Original Research Paper

METEOROLOGICAL VARIABLES THAT AFFECT VISIBILITY DEGRADATION AND THEIR SEASONAL TRENDS IN THE NIGER DELTA REGION OF NIGERIA

[1]Nwokocha C.O[*], [2]Okujagu C.U and [3]Enyinna P.I.

Department of Physics, Faculty of Science, University of Port Harcourt.

Abstract:

The study of visibility in the Niger Delta region is necessary because it reflects the atmospheric changes caused by economic expansion in Nigeria. Cities in the Niger Delta (especially Port Harcourt) are the most polluted cities in the country and therefore visibility degradation has become one of the major environmental challenge in Nigeria. Analysis of a 31 years (1981-2012) monthly mean horizontal visibility data and monthly mean datasets of meteorological parameters such as relative humidity and wind direction obtained from Nigerian Meteorological Agency (NIMET) and the National Centre for Environmental Prediction (NCEP) for Calabar, Uyo, Port Harcourt, Owerri, Warri and Akure was done using statistical techniques. A correlation analysis was done and the annual visibility variability indexes from (NIMET) shows significant correlation with the (NCEP) datasets for R/humidity at r=0.1334 and Wind direction at r=0.1210 respectively at 90% confidence level from t-test. This study concluded that the relationship of the atmospheric visibility and meteorological factors are closely related. The results showed that visibility is more correlated with Relative humidity in places with high hydrocarbon activities leading to excess aerosol loading like Port Harcourt while it is better correlated with wind direction in places with less hydrocarbon activities like Calabar and Akure. The results of this study can assist policy makers and operators in establishing positive strategies to improve the air quality.

Keywords: Meteorological, Variables, Visibility, Degradation, Seasonal trends, Niger Delta.

Introduction:

Dramatic economic and industrial developments as well as vigorous urbanization in Nigeria have led to increased emission of pollutants from urban areas, making visibility degradation one of the severe environmental problems in such a rapidly changing country. Low visibility in Nigeria (especially in the Niger Delta region) is reported to cause 527,000 deaths due to road, air and sea accidents annually according to World Health Organization (WHO). The cities in the Niger Delta (especially Port Harcourt) are the most polluted cities in the country. Therefore visibility degradation has become one of the major environmental challenges in Nigeria, especially in the Niger Delta region that requires constant monitoring.

Studies according to Schichtel et al (2001), Doyle and Dorling (2002) and Molnar et al (2008) have evaluated long-term visibility observations and impacts of dominant air pollutants on local visibility. Also, the degree of visibility degradation in the Niger Delta Region has been found to be a function of season and region mainly due to the different concentrations of aerosols at different season and location owing to its variations of climates. The climate of Nigeria is usually characterized by two distinct seasons, namely; Summer (dry season) and Harmattan (cold-wet season), Kehinde, Ayodeji and Vincent (2012).

Another study by Zhao et al (2011) recognized dust haze as the principal pollutant in Nigeria and in the Niger Delta that causes low visibility. This is due to the position of Nigeria in sub-Saharan West-Africa where dust aerosols are being transported regularly from Sahara desert. Dust aerosols are also emitted and circulated locally due to favorable weather conditions, especially in the northern part of Nigeria, even though, significant economic and population growth are obvious in Nigeria (http://www.who.africa.org (accessed on 28th March 2016). The emission and transportation of these particles are increasing annually and seasonally with increasing number of hazy days. Low visibility has been reported to have adverse effects on traffic safety, economy, human health and many more in Nigeria (Kehinde et al 2012, Zheng et al 2015, Adefolalu, 1983).

Study Area:

Figure (1) shows the map of Nigeria indicating the Niger Delta states. The Niger Delta area in Nigeria is situated in the Gulf of Guinea between longitude (5.05E-7.17E and latitude 4.15 N-7.17 N). It is the largest wetland in Africa and the third largest in the world consisting of flat low lying swampy terrain that is cress crossed by meandering and anatomizing streams, rivers and creeks. It covers 20,000km^2 within wetlands of 70,000km^2 formed primarily by sediment depositions. It constitutes about 7.5% of Nigeria's land mass with an annual rainfall total averaging from 2400-4000mm. The area is influenced by the localized convection of the West African monsoon with less contribution from the mesoscale and synoptic system of the Sahel (Ba et al., 1995). The rainy (wet) season over the region starts in May, following the seasonal northward movement of the Intertropical Convergence Zone (ITCZ), with its cessation in October (Druyan et al., 2010; Xue et al., 2010). It has an equatorial monsoon climate influenced by the south west monsoonal winds (maritime tropical) air mass coming from the South Atlantic Ocean. It is home to 20 million people drawn from nine states of the country namely Abia, Akwa-ibom, Bayelsa, Cross- River, Delta, Edo, Imo, Ondo and Rivers states with 40 different ethnic groups. This flood plain makes 7.5% of Nigeria's total land mass (Baird, 2010). The study is restricted to six states in the Niger Delta namely Calabar, Uyo, Port Harcourt, Owerri, Warri and Akure because there are no available data in the remaining stations Yenegoa, Umuahia and Asaba as shown in Table 1 below.

Table 1: Coordinates of the study locations, their elevations and duration of study.

S/N	LOCATIONS	LAT(N)	LONG(E)	ELEVATION(M)	DURATION OF STUDY
1.	CALABAR	4.976	8.347	47.0	1981-2012
2.	UYO	5.038	7.909	65.0	1981-2012
3.	PORTHARCOURT	4.8156	7.0498	468.0	1981-2012
4.	OWERRI	5.483	7.0176	71.0	1981-2012
5.	WARRI	5.516	5.750	6.0	1981-2012
6.	AKURE	7.247	5.301	335.0	1981-2012

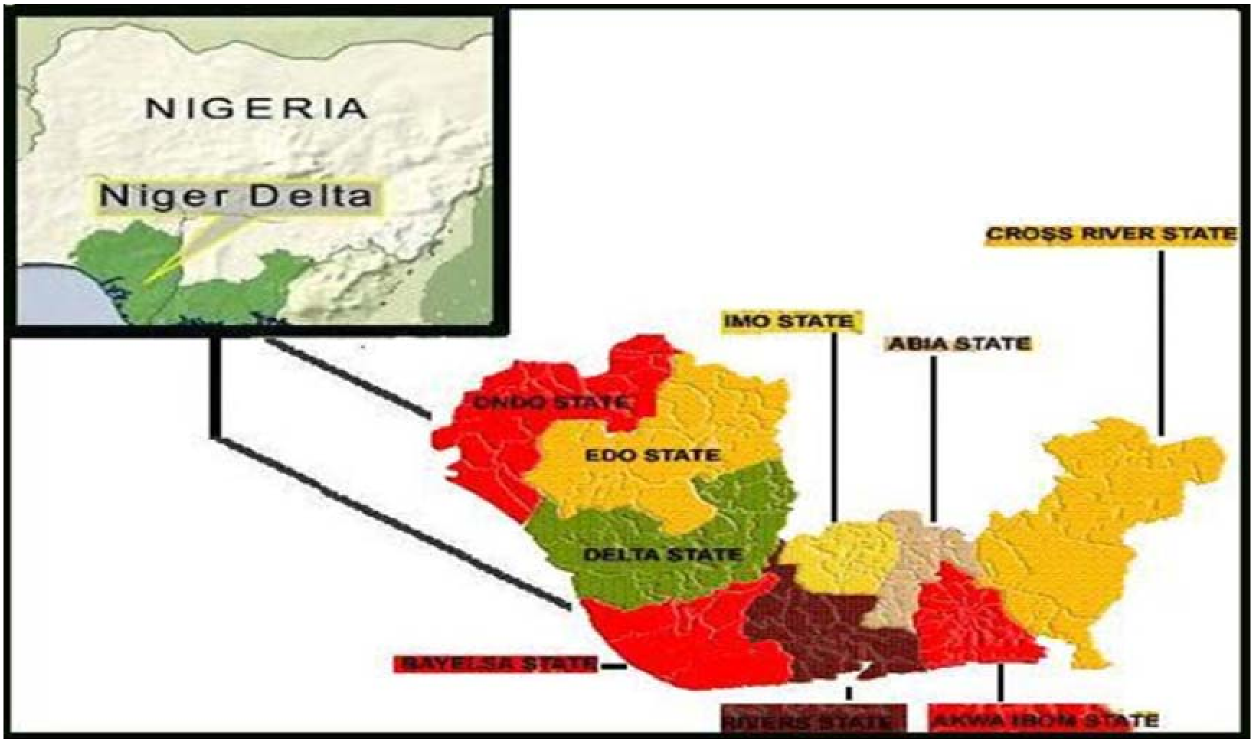


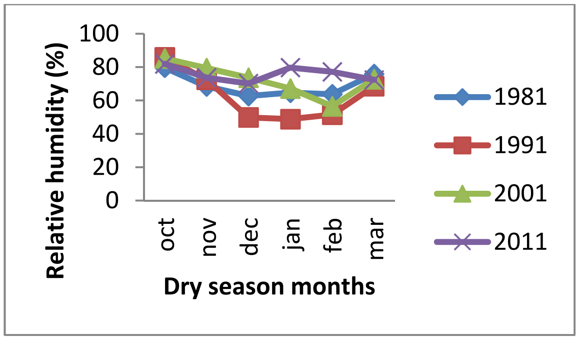
Fig 1: Map of Nigeria showing the Niger Delta region (5.05E-7.17E and latitude 4.15 N – 7.17 N) shaded with colors.

Data Availability:

A 31 years record of observational data between (1981-2012) of monthly mean horizontal visibility for some coastal weather stations in the Niger Delta Region Nigeria, Calabar (8.32E, 4.95N), Uyo (7.91E, 5.03N), Port Harcourt (7.00E, 4.75N), Owerri (7.03E, 5.48N),Warri (5.75E, 5.52N), and Akure (5.19E, 7.25N), were obtained from Nigerian Meteorological Agency Abuja (NIMET) which is the agency responsible for collecting and archiving meteorological data in Nigeria and reanalysis data for relative humidity and wind direction for the period (1981-2012) from the National Centre for Environmental Prediction (NCEP) and its available online at http://www.ncep.noaa.gov which were also extracted using Grid Analysis Display system (Grads) prepared on a resolution of 2.5° by 2.5° global grid (approximately 180km) . However statistical trend analysis has been followed.

Results and Discussion:

Relative humidity values and seasonal trends in the Niger Delta Region of Nigeria.



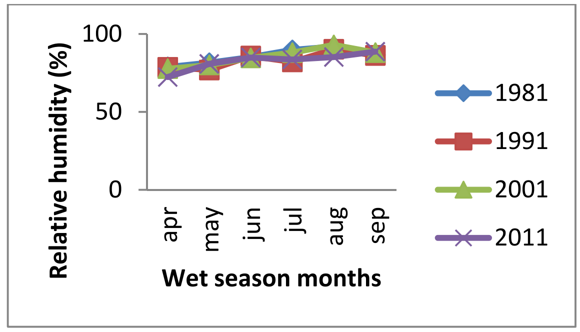
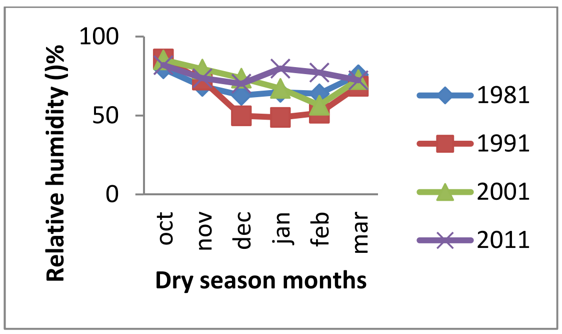


Figure 2 (a) Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Calabar..



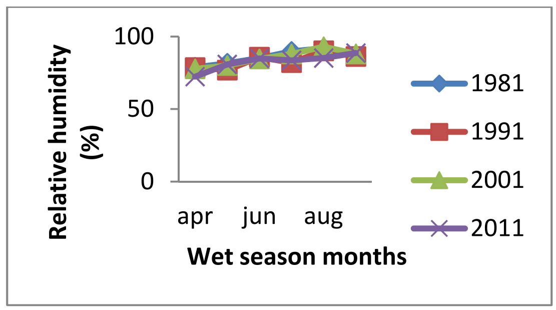
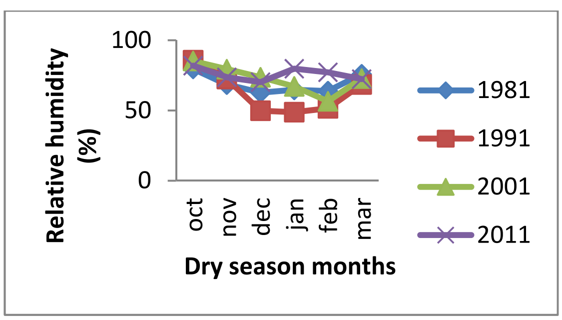


Figure 2 (b) Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Uyo.



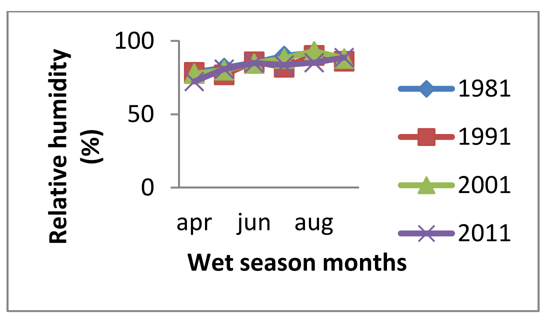


Figure 2 (c) Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Port Harcourt.

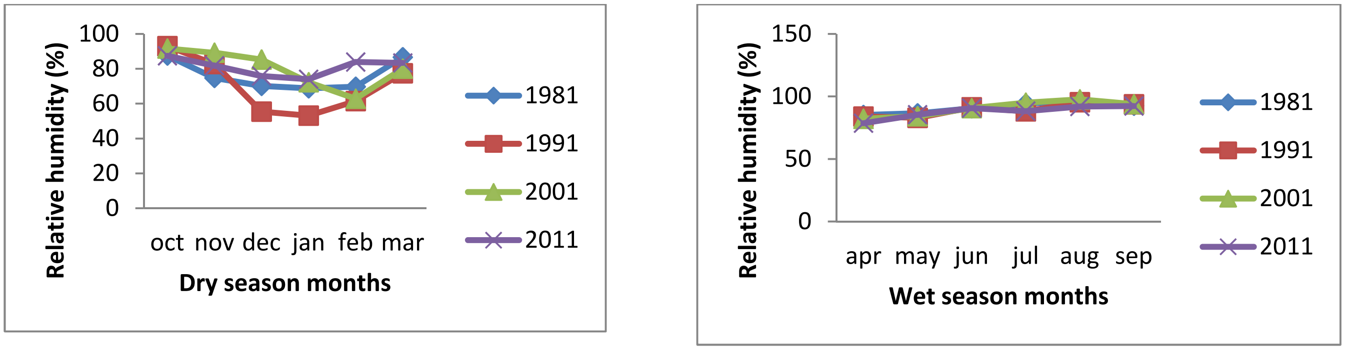


Figure 2 (d) Seasonal trends for (i) dry season months and (ii) wet season months for relative humidity in Owerri.

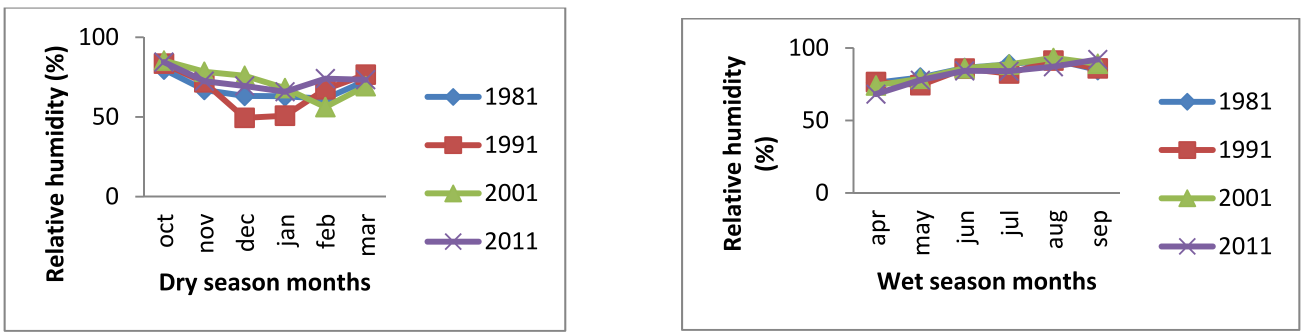


Figure 2 (e) Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Warri.

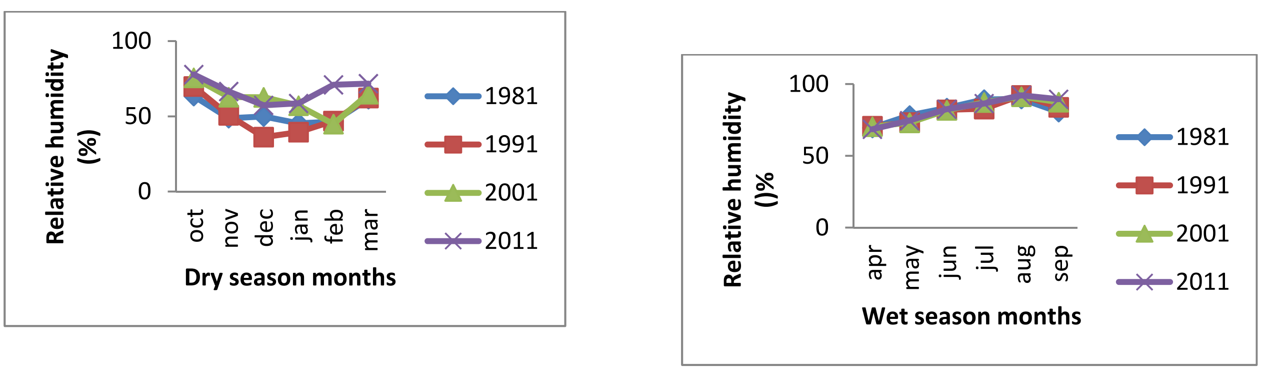


Figure 2 (f) Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Akure.

WIND DIRECTION VALUES AND SEASONAL TRENDS IN THE NIGER DELTA REGION OF NIGERIA.

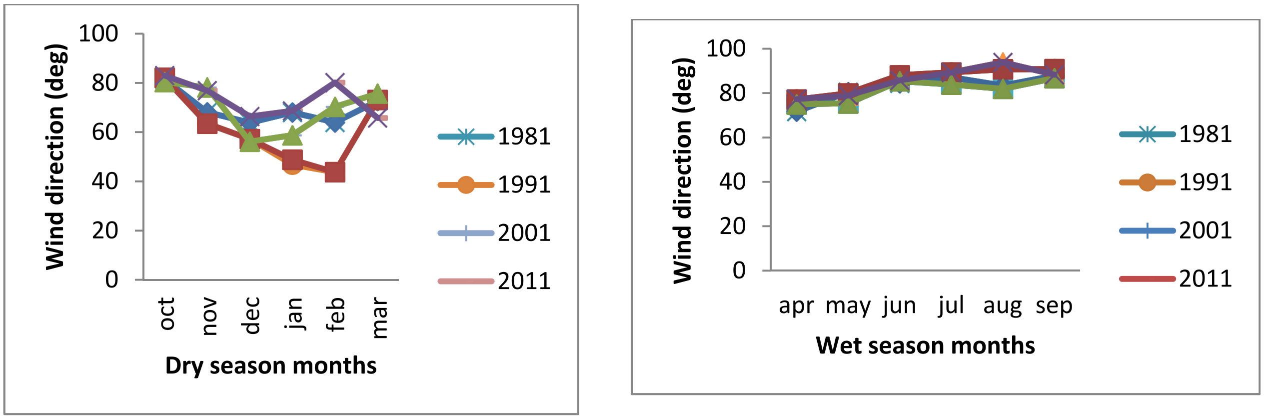


Figure 3 (a) Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Calabar..

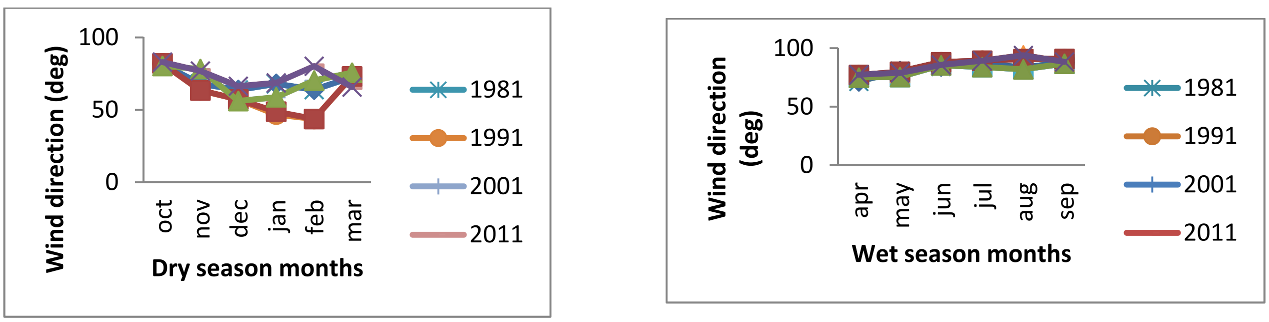


Figure 3 (b) Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Uyo..

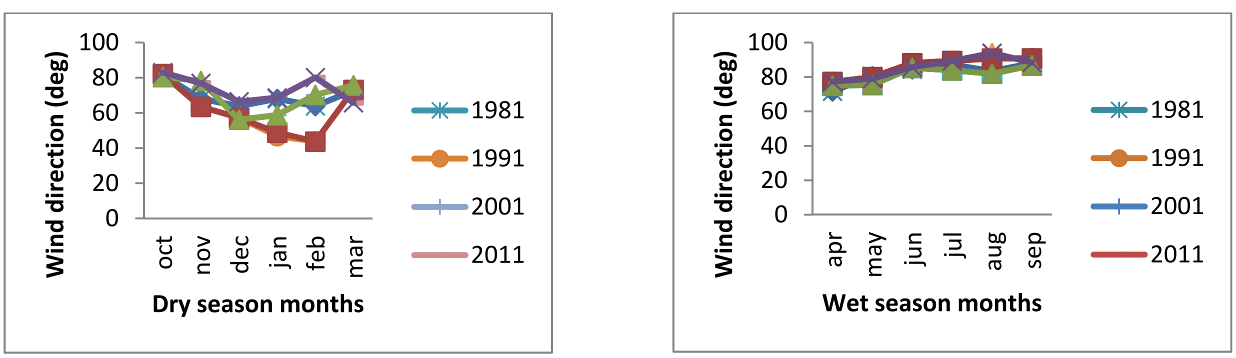


Figure 3 (c) Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Port Harcourt..

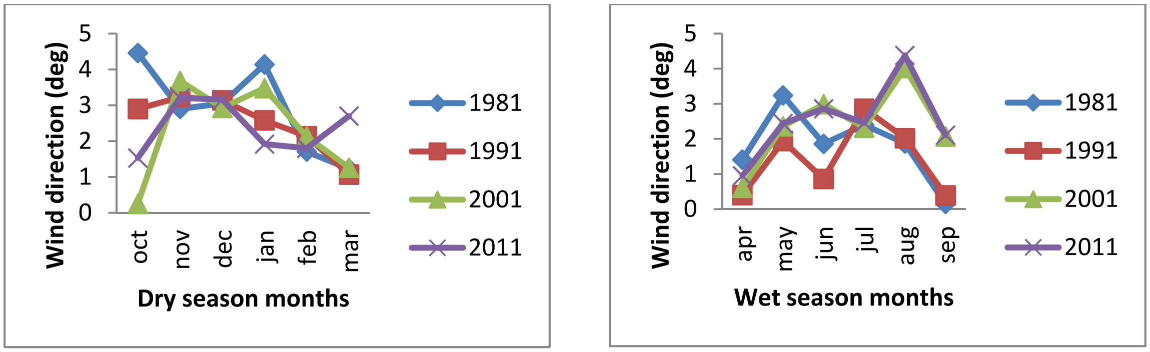


Figure 3 (d) Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Owerri.

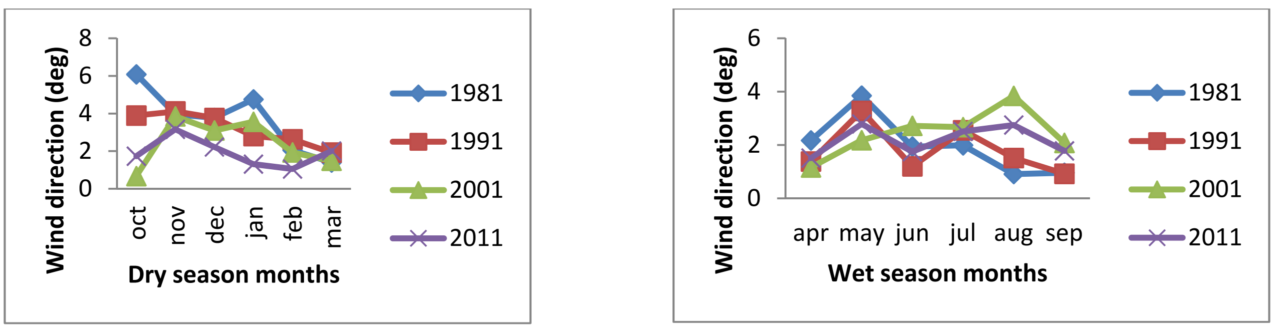


Figure 3 (e) Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Warri.

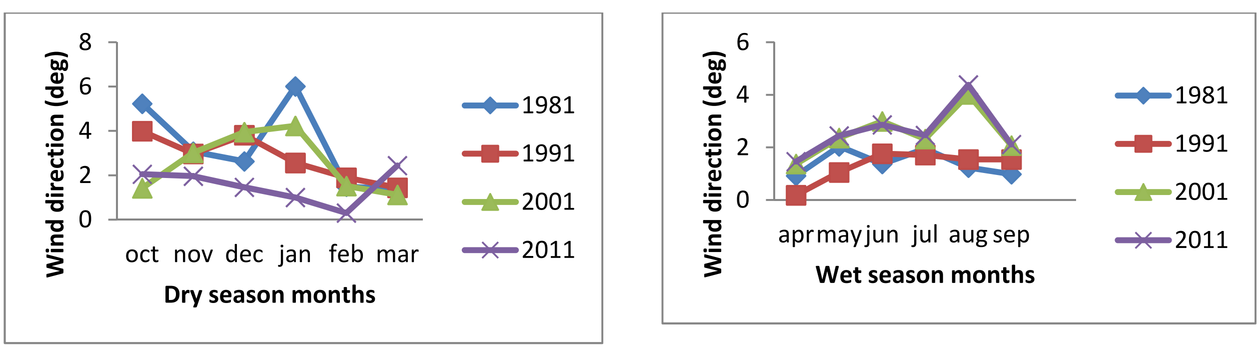


Figure 3 (f) Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Akure..

Seasons in Nigeria is divided into dry (hot) and wet (rainy) seasons. Relative humidity is classified as follows for the purpose of the discussion in this work, namely below 70% is low to very low relative humidity ie the atmospheric water content (hygroscopic potential) is very low while above 70% is high relative humidity where the atmospheric water content (hygroscopic potential) is high to very high. Using this criteria, the performance of relative humidity for the months (season), years and cities are as presented.

A. Relative humidity trends in Dry season months (Oct, Nov, Dec, Jan, Feb, March).

Relative humidity values are generally low in dry season months of Nov, Dec, Jan, Feb and March. December and February are the months with highest cases of low RH for all the years studied. Of the dry season months October has the fewest cases of low RH for all the stations and for all the years considered. This result shows that dry season months generally has less moisture in the atmosphere as a result of the high evaporation and transport of water taking place on the earths surface to higher levels in the atmosphere.

B. Relative humidity trends in Wet season Months.(April, May,June,July,Aug,Sept).

The results in Table 2 also shows wide spread of high relative humidity throughout all the wet months for all the years and cities under consideration. In addition the result shows that most cities and years in the wet season months recorded high relative humidity as well. This is indicative of the fact that relative humidity values in the Niger Delta Region are very high due to the high moisture in the atmosphere as a result of its proximity to the Atlantic Ocean and the presence of rivers and creeks in the area.

Relative humidity is usually low from January through March, then it starts to improve from April through to September and even to October before dropping again. The months of high Relative humidity are those months when the region is under the influence of West African Moonsoon as the inter-tropical convergence zone (ITCZ) moves up into the land areas of the region while the month of low relative humidity coincides with those months when the region is under the influence of the dry cold North-East Trade Wind from the sahel which dries the atmosphere which generally lowers the water content of the atmosphere in the Niger Delta region.

Relative Humidity Trends for the Cities in the Niger Delta

Table 2: Relative humidity analysis spread for the cities in the Niger Delta region.

City	Low RH values (%)	High RH values (%)
Cal	11	37
Uyo	11	37
PHC	10	37
Owerri	10	38
Warrri	14	34
Akure	21	27

The analysis spread shows that Calabar, Uyo, PHC and Owerri have high relative humidity as tallied from the locations in the years under study from 1981-2012 in the relative humidity data, these values indicate that these cities are highly humid for most of the months as shown in table 2.On the other hand, Warri and Akure have more low R-H values indicating that these cities have drier atmosphere for the years under consideration. The highest R-H values observed for Owerri, even higher than those in the cities of Cal, Uyo and PHC seem to be a misnomer to the expected values of R-H in Owerri for the years under consideration. Nevertheless, this seems to tally with the high visibility values also observed for Owerri when it is expected to have degraded visibility level.

SEASONALITY OF WIND DIRECTION VALUES IN THE NIGER DELTA REGION.

Wind direction values were found not to be uniform throughout the region. Three eastward cities namely Calabar, Uyo and Port Harcourt have very high wind direction values of mostly 40 and above. For these cities, the wind values have been classified as follows for the purpose of discussion in this work. Wind direction values of between 70 and 40 are considered low values while values above 70 are considered high wind direction values as also tallied with the locations in the wind direction data for the years under study 1981-2012.

On the other hand, three westward cities namely Owerri, Warri and Akure that lie more to the west of the region have low wind direction values ranging from about 0 to 7 as tallied in the wind direction data for the locations under study 1981-2012. For these cities values of between 1 and 3 are considered low values of wind direction whereas values between 3 to 7 are considered high wind direction values. Using these criteria, the performance of wind direction is as presented respectively.

A. **Wind Direction Trends for the Cities under Consideration**

Table 3: Wind direction spread analysis for the Eastern and Western cities.

City	Eastern Cities		City	Western Cities	
	Low values (deg)	High Values		Low values (deg)	High Values
Calabar	13	35	Owerri	11	37
Uyo	13	35	Warri	14	34
Port harcourt	13	35	Akure	12	36

From the spread analysis above, it is obvious that all the Eastern cities of the region have uniform spread of high and low values of wind direction spread. Whereas the western cities (including Owerri) do not have uniform spread. Owerri has higher values of wind values. This is followed by Akure and then Warri. The spread does not also follow westerly trend as the values for Akure are higher than those for Warri.

Conclusion

The seasonal trends of Relative humidity and Wind direction as shown have their peaks in the dry season months, October to March, the implication is that most of these dry season months are when most of the region is under the influence of the North Easterly winds which is cold, dry and brings dust from the desert especially cities which are in the heart of the hydrocarbon industry like Calabar, Uyo and Port Harcourt. Visibility degradation is not only influenced by concentrated air pollutants but also by complicated meteorological factors such as relative humidity, wind speed, atmospheric pressure, this is evident hence the annual visibility variability indexes from (NIMET) shows significant correlation with the (NCEP) datasets for R/humidity at r=0.1334 and Wind direction at r=0.1210 respectively at 90% confidence level from t-test (Nwokocha and Okujagu, 2016). This study concluded that the relationship of the atmospheric visibility and meteorological factors are closely related. This comparison does not provide all the uncertainties that would be found from each of the dataset over the Niger Delta but it's a measure of the expected minimum uncertainty in the dataset which should guide scientists and researchers carrying out studies on regions of this scale.

ACKNOWLEDGEMENT

The corresponding author is grateful to the Nigerian Meteorological Agency (NIMET) Abuja Nigeria and the National Centre for Environmental Prediction for making available the Relative humidity and Wind direction data used for this research work and to Alvan Ikoku Federal College of Education Owerri, Nigeria for the study leave. Appreciation goes to Dr Mrs Bosco Anyanwu of NIMET Port Harcourt Airport and anonymous reviewers of this work for their assistance.

References

Appel, B.R., Tokiwa, Y., Hsu, J., Kothny, E.I., Hahn, E (1985). Visibility as related to atmospheric aerosol constituents. *Atmos. Environ*. 19, 1525–1534.

Baird, J (2010). Oils Shame in Africa. Newsweek, 27. (July 26, 2010).

Bridgman, H.A., Davies, T.D., Jickells, T., Hunova, I., Tovey, K., Bridges, K. & Surapipith, V. (2002) Air pollution in the krusne Hory region, Czech Republic during the 1990s. *Atmospheric Environ*. 36, 3375-89.

Q. H. Zhang, J. P. Zhang, and H.W. Xue (2010). The challenge of improving visibility in Beijing. *Atmos. Chem. Phys*., 10, 7821–7827.

Charlson RJ, Lovelock JE, Andreae MO, Warren SG (1987).Oceanic phytoplankton, atmospheric sulfur, cloud albedo and climate. *Nature*,326:655–61.

Chan, Y.C., Simpson, R.W., Mctainsh, G.H., Vowles, P.D., Cohen, D.D., Bailey, G.M., (1999). Source apportionment of visibility degradation problems in Brisbane (Australia)—using the multiple linear regression techniques. *Atmos. Environ*. 33, 3237–3250.

Chung, S. Y,Chang, G. L, San, H L, Jui, C.C, Ching, Y, Hong Y. Y. (2006). Correlation of atmospheric visibility with chemical composition of Kaohsiung aerosols. *Atmospheric Research* 82 663-679.

Conner, W.D., Bennett, R.L., Weathers, W.S., Wilson, W.E., (1991). Particulate characteristics and visual effects of the atmosphere at Research Triangle Park. *J. Air Waste Manage. Assoc.* 41, 154–160.

Cuhadaroglu, B., & Demirci, E. (1997) influence of some meteorological factors on air pollution in Trabzon. *Energy Buildings* 25, 179-184.

Dzubay, T.G., Stevens, R.K., Lewis, C.W., (1982). Visibility and aerosol composition in Houston, Texas. *Environ. Sci. Technol*. 16, 514–525.

Ebru, K.A, Sinan, A, Hakan F.O.(2011). Statistical analysis of meteorological factors and air pollution at winter months in Elazig, Turkey. *Journal of Urban and Environmental Engineering* Vol 3 (1)p. 7-16.

Ghim Y. S., Oh H. S. and Chang Y. S. (2001). Meteorological effects on evolution high ozone episodes in greater Seoul area. *Journal of air waste management*. 51: 185- 202.

Groblicki, P.J., Wolff, G.T., Countess, R.J., (1981). Visibility reducing species in the Denver Brown Cloud—1. Relationships between extinction and chemical composition. *Atmos. Environ.* 15, 2473–2484.

Goyal.P., Sumer Budhiraja., Anikender Kumar (2014.). Impacts of air pollutants on atmospheric visibility in Delhi. *International journal of Geology, Agriculture and Environmental Sciences*, Vol 2 (2) April .

Hodkinson, J.R.,(1966). Calculations of color and visibility in urban atmospheres polluted by gaseous NO_2. *Int. J. Air Water Pollut.* 10, 137–144.

Latha, K.M., Badarinath, K.V.S., (2003). Black carbon aerosols over tropical urban environment—a case study. *Atmos. Res*. 69, 125–133.

Lohmann U, Lesins G (2002). Stronger constraints on the anthropogenic indirect aerosol effect *[J]. Science,* , 298 (5595): 1012-1015.

Menon S, Hansen J, Nazarenko L, (2002). Climate effects of black carbon aerosols in China and India *[J]. Science*, 297 (5590): 2250-2253.

Nwokocha C.O, Okujagu C.U (2016). Correlation of atmospheric visibility and meteorological variables in nigeria: the niger delta. *International Journal of Scientific & Engineering Research*, Volume 7, Issue 11.

Ogunjobi K. O., Kim J. Y., Adedokun J. A., Ryu S. Y., and Kim J. E. (2002). Analysis of sky condition using solar radiation data at Kwangju and Seoul, South Korea and and Ile- Ife, Nigeria. *Theoretical and applied Climatology*. 72: 265-272.

Okoro , U.K., Wen, Chen., Chineke, C., & Nwofor, O.K (2014). Comparative analysis of Gridded datasets and Guage Measurements of Rainfall in the Niger Delta Region. *Research Journal of Environmental Sciences* 8 (7) =373-390,.

Owoade, O.K.; Olise, F.S.; Ogundele, L.T.; Fawole, O.G. and Olaniyi, H.B (2012). Correlation between particulate matter concentrations and Meteorological parameters at a site in ile-ife, Nigeria. Ife Journal of Science vol. 14, no. 1 .

Penner J E, Dong X.Q, Chen Y (2004). Observational evidence of a change in radiative forcing due to the indirect aerosol effect [J]. *Nature*, 427(6971): 231-234.

Tegen I, Koch D, Lacis A.A, Sato M (2000). Trends in tropospheric aerosol loads and corresponding impact on direct radiative forcing between 1950 and 1990: a model study. J *Geophys Res*; 105:26971–90.

Sloane, C.S.,Watson, J.G., Chow, J.C., Pritchett, L.C., Richards, L.W., (1991). Sized-segregated fine particle measurements by chemical species and their impact on visibility impairment in Denver. *Atmos. Environ*. 25A, 1013–1024.

Tang, I.N., Wong, W.T., Munkelwitz, H.R., (1981). The relative importance of atmospheric sulfates and nitrates in visibility reduction. *Atmos. Environ*. 15, 2463–2471.

Tsai, Y.I., Cheng, M.T., (1999). Visibility and aerosol chemical compositions near the coastal area in central Taiwan. *Sci. Total Environ*. 231, 37–51.

Tie X,Madronich S, Li GH, Ying ZM,Weinheimer A, Apel E,(2009a) . Simulation of Mexico City Plumes during the MIRAGE-Mex Field campaign using theWRF-Chem model. *Atmos Chem Phys*, 9:4621– 38.

Tie X, Wu D, Brasseur G (2009b). Lung cancer mortality and exposure to atmospheric aerosol particles in Guangzhou, China. *Atmos Environ*;43:2375–7.

Turalioglu, F.S., Nuhoglu, A & Bayraktar, H. (2005). Impacts of some meteorological parameters on SO_2 and TSP concentrations in Erzurum, Turkey, *Chemosphere* 59, 1633-1642.

Watson, J.G., (2002). Visibility: Science and Regulation. *J. Air Waste Manage. Assoc*.52,628–713.

Wu, D, Deng, X.J, Bi, X.Y, Li, F, Tan H.b, Liao G.L (2007). Study on the visibility reduction caused by atmospheric haze in Guangzhou area. *Journal of tropical meteorology*, vol 13 (1).

Xue, Y., F. de Sales, W.M. Lau, A. Boone and J. Feng., (2010). Inter comparison and analyses of the climatology of the West African Monsoon in the West African Monsoon modeling and Evaluation project (WAMME) first model intercomparison experiment. *Clim Dyn.*, 35: 3-27.