Correlating between global solar radiation and greenhouse gases over Nigeria

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Abstract. The need to study the variations of climate change in Nigeria becomes necessary at a time the universe and Nigerians, in particular are passing through challenges due to climate change as a result of emissions. The atmospheric gases have a greater transparency for incoming solar radiation, while the outgoing are trapped and re-emitted back to the Earth. This study correlated between global solar radiation and greenhouse gases over Nigeria using neural network. The results showed that positive correlations exist between solar radiations: CO₂ and CH₄ respectively, while exhibiting negative correlations with tropospheric ozone and water vapour. Consequently, an increase in 0.1017, 0.1350 units of CO₂ and CH₄, respectively could enhance the trapping and transmission of solar radiation in the atmosphere, while an increase of 1.1234 and 0.1530 units of tropospheric ozone and water vapour could cause absorption of solar radiation. The trapped energy is re-radiated back to the Earth, this warms up the atmosphere and the surface of the Earth resulting to global warming. Coefficient of determination revealed that 18%, 30%, 20%, and 29%, of the variances of solar radiation being studied is explained by the variance of the water vapour, tropospheric O₃, CO₂, and CH₄, respectively.

1. Introduction

Solar radiation travels to Earth through space from the, some get to the Earth’s surface while others are absorbed and scattered by atmospheric activities. Therefore solar radiation interacts with atmospheric parameters such as gases, liquid, and particles [2]. The amount of solar radiation that
reaches any particular point on the ground depends on the time of the day, the day of the year, the amount of cloud cover, and the latitude at that point [7, 10, 11]. When infrared radiations from the reach the Earth, some of these radiations are reflected into space while the rest is absorbed and re-radiated by greenhouse gases as shown in figure 1 [7]. This occurrence is referred to as the greenhouse effect [15]. Greenhouse effect is the natural process of warming the Earth’s surface through absorption and re-radiation of infrared radiation from the by greenhouse gases.

Life on Earth depends on energy from the and about 30% of the energy beams toward Earth is deflected by the outer atmosphere and scattered back into the space. The remaining 70% reaches the Earth’s surface and is reflected back into space again as a type of long wave energy called infrared radiation [14]. The heat produced as a result of this infrared radiation is naturally trapped by the greenhouse gases, thereby keeping the Earth warm enough for living organisms to survive, but excessive absorption and re-emitted back to the Earth brings about global warming and climate change. The energy according to [16] observed that it is affected by climate changes induced by greenhouse gases.

![Figure 1. Radiation absorption and Greenhouse Gases Emission Process [4]](image)

The human activities on the environment is rapidly increasing the levels of atmospheric greenhouse gases (GHG) which includes carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), chlorofluorocarbons (CFCs), perfluorocarbons (PFCs), and hydrocarbons (HFCs) [8].

Methane is a major greenhouse gas and produced during anaerobic decomposition of manure and accumulates around manure storage areas. The concentrations of CH₄ depend on the moisture content of the environment (which may enhance decomposition) from many plants such is produce water hyacinths release CH₄. High concentration of methane occurs in wet season and produced from wetland, decomposition of plants, rice paddies (anaerobic processes), enteric fermentation in mammals (ruminant) and termites [12]. This agrees with [12] and [1]. They stated that water hyacinth (Eichhornia crassipes) is a potential biomass source able to be converted into methane and that the increase in the rate of rice farming in Nigeria which occurs during the wet season is a major source of methane production. Termites are also a significant source of methane due to methanogenesis in the symbiotic metabolic breakdown in termite hindguts [17]. This study, therefore, correlated between global solar radiation and greenhouse gases over Nigeria by correlating the parameters. It investigated the rate of their influences on climate change and global warming.
2. Materials and Methods

2.1 Materials

2.1.1 The Study Area

The study areas used in this work are thirty-six (36) points station over Nigeria as shown in figure 2, which is the gridded map of selected stations in Nigeria, while table 1 shows the coordinates of the selected stations over Nigeria. These stations were selected based on the interval of 1.5° (from one point to the order) of the gridded map to cover Nigeria.

![Gridded Map of Nigeria Showing Data Points of the selected stations in Nigeria](image)

Figure 2. Gridded Map of Nigeria Showing Data Points of the selected stations in Nigeria

2.1.2 Sources of Data

The greenhouse gases data used in this work were gotten from www.gmes-atmosphere.eu/data from 2003 to 2015. Satellite data were used for this study because greenhouse gases have no ground-based measurements in Nigeria at the time of this study. The data which was in NetCDF format were extracted, converted to binary format, sorted, and merged to file using MATLAB software program. The interval for the study area from one point and another is 1.5° as showed in figure 2.

2.2 Research method

Neural network in MATLAB was used to carry out the modeling in this study. The designing and use of neural network for modeling require that one must systemic procedures [3]. The six basic steps followed in this study include:

- Data collection;
- Processing of data;
- Building the neural network;
- Training the neural network;
- Validations of the neural network using performance function; and
- Using the neural network (best network).

Equation (1) is the model used for the study from input layer to output layer as shown in the architecture in figure 3.
where $O_m$ is the output vector, $O_m$ depicts the output matrix containing the desired outputs. $I$ represent the input vector, while $I_m$ is the input matrix (year, day of the year (DOY), latitude, longitude), $I_{wm}$ depicts inputs weight matrix, $b_1$ is bias vector 1, $H_{vm}$ is the hidden variable matrix, $L_{wm}$ is layer weight matrix, $b_2$ is bias vector 2, tansig ($f_1$) is hyperbolic tangent sigmoid transfer function used between the input and the hidden layers as activation function, while purelin ($f_2$) is the linear transfer function used from hidden layers to the output layer as the activation function. Figure 3 showed that the size of $I_{wm}$ is h-by-4 because there are 4 inputs layer neurons. The size of $L_{wm}$ is 1-by-h because there is one output layer neuron. The sizes of $b_1$, $n_1$, $H_{vm}$, $b_2$, and $n_2$ are h x 1, h x 1, h x 1, 1 x 1 and 1 x 1 respectively, where h is the number of hidden layer neurons.

**Figure 3.** Neural Network Architecture from Input to Output

3. Results and Discussion
The results of the relationship between Greenhouse Gases (GHGs) and solar radiation were determined using programming language written with MATLAB codes to determine the linear regression and coefficients of determination. Figure (4) and table (1) presents the plots of linear regression, Correlation Coefficients and coefficients of determination for the greenhouse gases and solar radiation. The regression equations of the plots were shown from equation (2) to equation (5), where $M$, $C_d$, $T_o$, $W_v$, and SR depict methane (ppm), carbon dioxide (ppm), tropospheric ozone (ppm), water vapour (ppm),
and global solar radiation (W/m²), respectively. The statistical significance of the relationship between greenhouse gases and solar radiation at p-value < 0.05 confidence level was determined and presented in table 1.

![Figure 4](image_url)

**Figure 4.** Validations of Solar Radiation with: (a) Carbon dioxide, (b) Tropospheric Ozone, (c) Methane, and (d) Water Vapour.
3.1 Relationships between Greenhouse Gases and Solar Radiation

The results from figure 4 show positive relationships between solar radiation with CO$_2$ and CH$_4$ respectively, while having negative correlation with tropospheric ozone and water vapour. Consequently, from the equations (2) and (4), an increase in 0.1017 and 0.1350 units of CO$_2$ and CH$_4$ respectively could enhance transmission in solar radiation, while an increase of 1.1234 and 0.1530 units of tropospheric ozone and water vapour of equations 3 and 5 could cause absorption in the solar radiation.

Table 1, reveals that water vapour, tropospheric O$_3$, CO$_2$, and CH$_4$ influences 18%, 30%, 20%, and 29%, respectively to the changes of solar radiation in the atmosphere. Hence, methane has the highest positive relationship with solar radiation and water vapour has the least negative relationship with solar radiation, hence little or no direct influence on solar radiation.

Secondly, it can also be observed that the water vapour and tropospheric O$_3$ exhibit indirect relationship with solar radiation. This could imply that the amount of changes in solar radiation received on the Earth surface is reduced (absorbed or scattered) by the parameters. On the other hand, CO$_2$ and CH$_4$ have direct relationship with solar radiation. This could cause transmission of some amount of solar radiation in the atmosphere. This means that 18%, 30%, 20%, and 29%, respectively of the variances of the dependent variable (solar radiation) being studied is explained by the variance of the independent variables (water vapour, tropospheric O$_3$, CO$_2$ and CH$_4$), respectively.

The result on table 1 revealed that no gaseous pollutant or greenhouse gas can have 100% influences on the variance climatic parameters. This agrees with [18] who asserts that most practical effects of variations and trends of climate do not involve a single parameter but are the synergistic result of multiple parameters. The result was also confirmed by the Intergovernmental Panel report on climate change [13]. It was also stated that global warming increases because of increase in the emissions of GHGs particularly CO$_2$ and CH$_4$[9].

### Table 1. Correlation Coefficients (r), Coefficient of Determination ($r^2$) and p-value of Solar Radiation with Greenhouse Gases

| Greenhouse Gases       | Solar Radiation | p-value |
|------------------------|-----------------|---------|
|                        | $r$             | $r^2$   |          |
| Water Vapour           | -0.42           | 0.18    | 0.5931   |
| Tropospheric Ozone     | -0.54           | 0.30    | 0.0433   |
| carbon dioxide)        | 0.45            | 0.20    | 0.4811   |
| Methane                | 0.54            | 0.29    | 0.6504   |

\[
SR = 12.00 + 0.1017C_d \quad (2)
\]
\[
SR = 29.50 - 1.1234T_o \quad (3)
\]
\[
SR = 14.00 + 0.1350M \quad (4)
\]
\[
SR = 31.00 - 0.1530W_v \quad (5)
\]
The result of the significance level of the relationship between the greenhouse gases and solar radiation shows that some are statistically significant, while some are insignificant at p-value < 0.05(95%) confidence level. The p-values of 0.0433, 0.5931, 0.65042, and 0.48112 are for solar radiation and tropospheric ozone, water vapour, methane and carbon dioxide, respectively. This shows that at p-value < 0.05 level of confidence, solar radiation and tropospheric ozone are statistically significant, while others are insignificant.

4. Conclusion

Solar radiation which travels to the Earth through space is absorbed, scattered or and re-emitted back to the Earth by atmospheric greenhouse gases. This study validated the relationship between greenhouse gases and solar radiation. The results showed that positive relationship exists between solar radiation: CO$_2$ and CH$_4$, respectively, while negative correlation with tropospheric ozone and water vapour. This implied their rate on the influence of solar radiation. The investigations show their influences on climate change and global warming.

Consequently, it revealed that an increase of 0.1017 and 0.1350 units of CO$_2$, and CH$_4$, respectively could enhance the trapping and transmission of solar radiation in the atmosphere, while an increase of 1.1234 and 0.1530 units of tropospheric ozone and water vapour could cause absorption of solar radiation. The trapped energy is re-radiated back to the Earth, this warms up the atmosphere and the surface of the Earth resulting in global warming. This process is referred to as greenhouse effect. The coefficient of determination result confirms that 18%, 30%, 20%, and 29%, respectively of the variances of the dependent variable (solar radiation) being studied is explained by the variance of the independent variables (water vapour, tropospheric O$_3$, CO$_2$, and CH$_4$), respectively. This infers that each of the parameters influences global solar radiation at different levels. In accordance with [6], increased in the concentration of greenhouse gases trap the outgoing infrared radiation in the atmosphere and as a result of this anomaly, the Earth’s climate is altered. This increase of the greenhouse gases concentrations in the atmosphere captures excess heat resulting to global warming.

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GFI organize the study and the modeling, TS supervise the study, CCE proofread the study, CAO and JEE worked on the review, PIA and AOA discuss the results.

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