Environmental Engineering and Management Journal August 2020, Vol.19, No. 8, 1389-1400
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

INFLUENCE OF SOLAR ACTIVITIES ON CLIMATE CHANGE

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Abstract

The solar energy received by the atmosphere of the Earth is universally distributed, which constitutes the atmospheric dynamics. The changes observed in the climate of the Earth are due to solar output variations. Some detailed reviews have accounted for the influence of solar activities on the climate using sunspot number derived from peak Sun hours, but has gaps in analyzing critical statistical background information, seasonal, latitudinal and solar activity year validation. A number of statistical concepts are explained in order to enhance our scientific knowledge of climate response to solar activity variation. The influence of geomagnetism to climate response is also examined. This review will serve as analysis and research methodology discourse which could be an application of scientific method. Additionally, this review discusses the influence of the solar activity on climate change based on the existing literature, by focusing on solar activities other than sunspot number alone. Here, we also validate methods using forward and inverse modeling, mean percentage difference, and relative variability. Results indicated that the total solar irradiance (TSI) has remained the main focus of Sun-climate interaction with somewhat negligent on energetic particle precipitation resulting from geomagnetic disturbance reaching the atmosphere. However, statistical concept remains asset to investigate the solar activity influence on climate in both local and global latitudes. We therefore recommend provision of solar quantities data to researchers for further study.

Keywords: climate change, energetic particles, geomagnetic latitude, solar influence, total solar irradiance

Received: November, 2019; Revised final: March, 2020; Accepted: May, 2020; Published in final edited form: August, 2020

1. Introduction

Adequate knowledge of climate variability or change over some period of record is very crucial. This idea gives a better understanding of the temporal and spatial environmental impact of climate change (Crowley, 2000). Climate variability has robust influence over different climate parameters (e.g. temperature, precipitation, cloud fraction). Additionally, these irregularities observed in the climate system are associated with the photochemical impact of the solar UV reaching the earth's atmosphere (Liang et al., 2019).

Research on the influence of solar radiation on climate change in general, usually focuses on long-term changes occurring in the Earth's troposphere. This is the region which serves as part of the atmosphere where the effects and influences of the solar activities are felt.

Climate change refers to the quasi-linear changes that occur for 30 years or more. However, how temperature varies with height in the atmospheric layer is beyond this review scope, and could be found in (Andrews, 2010; Hunsucker and Hargreaves, 2003). The Earth absorbs radiant energy at a rate of $(1-A)I_{TS}/4$ (Liang et al., 2019), where A is albedo of the earth and I_{TS}, Total Solar Irradiance (TSI). This irradiance is the total electromagnetic power to unit area covering Sun-Earth distance (Astronomical Unit). The factor 4 is due to Earth's intercept.

The variance observed in solar activities, solar motion, geomagnetic activities, and volcanic activity has been shown to contribute to climate change (Okeke and Audu, 2017). The main effect of solar

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activity on climate is likely variation in the energy budget, the variations and/or increase in temperature. The atmosphere is divided into three layers (Andrews, 2010), which are lower, middle and upper layer.

These layers are usually characterized by their temperature variance and also chemical compositions. The lower atmosphere comprises the troposphere and stratosphere. The middle atmosphere comprises the mesosphere and thermosphere, while the upper atmosphere is termed the exosphere or ionosphere. The lower atmosphere is where solar influences directly affect climate (Ammann et al., 2007). These layers strongly vary in altitude and depend on the season and topography (Anoruo et al., 2017).

Adequate knowledge of solar information on climate is available (Beer et al., 2006). The influence of solar activity on climate is an important climate change contribution; however TSI has always been used to represent these changes neglecting other factors. Lilensten et al. (2016) presented adequate understanding of how solar activity may impact climate. Solar activity is usually controlled by magnetic fields generated as a result of combining action of convection and differential rotation of the dynamo in the solar interior (Solanki et al., 2002). The solar atmosphere is made up of three layers; the photosphere represents the top of the convection zone. Most sunlight is emitted from this layer. Another layer where there is evidence of dark spots is called the sunspot and is surrounded by brighter areas known as the active regions. The chromosphere as well as the corona lies above the photosphere. The coronal hole is seen as a dark region. Here, the magnetic field is open and through it, the solar wind propagates outward. In some occasions, there always occur huge erupting bubbles known as the coronal mass ejections (CMEs) observed as the result of an eruption.

As a result of expansion of the solar atmosphere, the solar wind is affected by the changes observed in the solar activity. There exist two types of solar wind. These include the fast solar wind originating from the coronal holes where the magnetic field is open. It propagates with the velocity of 400km/s originating from regions close to the heliospheric current at the heliomagnetic equator. But during solar maximum, it originates above the coronal streamers in active regions where the magnetic field lines are closed.

Many current studies (Lean, 2000a; Lockwood et al., 2018; Solanki et al., 2000) have strongly indicated correlation between sunspot numbers and other climate parameters in studying the influences of solar activity on climate change. A recent advance has indicated the strong link between geomagnetic/cosmogenic indices (e.g. Kp and ap, Dst), solar flux index (e.g. F10.7), TSI and aurorae in studying the influence (Lockwood et al., 2018; Solanki et al., 2000). This review presents the solar activity indices other than the sunspot number and also some statistical parameters to close the existing gap of other literature. Using the sunspot number to study the influences of solar activities on the climate requires an adequate statistical background and ability to correlate the result with other climate parameters. However, the knowledge of the Sun-climate relationship returns that geomagnetic activities, aurorae show a different variation result over climate change study (Marsh and Svensmark, 2004).

1.1. Background information

The Sun is the source of energy in the earth's climate system. The number of different processes that occur in the sun convective zone is known as solar variability. A clear understanding of solar variability influence on earth's climate requires deep knowledge of solar-terrestrial interactions (Rind, 2002). The source of variation that is observed in the Sun as a result of solar activity affects the total radiant energy emitted by the Sun. Also, changes in the earth's orbit around the sun over thousands of years have direct affection on radiant energy amount reaching Earth. This energy of the Sun drives the Earth's climate system (Reid, 2000). The changes observed in the intensity of this radiant energy produce both global and regional climate change. This impact observed in the regional climate appears to be quite significant in a low latitude station like Nigeria, resulting to increase of greenhouse gases (Olusegun et al., 2014).

The review question is "does solar activity has distinctive latitudinal characteristics?" This question is essential. The knowledge of this variation is of great interest because of the keen interest in understanding and characterizing the variability and its contribution towards the observed climate change. The changes in the earth's surface resulting from anthropogenic emission and its interaction with solar irradiance usually results in the release of greenhouse gases. This simply causes the warming observed in earth's atmosphere. Typically, an observation of the increase in temperature, rainfall variability, intense heat waves observed in most geographic region is good example of the Sun-climate relationship trend. This is simply attributed to the influence of solar activities on climate change. Adequate knowledge of that will play a crucial role in predicting future climate (De Wit et al., 2015). Herschel, in 1801 was the very first scientist to make an argument about the Sun's variation. He suggested that the variations of the Sun play a crucial role in Earth's climate system. This has been followed by a good number of literatures (Herman and Goldberg, 1978; Hoyt and Schatten, 1992).

The possible method of investigating this review question is by performing statistical analysis of the annual or decadal variations of the Sun's activity and correlating it with other parameters other than sunspot numbers. Also, recent methods in validating solar influence on climate as seen in Ferreira et al. (2003) should be adopted. The parameters of aurorae, climate records, and geomagnetic and/or cosmogenic indices could serve better towards investigating the Sun's activities from climate change contribution. Though, most of the existing literature has poor quality of statistical background (Pittock, 1978).

However, solely concentrated more on using the sunspot number to investigate influence of Sun-climate relationship leaving out the other parameters.

The key knowledge of data mining and analysis is most required in establishing the magnitude, geomagnetic distribution and the seasonality of the solar activity influence on climate change.

1.2. Significance of study area

In this section, we present a distinction between local and global climatic change with somewhat background on local effect. The Earth is subdivided into the Antarctica, tropics of Capricorn, the Equator, tropics of Cancer, and the Arctic pole. The Equator, which lies at 0^0N or S and 0^0E or W prime meridian receives more radiant energy and should experience more influence of solar activity. This makes it so unique to study.

Nigeria, as an example, is located in the continent of Africa (9.0820° N, 8.6753° E). Its location is described as a low latitude zone, following the classification of geomagnetic latitude and longitude. The low latitude experiences more solar influence due to its location on the Earth's surface. Nigeria's rainy season begins in March and lasts until the end of July with a peak in June. The second phase of the rainy season has its peak in October. This rainy season is followed by a short dry break in August and lasts for two to three weeks.

Increase in ozone concentration is experienced during severe solar activity. This process causes stratospheric heating and some impact on the temperature gradient, thereby resulting in global circulation effect. Also, some changes in ionospheric parameters have shown evidence of solar activity. The typical example is the solar cycle, which increases atmospheric heating (Jarvis, 2006). Furthermore, the enhancement in global cloud coverage at low latitude modification of earth albedo correlates with solar cycle. It is suggested that the above effect is usually the result of cosmic ray modulation, resulting to atmospheric aerosol ionization (Tinsley et al., 2007).

In using models to estimate climate warming potential, Scafetta and West (2005) concluded that 50% of global warming since 1900's century had solar origin trace. This estimation is compatible with results of (Scafetta and West, 2007). However, Jones et al. (2012) and Meehl et al. (2013) used model to examine climate change potentials during solar minimum. The results estimated that TSI will be reduced by <0.1 K by year 2100. Some studies (Ermolli et al., 2013; Lean, 2000b; Merkel et al., 2011) has x-rayed climate model output shift from TSI to Solar Spectral Irradiance (SSI). However, Matthes et al. (2017) and Haberreiter et al. (2017) have suggested incorporating both data sets with energetic particles. Studies like those of Holt et al., 2012; von Clarmann et al., 2013, have already detailed this phenomena. However, Usoskin et al. (2011), Mironova and Usoskin, (2014) and Mironova and Usoskin, (2013) presented solar activity events and its effects over the lower stratosphere and upper troposphere along Polar Regions. They concluded that no direct relationship exists between ground level enhancement of cosmic ray and ionization over such regions. Seppälä et al. (2014) presented detail studies on solar influence on climate, extending the results of Gray et al. 2010. The study presented some shortfall over Gray and co-workers and added more knowledge on energetic particles and cosmic ray influence on climate. Additionally, the study presented how well models have predicted and reproduced existing results. Seppälä et al. (2014) reported that previous climate models focusing only on TSI have presented only small contributions to climate change influence from the Sun, and need to include SSI. This idea will give detail understanding of regional impacts on climate (Usoskin, 2017). Dudok de Wit et al. (2018) described more accurate data to be included in climate models for an enhanced result on solar activity on climate. However, Dudok de Wit and Watermann (2010) presented that the orientation of the Interplanetary Magnetic Field (IMF) is major contributing factor of Small Energetic Particle (SEP) entrance to the Earth's atmosphere. The IMF is the main mechanism of Sun-climate effect. It regulates interstellar energetic particle penetration rate into the atmosphere.

1.3. Significance of the review

The rate of solar radiation depends on geomagnetic latitude. However, Scafetta and Willson (2019) provided strong arguments that TSI variability result from solar influence as earth's main climate driver. This result is compatible with Scafetta (2013). The low and high latitudes of the ionosphere experience opposite responses during geomagnetic disturbance (Fig. 1).

The variation which is observed in the ionosphere is of two different kinds; The sudden and regular disturbances. The regular disturbance is deeply characterized by the solar cycle periodicity of approximately 11 years. The seasonal variation which could be associated with the Earth's revolution. The sudden variations are as the result of changes observed in the solar activity, which are driven by a magnetic storm (Dudok de Wit et al, 2009). This sometimes is called sudden storm commencement (SSC) or sudden ionospheric disturbance (SID). Solomon et al. (2019) concluded that global temperature increase has direct relationship with solar cycle maximum, resulting to global change. This attribute is not only limited to the local research and/or review papers, but internationally is also observed. In this review, a good understanding of solar activity influences on climate change has been accounted for.

Much statistical analysis have been listed in this review, which tends to assist in understanding more deeply the climate variations observed. Also, the method adopted (Chen et al., 2001; Conway et al., 1994; Piao et al., 2008; Vesala et al., 2010) should be used in validating such influence.

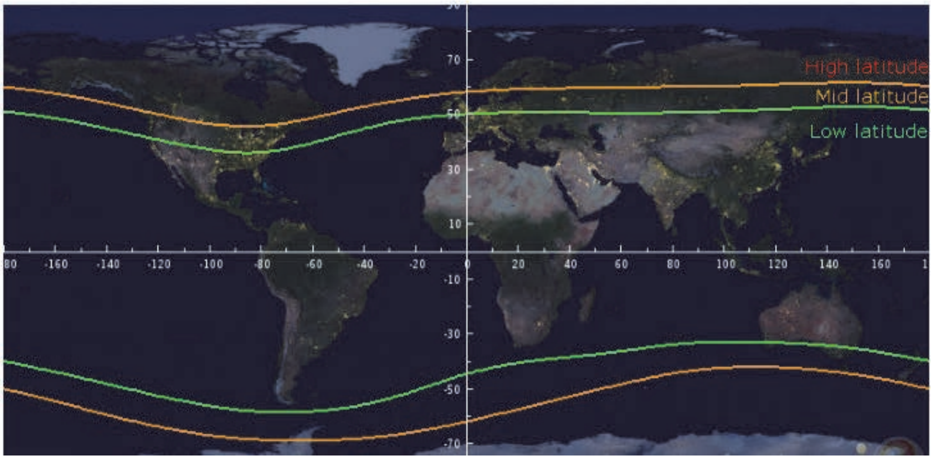

Fig. 1. Earth geomagnetic latitude (NOAA, 2017)

The seasonal index is obtained by dividing the yearly mean period from each monthly value. However, the idea of percentage difference correlation as in Ferreira et al. (2003) will checkmate the spectral seasonal index of solar activities influence on climate over the selected regions. The idea of the season is due to its characterized temperature conditions and weather patterns. A deeper understanding of the impact of the sun-climate relationship needs the historical data of the parameter listed and their influences.

However, full access to the potential of the influence of solar activities on the climate change on longer time scales requires adequate knowledge and data provision of the Total Solar Irradiance, cosmic ray, solar indices and energetic particles. This idea of using mean percentage difference in validating the seasonal variations of solar influence on climate is very essential in validating direct atmospheric composition (Conway et al., 1994).

2. Review of related literature

An investigation of the effect of solar activities on climate using the method of remote sensing began from the availability of satellite instruments in the year 1978. There has been evidence of solar activity on climate change ever then. This prompted the International Space Science Institute (ISSI) in 1999 to host a workshop on solar variability and climate. That served as a good platform for scientists across the discipline to update their knowledge of the 1993-1999 Sun-climate relationship trends.

The volume of the proceedings could be seen (Friis-Christensen et al., 2000). The availability of data measurement presented made it possible to estimate the temporal variations that are observed in climate change. Although, much attention has been paid on the Total Solar Irradiance (TSI) and energetic particles, yet their measurement has remained so complicate and also the precise calibration in terms of instrumentation towards acquiring a deeper knowledge of climate studies has turned out difficult (Krivova and Solanki, 2008).

Over the past years, the observation and understanding of the earth dynamics were so much a great task for scientists. This was made easier since the advancement of remote sensing. Remote sensing is defined as the method of accessing and collecting of information about an object and/or data without being in physical contact with the object, through the help of a satellite, using a global positioning system that is relevant to Geosciences.

Satellite data are becoming more widely used in the forecasting and environmental management activities of the earth. They are employed for estimating emissions, providing evidence for exceptional event declarations and monitoring of regional long-term trends. However, many scientists are not taking full advantage of the data for these applications, nor has the full potential of satellite data applications been realized. A key barrier is the inherent difficulties associated with accessing, understanding, processing, and properly interpreting observational data. The solution to this has been included in Frohlich (2006).

The rapid response to solar activities and its influence on climate change in Nigeria and globally has been examined by many researchers (Jones et al., 2012; Liang et al., 2019; Mironova and Usoskin, 2013; Okeke and Audu, 2017; Scafetta and West, 2007; Scafetta and West, 2005; Scafetta and Willson, 2019; Seppälä et al., 2014; Solomon et al., 2019; Versteegh, 2005). Figs. 2 -3 shows the impact of greenhouse gases on climate change. These impacts were inspected using 11 years solar cycles and revised to 9 years impact effect to see major contribution of solar interaction with global warming. It could be seen that observed temperature has a linear relationship with solar contribution when fitted with greenhouse gases. This feature is majorly seen in 11 years cycle. Most of these existing literature have accounted positive result (Mangini et al., 2005; Versteegh, 2005). These results have been uncertain due to poor statistical background and using other methods in validating the solar influence on climate.

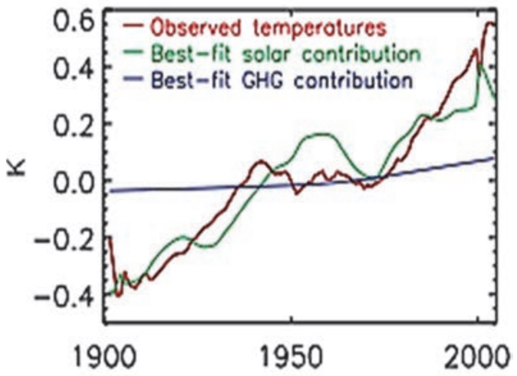

Fig. 2.11 year mean of greenhouse gas contribution on solar(Ingram, 2006)

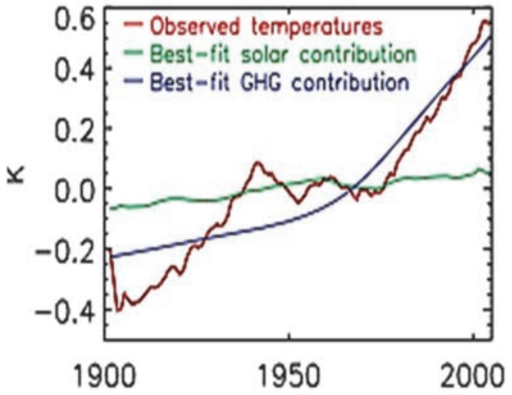

Fig. 3. Nine year reverse mean of greenhouse contribution on solar (Ingram, 2006)

El-Borie et al. (2010) attributed that this uncertainty is due to inconsistency existing in the statistical results. Solar activity influences climate and the surrounding atmosphere, and it is attributed to be the variation observed in the UV and TSI (Haigh, 2007). This influence is much experienced at the regional than the global (Dobrica et al., 2013; Lockwood, 2012a). Olusegun et al. (2014) performed an examination of solar influence on the climate of Nigeria using a correlation of temperature data over six stations. Duhau and Chen (2002) suggested the very best way to determine energetic emissions delay is by correlating aa index with sunspot numbers. The result concluded that variations in irradiance are from sunspot other than solar phenomena. Additionally, De-Jager (2005) opposed this result and concluded that sunspot number is not a proxy for solar phenomena. Solanki et al. (2000) also concluded that cosmogenic radionuclides could be used.

The concluding remarks noted that no significant correlation exists between the temperature records with solar activity. Contrary to that result, Okeke and Audu (2017) performed a minimum and maximum statistic of temperature data set and rainfall variability. Yet, a poor statistical background was maintained. Lockwood (2012b) posted an argument on the correlation effect existing in Herschel 1801. He attributed that Herschel in 1801 accepted the limiting correlation that exists in his literature, as well the shortfall of the correlation data having a limited season. Lockwood (2012a) suggested a more accurate methodology towards citing related literature on studying the influence of solar activities on climate change. Such existing literature could be seen (Damon and Laut, 2004; Eddy, 1976; Foukal et al., 2006). Field et al. (2009) attributed that the possible and most accurate methodology in studying solar activity and its influence is through taking an autocorrelation function of data spanning up to 25 years of study. Stauning (2011) studied solar activity-climate relationship using a regression statistical approach. The data span a long period of 135 years. The limitation observed in the research still tends towards using the sunspot number against temperature variations. Although, the results attributed that the variations observed in the temperature retrieval is as the result of the corresponding changes in the solar irradiance. Dergachev et al. (2004) used statistical analysis and attributed that cosmic ray fluxes is responsible for climate variations. Also, De Meyer (2003) and Mursula et al. (2003) used modeling of ^{10}Be to study solar influence on climate.

The result also attributed that the TSI is a major background in studying the Sun-climate relationship and its influence on climate change. Although the TSI deeply depends on the geomagnetic and geographic latitude, there is great need to investigate this influence using seasonal analysis of mean percentage difference. Zerbo et al. (2013) investigated solar activity and meteorological fluctuations in West Africa. The result has more emphases on the solar activity indices and the climatic parameters, e.g. temperature and rainfall over more than three solar cycles, yet recorded poor statistical background.

A deeper investigation over the 42 years study showed a positive correlation with rainfall. The study area falls on a low latitude geomagnetic zone. A close study on the mid and high latitudes should also be investigated. Ingram (2006) performed a multivariate regression on the 11 years and 9-year cycle of the solar influence on climate. Yet, the study is only limited to the climate records of temperature and the greenhouse gases contributions. The reproduction of the graphs is presented in Figs. 2, 3.

The study result output is limited in the statistical background, but contributed towards detecting how much of the 29th-century warming was due to greenhouse gases. A discussion of the solar impact on global warming is also attributed to increasing concentrations of greenhouse gases. This argument was posted by Friis-Christensen and Lasen (1991), as the result of the variations observed in the ultraviolet radiation that tends to produce the changes seen in temperature and ozone (Curtius, 2006; Goosse, 2006).

Isikwue et al. (2010) attempted to establish the contribution of solar indices over the stratospheric ozone variations in Nigeria. The result of the study was only limited to the variation of ozone with the correlation of sunspot numbers. The correlation shows a weak result. This possibly suggested a poor statistical background of the study. Similar studies could also be seen in (Rabiu and Omotosho, 2003).

2.1. Limitations of previous research

A good number of researches have contributed to the existing correlations between solar influence and its climate relationship. This has been reported in different geomagnetic latitudes. Most of these researches are accounted for (Baldwin et al., 2001; Gray, 2010; Labitzke, 1987; Labitzke and Van Loon, 1988), but are limited to using just the sunspot number. The idea of validating the influence of solar activities on climate should be expanded to other parameters.

Also, some extension of seasonal mean investigation, percentage difference, forward and inverse modeling, solar activity cycle on northern and southern hemisphere should be maintained. An argument with the sunspot number having very low evidence in the study of the solar-terrestrial climate influence is well detailed in Rasmus (2006). Friis-Christensen and Lassen (1991) stated, the less confidence observed in using the SSN towards investigating the solar influence on climate. Rather, both authors made more attributes in using the solar cycle.

The solar cycle is the 11year periodic changes in the Sun's activity. More about the solar cycle and its first to current investigation is found in (Stauning 2011). A close attribute of using other influence like that of aa index, aurorae, solar irradiance, geomagnetic indices, and neutrons can be seen in (Calisesi et al., 2006; Chapman et al., 2001; Gray et al., 2010; Pulkkinen et al., 2001). It is observed that few researches exist on the lower latitude of which Nigeria is located. However, all the existing contributions have been questioned on the statistical background (Damon and Laut, 2004; Haigh 2003, 2007). The idea of using models in investigating the solar influence on climate is also limited. A brief overview of such an attempt can be found in (Stott et al., 2003; Rind et al., 1999).

2.2. Recent advances in the solar influence on climate

The Sun-climate or the solar-terrestrial relationship is of great interest (Solanki et al., 2004). This is because the variability of the Sun and its interaction with earth effect is of good degree. Recent advances in using other solar activities like aa index, aurorae, solar irradiance, geomagnetic indices, neutrons and modeling in studying the influence of solar activities to climate change are of good help in understanding the Sun-climate behavior.

It is of great importance in understanding the Sun and its effect on climate. This has a great influence on understanding climate variability and also predicts its future state (Scafetta and West, 2005). In using the TSI with its correlation with other climate records to study the influence of solar activities on climate, Hoyt and Schatten (1992), Lean et al. (2002), Solanki and Krivova (2003) studied the sunspot darkening and its long-term changes observed in the climate. In using that of geomagnetic records, Lockwood and Stamper (1999) used the aa index to produce the TSI relationship with climate. The results of the study pose a good understanding of the Sun-climate relationship, because the data is not influenced by atmospheric changes. An argument by Houghton et al. (2000) concluded that Sun's influence on the climate system is negligible.

The result of ocean temperature in the IPCC Third Assessment Report (TAR)is not in agreement with Houghton et al. (2000). An investigation of the sea surface temperature (SST) was observed. There was a great influence of the solar activity on the SST as attributed by (Reid, 2000). White et al. (1997) investigated a temperature increase across the Indian, Pacific, and Atlantic oceans. Their finding is in good agreement with (Reid, 1987, 1991, 2000). Also, current evidence has shown that the regional mean air surface temperature is on the increase. This result was estimated as the result of climate sensitivity posed by the changes observed in TSI. An argument about the sunspot number having low evidence in the study of Sun-climate influence is well detailed in (Rasmus, 2006). Another observation of the resent influence is in land temperature. Friis-Christensen and Lassen (1991) performed a correlation analysis on the sunspot number with changes observed in land temperature. Their result suggested a positive correlation, indicating a strong influence.

Another attribute of solar influence on Earth's climate is observed in the electric power grid. This is experienced during the storm. The surges produced can cause network failures, as observed in Quebec Canada in 1989. Also, the effect observed in the navigation system. This is simply the degradation observed in the Global Position System (GPS). This certainly causes the poor GPS signal and loss in communication. The most observed is in radio frequency and internet network signals. Also, is the abnormal precipitation that keeps occurring and cyclones, which are large scale air mass that rotates around a center of low atmospheric pressure. This is the result of uneven TSI observed in the Earth's climate. Svensmark (1998) investigated the correlation existing between cloud cover and galactic cosmic ray (GCR).

He attributed that GCR influences cloud formation, which is linked to climate change. The result of the work was opposed by Sun and Bradley (2002). Richardson et al. (2002) then made a strong argument on the existing trend with GCR and cloud.

3. Discussion of the theory surrounding solar influence on climate

The sun provides the energy that drives the Earth's climate, due to that is attributed that the solar variability has the potential to alter the climate. The changes observed in TSI on time scale have been suggested to be the cause of change in climate.

In order to understand the actual effect of solar influence on climate, an adequate monitoring and assessment of the TSI variations and its correlation with other climate records are very essential. It is quite unfortunate that most existing literature have been limited to only using the sunspot number and correlating it with temperature.

The idea of using the aa index, geomagnetic/ cosmogenic index, solar flux (10.7cm), neutrons, aurora have been left out (Fig. 4). Mostly, studying the influence on low latitudes where the topography of Nigeria is accessed. Poor statistical backgrounds have been left as gap in the existing literature. To make clear the influence of solar activities on climate change, an adequate statistical background and/or correlations should be applied to the climate records. A good example is that of Hoyt and Schatten (1997).

Although, the results of their review are very questionable because the data presented suffer short trend retrieval. A balanced climate change index analysis like mean, minimum, maximum, absolute indices, threshold indices, duration indices, percentile-based indices, correlation, standard deviation, root means square error, standardized anomalies, seasonal index, mean percentage difference, forward and inverse modeling and test statistics seen in (Chen et al., 2001; Ferreira et al., 2003; Heimann et al., 1998; Piao et al., 2008) will certainly fill in the gap of poor statistical background that has been experienced on the existing literature.

More of the climate index analysis is discussed as an existing problem in the research literature (Section 3.1).

3.1. Existing problems in the related research area

The existing literature has posed some level of deficiency in the statistical background. An adequate proof of any monitoring and assessment of solar influence on climate change should always be balanced statistically. This certainly will ensure a strong background and make clear the uncertainties existing in literature conclusions (Love et al., 2011; Yiou et al., 2010).

Algorithms of some climate index analysis have been presented in the previous section. The mean as a statistical value returns average of the absolute deviations of data points. The minimum returns the smallest number in a set of values. The maximum returns the highest number. Then the percentile-based indices, the absolute indices, threshold indices, and the duration indices could be run on any climate records parameter. The percentile-based indices take care of the occurrence of cold and warm nights, as well as the occurrence of cold and warm days. The absolute indices take care of the maximum and minimum daily temperature and precipitation. The threshold indices take care of the annual occurrence of frost, ice, tropical and summer days, the number of heavy precipitation days and very heavy precipitation days.

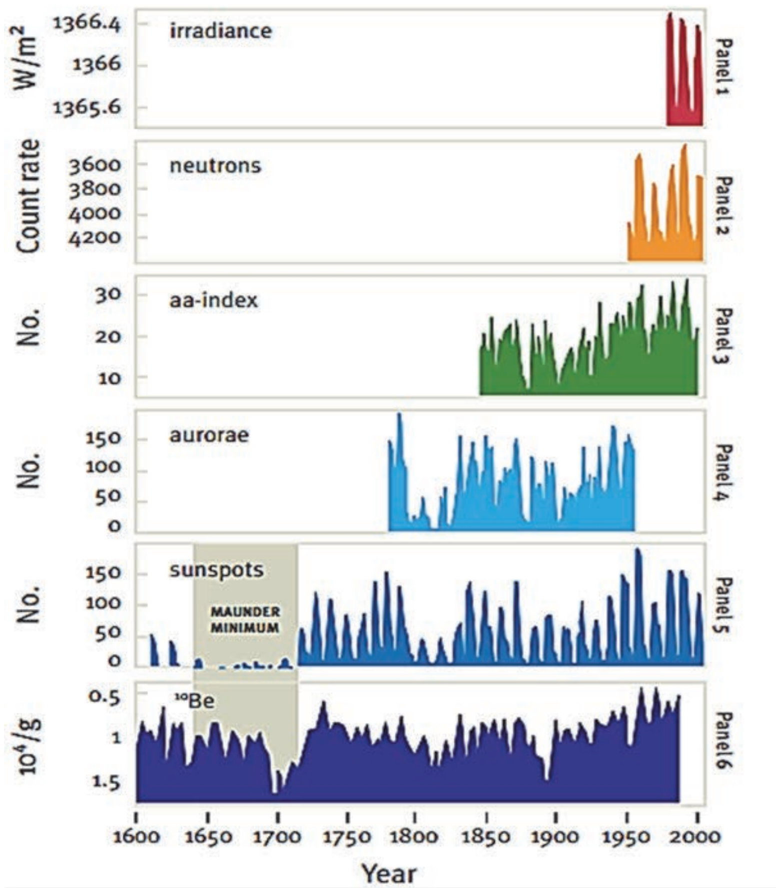

Fig. 4. The geomagnetic indices for solar influence study

Also, running the frequency distribution test known as F Distribution which returns the degree of diversity for two data, the variance will state clearer the solar activities influence on climate using data and will balance the statistical background of the claim. Adequate attention to statistics is paid in Wilks (2006). Also, the most appropriate method of investigating the influences on solar activities on climate is using mean percentage difference (Ferreira et al., 2003) in validating the seasonal mean.

4. Findings

In this review, we have presented the statistical background in explaining and/or understanding the influence of solar activities to climate change. Additionally, we have incorporated energetic particle view over climate change. The review studies of how the variations in solar activity associated with solar cycle can affect the atmosphere and hence, the dynamics is given (Fig. 5). The observations of solar activity and its link to climate change are to examine the solar quantities (eg, electromagnetic radiation, particles) that reach the earth. The knowledge about Sun-climate interaction is derived from data observations or model. Hence data quality is of importance in science and therefore should provide a framework for analytical Sun-climate inter-relationship.

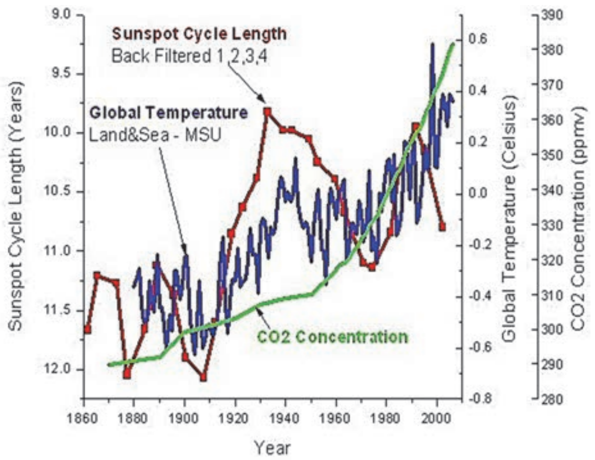

Fig. 5.10 year annual sunspot mean (upper curve), global sea-surface temperature anomaly (Marsh et al., 2005)

The impact of solar activity on climate is likely intense in the low latitude region due to geographic and geomagnetic latitude. However, the presented parameters seen in the existing literature were only limited to the correlation of the SSN with temperature and using just the SSN in investigating the solar influence on climate. The interaction of charged particles with atoms (collision between the electrically charged particles released from the Sun with gases of Oxygen and Nitrogen) in upper atmosphere prompts aurorae, resulting from magnetospheric disturbances caused by solar wind.

The aurorae are caused as a result of coronal mass ejection. This is simply the emission of some energetic charged particles from the Sun's corona. It is usually seen around the magnetic poles of the northern and southern hemispheres and serves as evidence of energetic particles influences on climate.

Also, the ^{10}BE neutron, a spallation product of galactic cosmic rays hitting atmospheric Oxygen, Nitrogen and Argon atoms which also has an impact, but not well studied. Additionally, aa index is the geomagnetic activity, which accounts for any small difference in the latitudes of the earth. It is also called the geomagnetic index like that of Ap, Kp. These indexes are derived from the K. Their measurement is related to the quiet day investigation, and it is very essential monitoring their variation and the effects they pose on the climate.

However, stratospheric signature of solar eleven cycle has been used to investigate geomagnetic activity correlation with climate change (Coughlin and Tung, 2004). The solar radio flux propagates with a wavelength of 10.7cm and a frequency of 2800MHZ is also a factor. It is an essential parameter in monitoring solar activity and its influence on the climate. This is because at solar maximum, the ionization density increases, causing absorption of wave propagation.

5. Conclusions

In conclusion, high energetic particles comprised of charged protons and electrons from the Earth's magnetosphere are forced by the solar wind into the earth's atmosphere. This action increases ionization and creates climate dynamics (Andersson et al., 2014). However, it has received less attention. Geomagnetic disturbances can be related to solar activity and the proxy of solar activity is mostly data from ^{10}Be, which are produced by cosmic ray with maximum production in upper troposphere and lower stratosphere (Svensmark, 1998). We therefore ascertain that:

1. An investigation of the literature attributed to the solar activity influences on climate has been reviewed. This review is not only limited to the solar influence on the climate local scale, but also globally.

2. An adequate investigation of the solar influence on climate change should be focused on understanding and monitoring energetic particles and cosmic ray other than TSI. Additionally, statistical background as attributed in the literature should be maintained.

3. The geomagnetic field is influenced by solar activities as the result of geomagnetic storms. This implies that the long-term measurement of the aa index will be very effective.

4. The long-term changes observed in the upper atmosphere have some influence on the lower atmosphere. Such observations are felt in the Global Positioning System and other communication systems that deeply depend on the radio wave propagation.

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