

Theme of 2024 IVSS**: -** Climate Investigations: Understanding Earth as a System.

**Title of Project**: **SPATIAL VARIABILITY OF CO2, CARBON MONOXIDE, AIR TEMPERATURE AND RELATIVE HUMIDITY IN AKURE CITY, NIGERIA**

**Grade Level:** Secondary School (grades 9 -12, ages 14 – 18 years)

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**Student Names**

1. **Ayomiposi Ojumu**
2. **Adedemeji Odunjo**
3. **Titilayo Olatunji**

**GLOBE Teacher Name**

Mr. Olawunmi Fasakin (*GLOBE Certified*)

**School Name**

**St. Peter’s Unity Secondary School, Akure (SPUSSA), Ondo State**

**Country**

**Nigeria**

**Date**

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**Abstract:**

The spatial variability of atmospheric carbon dioxide (CO2), carbon monoxide (CO), air temperature and relative humidity in Akure metropolitan city, Ondo State, Nigeria was carried out with the aim to determine how the earth systems are impacted by climatic changes. The objectives are to evaluate the relationships between the climate parameters. Four observational sites (A, B, C and D) were chosen within the area of investigation, which is the Federal University of Technology Akure (FUTA), Nigeria. The HANNA instrument was used to measure CO2 and CO emissions with the corresponding air temperature and relative humidity from the four locations. The interplay between CO levels, temperature, and humidity can have complex effects on local and regional climates. Persistent high levels of CO can lead to deteriorating air quality and health issues, as well as contribute to the warming of the atmosphere. There is a weak negative correlation between CO emissions and time (days) (correlation coefficient of -0.139). This suggests CO emissions may be slightly lower over time. There is a very weak positive correlation between CO2 emissions and time (days) (correlation coefficient of 0.005), which is close to zero and suggests no relationship. There is a moderate positive correlation between air temperature and relative humidity (correlation coefficient of 0.779). This means that as relative humidity increases, air temperature also tends to increase. There is a weak positive correlation between CO emissions and CO2 emissions (correlation coefficient of 0.204) and a weak negative correlation between CO emissions and air temperature (correlation coefficient of -0.111). It is therefore recommended to incorporate sustainable transportation system, adopt sustainable agriculture and forest management, and building sustainable infrastructure to reduce the CO2 emissions from buildings and building new low energy physical structures. Also, adopting renewable energies such as solar, wind, biomass and geothermal, that is, moving away from fossil fuels.

**Keywords**: Carbon dioxide, Carbon monoxide, Air temperature, Humidity, Climate change.

**Research Questions:**

1. Do human activities influence the climate change?
2. Does carbon dioxide, air temperature, relative humidity and carbon monoxide play significant roles in climate change?
3. What is the relationship between the physicochemical factors and climate change?

**Introduction and Review of Literature:**

The Carbon dioxide (CO2) emissions from human activity is increasing more than 250 times faster than it did from natural sources after the last ice age. Carbon dioxide in the atmosphere warms the planet, causing climate change. Effects of rapid climate change include global temperature rise and warming ocean. The large increase in industrial activity during the present century is discharging so much carbon dioxide into the atmosphere that the average temperature is rising at the rate of 1.5 degrees per century. Human activities have raised the atmosphere's carbon dioxide content by 50% in less than 200 years (Lindsey, 2023).

Both natural and human actions have contributed to high greenhouse gas emission and increased concentration of carbon dioxide in the atmosphere in the last four decades. This has led to global warming and subsequently to climate change (Amuka et al., 2018).

The Earth’s climate is a solar powered system. All over the world, the Earth systems —land surfaces (pedosphere), seas and oceans (hydrosphere), life (biosphere) and atmosphere—absorbs sunlight which drives photosynthesis, fuels evaporation, melts snow and ice, and warms the Earth system.

Figure 1 shows how Earth transforms sunlight into infrared (heat) energy. Greenhouse gases like carbon dioxide and methane absorb the infrared energy, re-emitting some of it back toward Earth and some of it out into space. The carbon dioxide theory states that, as the amount of carbon dioxide increases, the atmosphere becomes opaque over a larger frequency interval; the outgoing radiation is trapped more effectively near the Earth's surface and the temperature rises.

The study area, FUTA community, is within the domain of Akure South Local Government area which is located within Akure city.

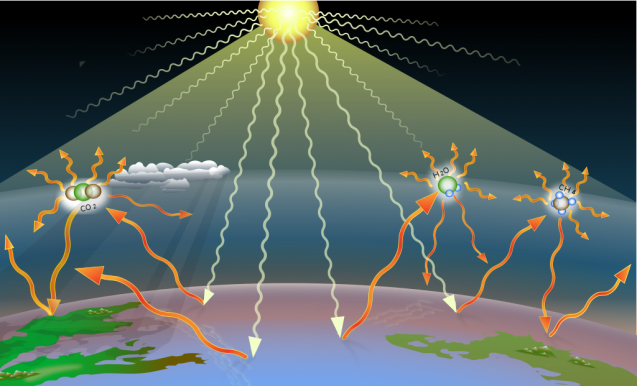


Figure 1. The principle behind why the Earth is warming. The more greenhouse gases (CO2, methane and water vapour) the atmosphere possess, the more heat is trapped and the more the temperature goes up.

The aim of this study was to determine how the earth systems are impacted by climatic changes. Data collected by the measuring device were uploaded to the GLOBE website via the GLOBE Observer app. The objectives are to visualize the relationships between carbon dioxide and the predictor variables

**Research Materials and Methods:**

1. **Research Materials**

The HANNA (AQ-9901SD) instrument was used for measuring the emissions of CO and CO2, while relative humidity and air temperature values were also obtained at the area of investigation using the same device. Figures 2 and 3 display the HANNA instrument while one of the probes is shown in Figure 3.

ArcGIS was used for generating the map of the study area (Figure 4). Four atmospheric sites at FUTA in Akure metropolis which is within Akure South local government, Ondo State, Nigeria (Figure 4).

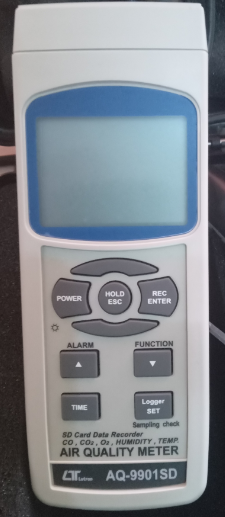
 

Figure 3. A sample of a probe attached with the device.

Figure 2. The HANNA air quality measuring device.

1. **Research Methods**

* **Data Analysis**

The team was assisted with the data analyses and processing procedures by STEAM Professionals. Statistical graphs were used to illustrate the trends or pattern of CO2, Co, air temperature and humidity from four sites. The software used was XLSTAT 2019.2.2.59614. Student’s *t*-test was used to analyze the impact of CO, CO2, air temperature and relative humidity (i.e., environmental or climatic parameters) on climate change while Pearson Correlation coefficient statistics were employed to explain the interrelationship between these earth spheres with respect to climatic dynamics at a significant difference of *p* < 0.05, that is, at 95% confidence interval and 5% error level.

We applied the following GLOBE Protocols in this research work: **Atmosphere protocols** – air temperature and relative humidity; **Carbon protocols** – carbon dioxide (CO2) emissions; **Air quality protocol** – carbon monoxide (CO); **Earth as a System.**

**Geographical Location of Akure City**

Akure is the capital of Ondo state which is located along latitude 7º15’00” N to 7º18’22”.32N and longitude 5º 09’12” E to 5º 14’10” E. The city is situated in the tropical rainforest zone in Nigeria. The city comprises of two local government areas - Akure South and Akure North (Figure 4b). Akure city is the trade centre for a farming region where cocoa, yams, cassava, corn and tobacco and cotton are grown. At the time of the colonial rule in Nigeria, Owo, Ondo and Ekiti regions were merged to form a new province with its headquarters in Akure metropolitan city. Akure became the capital of Ondo State in 1976 when the state was created. As the state capital, Akure city is the centre of commercial and administrative activities and has witnessed a steady increase in population since creation. The study area, Federal University of Technology, Akure (FUTA) community, is within the domain of Akure South Local Government area which is located within Akure city covering an area of 331km2 (Figure 4).

**Climate of Akure City**

Akure metropolitan city is situated in the Southern geopolitical zone of Nigeria. The tropical climatic environment is basically separated into two weather seasons namely: - dry season (November – March) and rainy season (April - October). The average yearly temperature ranges between 20 0C – 310C while humidity is relatively high. Its annual rainfall is about 1150 mm and its vegetation is present in the rainforest zone (Afolabi & Aladesanmi, 2018).

**Study Area (FUTA Community)**

The study area is a part of the Federal University of Technology, Akure (FUTA) campus. The University campus is situated on the northwestern flank of Akure City, and it occupies an area of about 5 km2 and lies between Latitudes 7°17′–7°19′N and Longitudes 5°7′–5°9′E.

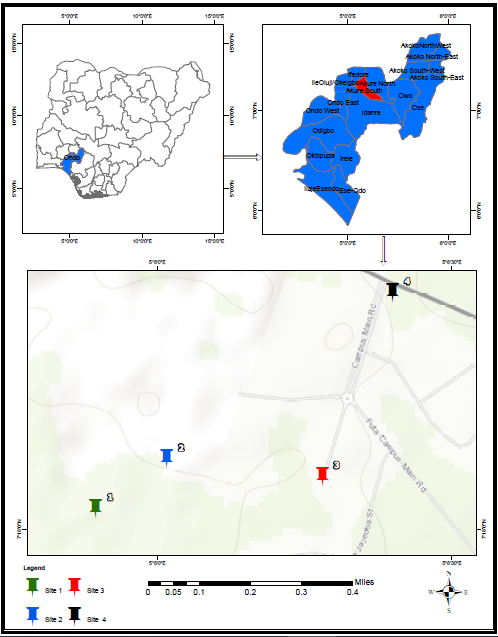


Figure 4. (a) Map of Nigeria, (b) 18 local government areas of Ondo State and (c) four observation sites at FUTA campus.

**Results and Data: *(Including GLOBE Data!)***

Figures 5 – 8 illustrate daily measurements of air temperatures, relative humidity, CO2 and CO from the four atmospheric sites.

Figure 5. Daily air temperature values (0C) from four observation sites from 07/01/2024 – 16/02/2024

1. Figure 5**:** This graph presents the air temperature data for the four sites. The y-axis shows the temperature in degrees Celsius, and the x-axis represents time in days. The temperature appears to be relatively stable across all sites, with minor fluctuations.

Figure 6. Daily relative humidity values (%) from four observation sites from 07/01/2024 – 16/02/2024

1. Figure 6**:** This graph illustrates the relative humidity percentages for the four sites. The y-axis shows the relative humidity, and the x-axis represents time in days. There are noticeable variations in humidity levels, with some sharp increases and decreases.

Figure 7. Daily carbon dioxide (CO2) emissions (ppm) from four observation sites from 07/01/2024 – 16/02/2024

1. Figure 7**:** This graph displays the CO2 levels for the four sites. The y-axis represents CO2 levels in ppm, and the x-axis represents time in days. The trends show that CO2 levels fluctuate over time, with some days showing significantly higher emissions.

Figure 8. Daily carbon monoxide (CO) emissions (ppm) from four observation sites from 07/01/2024 – 16/02/2024

1. Figure 8**:** This graph shows the levels of CO (Carbon monoxide) emissions in parts per million (ppm) on the right y-axis. The x-axis represents time in days. The data series for each site shows fluctuations in CO levels, with some peaks and troughs. Site A and Site B seem to have higher variations compared to Site C and Site D.

Figures 9 – 10 show the bar chart of the average daily carbon monoxide and carbon dioxide emissions for the four sites.

Figure 9. Average daily emission of carbon monoxide (CO) in (ppm) from four observation sites A-D.

Figure 10. Average daily emission of carbon dioxide (CO2) in (ppm) from four observation sites A-D.

Table 1. Correlation matrix of CO emissions

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | | | | |
| Time (days) | Site A | Site B | Site C | Site D |
| **1** | -0.390 | -0.325 | -0.075 | 0.132 |
| -0.390 | **1** | 0.749 | 0.268 | -0.121 |
| -0.325 | 0.749 | **1** | 0.574 | 0.245 |
| -0.075 | 0.268 | 0.574 | **1** | 0.863 |
| 0.132 | -0.121 | 0.245 | 0.863 | **1** |

Table 2. Model parameters (CO emissions)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Source | | Value | | Standard error | t | Pr > |t| | Lower  bound (95%) | | Upper bound (95%) |
| Intercept | | 8.190 | | 0.513 | 15.978 | **< 0.0001** | 7.178 | | 9.203 |
| DATE-Site A | | -1.571 | | 0.725 | -2.168 | **0.032** | -3.003 | | -0.140 |
| DATE-Site B | | -2.333 | | 0.725 | -3.219 | **0.002** | -3.765 | | -0.902 |
| DATE-Site C | | -2.071 | | 0.725 | -2.857 | **0.005** | -3.503 | | -0.640 |
| DATE-Site D | | 0.000 | | 0.000 |  |  |  | |  |
| Source | Value | | Standard error  Table 3. Model parameters (CO2 emissions) | | t | Pr > |t| | | Lower bound (95%) | Upper bound (95%) | |
| Intercept | 564.071 | | 5.318 | | 106.071 | **< 0.0001** | | 553.571 | 574.572 | |
| DATE-Site A | -67.048 | | 7.521 | | -8.915 | **< 0.0001** | | -81.897 | -52.198 | |
| DATE-Site B | -36.048 | | 7.521 | | -4.793 | **< 0.0001** | | -50.897 | -21.198 | |
| DATE-Site C | -41.190 | | 7.521 | | -5.477 | **< 0.0001** | | -56.040 | -26.341 | |
| DATE-Site D | 0.000 | | 0.000 | |  |  | |  |  | |

Table 4. Model parameters (Relative Humidity %)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Source | Value | Standard error | t | Pr > |t| | Lower bound (95%) | Upper bound (95%) |
| Intercept | 32.669 | 2.296 | 14.227 | **< 0.0001** | 28.135 | 37.203 |
| DATE-Site A | 0.690 | 3.247 | 0.213 | 0.832 | -5.722 | 7.103 |
| DATE-Site B | 0.579 | 3.247 | 0.178 | 0.859 | -5.834 | 6.991 |
| DATE-Site C | -0.636 | 3.247 | -0.196 | 0.845 | -7.048 | 5.777 |
| DATE-Site D | 0.000 | 0.000 |  |  |  |  |

Table 5. Model parameters (Air Temperature 0C)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Source | Value | Standard error | t | Pr > |t| | Lower bound (95%) | Upper bound (95%) |
| Intercept | 36.717 | 0.344 | 106.742 | **< 0.0001** | 36.037 | 37.396 |
| DATE-Site A | -0.464 | 0.486 | -0.954 | 0.341 | -1.425 | 0.496 |
| DATE-Site B | -1.512 | 0.486 | -3.108 | **0.002** | -2.472 | -0.551 |
| DATE-Site C | -0.360 | 0.486 | -0.739 | 0.461 | -1.320 | 0.601 |
| DATE-Site D | 0.000 | 0.000 |  |  |  |  |

Table 6. Correlation matrix (Pearson)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | Time (days) | CO | CO2 (ppm) | Relative Humidity (%) | AIR TEMP (°C) |
| Time (days) | **1** | -0.139 | -0.005 | **0.779** | **0.265** |
| CO | -0.139 | **1** | **0.204** | -0.028 | -0.111 |
| CO2 (ppm) | -0.005 | **0.204** | **1** | 0.077 | 0.043 |
| Relative Humidity (%) | **0.779** | -0.028 | 0.077 | **1** | **-0.249** |
| AIR TEMP (°C) | **0.265** | -0.111 | 0.043 | **-0.249** | **1** |

Table 7. p-values from Correlation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | Time (days) | CO | CO2 (ppm) | Relative Humidity (%) | AIR TEMP (°C) |
| Time (days) | **0** | 0.073 | 0.954 | **< 0.0001** | **0.001** |
| CO | 0.073 | **0** | **0.008** | 0.721 | 0.151 |
| CO2 (ppm) | 0.954 | **0.008** | **0** | 0.319 | 0.576 |
| Relative Humidity (%) | **< 0.0001** | 0.721 | 0.319 | **0** | **0.001** |
| AIR TEMP (°C) | **0.001** | 0.151 | 0.576 | **0.001** | **0** |

**Discussion:**

1. Do human activities influence the climate change?

From Figures 8 and 9, Site D has the highest average daily CO emission, followed by Site A, Site C, and then Site B. The chart does show that there is variability in the emissions between the four sites. Site D is an area with the highest traffic activities when compared with the others. This reflects in this result. The fluctuations in CO levels could indicate varying levels of human activity or natural events that influence CO emissions. Higher CO levels contribute to the greenhouse effect, which can lead to global warming. The relative stability in temperature across the sites suggests that this data set might not be showing extreme temperature variations that could be indicative of climate change within the short 41-day period (Figure 5). Relative humidity can affect the concentration of pollutants like CO. Higher humidity can lead to more stagnant air, which might increase the concentration of CO at ground level (Figure 6).

Figures 7 and 10 indicate that CO2 levels also vary, with some sites showing more pronounced fluctuations than others. This could be related to localized sources of CO2, such as traffic or industrial activities.

The interplay between CO levels, temperature, and humidity can have complex effects on local and global climates. Persistent high levels of CO can lead to deteriorating air quality and health issues, as well as contribute to the warming of the atmosphere.

1. Does carbon dioxide, air temperature, relative humidity and carbon monoxide play significant roles in climate change?

Table 1 shows a correlation matrix between CO emissions (ppm) measured at four sites (Site A, B, C, and D) and time (days). It was observed that there is a weak negative correlation between time (days) and CO emissions (ppm) at Site A (correlation coefficient of -0.390). Sites A and B have a moderate positive correlation (correlation coefficient of 0.749), which means that CO emissions tend to rise and fall together at these two sites. There is a weak positive correlation between Sites B and C (correlation coefficient of 0.574) and Sites C and D (correlation coefficient of 0.863). This means that CO emissions also tend to move in the same direction at these sites, but to a lesser extent than Sites A and B. Site D has a weak positive correlation with time (days) (correlation coefficient of 0.132).

Table 4 shows the trends in relative humidity over time at each location. Site A has a positive coefficient with a statistically significant p-value (e.g., p<0.05), it suggests that relative humidity is increasing over time at Site A. Site B has a negative coefficient with a statistically significant p-value, it suggests that relative humidity is decreasing over time at Site B while Site C has a coefficient close to zero with a high p-value (e.g., p>0.05), it suggests that there is no statistically significant trend in relative humidity over time at Site C.

Table 5 predicts trends in air temperature over time at each location. Site A has a positive coefficient with a statistically significant p-value (e.g., p<0.05), it suggests that air temperature is increasing over time at Site A. Site B has a negative coefficient with a statistically significant p-value, it suggests that air temperature is decreasing over time at Site B. Site C has a coefficient close to zero with a high p-value (e.g., p>0.05), it suggests that there is no statistically significant trend in air temperature over time at Site C

1. What is the relationship between the physicochemical factors and climate change?

Tables 6 and 7 presents correlation matrices and p-value tables that show the relationships between CO emissions, CO2 emissions, air temperature, relative humidity, and time (days). There is a weak negative correlation between CO emissions and time (days) (correlation coefficient of -0.139). This suggests CO emissions may be slightly lower over time. There is a very weak positive correlation between CO2 emissions and time (days) (correlation coefficient of 0.005), which is close to zero and suggests no relationship. There is a moderate positive correlation between air temperature and relative humidity (correlation coefficient of 0.779). This means that as relative humidity increases, air temperature also tends to increase. There is a weak positive correlation between CO emissions and CO2 emissions (correlation coefficient of 0.204) and a weak negative correlation between CO emissions and air temperature (correlation coefficient of -0.111).

In general, a p-value less than 0.05 is considered statistically significant. Looking at the p-value table, most of the correlations are not statistically significant because their p-values are greater than 0.05. The exceptions are the positive correlation between relative humidity and air temperature (p-value < 0.0001 which is highly statistically significant).

Overall, the data suggests a weak negative correlation between CO emissions and time at this location, but this finding is not statistically significant. There is a moderate positive correlation between relative humidity and air temperature, which is statistically significant.

**Conclusion:**

The combined analysis of these graphs can provide insights into the environmental conditions at each site and how they might be interrelated. For instance, higher CO and CO2 levels could be indicative of increased fossil fuel combustion, which is a significant contributor to climate change. The relative humidity and air temperature data can help in understanding the local climate dynamics and how they might be influenced by or contribute to broader climatic trends.

The interplay between CO levels, temperature, and humidity can have complex effects on local and global climates. Persistent high levels of CO can lead to deteriorating air quality and health issues, as well as contribute to the warming of the atmosphere.

This research work is in support of the Year of Climate and Carbon (YCC), a GLOBE action and awareness campaign from August 2023 – August 2024.

**Recommendation**

How to prevent global warming include the following:

1. Adoption of renewable energies such as solar, wind, biomass and geothermal, that is, moving away from fossil fuels.
2. Reducing our consumption of energy and water by using more efficient devices such as Light Emitting Devices (LED) light bulbs, innovative shower systems.
3. Promoting sustainable transportation system. Examples are electric trains.
4. Building sustainable infrastructure to reduce the CO2 emissions from buildings and building new low energy physical structures.
5. Sustainable agriculture and forest management.

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3. We also appreciate the efforts and dedication of our GLOBE Teacher in person of Mr. O. O. Fasakin. He is focused towards the attainment of the vision and mission of the GLOBE programme. We salute his courage and time during the research project.
4. We thank and appreciate the support of the Country Coordinator, in person of Mrs. Aminulai Modupe Salamotu.

**Badge Descriptions/Justifications**

**I am a Collaborator:** Working together (in collaboration) as a team has contributed to our research by identifying potential greenhouse gases and their effects. Moreover, we have three connected GLOBE teams working as a group. The members include Feranmi Ehindero, Ayodeji Ayotunde, and Olayinka Oloda

The second team was responsible for collection data such as CO2, CO, air temperature and relative humidity measurements. The team members are Bukola Adewole, Faith Adedugbe and Esther Oluborode. The third team was responsible data gathering and collation. The members include Ojumu, Olatunji and Michael Solomon. They create a database record of the results analysis before sending to GLOBE database server through the GLOBE app.

**I make an Impact:** By advising the school management on how to mitigate the effects of climate change and possible hazards.

**I am a STEM Professional:**

Dr. S. O. Oladele from the Agricultural Engineering Department, School of Engineering and Engineering Technology (SEET), Federal University of Technology, Akure, Ondo state, Nigeria is a Lecturer who assisted in the aspect of data interpretation and analyses. Prof. Babasola Williams from Federal University of Technology, Akure, Ondo state, Nigeria who assisted in procuring the measuring device.

Mr. Oluwafemi Olawale from the University of Toledo, Ohio, USA for technical support and assistant. Mr. Olawunmi Fasakin (*GLOBE Teacher*) from St. Peter’s Unity Secondary School, Akure, Nigeria, who is an Educational Physicist, led the GLOBE team through taking improved precision in the course of taking the data/observations with assistance in the areas of project write-up, editing and constructive ideas.

These professionals helped the students on precautionary steps taken during the course of our research so as to maintain GLOBE standardized protocols and rubrics.

**I am a DATA Scientist:**

GLOBE SPUSSA members collected data measurements on environmental variables or physicochemical parameters that influence the climate change in the study area. Data analyses and data interpretations were carried out using statistical charts, tabular presentation of numbers, statistical techniques and tools or software.