Covenant Journal of Physical & Life Sciences (CJPL) Vol. 8 No. 1, June 2020
ISSN: *p. 2354 – 3574 e. 2354 – 3485* **DOI:** *xxxxxxxxxxxxxxx*

An Open Access Journal Available Online

Mean Annual Weather Cycles of some Weather Variables over Warri, Delta State, Nigeria during 2009 to 2018

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Received: 17.05.2020 Accepted: 10.06.2020
Date of Publication: June, 2020

Abstract: The importance of analysing the weather cycles of any region cannot be over emphasized considering the dynamic nature of weather and its undesirable impacts on the environment. This study examines the mean annual cyclic behaviour of some weather variables over Warri, Delta State, Nigeria using recent weather data from NiMet for a period of ten years (2009 to 2018). It was observed from the cyclic behaviours from the various weather variables for the ten years period under consideration, that the annual maximum and minimum temperature, vapour pressure and cloud amount cycles follow similar trends, likewise the undulation of the annual soil heat flux cycles. The annual rainfall, wind speed, maximum and minimum relative humidity cycles were found to fluctuate in different patterns. In periods of limited rainfall, relative humidity is at the threshold of ~ 50.0%. A roughly curvilinear fit was noticed between the annual rainfall and relative humidity. While, rainfall appears insensitive to relative humidity changes during the months with lower relative humidity, which tends to be linear during the months with higher relative humidity. Hence, as the rainfall amount increases, there is an increasing tendency towards a curvilinear relationship. The occurrence of the maximum in temperature preceding that of wind speed indicates that the prevalent winds over Warri could be thermally obsessed. The results obtained would assist in providing appropriate panacea to mitigating weather induced environmental hazards, thereby improving agriculture, efficient economic productivity and advance scientific research.

Keywords: cyclic behaviours; weather variables; linear function; curvilinear relationship; polynomial functions

Introduction

Meteorological study which is mostly centred on the study of weather or climate as the case may be is as old as the creation of mankind and has always had a significant influence on the lives of people and shaped their cultures, beliefs, habits, attitudes, behaviour and their environments in general right from the beginning of creation [1-9].

Weather has always been a universal concern that plays a major role in our everyday lives [10-14]. Weather measurements, monitoring and analysis potentially help in keeping track of different meteorological variables such as temperature, relative humidity, atmospheric pressure, light intensity, wind speed, wind direction, precipitation, altitude, solar radiation, light intensity, dew point temperature, specific humidity, absolute humidity, virtual temperature, evaporation, etc. These variables have great importance and have several applications in agricultural, transportation, construction, military operations, radio signal transmission, power generation, solar devices and many other personal and industrial aspects of human lives [1-9]. Weather or meteorological measurements, monitoring and analysis have developed over the years and a lot of knowledge and information have been gathered that have helped in understanding the meteorological conditions of the universe [2-5, 12]. There are many factors that influence weather, some of which are visible and others invisible. These factors include but not limited to the following; latitudinal location, proximity to water bodies, solar distance, air masses, air pressure and elevation [5, 15].

Man has always tried in finding out the causes of different meteorological conditions within his environs and possibly monitors what the weather would be at any given time because there cannot be the study of weather nor its prognostication without the knowledge of the prevailing conditions of the atmosphere. The weather or meteorological variables measured are used for monitoring of the atmospheric conditions. Hence, appropriate studying of the meteorological conditions would make a difference for the survival and prosperity of the human race [2-5]. For this reason, man has always devised means of measuring different variables of the weather and with advancement of technology, new methods and equipment have been developed to measure, collect, monitor and analyse meteorological information and today a whole field of study known as meteorology is dedicated to its study. Meteorology is the science that deals with the study of the atmosphere and its phenomena; especially those aspects that have to do with weather monitoring and prognostications. Its domain is mainly the lower atmosphere (troposphere) of the universe and its practice involves the daily cooperation of every action on the universe. Meteorology is a branch or sub-discipline in Atmospheric Science. Other sub-disciplines of Atmospheric Science include: Climatology, Atmospheric Physics and Atmospheric Chemistry [12]. Meteorological processes are observable climatic events that are illustrated using meteorological terms. These meteorological processes are described and their values/quantities are known by the weather/climate variables or parameters of the earth's atmosphere together with their variations and interactions over time. Hence, the meteorological variables measured and collected are used in monitoring of the various atmospheric conditions and are useful in one way or the other in the course of our daily activities [2-5, 16, 17].

The weather cycles concept as to do with the periodic re-occurrence of the various weather phenomena. It is the average weather events tend to repeat themselves with some order. In this context, cycles entail patterns and order in the average state. Since the departures from the average are not taken into account [18, 19].

Geophysical analogues of weather cycles include: solar, rock and hydrological cycles.

- Solar cycle as to do with the earth revolves round the sun approximately every 365 days.
- Hydrological cycle as to do with rain falls to the earth surface and goes back to the atmosphere through evaporation and transpiration.
- Rock cycle as to do with the transformation of rock from one rock type to another.

Weather cycles may be categorized into two namely: simple cycles and complex cycles. As a result of these cycles, there is an increasing consensus about the anthropogenic impact on the recent change of the earth's climate. Records have it that the global mean near surface air temperature has risen tremendously over the last with a warming rate over the last decades that have no precedent in the instrumental records and this trend is projected to continue in the future [20]. Nevertheless, climate projections are still affected by some important uncertainties, especially related to the role of aerosols and clouds in the climate system. Due to the fact that there is no evidence of natural processes with weekly cycles, the study of such cycles in meteorological variables has become an interesting way to establish links between human activities and their influence on the climate. Apparently, human induced activities such as commercial transportation, industrial activity, etc. are commonly reduced during weekends compared to weekdays, especially in the industrialised regions in the western advanced countries. Consequently, if the mean values of meteorological variables show a weekly cycle, these variations might be linked to human influence and are considered as anthropogenic signals [20].

An increasing number of studies have been devoted to the cycles of meteorological variables over large areas [18-24]. Most of these studies focus on the examination of average values of meteorological variables in order to show weekly cycles or weekly effects. The analyses were designed to find differences between the weekend and the working week, using the Saturday through Monday and Wednesday through Friday periods to define both periods respectively [20].

Over the Atlantic coast of the United States and neighbouring oceanic areas, weekly cycles has been observed in the rainfall and tropical cyclones activity and linked to the downwind pollution transport from the urbanized eastern seaboard [25].

In eastern China, winter diurnal temperature ranges anomalies tend to be larger for weekends compared to weekdays and are associated with increased maximum temperature and total irradiance but decreased relative humidity [26]. On the other hand, the summertime diurnal temperature range anomalies display a much stronger negative weekend effect that is; smaller diurnal temperature range in weekends, linked to decreased maximum temperature and decreased total solar irradiance but increased relative humidity and a greater number of rainy days. The weekly difference is suggested to be physically related to the direct and indirect effects of anthropogenic aerosols [26].

The underlying notion in the search for an orderly behaviour in the weather is that much of the activity's humans engage in, like what to eat or wear clothes are affected by the rhythms of the weather daily. The cyclic behaviour of the weather affects us in all its variety; most of the time these effects are familiar. However, weather never repeats in exactly the same fashion. This underscores the need to search weather records for the occurrence of cycles. Within the meteorological community the debate continues as to whether patterns exist and if they do, whether they are sufficiently well established to provide the physical basis for weather prognostications [18, 19].

There is no doubt that the utilization of inadequate meteorological information for environmental planning and inaccurate analysis of the state of the atmosphere have resulted in widespread weather-induced environmental hazards that have affected agriculture and other aspects of human endeavours and most of these effects are cause by the dynamic nature of weather. The importance of analysing the weather cycles of any region cannot be over emphasized, considering the dynamicity and influence of weather in our everyday lives [2-5, 11, 12]. This study become desirable because records within are disposal show that are limited research studies on weather cycles within the study area (Warri, Delta State, Nigeria). Although, Onyenucheya and Nnamchi [18], analysed the mean diurnal and annual cycles of some weather variables over Nsukka, Enugu State using the weather data for only two years (2010 and 2011). This study examines the annual cyclic behaviour of some weather variables (minimum temperature, maximum temperature, relative humidity, rainfall, wind speed, vapours pressure and cloud amount) over Warri, Delta State, Nigeria for a period of ten years (2009 to 2018). The rapidly increasing urban population in this city necessitates an improved understanding of the basic meteorological features. Hence, examinations of the annual (during the course of the year) weather cycles and the establishment of the relationship between the annual weather cycles of these weather variables over Warri, Delta State.

Materials and Methods

The Study Area

Warri in Delta State, Nigeria is located on latitude 5.520N and longitude 5.750E with an elevation of about 6.0 m above sea level having a population of over five hundred thousand. The city shares boundaries with Ughelli/ Agbarho, Sapele, Okpe, Udu and Uvwie although most of these places, notably Udu, Okpe and Uvwie, have been integrated to the larger cosmopolitan Warri [27]. The city is one of cosmopolitan cities in southern Nigeria comprising predominantly of Urhobo, Itsekiri and Ijaw people. Warri is predominantly Christian with mixture of African traditional religions like most of the Southern Nigeria. The city is known nationwide for its unique Pidgin English language [27].

The city of Warri is an oil hub in Delta State which is located in the Niger Delta/South-South region of Nigeria. The bulk of the petroleum from Nigeria is from Delta State and this makes Nigeria one of the largest petroleum producers in Africa and around ten largest producers and six largest exporters among the Organization of Petroleum Exporting Countries (OPEC) members of crude oil in the world. The region is so rich in petroleum resources and this has continually made the region a centre of attraction and concern by the local, national and international community economically, politically and otherwise. Despite the huge amount of wealth coming from its exploration and exportation of petroleum, this region is not without numerous disturbances and interruptions. The issue of environmental contaminations as a result of these petroleum activities is now as serious threat not only to this region but the entire country at large [28-31].

Figure 1 shows the map of Nigeria indicating Warri, Delta State.

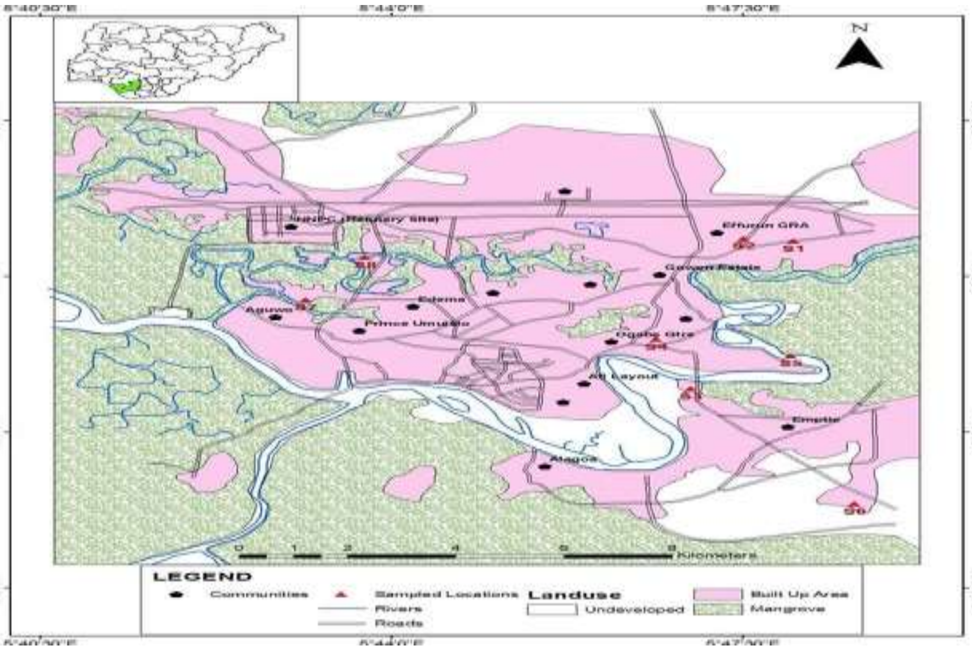

Figure 1: **Map of** Warri, Delta State, Nigeria

Collection of Data

Data for this project work were weather variables which were collected from the archive of the Nigerian Meteorological Agency (NiMet). In this study monthly minimum and maximum temperature (^{0}C), rainfall (mm), vapour pressure (kpa), minimum and maximum relative humidity (%), wind speed (knots), soil heat flux (^{0}C) and cloud amount (oktas) for ten years (2009 to 2018) for Warri, Delta State, Nigeria were used for the analyses.

Analysis of Data

Data on continuous weather variables (minimum and maximum temperature, soil heat flux, minimum and maximum relative humidity, rainfall, wind speed, vapours pressure and cloud amount) were analysed on monthly basis.

On the other hand, rainfall occurrence is considered discrete in time and so the monthly accumulated amounts were analysed. The mean state, the ten year mean of each weather variable were also calculated.

The relationship between the annual rainfall cycles and relative humidity cycles was investigated using a three-stage curve fitting procedure. First, we employed a linear fit (first order model). Then realizing the curve linear nature of the variables when paired, they were modelled using second and third order polynomial functions.

Given a weather variable (P) which is taken to be a response variable that evolves with another (Q) taken to be the predictor variable, the first order model of their linear relationship is given by the function:

$$P = x_1 + x_2 Q + \varepsilon \quad (1)$$

where x_1, x_2 and ε are the intercept, slope of the curve and error term respectively.

Eqn. (1) is a simple linear function, representing the relationship between two weather variables P and Q. However, if the time evolution of P and Q is not linear, it becomes necessary to describe their relationship using other curve fitting methods. Here, we find that the appropriate model will require polynomial terms and may be generalized as follows:

$$P = x_1 + x_2 Q + x_3 Q^2 + \ldots + x_n Q^n + \varepsilon \quad (2)$$

where n represents the order of the polynomial terms.

Results and Discussion

Annual Weather Cycles

The annual weather cycles for the various weather variables used are analysed below:

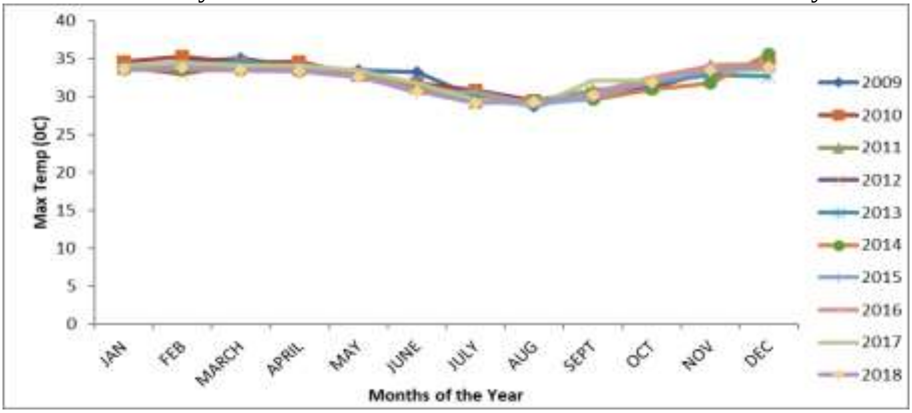

Figure 2: Annual Maximum Temperature Cycles for 2009-2018

From Figure 2, it was observed that the annual maximum temperature cycles for the period under consideration (2009 to 2018) follow similar trends, having the highest value of 35.60 ^{0}C in December, 2014 and lowest value of 28.70 ^{0}C in August, 2009 with an overall average of 32.39 ^{0}C for the ten years period under consideration.

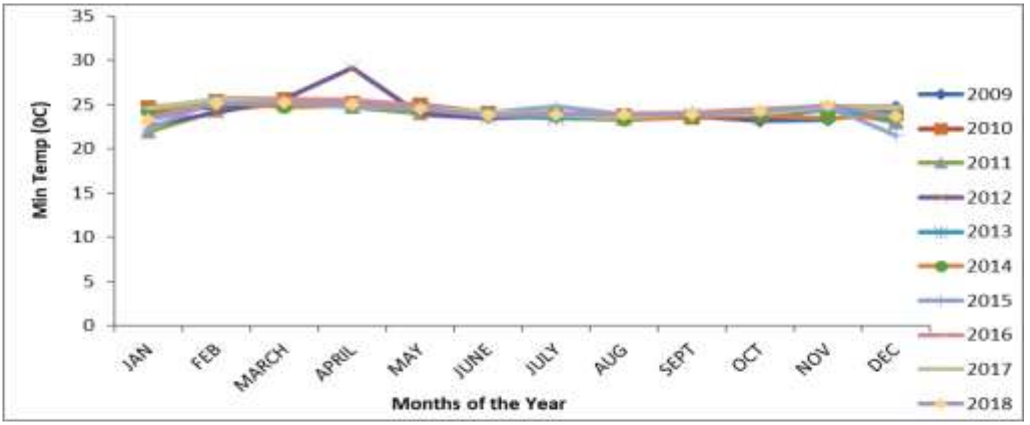

Figure 3: Annual Minimum Temperature Cycles for 2009-2018

From Figure 3, it was observed that the minimum temperature cycles for period under consideration (2009 to 2018) also follow similar trends, except for in the month of April, 2012 where there was a slight increase; having the highest value of 29.10 ^{0}C in April, 2012 and lowest value of 21.50 ^{0}C in December, 2015 with an overall average of 24.25 ^{0}C for the ten years period under consideration.

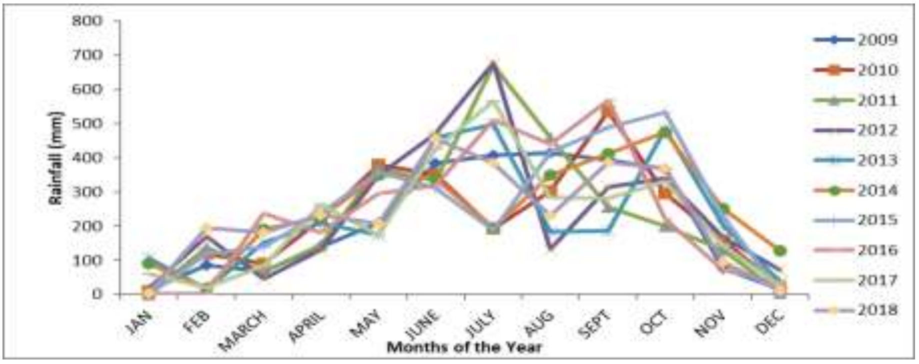

Figure 4: Annual Rainfall Cycles for 2009-2018

From Figure 4, it was observed that the annual rainfall cycles for the under consideration (2009 to 2018) were found to fluctuate in different patterns, having the highest value of 678.10 mm in July, 2011 and lowest value of zero in January, 2011 and 2015, with an overall average of 232.81 mm for the ten years period under consideration.

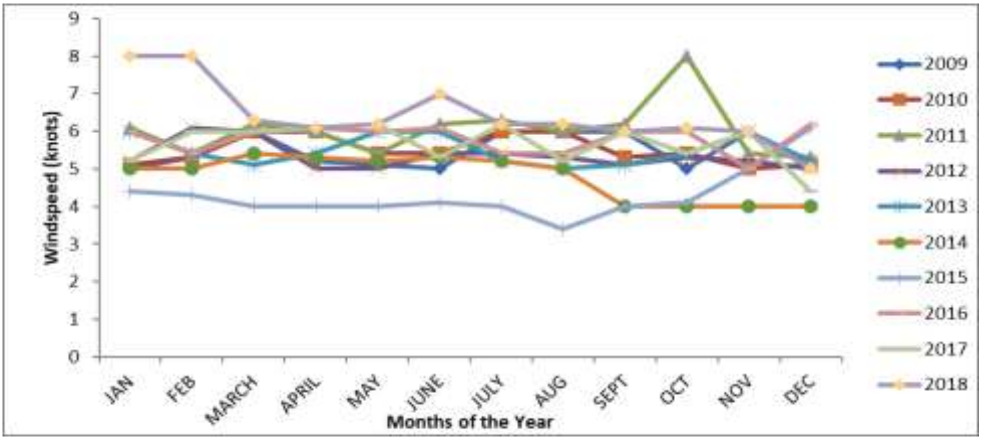

Figure 5: Annual Wind Speed Cycles for 2009-2018

From Figure 5, it was observed that the annual wind speed cycles for the period under consideration (2009 to 2018) were found to fluctuate in different patterns, having the highest value of 8.00 knots in January and February, 2018 and lowest value of 3.40 knots in August, 2015, with an overall average of 5.48 knots for the ten years period under consideration.

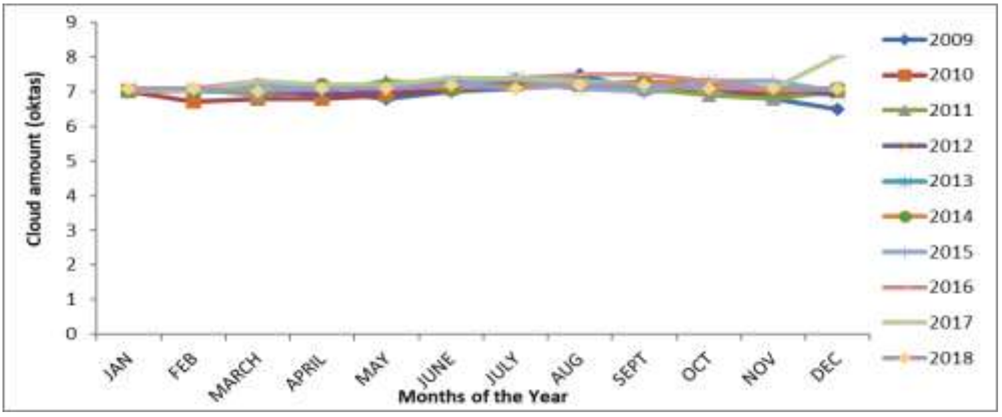

Figure 6: Annual Cloud Amount Cycles for 2009-2018

From Figure 6, it was observed that the annual cloud amount cycles for the ten years period under consideration (2009 to 2018) follow similar trends, having the highest value of 8.0 oktas in December, 2017 and lowest value of 6.5 oktas in December, 2009, with an overall average of 7.12 oktas for the ten years period under consideration.

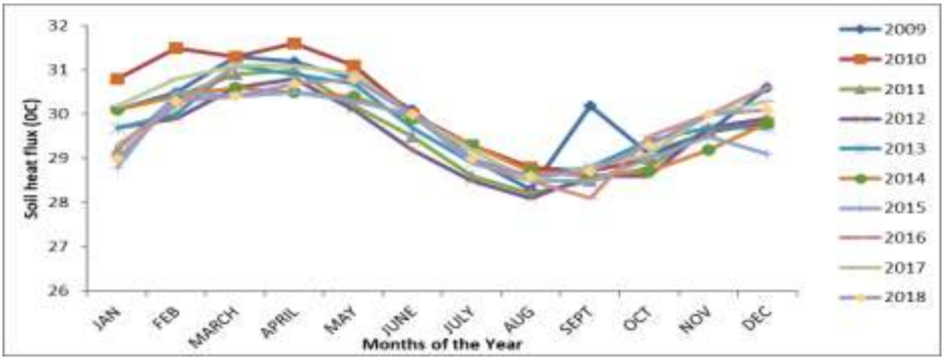

Figure 7: Annual Soil Heat Flux Cycles for 2009-2018

From Figure 7, it was observed that the annual soil heat flux cycles for the ten years period under consideration (2009 to 2018) undulate with similar trends, having the highest value of 30.60 ^{0}C in April, 2010 and lowest value of 28.10 ^{0}C in August and September, 2016, with an overall average of 29.21 ^{0}C for the ten years period under consideration.

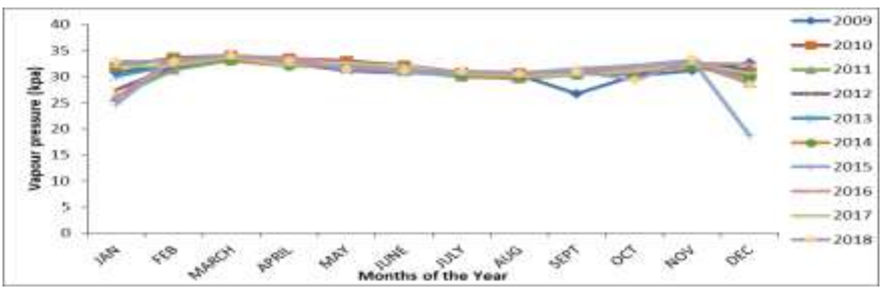

Figure 8: Annual Vapour Pressure Cycles for 2009-2018

From Figure 8, it was observed that the annual vapour pressure cycles for the ten years period under consideration (2009 to 2018) follow similar trends, except for December, 2015; having the highest value of 34.0 kpa in March, 2018 and lowest value of 18.70 kpa in December, 2015, with an overall average of 31.30 kpa for the ten years period under consideration.

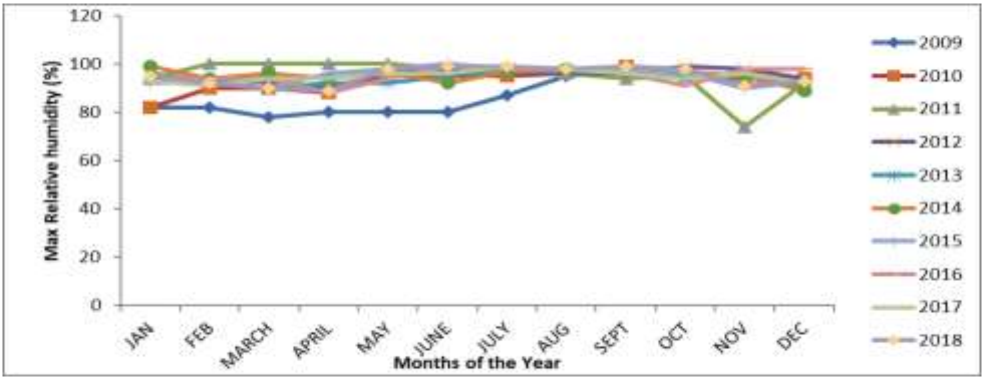

Figure 9: Annual Maximum Relative Humidity Cycles for 2009-2018

From Figure 9, it was observed that the annual maximum relative humidity cycles for the ten years period under consideration (2009 to 2018) fluctuate in different patterns, having the highest value of 100.0% in February to May, 2011 and June, 2015 and lowest value of 74.0% in November, 2011, with an overall average of 94.03% for the ten years period under consideration.

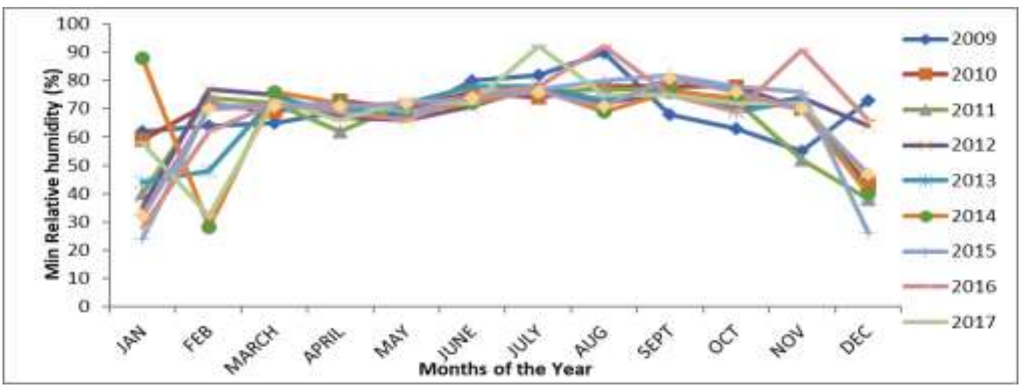

Figure 10: Annual Minimum Relative Humidity Cycles for 2009-2018

From Figure 10, it was observed that the annual minimum relative humidity cycles for the ten years period under consideration (2009 to 2018) also fluctuate in different patterns, having the highest value of 92.0 % in July, 2017 and August, 2015 and lowest value of 24.0% in January, 2015, with an overall average of 67.96% for the ten years period under consideration.

Nevertheless, the cyclic behaviours from the weather data used to some extent are in conformity with the work of Onyenucheya and Nnamchi [18], where they carried out the diurnal and annual weather cycles over Nssuka area in Nigeria. We would not be far from the truth to assert that the occurrence of the maximum in temperature preceding that of wind speed is an indication that the prevalent winds over Warri could be thermally obsessed.

Relationship in Annual Cycles of the Weather Variables

The relationship between the annual rainfall cycles and relative humidity cycles using the ten years monthly mean data are shown in Figure 11. The relationship between the annual rainfall cycles and relative humidity cycles over Warri appears to be best described by polynomials in the range of $1 \geq n \leq 3$; where $n = 1$ corresponds to a linear function of the form shown as Eqn. (1).

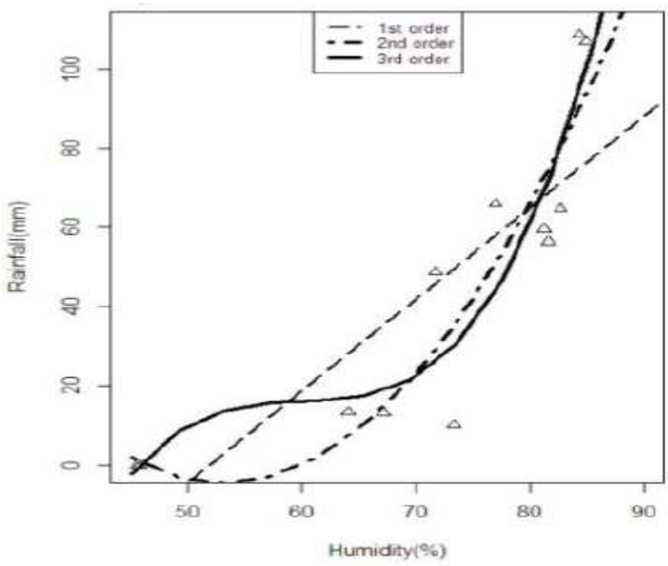

Figure 11: Relationship between the Annual Rainfall Cycles and Relative Humidity Cycles

From Figure 11, it can be seen that at periods of little or no rainfall, relative humidity is at the threshold of ~ 50.0%. From the annual cycle plots, we could suggest that this occurrence is mainly during the dry season. Even though, the atmospheric water vapour content may fluctuate, it hardly reaches saturation. It is observed that as the rainfall amount increases (during the months with high rainfall), there is an increasing tendency towards a curvilinear relationship.

Conclusion

This research study examined the annual cycles of some weather variables (minimum temperature, maximum temperature, relative humidity, rainfall, wind speed, vapour pressure and cloud amount) over Warri, Delta State, Nigeria. The study further described a curvilinear relationship between relative humidity and rainfall using monthly weather data.

It is important to note that the analysis carried out in this study is based on ten years (2009 to 2018) for which uninterrupted record are available. In essence, long term changes in the weather cycles due to inter-annual, decadal or multi-decadal modulations in the climate system are not accounted for in this study. Despite this caveat, the results provide key features of the annual weather cycles of weather over Warri, Delta State, Nigeria. We would therefore suggest that further studies utilizing longer time series should be carried out to characterize inter-annual, decadal or multi-decadal modulations in the climate system.

Albeit, the results obtained from this research study hitherto will assist in providing the appropriate panacea to mitigating meteorological induced environmental hazards, thereby improving agriculture and economic efficiency and productivity, as well as advance scientific research.

Competing Interests

The authors declare that they have no conflict of interest.

Acknowledgements

The authors are particularly grateful to the Nigerian Meteorological Agency (NiMet) for providing the data used for this study. The assistance of Prof. Augusto José Pereira Filho of the Institute of Astronomy, Geophysics and Atmospheric Sciences, University of Sao Paulo, Brazil are and also Dr. Seyni Salack and Dr. Inoussa Saley of the West African Science Service Center on Climate Change and Adapted Land (WASCAL), Competence Center, Ouagadougou, Burkina Faso are highly appreciated. We also wish to thank the reviewers for the improvement of the article through their useful suggestions.

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