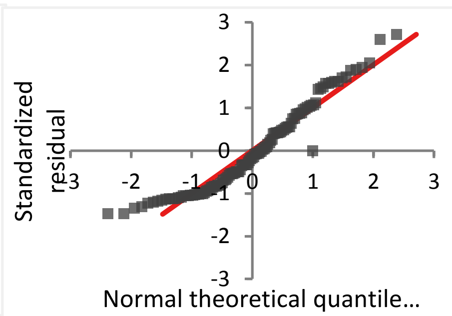


Figure 2.0c: Scattered diagram showing the association between standardized residuals and the years from regression analysis.

Table 2.0b: Results of the regression analysis establishing a dependency relationship between Yearly Mean Sunspot Number and the years of study

FIT					
N	115				
Equation	Yearly Mean Total Sunspot Number = -435.8 + 0.2679 YEAR				
R^2	0.018				
R^2 adjusted	0.009				
SE of fit (RMSE)	66.914				
Parameter	Estimate	95% CI		SE	p-value
Constant	-435.8	-1165	to 293.1	367.90	0.2387
YEAR	0.2679	-0.1045	to 0.6403	0.18796	0.1569
H0: $\beta = 0$, The parameter is equal to 0. H1: $\beta \neq 0$, The parameter is not equal to 0.					
EFFECT OF MODEL					
Source	SS	DF	MS	F	p-value
Difference	9092.75	1	9092.75	2.03	0.1569
Error	505951.46	113	4477.45		
Null model	515044.21	114	4517.93		
H0: $E(Y\|X=x) = \mu$, The model is no better than a null model $Y=\mu$. H1: $E(Y\|X=x) = \alpha + \beta x$, The model is better than the null model.					
EFFECT OF TERMS					
Term	SS	DF	MS	F	p-value
YEAR	9092.75	1	9092.75	2.03	0.1569
H0: $\beta_{Term} = 0$, The term does not contribute to the model. H1: $\beta_{Term} \neq 0$, The term contributes to the model.					





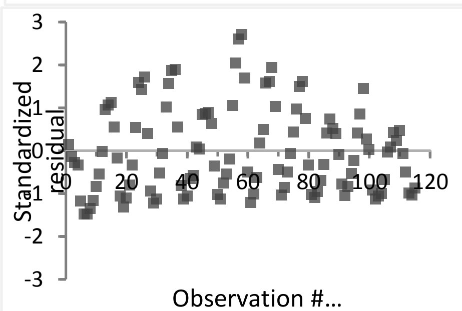


Figure 2.0d: Residuals of the regression analysis showing: (a) the relationship between standardized residuals and frequency, (b) standardized residual and observation and (c) standardized residual and Normal theoretical quantile of the yearly mean number of sunspots and the years.

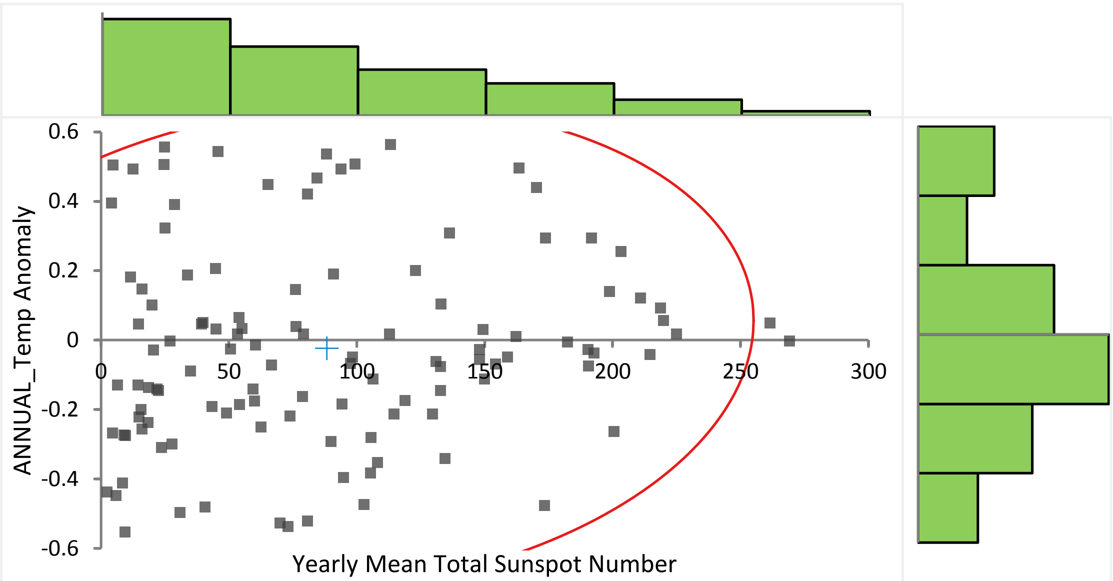


Figure 3.0a: Scattered diagram superimposed on histogram showing the correlation between annual mean temperature anomaly and the yearly mean sunspot numbers.

Figure 3.0a: Scattered diagram superimposed on histogram showing the correlation between Yearly Mean Total Sunspot Number and the annual temperature anomaly

Table 3.0a: Result of the Correlation analysis showing the relationship between the annual mean temperature anomaly and the yearly mean sunspot numbers.

N	115	
Pearson's r	0.114	
Fisher 95% CI	-0.071	to 0.291
Hypothesized value	0	
t approximation	1.22	
DF	113	
p-value	0.2266	

H0: ρ = 0, The correlation coefficient ρ of the bi-variable population is equal to 0.
H1: ρ ≠ 0, The correlation coefficient ρ of the bi-variable population is not equal to 0.

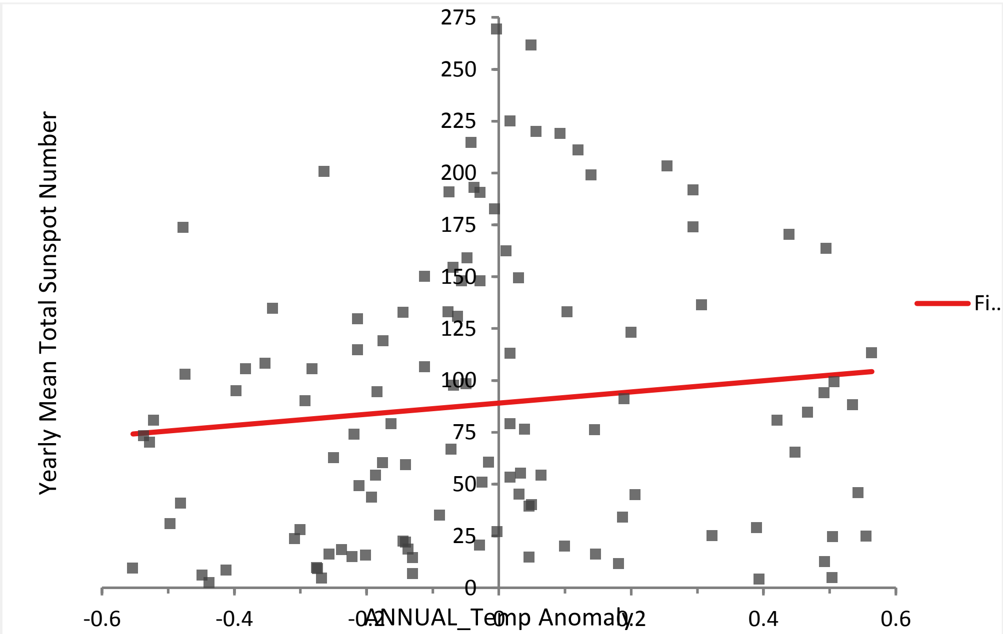


Figure 3.0b: Scattered diagram showing the association between Yearly Mean Sunspot number and the annual temperature anomaly from regression analysis.

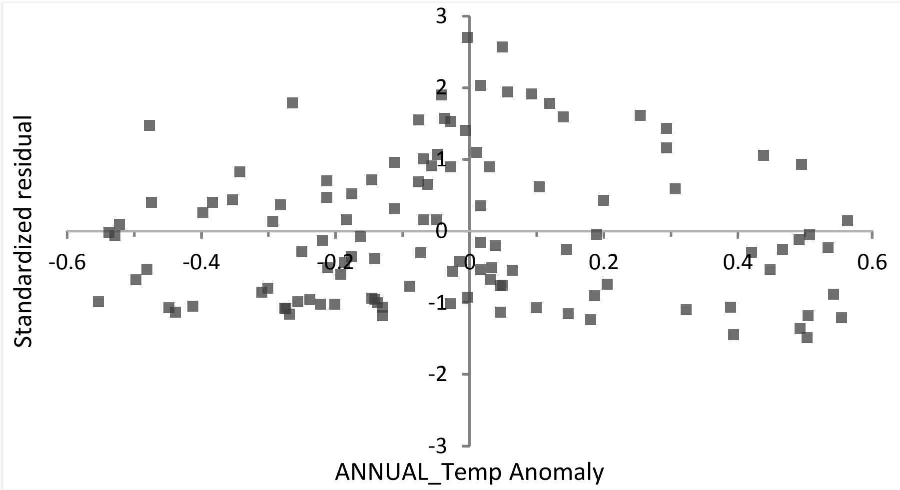


Figure 3.0c: Scattered diagram showing the association between standardized residuals and the annual temperature anomaly from regression analysis.

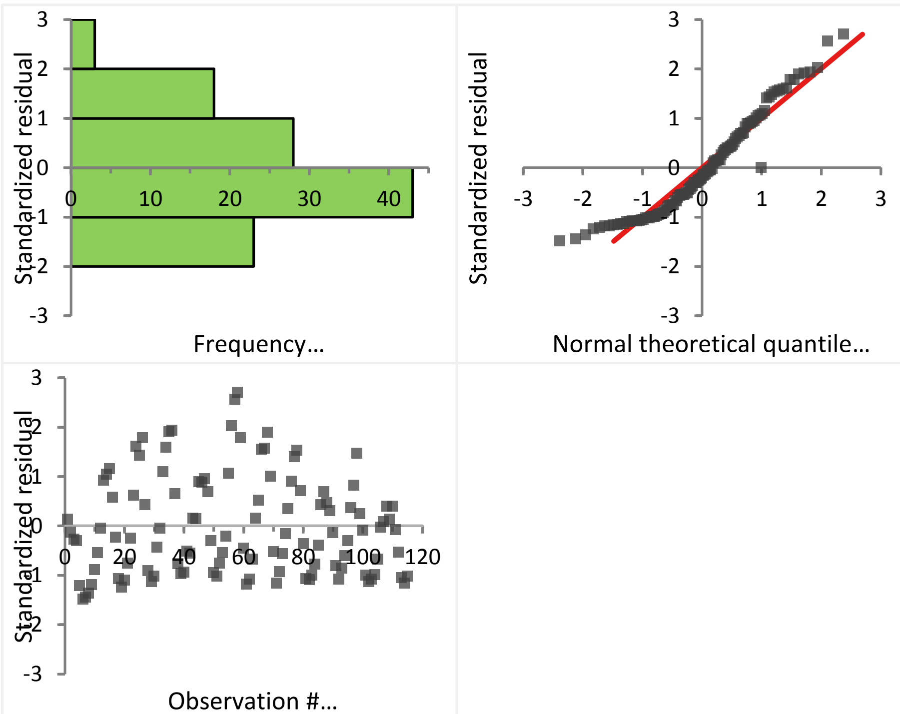


Figure 3.0d: Residuals of the regression analysis showing: (a) the relationship between standardized residuals and frequency, (b) standardized residual and observation and (c) the standardized residual and Normal theoretical quantile of the yearly mean number of sunspots and the annual temperature anomaly.

Table 3.0b: Results of the regression analysis establishing a dependency relationship between Yearly Mean Sunspot Number and the annual temperature anomaly

FIT					
N	115				
Equation	Yearly Mean Total Sunspot Number = 89.04 + 26.92 ANNUAL_Temp Anomaly				
R^2	0.013				
R^2 adjusted	0.004				
SE of fit (RMSE)	67.075				
Parameter	Estimate	95% CI		SE	p-value
Constant	89.04	76.61	to 101.5	6.2766	<0.0001
ANNUAL_Temp Anomaly	26.92	-16.95	to 70.79	22.143	0.2266
H0: $\beta = 0$, The parameter is equal to 0. H1: $\beta \neq 0$, The parameter is not equal to 0.					
EFFECT ON MODEL					
Source	SS	DF	MS	F	p-value
Difference	6651.36	1	6651.36	1.48	0.2266
Error	508392.85	113	4499.05		
Null model	515044.21	114	4517.93		
H0: $E(Y\|X=x) = \mu$, The model is no better than a null model $Y=\mu$. H1: $E(Y\|X=x) = \alpha + \beta x$, The model is better than the null model.					
EFFECT ON TERMS					
Term	SS	DF	MS	F	p-value
ANNUAL_Temp Anomaly	6651.36	1	6651.36	1.48	0.2266
H0: $\beta_{Term} = 0$, The term does not contribute to the model. H1: $\beta_{Term} \neq 0$, The term contributes to the model.					

DISCUSSION OF RESULTS

From Table 1.0a and Figure 1.0a, The Pearson's r value of 0. 889 which is very close to 1 at 95% confidence interval, was obtained in the correlation analysis which seeks to establish the relationship between the annual temperature anomaly and the years of study. The Pearson's r value obtained connotes a very strong and positive correlation between the years and temperature. Also, the p-value (which tests the null hypothesis that the coefficient is equal to zero or of no effect) obtained is less than 0.0001 (which is less than $\alpha = 0.05$) also implies that there is a statistically significant correlation between these two variables thereby rejecting the null hypothesis. The R^2 value (coefficient of determination) of 0.790 and R^2 adjusted value (which adjusts for the number of terms in the model) of 0.789 obtained in the regression analysis

(See Table 1.0b and Figures 1.0b &c) implies a very strong and positive statistically significant relationship between the years and the global annual temperature anomaly and that there is a linear association between the two continuous variables. This defines the degree of dependency of the two variables. This means that increase or decrease in the years do significantly relate to increase or decrease in the annual temperature anomaly. Therefore, increase in year also leads to increase in the annual temperature anomaly on the Earth surface, thereby implying that the temperature of the Earth is on the increasing trend as the year increases. It can thus be statistically safe to infer that the Earth is much hotter today as it used to in past years. This is in synchrony with the current claim that the Earth is indeed getting hotter (Solomon et al, 2007; Lemke et al, 2007) and since temperature is a major driver of climate change, the impact of climate change can be said to be on the increasing trend annually. In fact the hottest year in the Earth's history was recorded with a temperature of 0.68degree Celsius in 2014 followed by 2010 with a temperature of 0.67degree Celsius and 2005 with 0.66degree Celsius (Elena, 2015). More recent investigation by NASA's Goddard Institute for Space Studies (GISS) which is also supported by Scientists from the National Oceanic and Atmospheric Administration also revealed that 2015 is hotter than 2014 and that 2016 will likely be hotter than 2015. This proves that the Earth's temperature warms in an upward trend which has a direct effect on the earth's climatic condition.

The result of the regression analysis conducted with the aim of investigating the statistical relationship between the global mean number of sunspots and the years resulted into a R^2 value of 0.018 and R^2 adjusted value of 0.009 at 95% confidence interval (see Table 2.0b and Figures 2.0 b-d) implies that there is a weak positive association between the global mean number of sunspots and the years of study and that there is no linear association between the two continuous variables (global mean number of sunspots and the year). This suggests a very weak dependency relationship between the two variables which implies that increase in the number of years may not necessarily imply increase or decrease in the number of sunspots. This result is in consonance with the conclusion of Jennifer Bergman (2008) and it is also supported by the outcome of the correlation analysis (See Figure 2.0a and Table 2.0a) which gave a Pearson's r value of 0.133 and p-value of 0.1569 implying that there is a weak relationship between the two variables and that there is no statistically significant correlation between them because we do not have enough statistical evidence to reject the null hypothesis. Based on these results, the Authors do not have enough statistical evidence to affirm that the number of global sunspots increases or decreases as the year increases.

Since the Pearson's r value of 0.114 is less than and not close to 1 in the correlation analysis which seeks to establish the statistical relationship between annual temperature anomaly of the Earth and the global mean sunspot numbers (See Table 3.0a and Figure 3.0a), it can be inferred that there is a very weak correlation between the Yearly Mean Total Sunspot Number and the Yearly mean temperature anomaly. This is also buttressed by the p-value obtained as 0.2266 which is higher than $\alpha = 0.05$. This implies that there is no statistically significant correlation between the two variables since we do not have enough statistical evidence to reject the null hypothesis. This can also be observed in the scattered plot presented as Figures 3.0b - d and the regression analysis result presented in Table 3.0b. The implication of this is that there is no statistically significant relationship between the global Sunspots and the temperature anomaly within the years understudied (1900 - 2014). It is thus the authors' opinion that the increase or decrease in the annual rate of sunspots globally has no direct statistical impact on the temperature of the Earth. This claim is also supported by the outcome of the regression analysis. The R^2 value of 0.013 obtained implies that there only exist a very weak positive association between the global sunspots and the temperature anomaly within the years of study. The 0.004 R^2 value obtained signifies that there is no linear association between the two continuous variables (global mean Sunspots number and annual temperature anomaly). It is thus safe to infer that increase or decrease in the global annual sunspot numbers may not necessarily result into increase or decrease in Earth's temperature thereby having no direct impact on the Earth's climate and even if/when it does affect it, the impact is largely very little or statistically insignificant which at best attest to the indirect impact that has been observed by NASA's Marshall Space Flight Center in July 22, 2009 and the scientists from the American Institute of Physics in 2014, while Charles (2013) opined that this impact may be more of a regional effect than a global one.

CONCLUSION

The following conclusions were made based on the findings of this research:

- There is a strong and positive correlation which is statistically significant between the years and the annual temperature anomaly. Increase or decrease in Years results into increase or decrease in the temperature of the Earth. Since the years have always been on the increasing trend, the Earth's temperature also has been increasing over the years.
- There is a weak, though positive correlation which is not statistically significant between the years understudied and the global mean sunspot numbers. Increase in the years may not necessarily result into increase in the global number of sunspots
- Finally, it was observed that the correlation between the annual temperature anomaly and the global mean sunspot number is positive though weak and statistically insignificant. Increase or decrease in the global mean sunspot numbers has a very weak effect on the Earth's temperature. This implies that the impact of sunspots on Earth's climate is very weak or little.

RECOMMENDATION FOR FURTHER STUDIES

Since this research investigated the direct effect of sunspots on Earth's climate using statistical means, further studies will attempt to investigate the indirect impact of the existence and cycles of sunspots on earth's climate. We shall also consider the study on regional basis to verify the validity of the claim of Charles (2013) which suggest that the impact may be more of regional impact than a global one.

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