Centre for Atmospheric Research

2018 MONOGRAPH OF ATMOSPHERIC RESEARCH

Edited by **A.B. Rabiu and O. E. Abiye**

A Publication of
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PREFACE

The Centre for Atmospheric Research was established in January 2013 with a compelling mission to improve our understanding of the behaviour of the entire spectrum of the Earth's atmosphere; promote capacity development in relevant atmospheric sciences as a way of facilitating international competitiveness in research being conducted by atmospheric scientists; and disseminate atmospheric data/products to users towards socio-economic development of the Nation. CAR's extant core research focus includes: space weather, tropospheric studies, atmospheric research software and instrumentation development, microgravity and human space technology, and atmospheric chemistry and environmental research.

Pursuant to the above, The *Monograph of Atmospheric Research* published by the Centre for Atmospheric Research (CAR), is a collection of peer-reviewed manuscripts in Atmospheric Sciences and closely related fields. This maiden edition comprises articles presented during two separate workshops; *1st National Workshop on Microgravity and Environmental Research* (26 - 29 November, 2017) and *1st National Workshop on Air Quality* (13 - 16 March, 2018). Such workshops are integral part of CAR's capacity building program and they were primarily aimed at advancing the course of atmospheric research in Nigeria towards sustainable development. The Microgravity workshop was geared towards introducing new research opportunities in space life science by simulating microgravity conditions here at the earth's surface as a means of investigation space biological environment. The Air Quality workshop was organized in collaboration with Ministry of Environment and Nigerian Meteorological Agency (NIMET). The workshop analysed current Air Quality scenario in Nigeria, explored new opportunities for collaborative research and offered novel means of improving the present quality of life of the populace without jeopardizing the chance of the future generation. Cumulatively 196 participants participated in these two workshops and about 52 articles were eventually submitted for publication consideration in this monograph. The twenty-one articles in this very monograph are the articles that eventually made it through the rigorous peer-review process. We remain grateful to the reviewers for doing thorough work on the articles.

Thus, we are very pleased to present the *2018 Monograph of Atmospheric Research* which contains twenty-one articles, including some review papers, to readers in all spheres of interest across Nigeria and beyond. It is our hope that this effort will continue and will serve as a reference to atmospheric researchers in Nigeria.

Prof. A. B. Rabiu and Dr. O. E. Abiye,
Editors

Centre for Atmospheric Research

Evaluation of harmattan dust events over Kano, Nigeria

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ABSTRACT

Dust occurrence is an important challenge to the inhabitants of the Kano metropolis, especially to the aviation, health, agricultural sectors among others, as it is responsible for many flight cancellation, delays, animal and human health casualties among others.
This study investigated the temporal variability of dust events in Kano (12^{o}00"N, 8^{o}31"E) by using a diurnal, monthly and annual variations of dust occurrences of five years (2011 to 2015) of dust observations data acquired from the archives of Nigerian Meteorological Agency,at the Mallam Aminu Kano Airport, Kano. Averages on the number of hourly, monthly and annual occurrences were made and plotted graphically. Results of analyses made indicated that the year 2015 experienced the highest frequency of dust events and the December/January period happens to be the most critical time of the year. December month was the most dust prone month having 47% contribution to the occurrence of dust for the year, closely followed by January with 41% dust contribution and then February contributed 12% of dust. The critical times of the day in which dust events occur were seen to be between 0900Z and 1100Z, and 1500Z.

Keywords: Dust, Harmattan, Weather, Hazards, Visibility

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INTRODUCTION

The Harmattan is a season in the West African subcontinent, which occurs between the end of November and the middle of March. It is characterized by dry and dusty northeasterly trade wind, of the same name, which blows from the Sahara Desert over West Africa into the Gulf of Guinea. (*Minka et al, 2013*). The Harmattan blows during the dry season, which occurs during the lowest-sun months. In this season the subtropical ridge of high pressure stays over the central Sahara Desert and the low-pressure Intertropical Convergence Zone (ITCZ) stays over the Gulf of Guinea. During the winter months the seasonally variable Harmattan current transports large amounts of mineral dust at irregular intervals from the Chad Basin to the Sahel and Guinean coast where it reduces visibility, relative humidity and temperatures (*Kalu, 1979; McTainsh and Walker, 1982; Adedokun et al., 1989; Stahr et al., 1996; Breuning-Madsen and Awadzi, 2005*).

According to the UK Met office, dust haze is defined as an assortment of particles of dirt, or sand, smartly upraised to nice heights by a powerful and turbulent wind and also the visibility is reduced to below 1000m (*UK MET Office, 1991*).

The Harmattan dust haze is a seasonal weather phenomenon that occurs due to the existence of the Inter-tropical Discontinuity (ITD) which is the driving mechanism for weather phenomenon and season in West Africa and Nigeria. The Harmattan period lasts for about five months from November to March. Most countries near the Gulf of Guinea in West Africa are affected by this dusty wind phenomenon (*Sunnu, 2006*). During the dry season, the entire country is usually dominated by the Northeasterly trade winds commonly referred to as Harmattan and experiences large quantities of dust and smoke from biomass burning that is transported by the prevailing north-east trade wind as illustrated in figure 1 by *Hastenrath (1988)*.

During this period, dust emission, circulation and distribution in the atmosphere are significantly influenced by favorable weather conditions. This is in addition to anthropogenic activities that normally arise from high-energy demands and increase the pressure on land for agricultural purposes and infrastructure. Nigeria is described as one of the heavily aerosol-laden regions of West Africa, where aerosol studies are of great interest (*Anuforom et al, 2006*).

The occurrence of severe dust situations have several socio-economic effects which affect important sectors such as aviation, health, marine, agriculture etc. During low-visibility events, many flight operations are suspended or delayed, which leads to a significant economic loss for the Aviation sector in Nigeria (*Kehinde et al, 2012*).

Hence, this study is designed to:

- To analyze the temporal variability of dust occurrences at Kano.
- To identify the most critical month(s) or period of dust occurrence within a year
- To detect the most critical time(s) of the day in which dust occurs

DATA AND METHODOLOGY

The hourly dust event data occurrence of five year period (2011 to 2015) was obtained from the archives of the

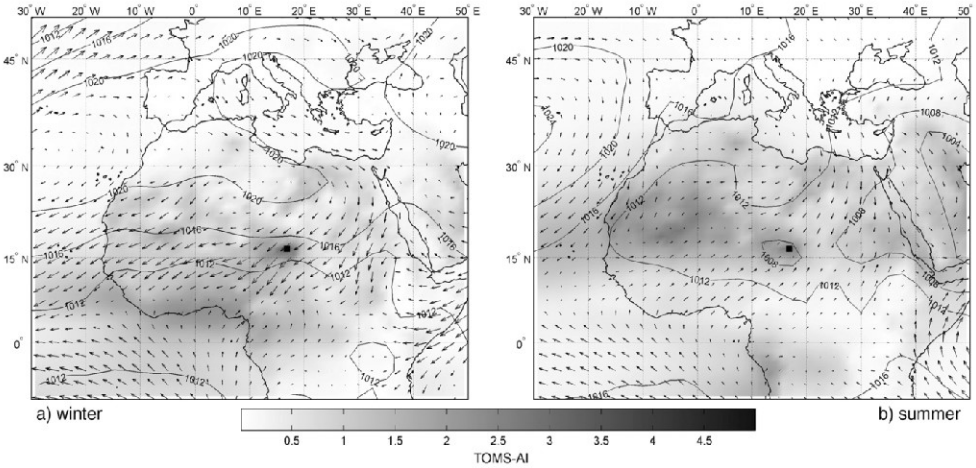


Figure 1: Mean annual atmospheric mineral dust concentrations quantified by TOMS aerosol index (dimensionless) and NCEP/NCAR horizontal wind vectors at 925 hPa in winter (December to February) and summer (June to August) during the years 1978–1993. The black square indicates the location of the Bodélé Depression (Hastenrath, 1988).

Nigerian Meteorological Agency (NiMet) for Mallam Aminu International Airport, Kano. The study area covers the confines of the Kano metropolitan city in Kano State, centrally located at latitude 12°00"N and longitude 8°31"E. It is 481 meters (1,578 feet) above sea level.

METHODOLOGY

The daily mean horizontal visibility value and daily dust haze occurrence was calculated. Visibility classification or target for dust haze occurrence was set at when visibility is less than or equal to 1,000m as adopted by *Anuforum (2007)*, *Goudie et al. (2001) and Engelstaedter et al. (2006).*

Simple statistical analysis such as summation and averaging were carried out on the data. The output will be subjected to graphical analysis in order to show the temporal variation of dust occurrence over the study area.

Monthly mean values were computed from the daily data and the total number of dust haze event for each year was also computed for the period considered. Hourly diurnal, monthly and annual variations were also computed and displace graphically.

RESULTS AND DISCUSSION

A yearly analysis of dust occurrence is shown in figures 3.1 to 3.4 and it shows that each year is unique with its own frequency and time of event as peculiar in terms of the time of occurrence of dust haze events.

Monthly Variation of Dust

Figure 3.1 shows the average monthly variation of dust events within the period of study. A study of the average monthly occurrence as shown in this figure indicates the most common period of the year for dust haze occurrence are December, January and February. December had an average occurrence of about eight events, closely followed by January with seven events and February had two events. This means that the highest dust haze frequency of occurrence period is the December and

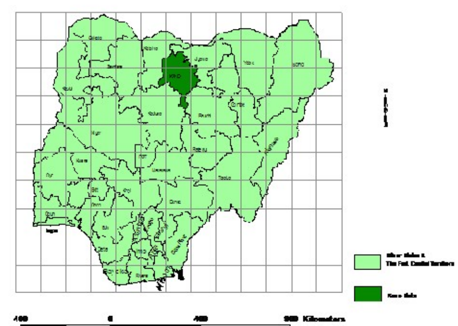


Figure 2: Map of Nigeria showing the Study Area (Kano)

January, contributing to about the 88% of the total events in a year. This could be attributed to the fact that the ITD is at its southernmost position which allows for the predominant inflow of dust laden winds (Northeasterly trade wind) from the source regions into the area of study within this period of the year

However, there was no case of dust haze occurrence in the months of March-November all through the period of study. This is due to the fact that climatologically, the ITD's position would not allow the occurrence of such events as it would have advanced northwards by this period of the year. At this time, the moisture laden wind (southwesterly wind) moves with the advancement of the ITD and flows into the country, bringing rainfall with it which serves as a sink for dust in the atmosphere and this is in support of *Zender et al. (2003)* which reveals that the temporal variability of dust haze is determined by rate of injection and removal of dust particles from the atmosphere.

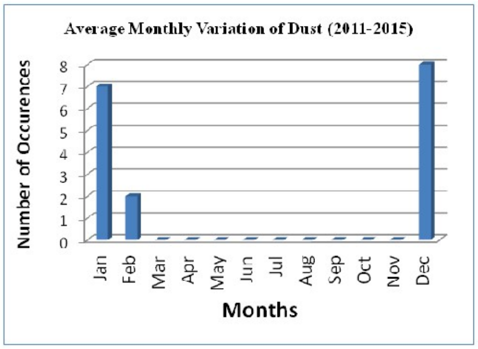


Figure 3.1: Average monthly variation of dust events over Kano

Diurnal Variation of Dust over Kano

A year to year analysis of the diurnal variation of dust events over Kano is shown in Figure 3.2 (a-d). It depicts a general trend whereby the peak period of this dust event was between 0900Z and 1200Z. According to figure 3.2a, significant increase in dust began in the year 2011 at a time of 0600Z with two occurrences, and peaked at 1000Z. From 1200Z, there was a drastic reduction in the occurrence of dust events up till the end of the day. Figure 3.2b shows the diurnal variation of dust in figure 3.2b with a significant rise in the occurrence at 0600Z, just like that of 2011 as shown in figure 3.2a. It dropped at 1200Z like the previous year, and remained consistent for most of the rest of the day. Figures 3.2c and 3.2d show a similar trend in which an increase in the dust events was observed at 0500Z unlike the previous two years, though 2014 experienced its increase at a time of 0600Z both 2012 and 2013 peaked at 0900Z with 2014's peak extending to 1000Z. Both years had a second peak at 1400Z, and then a decreasing trend afterwards. Figure 3.2d shows the diurnal variation of dust events in 2015. Like the previous two years, noticeable dust event was noticed at 0500Z, with a peak at 1000Z, and a downward trend afterwards.

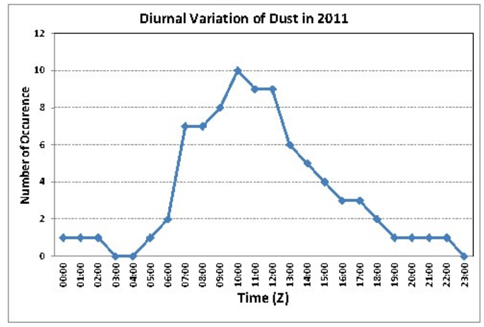
Average Diurnal Variation of Dust Events

Figure 3.3 shows a summary of the average diurnal variation of dust events as they vary with time over Kano. On a diurnal basis, the highest frequency of dust events was observed on the early morning hours, from 0900Z - 1100Z with the peak of its occurrence being at 1000Z with twelve (12) cases within the five years under study and closely followed by 0900Z and 1100Z which both had ten (10) occurrences. This is the highest period of dust occurrence over this location within this period of study. Another peak was observed at 1500Z, which suggests a bi-modal nature of dust occurrence during the day.

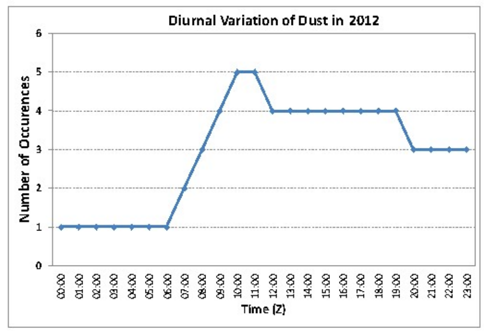
Total Annual Variation of Dust Events

Figure 3.4 shows the annual total number of the dust haze events for the 5-year period (2011–2015). The year 2015 had the highest number of dust occurrences (Two hundred and six), followed by 2013 with occurrence of 89 (eighty nine) whereas the lowest

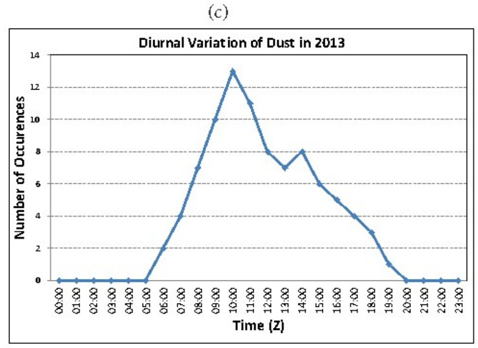
(a)



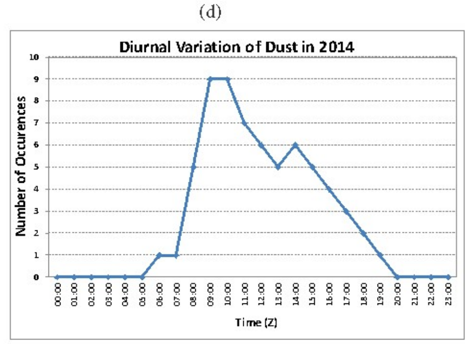
(b)



(c)



(d)



(e)

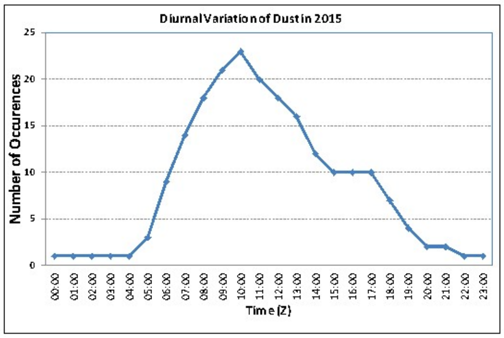


Figure 3.2(a-e): Diurnal Variation of Dust over Kano for 2011, 2012, 2013, 2014 and 2015

(three) occurred in 2014, closely followed by 2011 which had eighty three occurrences. 2012 and 2014 had considerably low amount of dust event occurrence when compared to the other years. Subsequent studies are intended to be carried out to investigate why 2015 had such a high number of dust occurrence compared to other years.

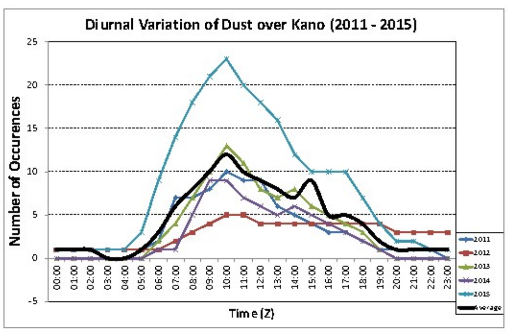


Figure 3.3: Average Diurnal Variation of Dust Events over Kano

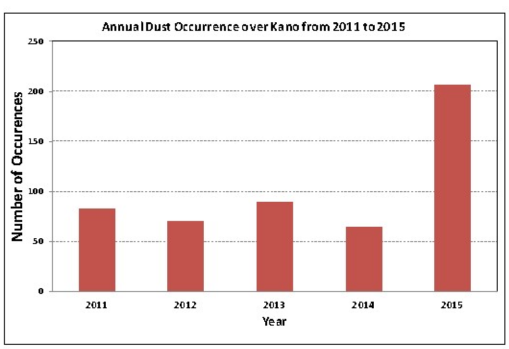


Figure 3.4: Total Annual Variation of Dust Events over Kano

CONCLUSION

This study has been revealed the extent of the frequency of dust occurrence at Kano. With the year 2015 experiencing the highest frequency of dust events, the December/January period happens to be the most critical time of the year in which meteorologists and forecasters will have to watch out for so as to provide adequate information to the public with a view to providing accurate forecasts even though it will be in the form of nowcasting or short-range forecasting. December being the most dust prone month and having a 47% contribution to the occurrence of dust for the year, closely followed by January which contributed 41% and then February with a contribution of 12%. Also, it has been established that at this location, the peak periods of dust occurrence were between 0900Z and 1100Z and at 1500Z.

This information will be useful in the effective management of dust-related hazards as adequate planning and preparation will lead to reduction in casualties resulting from meteorological phenomena. Weather forecasters can always gear up on their duties within the period of December and January with a view to providing timely weather alerts and advisories to the stakeholders of potential sectors that can be affected, so as to minimize the impact of high duration of dust situations at any point in time.

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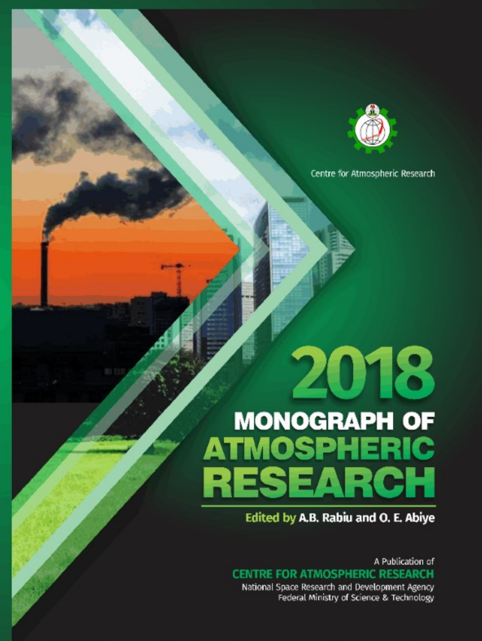

Our Mandates

The Center for Atmospheric Research, CAR, is a research and development center of NASRDA committed to research and capacity building in the atmospheric and related sciences. CAR shall be dedicated to understanding the atmosphere—the air around us—and the interconnected processes that make up the Earth system, from the ocean floor through the ionosphere to the Sun's core. The Center for Atmospheric Research provides research facilities, and services for the atmospheric and Earth sciences community.

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