# EFFECTS OF SOME WEATHER PARAMETERS ON FLIGHT OPERATIONS IN KANO AND ABUJA INTERNATIONAL AIRPORTS, NIGERIA

**BY**

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## DECLARATION

I declare that the work in this thesis entitled Effects of Some Weather Parameters on Flight Operations in Kano and Abuja International Airports has been carried out by me in the Department of Geography under the supervision of Professor E. O. Iguisi, and Dr. B. A. Sawa. All information derived from the literature has been dully acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another Degree or Diploma at this or any other University.

| _____ | _____ | _____ |
|---|---|---|
| Name of Student | Sign | Date |

## CERTIFICATION

This thesis entitled EFFECTS OF SOME WEATHER PARAMETERS ON FLIGHT OPERATIONS IN KANO AND ABUJA INTERNATIONAL AIRPORTS BY CHRISTOPHER MAIKANO MUSA, meets the regulation governing the award of the degree of Masters of Ahmadu Bello University Zaria and is approved for its contribution to knowledge and literary presentation.

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**ABSTRACT**

*The purpose of the study was to assess the degree or extent of effects of wind, horizontal visibility and cloud cover on flight operations (air crash) in Kano and Abuja International airports. Hourly records of wind, daily records of low horizontal visibilities in the range of 0-99, 100-199, 200-388 and 300-999,daily amount of cloud cover, both for Kano and Abuja Airports, and total number of air crashes in Nigeria from 1986-2005 were collected from secondary and online sources. Descriptive, relationships and significance in correlation statistical methods were applied for both analyses and presentation of the data using Microsoft excel statistical package. The significance of correlations was 99.8 % - 99.9 %.Trends revealed steady increase of weather elements in Kano airport over the years, while higher increase in Abuja airport. Air crashes and casualties in Nigeria are generally on the increase. While the world weather-related airline fatal accidents and fatalities show general decrease trends in the number of crashes and casualties over the years, the study reveals positive statistical relationship between weather parameters and flight operations (air crash) at 95% confidence level. However, the degree of the relationship is not significant. This implies that the effects these weather parameters have on flight operations is insignificant, hence not solely responsible for plane accidents recorded in Nigeria in recent years. Therefore, flight operations could possibly be more affected by human, economic and mechanical factors. Emanating from the study, recommendations and suggestions were made.*

# CHAPTER ONE: INTRODUCTION

## 1.1 BACKGROUND TO THE STUDY

Weather extremes have tremendous influence on flight operations. From time immemorial, flight operations like any other human endeavours have been significantly affected, in terms of takeoff, landing and even in-flight by extreme weather. Extreme weather values have long been known to be threatening to all aspects of air transportation. Each year more than one quarter to one-half of all accidents is weather related. While the economic losses due to flight delays, diversions, cancellations, and accidents caused by weather are estimated at more than one billion per year (National Weather Service [NWS], 2008). However, the measurement of weather elements viz: temperature, rainfall, pressure, wind, cloud cover, and visibility provide information on the state of any prevailing weather condition at any point in time, thereby preventing or mitigating delays, diversions, cancellations and accidents of flight, as well as economic losses.

``Flight operations'' deals with flight and aircraft dispatch, flight Crew and flight watch. In other words, ``Flight operations'' is such a generalized term which encompasses many things in the aviation operations, and that definitions given to this term are based on Airlines at a local station of operation. For many Airlines, at a local station, flight operations refer to the agents who perform weight and balance functions for flight transiting their city. However, it is more acceptably defined, as the central decision-making center for the Airline that handles flights (Civil Aviation Forum, 2001 and 2005). Webster Online Dictionary (2009) described flight operations as a department constituting sections such as flight training, flight control, flight dispatching and a meteorological section, strictly supervised by a Manager to ensure maximum operating efficiency and air traffic safety. Other sections identified by Civil Aviation Forum (2001 and 2005) are flight engineers, flight crew, flight watch and aircraft flight: departure and

arrival. The aircraft flight section constitutes three important phases of flying viz takeoff, in-flight and landing. Of these, landing has been observed to be the most troublesome phase of flight operations, followed by takeoffs. Studies on aviation accidents have shown that approximately 80 percent of all aviation accidents occur shortly before, after, or during takeoff or landing, and often described as resulting from ``human error''. While, mid-flight disasters are rare but not entirely unheard of (Wikipedia online version, 2008). For example, the investigations into the crashes of Bellview and Sosoliso airlines in 2005 and ADC airline in 2006 in Nigeria were reported to occur between takeoff and landing and caused by wind shear (variation in the local wind speed and direction) however, induced by human error (AllAfrica Global Media, 2005 and Ayigbe, 2006). This research work is focused on this aircraft aspect of the flight operations.

Weather, which is defined as the sum total of the atmospheric conditions of a given place at a given time, or simply described as an everyday experience (Stringer, 1989), can evolve at a rapid rate, over a wide spatial extent when compared with other factors that may affect the safe conduct of flight. This is apart from aircraft maintenance: runway status, airspace sector access and support services. Thus, the spectrum of weather information is an important component for the safe conduct of a flight and the efficient management of air traffic in future (Mirza, Page & Geinde, 2009). According to Olusegun, Ahmed, Adeleke and Leong (1992), the safety of modern air transportation is closely tied to accurate weather reports from the meteorological stations. Therefore, knowledge on weather phenomena is very important for flight operations. Studies by Ayoade (2004) have revealed that adverse weather conditions may cause delays, diversions, accidents and even outright cancellations of journeys, causing loss of time, revenue and even lives. In addition, Bisiriyu (2006) reports that in aviation, weather has remained the important

parameter in determining safety, regularity and efficiency of aviation operations. The World Meteorological Organization (WMO) bulletin of October 1995 in Bisiriyu (2006) reported that 40 percent of all general aviation accidents are weather related. Mirza et al. (2009) also discovered that weather phenomena that may affect one flight might have no relevance to a flight that follows by ten minutes later, but it may affect a different flight, which it may encounter in the same period. It is because of this importance of weather report to flight operations that the Federal Government of Nigeria in 2007 announced her readiness to acquire state of the art equipment to ensure safety compliance of major airports in the country (The Total Radar Coverage for Nigeria [TRACON] project by Nigerian Airspace Management Agency [NAMA] for Lagos and Abuja airports). More so, the building of website for Nigerian Meteorological Agency (NIMET), to make it possible for travelers to check weather forecast before embarking on trips (Olayinka, 2009).

Weather parameters critical to aviation operations, acquired from the ground surface are sky condition (cloud cover), visibility, pressure, temperature, dew point, wind speed and direction, and precipitation accumulation (National Weather Service, 2008). Other observations include severe turbulence: thunderstorm, microburst (a small intense downdraft that descends to the ground resulting in a strong wind divergence) and wind shear (AllAfrica Media, 2008). Aviation Weather Services (1995) revealed that these weather parameters are of greater value when summarized in forms of aviation decision-aids, which may be visualization, graphical representations, or recommendations that support the decision- processes. These parameters can be hazardous enough to cause flight accidents and incidents because according to Griffiths (1979), flight operations depend on these short-term period weather phenomena and not so much on climatic conditions for its smooth operations. Therefore, the extremes of these weather

conditions often cause much inconvenience and bring about great increases in delays, diversions, cancellations and accidents rates. Griffiths (1979) revealed that, information concerning the incidence of wind speed and direction, cloud ceiling and visibility is fundamental to the successful operation of an airport. The direction or the orientation of the runway is decided by the prevailing wind directions so that the aircraft may land and takeoff approximately into the wind to minimize the effect of crosswind: wind blowing at right angle to the direction of flight. In addition, the runway air temperatures are also needed for use in the calculation of life and cargo carrying of aircrafts, and the fuel consumption of aircraft engines. Knowledge of all these, according to the studies is essential to complete aircraft safety, even the latest civil and military aircraft equipped with radar, which flies above many of the vagaries (unexpected changes) of the weather need this information for safety and economical operations.

Poor visibility is the single most important weather hazard to all forms of transportation especially air transportation (Ayoade, 2004). Shadere (2005), reports that poor visibility is perhaps a greater danger to safe plane landing because the control over it is more difficult than flooding on the runway. Poor visibility can be cause by thick fog, snow, rain, thunderstorm, harmattan dust, mist, volcanic ash or smoke, urban smoke, low ceilings and even smog. Studies by Riehl (1965) have shown that low ceilings and visibilities cause the major traffic disruptions at airport terminals, and the problem is said to remain unchanged over the years. In addition, Smith (1975) reports that despite increasing sophistication of automatic landing equipment, poor visibility from layer of fog, mist or thick haze and low cloud ceilings is probably the major impediment to airport operations throughout the world. The Sosoliso plane crash in 2006 was partly caused by poor visibility because of thunderstorm and rain when trying to land in Port Harcourt airport (Ayigbe, 2006).

Wind is a horizontal current of air varying from light air to hurricane that can have a vertical movement (Ati, 2002). A study on wind, especially near the surface, has been reported by Lankford (2001) to be a major factor in nonfatal and non-injurious aviation accidents. Crosswinds and gustiness account for the largest percentage of problems in aircraft landing and takeoffs. However, long landings, down wind or crosswind landings, delayed landings, go-around and overshoot landings account for a significant number of the problems of flight operations. The study also shows that wind direction and speed is crucial for determining crosswind components. Variable wind direction can make takeoff and landing difficult, even at relatively slow speeds. Therefore, wind direction, speed and character (gusts and squall line) must be considered when determining crosswind components in landing at any particular airport.

Wind speed aloft also significantly affect aircraft operation and performance. Because wind aloft, accompanied by poor planning, account for a number of fuel exhaustion accidents every year. Mountains, valleys, and water surfaces affects small scale (sub-synoptic) wind systems, which are superimposed on the larger (synoptic) circulation. These include sea and land breezes, mountain and valley winds, upslope and down slope winds, and mountain waves. Of these, down-slope winds and mountain waves are often the most significant to aviation operations. The studies revealed that stronger than forecast winds should be expected in relief areas, especially within 1,524meters (5000ft) of terrain.

Guerney and Skiera (1974) pointed out the need for a pilot to know the wind direction and speed at his cruising altitude. Since high winds on takeoff reduces the ground roll of airplane and increase the angle of climb. On the other hand, a crosswind demands increased skill both on takeoff and on landing for safety. High surface wind, he said, present problems in taxiing

especially in light airplanes. Winds also play a role in the formation of fog and clouds, the production of precipitation, and the horizontal and vertical distribution of temperature and water vapour. It brings about the redistribution of the atmospheric mass thereby causing the change in pressure and determines visibility to some extent. Thus, Guerny and Skiera (1974) in their words said,

> "If it were not for wind, air navigation would be simple, for a reliable position could be obtained from a true heading, airspeed and elapsed time. It is moving air, sometimes blowing at 5 Knots and at times, "jet streaming" at 200 Knots that complicates navigation. A general understanding of wind theory is therefore imperative for aviators."

A cloud is simply an aggregate of particles chiefly of water in either liquid or frozen state, which is formed by the chilling of moist air to a temperature below dew point. The formation of cloud gives rise to the formation of precipitation (Sutton, 1962). Cloud is specified by the proportion of the sky covered by cloud of any type (Ayoade, 2004). All the three categories of clouds viz: cirrus, stratus and cumulus affect air navigation system in one way or the other depending on the prevailing weather condition during flight. Of all the clouds, the most troublesome is the cumulonimbus cloud because it produces thunderstorm, rainfall and other severe weather phenomena that are hazardous to flight operations. Cumulonimbus clouds are low clouds of about 2 kilometer above ground level and are associated with turbulence, hail and lightening, poor visibility (cloud ceiling) and bumpiness, and cause aircraft accidents (Abdulazeez, 2009).

## 1.2 STATEMENT OF THE RESEARCH PROBLEM

It was reported by Ayigbe (2007) that the civil aviation practice in Nigeria has come to the front burners in recent years because of the fear to fly as a result of the countless plane crashes that

had drummed up public debate on the safety of lives and property. The crashes of ADC, Sosoliso, Dornier 288 (military), Bellview aircrafts among others has safely placed Nigeria as one country with worst safety record in the preceding years, and this has resulted in Nigeria been ranked number four (4) in the world coming after Congo, Uganda and Tanzania in air traffic disaster. One of the reasons given by the then Minister of Aviation to be responsible for the rampant accidents and incidents was that reports from flight operators, especially Pilots indicated that weather reports were highly unreliable for safe navigation. Therefore, the Minister called on the Nigerian Meteorological Agency (NIMET) to improve in the year 2007.

The problem being envisaged in finding solutions to the rampant air disaster in Nigerian airspace by the aviation authority is the negligence in addressing the weather factors identified among the causative factors. This is because when air disasters occur blames are being apportioned to the human and the economic factors with little or nothing been said about the weather (natural) factors, such as wind shear, visibility, heavy rainfall, crosswind (strong wind) and over flooding. For instance, reports by Shadare (2005) shows that on 11 June 2005, an EAS plane overshot its runway by 40 meters in Jos airport before being stuck in mud due to inclement (severe) weather. Day after this, Chanchangi airliner, B727 similarly overshot the runway by about 100 meters before been stopped by a drainage channel in Lagos airport due to over flooding, as a result of the day's rainfall which rendered the plane brakes ineffective. In addition, an EAS plane hovered over the airport for more than two hours before landing due to flooding from heavy rains. Instead of looking at the real cause of the accidents, the then Minister of Aviation suspended the Pilots of the two planes. In addition, the recommendations given to address the situation were the maintenance of aircrafts, routine check of the planes, pilot's exposure to more training and refresher courses and lightening of the runway without looking into the real cause of the

accidents. Based on these happenings, it was observed through public opinion that the Nigerian aviation industry has not been able to overcome these vagaries (unexpected changes) of weather such as the rains and harmattan, meaning that she was not operating with the times.

On Wednesday, July 13, 2005, a DC-10 cargo plane, flight 0587 from Amsterdam skidded off the runway due to slippery runway engendered by a downpour in Lagos airport. This happened after going round the air for about 25 minutes before the bad landing, while KLM, Lufthansa, Alitalia, British and South African Airways were diverted, and landed in Kotoko Airport Accra, Ghana. Nothing was said about the weather. The emphasis was just on basic repairs and acquisitions for effective performance (Igbokwe, 2005). On 12 March 2005, a Chanchangi airliner skidded off the Nnamdi Azikwe international Airport Abuja even after successfully touching the ground. An accident caused by strong wind (crosswind), which pushed the aircraft about 30 miles away from the runway. Until today, the matter has not been heard of again (Editorial, 2005). These, and many other related cases worst than the few mentioned here are growing concern to all Nigerians. The breakdown of plane crashes and their causes are presented on table 1.1 (See Appendix). From table 1.1, high percentage (63.0%) of the cause of the air crashes is attributed to human and economical factors while weather shares 37% with some other factors. Yet aviators keep crying against the weather everyday as one of the major problems of flight operations.

From the foregoing, it is obvious that the effect of weather have not been properly accounted for vis-à-vis flight operations, despite the fact that statistics indicates that weather solely contribute up to 30% of civil aviation accidents worldwide (Muhammad, 2009). This is because in Table 1.1 the effect of weather was not specifically quantified among the other factors that caused the

37% accidents. Even the human and mechanical or economical factors could be weather-induced. For example pilot error, loss of situational awareness, rusting of machinery; breaking away of aircraft parts or aircraft breakdown, air traffic controller error and fuel exhaustion while in motion can be weather-induced according to Wikipedia online version (2008), Ayoade (2004) and Griffiths (1976). Therefore, this study seeks to quantify the extent or degree of the effects of some of the weather parameters considered critical to flight operations, namely wind, horizontal visibility and cloud cover as only few studies to the best of my knowledge have really quantified the extent or degree of the effects of these weather parameters on air crash in Kano and Abuja International Airports. It has been on the general identification of weather as one of the causative factors and the general effects of some of the parameters on air transport in the study areas. This study will reveal the proximate effect of the weather factor vis-à-vis flight operations in Nigeria. The following questions were formulated to guide the study, they are;

i. What is the trend of the weather and weather-related air crash for the period under study?
ii. Is there any relationship between weather and flight operations in Nigeria, and what is the significance of the relationship?
iii. Is weather, human or economical factor, the problem of flight operations in Nigeria, and what is the implication of the study?

## 1.3 AIM AND OBJECTIVES

The aim of this research is to determine the effects of some weather parameters (wind, visibility and cloud cover) on flight operations in Kano and Abuja International Airports from 1986-2005. This aim will be achieved through the following objectives, which are to:

i. determine the trend of the three weather parameters: wind, cloud cover and visibility, and air crash from 1986-2005.

ii. assess the extent or degree of the relationships of the three weather parameters and flight operations, and assess the most critical of the three parameters to flight operations.

iii. Highlights the implication of the study and recommendations emanating from the study results.

## 1.4 JUSTIFICATION OF THE STUDY

Air transport is recognized world over as the quickest, safest and the most reliable means of movement from one continent to another (Muhammad, 2009). Moreover, according to Mirza et al. (2009), air traffic is expected to double or triple worldwide within the next 20 years, and this could lead to an increase of aircraft accidents in the same or higher proportion. This is because adverse weather, which is one of the causes of accidents, can evolve at rapid rates over a wide spatial extent when compared to other factors that may affects the safe conduct of flight. Thus, weather information is an important component for the safe conduct of a flight, and in the future for the efficient management of air.

Nigeria is hoping to diversify its economy from oil-dependent one to other sectors such as tourism, solid minerals and information technology. Tourism, being one of the global means of generating revenue, can only takeoff fully if the skies are safer (Muhammad, 2009). Moreover, there are few studies on the effects of wind, cloud and visibility in Kano and Abuja airports. In addition, the increased in number of flight into Nigeria and freight per ton over the years in Abuja and Kano airports in particular, is an indication that the industry is influential, lucrative

and full of prospects (Wikipedia online version, 2009). However, the ranking of Nigeria as number 4 in air disaster in the world is worrisome and can seriously impede the nation's progress if measures are not taken to mitigate the situation. Since weather elements are known to be distributed in space and time, an understanding of their trends over the past years will provide good knowledge on what to be expected and how to go about mitigating or avoiding them. Therefore, it is deemed necessary to complements the country's effort by improving or providing deeper weather knowledge of its air space for smooth flight operations. This study intends to contribute to this needed knowledge.

Abuja and Kano International airports are chosen by virtue of their importance as the nation's capital and commercial city respectively, and both double as international and domestic airports, which serve as landing and takeoff centres for aircrafts for both local and international trips.

## 1.5 SCOPE AND LIMITATION OF THE STUDY

The scope of this study is limited to Kano and Abuja international airports because of financial constraint. The study covered 200 km radius of airspace away from the airports to capture only landing and takeoff phases of aircraft flight operations. Furthermore, data for the three weather parameters (wind, visibility and cloud cover) and air crashes covered 20 years (1986-2005) for both Kano and Abuja Airports. The study also determined the trends of the occurrence of the weather parameters, air crashes and casualty for the period of study and assessed the extent of the effects of the weather parameters on flight operations. However, the study has limitations as follows; first, the study intended to cover 30 years (1978-2007) but was limited to 20 years for insufficient data due to inadequate record keeping at the airports. Secondly, data on flight delay,

flight diversion and flight cancellation, which are part of the study, were inaccessible due to security reasons therefore traffic data was limited to air crash.

# CHAPTER TWO: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

## 2.1 Introduction

The aviation industry is a life important industry in the world. Its use cuts across important sectors such as transportation, military, agriculture, tourism and even health. The industry is very influential because of its elite and lucrative nature. However, the industry is weather dependent in terms of its operations and maintenance. Therefore, this chapter discusses theoretical framework and review existing knowledge relevant to this study. The literature review focuses on the state of the atmosphere, weather forecast application in relation to the weather elements being studied and automation of aeronautical meteorological observation. It also review aircraft accidents and their causative factors, flight phase and accidents, and relationships in terms of cause and effects between the weather elements in view and flight operations.

## 2.2 Theoretical Framework

It is not strange that weather is extremely variable because the atmosphere that constitutes it is never static. It is said to be in constant turmoil (Riehl, 1965). That is why science accepts that large variations in the physical state of the atmosphere are inevitable and arise in a manner not completely understood. These variations occur because of the particular composition of air and the atmosphere rest on a spinning body of irregular surface unequally heated by the sun. That is why it is commonplace to know weather changes rapidly (Sutton, 1962). Thus, it is important to understand the mechanism of this variation to mitigate it. Atmospheric characteristics change from place to place and over time at any given place on time scales ranging from microseconds to hundreds of years (Ayoade, 2004). In the same country, or even a small area, weather can vary tremendously. It may be sunny in one part of the area, but raining heavily a few kilometers away. Small gales may be experienced along the coast, while the interior may be relatively calm. So

any place can be subjected to haphazard changes in weather at any time. Therefore, the degree of variability in the weather of any country also differs (Olusegun et al. 1992). The general public and the aviation sector in particular has greatly become aware, and feeling the impact of the variability of this state of the atmosphere in which they live in, and interact with. Jerome (1999) revealed that, the major challenge facing the aviation industry has been to adapt to the vigorous of an extreme and variable weather environment. In view of this fact, it becomes highly desirable to ascertain the nature of weather parameters in an area. This is because, the safety of modern air communication is closely tied to accurate weather reports from the meteorological stations, and weather conditions influence the performance and durability of machinery. For instance, adverse weather conditions may cause accidents, delays, diversions, and even outright cancellations of journeys, thereby causing loss of time, revenue and lives (Olusegun et al. 1992). More so, wind affects the degree of smoothness of the air and brings about changes in weather, which may make a difference between safe flight and disaster (Federal Aviation Agency [FAA], 1965). The fear is that, the incessant air disaster of recent, mostly because of this natural factor (bad and inclement weather) may remain or even increase with the present concept of climate change and its resultant global warming if something is not done to mitigate the situation. Therefore, this research work intends to assess the extent of the effects wind, cloud cover and visibility have on flight operations in Abuja and Kano international airports.

## 2.3 Literature Review

### 2.3.1 The State of the Atmosphere

According to Smith (1975), there are generally three kinds of weather aspect associated with transportation. First, is the influence of the actual weather conditions encountered in flight path. Second is weather forecast, particularly in flight planning, and third, is the importance of weather

modification, such as clearing of fog at airports. Airline industry is perhaps the most affected and influenced by these three aspects of weather, since weather forecast, right or wrong must be taken into account in most flight planning. Therefore, weather knowledge helps to improve the operational efficiency of airlines in terms of safety, comfort and economic incentives. The challenge in flight operations is that, the economic factor is considered more important than the safety factor, base on the claim that flying hazards has been much reduced to a certain extent. This is a mistaken fact because of the common experience of flight delays, cancellations, diversions and even crash landing of aircrafts because of bad weather, which ranges from low cloud ceiling, wind and visibility. For instance, Gabriel (2005) reports that one Captain Tito, a retired Nigerian Airways Pilot pointed out that Nigerian Pilots often ignored safety rules in a bid to make more money. The reason being that they are paid according to the number of flights they do and the number of hours they log, so they do not mind embarking on trips that are not safe. If any particular Pilot refuses to fly a plane for safety reasons, somebody is standing by to go for economic reasons. In any case, safety cannot be entirely divorced from economic considerations, because no commercial airline can remain profitable with poor safety record. There are a number of developments in study, analysis, estimation and prediction that have direct relevance and applicability in organizational forecasting. These have been necessitated by the increasing complexity, competitiveness and rates of change in the environment (Abdulazeez, 2009). The trend in been able to predict accurately more events aim at reducing the uncertainty of weather is essential.

### 2.3.2 Weather Forecast and Flight Operations

Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and a given location. Human beings have attempted to predict the

weather informally for millennia, and formally since at least the nineteenth century. Weather forecasts are made by collecting quantitative and qualitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve (Wikipedia online version, 2010). There are varieties of end users to weather forecasts. Weather warnings are important forecasts because they are used to protect life and property. Forecasts based on temperature and precipitation are important to agriculture, and therefore to traders within commodity markets. Utility companies to estimate demand over coming days use temperature forecasts. On an everyday basis, people use weather forecasts to determine what to wear on a given day. Since outdoor activities are severely curtailed by heavy rain, snow and the wind chill, forecasts can be used to plan activities around these events, and to plan and survive them (Wikipedia online version, 2010).

Frequently, there is a time lag between awareness of an impending event or need and occurrence of that event. This lead-time is the reason for planning and forecasting. In this situation, forecasting is needed to determine when an event will occur or a need arise, so that appropriate actions can be taken (McGee, 1982) in Abdulazeez (2009). Meteorology and Climatology, according to Smith (1975) have been applied to the problems of aviation ever since man first started to fly. The meteorological agencies in the nation's airports have done a lot in discharging their principal functions of providing service to the state's military and civil aircrafts in forecasting the weather. Different techniques are used for the various types of forecasts to know the state of the atmosphere at any given moment, and to know the physical laws that govern the changes of that state (Ayoade, 2004). Some studies have been successful in developing methods for predicting weather at airports. One of such is the low stratus and fog situations connected with cyclones and their fronts by Riehl (1965). Nevertheless, local air currents and random

factors often complicate the situation. A large fog may end suddenly a few miles from an airport on one day, and under similar conditions, it may cover the field on another day.

Aviation industry in Nigeria depends on Nigerian Meteorological Agency (NIMET) for its weather reports. NIMET supply the weather reports and the flight operations department plan flights base on the reports. However, the recent spate of untoward accidents and incidents in some airports across the country was attributed to high unreliable weather reports from NIMET (Ayigbe, 2007), which put a big question mark on the ability for the aviation authority in Nigeria to make the environment safe and conducive for flying (Oketunbi & Shadere, 2005). The incidents were so bad that some Airlines, according to Shadere (2005) struggled to recover from the misfortunes that befall them because of wrong information given from the control towers.

### 2.3.3 Automated Aeronautical Meteorological Observation

Automation of Aeronautical meteorological observation was introduced in Nigeria in February 2003 with the first implementation at the Nnamdi Azikiwe International Airport Abuja, the Federal capital city of Nigeria. Before the introduction of the new system, observations were taken from the manually observed stations by the observers, and visibility measurements were visual observations. This information is then forwarded to the Traffic Services providers. With the new system in place, a fully automated METAR (routine weather message/report) including algorithms for cloud and weather and the AUTO TREND is achieved. The MIDAS IV System (Vaisala Product) deployed at the Airport is providing all the basic Authomatic Weather Observing System (AWOS) parameters with Transmissometers, Ceilometers and Present Weather Sensors for visibility measurements. At present Low Level Wind Shear Alert System (LLWAS) has been added to the System in Abuja in order to conform to the request made by the

government of Nigeria. Before the introduction of the new system, NIMET relied on manually observed stations to take in-situ measurements. From 2003 to 2005, Automatic Weather Observing Systems (AWOS) were installed in most of NIMET stations, including the four major airports (Lagos, Port Harcourt, Abuja and Kano). That was done to complement measurements from conventional instruments. These Weather Observing Systems (AWOS) produces the basic weather parameters such as Air Temperature, Relative Humidity, Pressure, Precipitation, Wind Speed, Wind Direction and Solar radiation (Aderinto & Dahunsi, 2008).

Doppler Weather Radar (DWR) is highly sophisticated weather monitoring equipment used for the detecting, tracking and monitoring convective systems such as severe storms, microburst, line squalls, wind shear, thunderstorms etc. It detects the location, severity, speed and direction of convective systems. Six Doppler Weather Radars have been located each in Abuja, Kano, Lagos, Maiduguri, Port Harcourt and Yola airports (Aderinto & Dahunsi, 2008). Another critical project embarked upon, for more accurate weather forecasts in the ongoing aviation sector transformation is the procurement and installation of Upper Air sounding equipment. With financial support from the Federal Government, the Nigerian Meteorological Agency has completed the procurement and installation of Upper Air Sounding equipment at Lagos, Maiduguri and Enugu airports (Aderinto & Dahunsi, 2008). Other initiatives include, the establishment of a National Weather Forecasting and Research Centre in Abuja; installation of new conventional meteorological instruments in the NIMET's weather observatories nationwide to replace the obsolete ones, establishment of marine meteorological stations along the countries coastal belt; human capacity development, particularly for the professional cadre of NIMET (Aderinto & Dahunsi, 2008). See figures 2.1 to 2.11 and Tables 2.1 to 2.2.

#### 2.3.3.1 MIDAS IV AWOS

The new Vaisala MIDAS IV Automatic Weather Observing System (AWOS) implemented at the four major Airports in Nigeria is a system designed for the needs of air traffic controllers, observers, forecasters, and other airport personnel. It collects, processes, monitors, distributes and archives meteorological data measured by a dedicated set of meteorological sensors located along the runway(s). Observations performed by the system provides all necessary meteorological data required in operations at the airport and to optionally provide detailed observation data to the regional and national meteorological information networks. The following meteorological observations and calculations are performed automatically: Wind Speed & Direction, Pressure (QFE, QNH, QFF), Temperature, Humidity (Dew Point Temperature), Meteorological Visibility, Runway Visual Range Assessment, Rain Amount, Present Weather, Cloud Height and Solar Radiation. All the observations and calculations listed above are displayed on MIDAS IV Central Data Units (CDUs) and workstations as well as Frequentis ATC (air traffic control) display terminals, such as the Meteorological System Field Sensors (fig. 2.1) and field equipment that show how the sensors are distributed along the measurement sites on the runways (Table 2.1), and the Central Data Units (CDU), which are the main computers of the MIDAS IV system equipped with additional communication hardware to connect to the field sensors, workstations, Display Units, Indoor Equipment, Server Rack, End-user Software applications (Architectures), Air Traffic Control (ATC) Profile, Diagnostic Monitor and other systems. They process data from the sensors and distribute it to the workstations and other users of AWOS. Reporting interval is adjusted from 3 seconds to 60 seconds depending on the importance of the weather parameter. Weather parameters having sudden changes, such as wind, have more frequent reporting interval. Both measured and derived

weather information can be displayed in different kind of format and by various means in relevant locations around the airport. (Aderinto & Dahunsi, 2008). See figures 2.2 to 2.9 and Table 2.2).

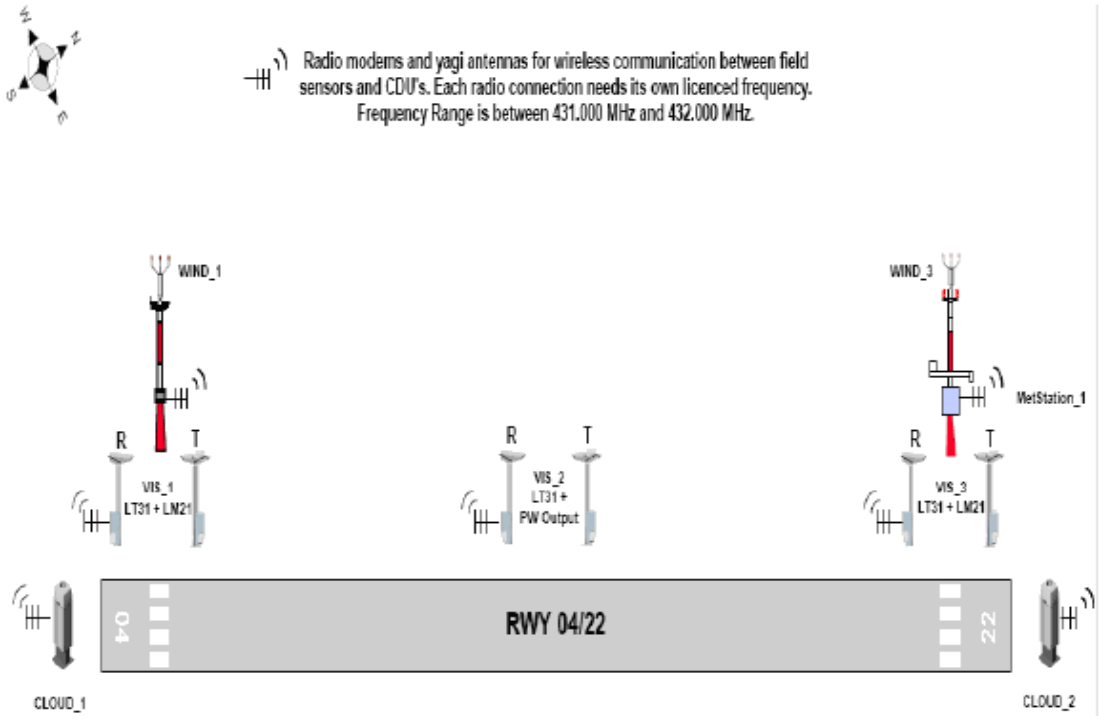



**Figure 2.1: Sensors and data collection system at the Airports**

***Source: Aderinto & Dahunsi, 2008.***

Figure 2.1 collects and measured meteorological data along the runway(s), while table 2.1 indicates the type of field instruments at Abuja International Airport and how the sensors are distributed along the measurement sites and total amount of each sensor/module type applied.

**Table 2.1: Field equipment at Abuja International Airport (RWY 04/22)**

| Instrument Systems | TDZ 04 | MID 04/22 | TDZ 22 |
|---|---|---|---|
| Runway Visual Range - LT31 | X | X | X |
| Present Weather Output - PWD22 | | X | |
| Cloud Height - CL31 | X | | X |
| Automatic Weather Station - MAWS301 | | | X |
| Wind Speed - WS425 | X | | X |
| Wind Direction - WS425 | X | | X |
| Atmospheric Pressure - PTB220 | | | X |
| Air Temperature - HMP45D | | | X |
| Air Humidity - HMP45D | | | X |
| Rain Amount - RG13 | | | X |
| Rain Detection - RG13 | | | X |
| Solar Radiation - CM6B | | | X |

***Source: Aderinto & Dahunsi, 2008.***

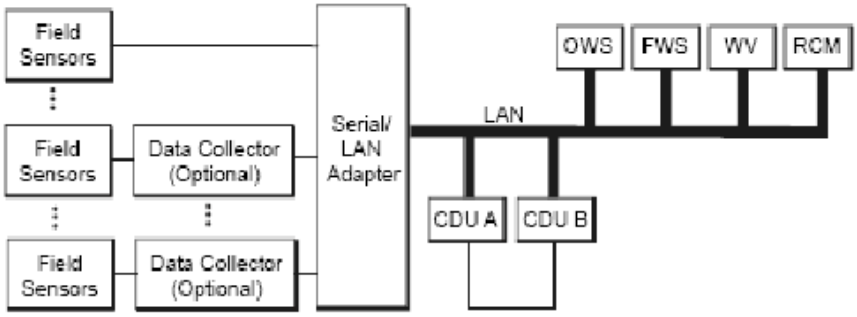



**Figure 2.2: Duplicated Central Data Display Unit (CDU)**

***Source: Aderinto & Dahunsi, 2008.***

The CDU in figure 2.2 validates the measurement data, calculates the values based on the data, and distributes the weather data and alarms to user workstations. In user workstations, users can

view weather data and alerts with the Weather View application. The values are being stored in the ASCII Log View application. Event Monitor and Actual applications are for monitoring and handling system error situations. Weather reports can be edited and sent with METAR/MET REPORT and other weather report applications. Figure 2.3 shows the data connection principles and indoor equipment installed in the Abuja International Airport (Aderinto & Dahunsi, 2008).

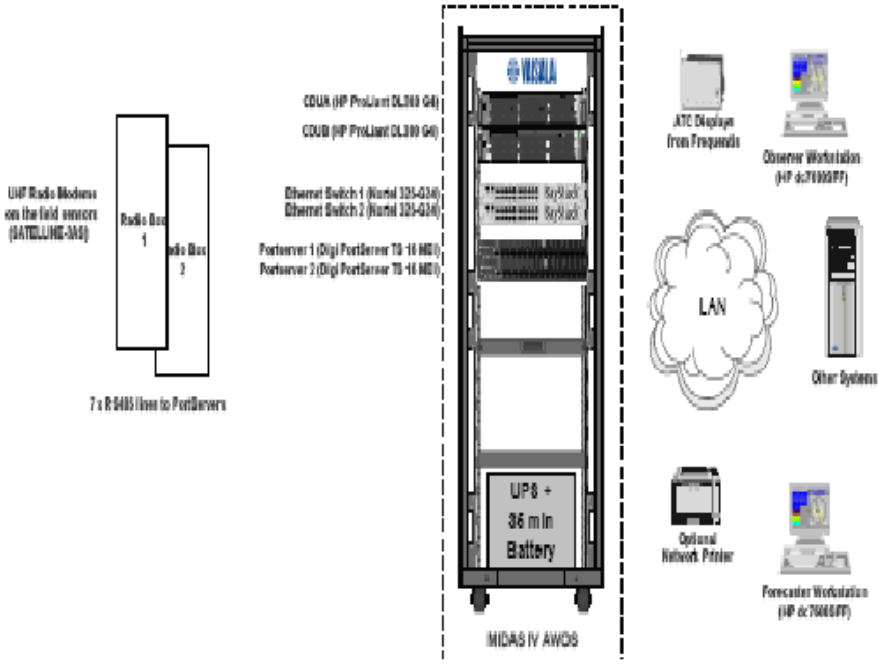



**Figure 2.3: Indoor Equipment at Abuja International Airport**

***Source: Aderinto & Dahunsi, 2008***

Figure 2.4 below is a central data processing unit (CDU), which is one of the main computers of the MIDAS IV installed in the rack mountable server and used for either receiving data from the field sensors or sending data. Figure 2.5 is MIDAS IV Architecture, which is an application used by technical maintenance personnel to allow them view the events generated by CDU maintenance and troubleshooting (Aderinto & Dahunsi, 2008).

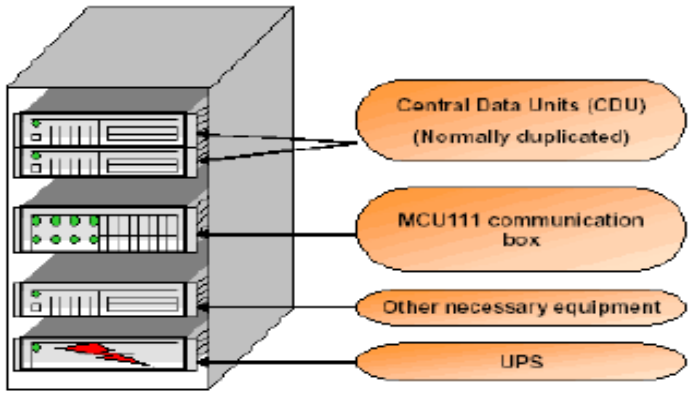



**Figure 2.4: MIDAS VI CDU Server Rack**

***Source: Aderinto & Dahunsi, 2008.***

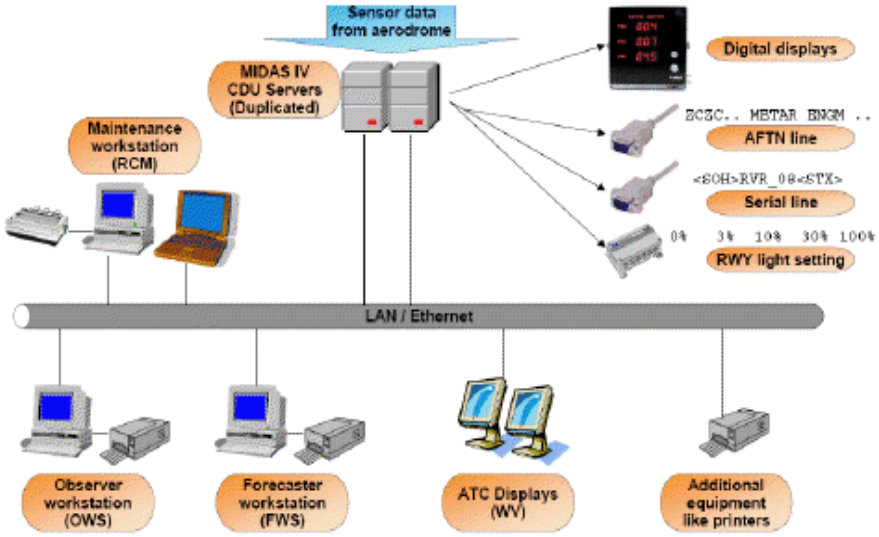



**Figure 2.5: MIDAS IV Architecture**

***Source: Aderinto & Dahunsi, 2008.***

**Table 2.2: MIDAS IV AWOS Applications in Workstation**

| Application | OWS | FWS | WV | RCM |
|---|---|---|---|---|
| Weather View | x | x | x | |
| Event monitor | x | x | | x |
| ASCIILog View | x | x | | |
| METAR/MET REPORT | x | x² | | |
| Actuals | x | | | |
| METAR/MET REPORT MANAGER | x | | | (x) |
| Diagnostic Manager | | | | x |
| Sensor Terminal | | | | x |
| Sensor IO monitor | | | | x |
| Data Source Manager | x | | | (x) |
| AFTN Monitor | x | x | | |
| AFTN Viewer | x | x | | |
| AFTN addressee Manager | x | | | (x) |
| Runway in use Manager | | | | x |
| History monitor (Optional) | x | | | |
| SYNOP (optional) | x | | | |
| Climax (Optional) | x | | | |
| TAF(Optional) | | x | | |
| SIGMET(Optional) | | x | | |
| GAMET(Optional) | | x | | |
| AIRMET(Optional) | | x | | |
| AD WRNG(Optional) | | x | | |
| WS WRNG(Optional) | | | | |
| SNOWTAM(Optional) | x³ | | | |
| Dial - up manager(Optional) | x4 | | | x4 |
| Database RecordingTool(Optional) | | x | | |

***Source: Aderinto & Dahunsi, 2008***

Table 2.2 is MIDAS IV AWOS Applications in Workstation, which includes observer profile, who fills in the required manual observations and automatically generated data, Air Traffic Control Profile and Maintenance Profile. Figure 2.6 is MIDAS IV Diagnostic Monitor, which provides access to all data in MIDAS IV, view-running services, view applications connected to the system, view contents of ROA objects and select active CDU in duplicated System (Aderinto & Dahunsi, 2008).

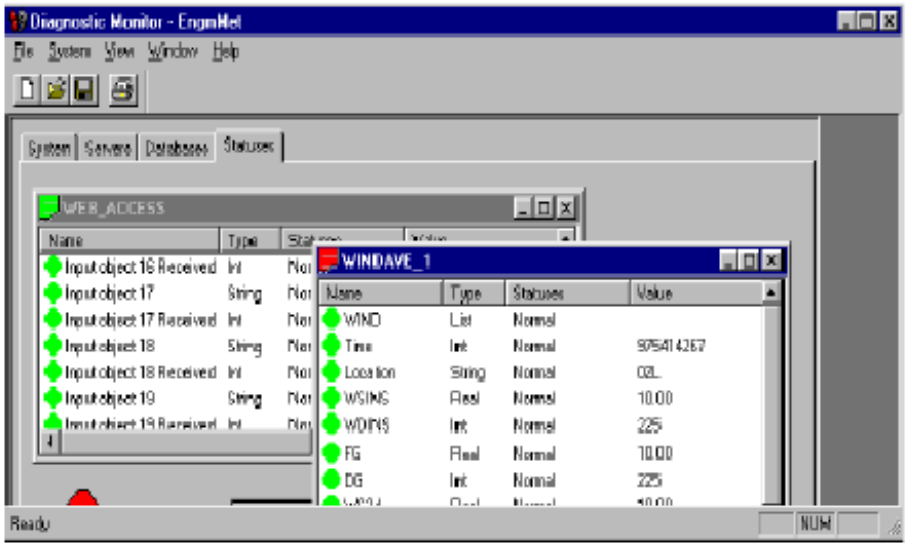



**Figure 2.6: MIDAS IV Diagnostic Monitor**

***Source: Aderinto & Dahunsi, 2008***

The MIDAS IV AWOS software (figure 2.7) focuses on the following aspects of airport weather observation: displaying current weather data (Weather View), sending weather reports (report applications, for example, METAR/MET REPORT), and ensuring the validity of weather data by monitoring the operation of the system (Event Monitor). In exceptional situations, it replaces automatic sensor data with manual input (Actuals and Data Source Manager) and viewing past weather data (ASCII Log View, History Monitor). Figure 2.8 is weather view application software used for viewing current meteorological data in numerical and graphical format. It can also display the status of sensors and the status of the data. Optionally, the Weather View application can include the audiovisual alarm function. Another weather view application software is Statuses of Weather View (figure 2.9) report by Aderinto & Dahunsi (2008).

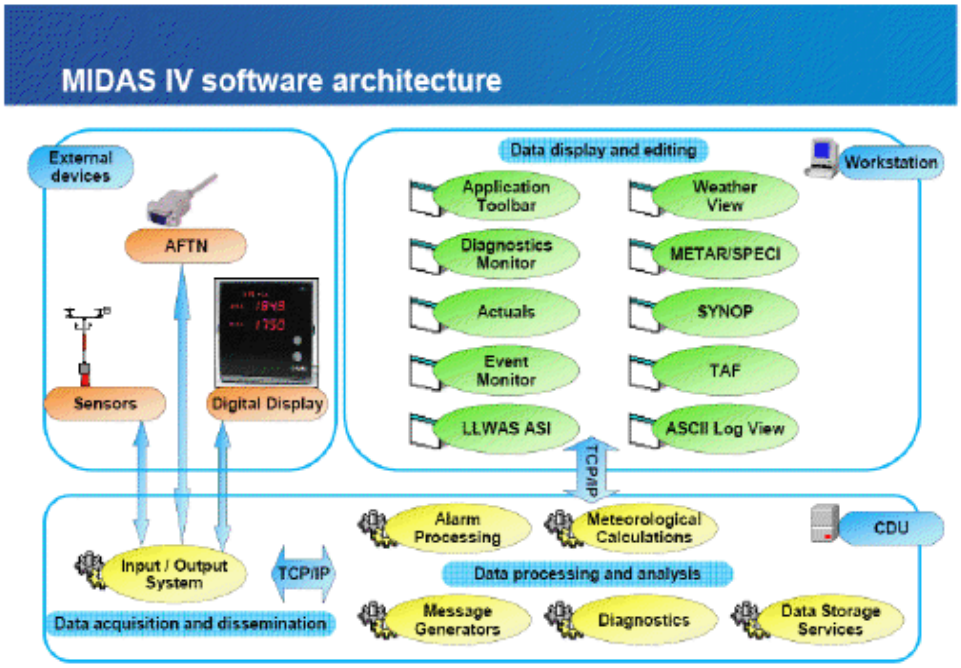



**Figure 2.7: MIDAS IV Software Architecture**

***Source: Aderinto & Dahunsi, 2008.***




**Figure 2.8: Current Meteorological Data in Digital form**

***Source: Aderinto & Dahunsi, 2008.***

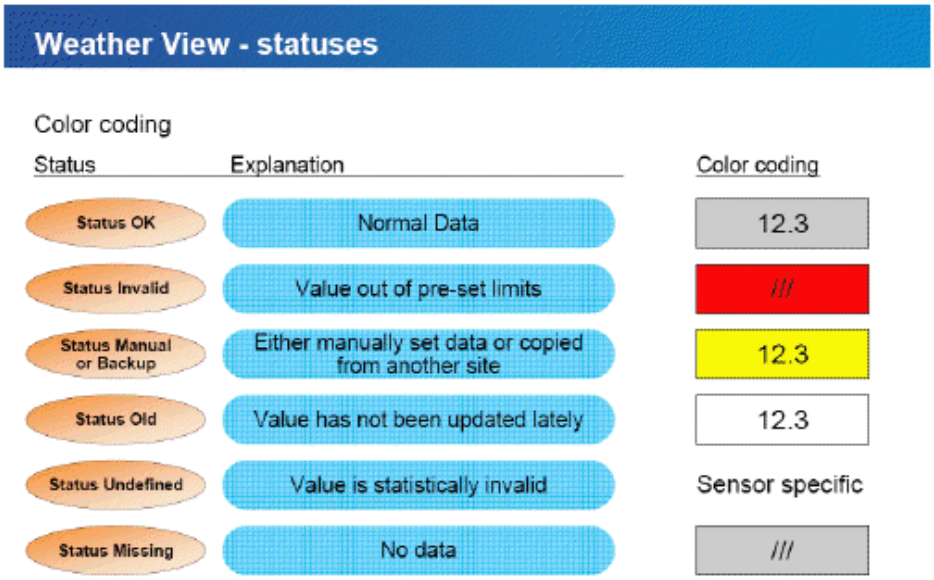



**Figure 2.9: The Statuses of Weather view**

***Source: Aderinto & Dahunsi, 2008***

### 2.3.3.2 Low Level Wind Alert System (LLWAS)

Nigeria is located within the equatorial region of West Africa and is therefore regularly exposed to severe tropical thunderstorm activity with the associated danger of wind shear or microburst activity, particularly dangerous to air transport around airports during landing and take-off. Therefore, the Nigerian Meteorological Agency felt that safety of lives could not be guaranteed with the implementation of MIDAS IV AWOS without Wind Shear Alert System. After the completion of MIDAS IV AWOS installation, the low-level wind shear alert system (LLWAS) installation was implemented in 2008 at Abuja International Airport. The Low-Level Wind Shear Alert System (LLWAS) is designed to detect low-level wind shear in the terminal area (TMA). See figures 2.10 and 2.11. The ground-based system provides both audio and visual alarms to ATC personnel in clearly represented numerical and graphical form. In locations where

Low-Level Wind shear is known to be experienced, LLWAS systems significantly increase the operational efficiency and safety of the airport (Aderinto & Dahunsi, 2008).

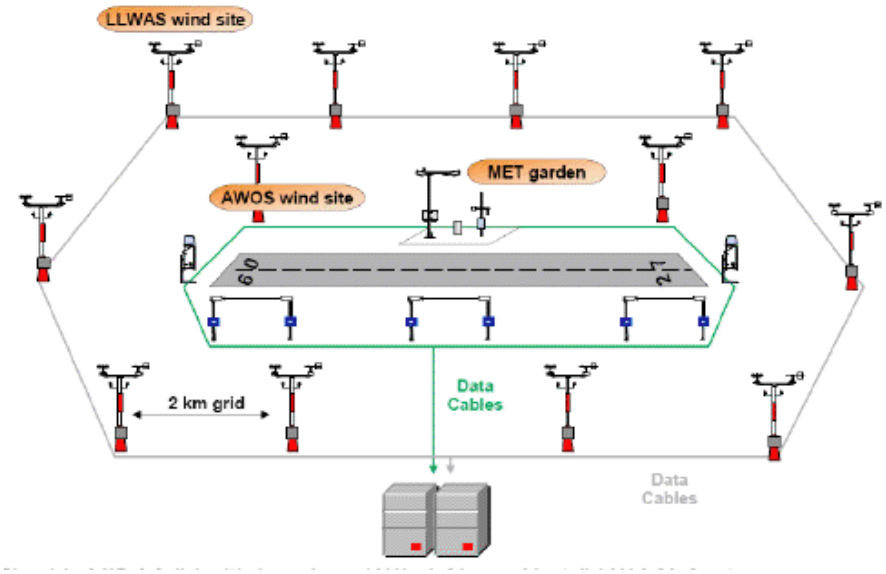



**Figure 2.10: MIDAS IV LLWAS System**

***Source: Aderinto & Dahunsi, 2008***

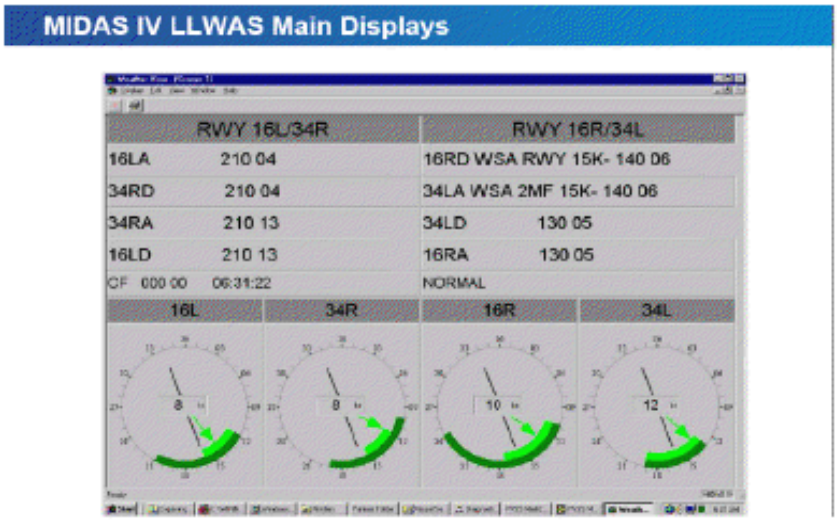



**Figure 2.11: Wind Force at different Wind Sites**

***Source: Aderinto & Dahunsi, 2008***

The introduction of a new automated system for Airports in Nigeria has indeed improved the quality of aeronautical information being provided to users due to availability of state of the earth weather instruments installed along the runways to take measurements at the airside as well as the algorithms used to obtain information. The conventional measurements continue to serve as backup to the automated measurements. The most delightful thing is report shows that the Nigerian Meteorological Agency has about 55 surface manual observing stations spread across the country in addition to the stations at the airports. For accurate and up-to-date weather information, which is essential for the safety of life and protection of property as well as for general welfare and well-being of people, a quality assurance group was established from the department of weather forecasting services to observe the performance of these automatic observing stations. This group periodically downloads the archived data from the weather stations' computers in all the stations. This exercise enabled the group to detect errors resulting from instrument measurements. Its observations were forwarded to the engineering and technical services department for remedial action to be effected. Based on the group report, Engineers/Technicians from this department would in turn either calibrate the malfunctioning sensor or effect a replacement as the case may be (Aderinto, 2008). This is maintenance effort to keep the equipment current.

### 2.4 Aircraft accidents/incidents and causative factors

Globally, it was estimated that approximately 80 percent of all aviation accidents occur shortly before, after, or during takeoff or landing (Wikipedia online version, 2008). Weather is among the causes of the accidents as shown in tables 2.3 and 2.4.

**Table 2.3: An accident survey of 1843 aircrafts from 1950 through 2006 and their causes, - excluding military, private and charter aircrafts**

| Total no. of accidents | Causes of accidents | Percentage (%) |
|---|---|---|
| 1843 | Pilot error | 53 |
| | Mechanical failure | 21 |
| | Weather | 11 |
| | Other human error such as air traffic controller, improper loading of aircraft improper maintenance, fuel contamination, language miscommunication, among others | 8 |
| | Other cause | 1 |

***Source: Wikipedia online version, the free encyclopedia.mht January 2008***

**Table 2.4: Primary cause of Airline hull loss accidents of commercial Jet fleet from 1996 through 2005**

| Causes of accidents | Percentage (%) |
|---|---|
| Flight crew error | 55 |
| Airplane | 17 |
| Weather | 13 |
| Miscellaneous/others | 7 |
| Air traffic control | 5 |
| Maintenance | 3 |

***Source: Wikipedia online version, the free encyclopedia.mht January 2008***

The specifications of weather effect, 11% and 13% in causing the accidents in tables 2.3 and 2.4 respectively are given. However, this may not be the true situation of weather-induced accidents because pilot error and mechanical failure accidents can be weather-induced. In addition, the findings did not indicate the weather parameters involved.

A study by National Aviation Safety Data Analysis Centre ([NASDAC] 2003) revealed that, between 1994 and 2003, there were 19,562 aircraft accidents involving 19,823 aircrafts. Weather was a contributing or causal factor in 4,159 (21.3%) of these accidents, and 4,167 aircrafts were involved. These weather factors, according to NASDAC varied based on the operating rules the aircraft was flying under at the time of event, and that the operating rules were based on Title 14 Code of Federal Aviation Regulations (FAR), which are rules designed to promote safe aviation operation, protecting pilots, passengers, and the public from unnecessary risk. In addition, regulate typical airline flight activities among others. The summary of the findings shows that:

i. 116 weather-related accidents involved FAR Part 121 Air Carrier operations (2.8% of total weather related accidents). Of these, the major weather factors were turbulence (74.2% of weather-related citings) and wind (8.9% of weather-related citings).

ii. 257 weather-related accidents involved FAR Part 135 Commuter/Air Taxi operations (6.2% of total weather-related accidents). Of these, the major weather factors were visibility/ceiling (39.1% of weather-related citings) and wind (26.6% of weather-related citings).

iii. 141 weather-related accidents involved FAR Part 137 Agricultural operations (3.4% of total weather-related accidents). Of these, the major weather factors were wind

(44.8% of weather-related citings) and density Altitude (25.0% of weather-related citings).

iv. 3,617 weather-related accidents involved FAR Part 91 General Aviation operations (86.8% of total weather-related accidents). Of these, the major weather factors were wind (51.0% of weather-related citings) and visibility/ceiling (19.8% of weather-related citings).

Based on FAR 91's primary types of operation, the summary shows that:

v. 2,588 weather-related accidents were in the "Personal Use" category (71.6% of the Part 91 weather-related accidents). Of these, the major weather factors were wind (49.7% of weather-related citings) and visibility/ceiling (20.4% of weather-related citings).

vi. 420 weather-related accidents were in the "Instructional Use" category (11.6% of the Part 91 weather-related accidents). Of these, the major weather-related factors were wind (72.4% of weather-related citings) and Icing (7.7% of weather-related citings).

vii. 213 weather-related accidents were in the "Business Use" category (5.9% of the Part 91 weather-related accidents). Of these, the major weather factors were visibility/ceiling (34.3% of weather-related citings) and wind (33.3% of weather-related citings)

viii. 26 weather-related accidents were in the "Executive/Corporate Use" category (0.7% of the Part 91 weather-related accidents). Of these, the major weather factors were visibility/Ceiling (47.2% of weather-related citings) and wind (27.8% of weather-related citings).

This study revealed the proximate effects of turbulence, density, altitude, wind, cloud cover (ceiling), icing and visibility in causing the 4,159 (21.3%) weather- related accidents. Wind, cloud cover and visibility were the critical of the six factors. This finds relevance in the work of Wen-Lin Guan (n.d.) that low clouds, fog and wind are the most hazardous factors, in which gust, wind shear and turbulence being most dangerous. In addition, the study revealed that from 1994 to 2003 the annual number of weather-related accidents has declined. However, it has remained roughly constant as a percentage of total accidents. The declined trend of the annual number of weather-related accidents revealed by the study may not be a true picture because the study did not indicate the other factors responsible for the remaining 15,303 (78.7%) accidents out of the 19,562 that occurred, as some of the factors could be weather-induced.

According to statistics of Aviation Safety Network ([ASN] 2006) of United States in Wen-Lin Guan (n.d.), from 1950-2000, there were 40 aviation accidents caused by turbulence or crosswind and 39 accidents by wind shear or downdraft (downwards airflow). ASN (2006) statistics also shows that from 1990-2000 two major accidents were caused by wind shear with over 90 fatalities while three major accidents were caused by turbulence and crosswind with over 50 fatalities. From PlaneCrashInfo.com accident database Kebabjian (2009) compiled and presented 1,300 fatal accidents involving commercial aircraft, world-wide, from 1950 through 2008 for which a specific cause is known. Aircraft with 10 or less people aboard, military aircraft, private aircraft and helicopters were not included. The study shows that pilot error (29%), mechanical failure (22%) and weather factors (28%) were the most critical factors responsible for the accidents in the six decades (table 2.5). "Pilot error (weather related)" represents accidents in which pilot error was the cause but brought about by weather related phenomena. "Pilot error (mechanical related)" represents accidents in which pilot error was the

cause but brought about by some type of mechanical failure. "Other human error" includes air traffic controller errors, improper loading of aircraft, fuel contamination, improper maintenance procedures and non-adherence of ground crews to the procedures of operating aircrafts. Sabotage includes explosive devices, shoot downs and hijackings. Where there were multiple causes, the most prominent cause was used (Kebabjian, 2009). An important aspect Kebabjian did not indicate is the individual parameters responsible for the accidents. This is because factors such as human error, mechanical failure and other cause can be weather induced.

**Table 2.5: Causes of Fatal Accidents by Decade in Percentage (1950-2008)**

| Cause | 1950s | 1960s | 1970s | 1980s | 1990s | 2000s | All |
|---|---|---|---|---|---|---|---|
| **Pilot error** | 40 | 32 | 24 | 25 | 27 | 25 | **29** |
| **Pilot error (weather related)** | 11 | 18 | 14 | 17 | 21 | 17 | **16** |
| **Pilot error (mechanical related)** | 7 | 5 | 4 | 2 | 4 | 3 | **4** |
| **Other human error** | 0 | 8 | 9 | 6 | 8 | 9 | **7** |
| **Weather** | 16 | 10 | 13 | 15 | 9 | 8 | **12** |
| **Mechanical failure** | 21 | 20 | 23 | 21 | 21 | 28 | **22** |
| **Sabotage** | 5 | 5 | 11 | 13 | 10 | 9 | **9** |
| **Other cause** | 0 | 2 | 2 | 1 | 0 | 1 | **1** |
| **Total** | **100** | **100** | **100** | **100** | **100** | **100** | **100** |

***Soure: Kebabjian, 2009 (modified)***

Ranter (2003) revealed that in 2002 Africa was the most unsafe continent. Nearly 27% of all fatal airliner accidents happened in Africa, while she only accounted for approximately 3 percent of all world aircraft departures. All regions (Europe, North America, South America, and Central America) recorded a steadily decreasing accident rate in a moving 10-year average trend over the past 11 years (1992-2002) accept Africa. However, the average number of accidents per year in

Australia was not moving much since 1995 (See table 2.6). In 2006, Africa was again the unsafe region, with a record of 18.5% of all fatal airliner accidents. The study gives a picture of the situation in Africa. However, it did not account for the factors (human, mechanical or weather) responsible for the accidents.

**Table 2.6: Fatal Airliner Accidents Statistics trends from 1999-2002**

| Continent | 2002 | 2001 | 2000 | 1999 |
|---|---|---|---|---|
| **Africa** | 10 | 4 | 9 | 9 |
| **Asia** | 11 | 4 | 8 | 12 |
| **Australia** | 0 | 0 | 0 | 3 |
| **Central America** | 0 | 2 | 4 | 2 |
| **North America** | 7 | 10 | 5 | 7 |
| **South America** | 5 | 5 | 1 | 6 |
| **Total** | **37** | **34** | **36** | **45** |

***Source: Ranter, 2003***

Table 2.6 shows an increase trend of fatal airliner accidents in Africa against decrease in other continents of the world.

In the same vein, Joseph (2005) reported that Nigeria occupies position 21on the list of world's 25 most dangerous skies with 33 numbers of accidents and 1,070 fatalities from 1945-2005. (Military accidents, Corporate Jets, hijackings and other criminal occurrences not included). He added that while some attributed the cause of the accidents to ageing aircraft, the International Air Transport Association (IATA) said human error weather-related and human error safety-management deficiencies were responsible, and accounted for 71% of all accidents in the

continent. Africa is a big issue on safety with 25% accident rate, which is six times less safe than the world rate.

### 2.4.1 Flight Phase (departure and arrival) and Accident

Weather is responsible for the problematic nature of flight phases because International aeronautics and meteorology society generally acknowledged that low-level wind shear, among other weather parameters is a severe hazard to aircraft during takeoff, approach and landing. Twenty-three out of twenty-eight accidents were in the epoch of approach and landing (Wen-Lin Guan, n.d.).For instance, the Sosoliso plan crash in 2005 in Port Harcourt, Nigeria happened during approach and landing phase (Ayigbe, 2006). Ranter (2003) revealed that the year 2002 witnessed a rise in the number of approach and landing accidents, which is one ofthe four most pressing safety problems facing the aviation industry. It accounted for 54% of all accidents, compared to 38% in 2001 as shown in table 2.7.

**Table 2.7: Flight Phase and Number of Accidents from 1999-2002**

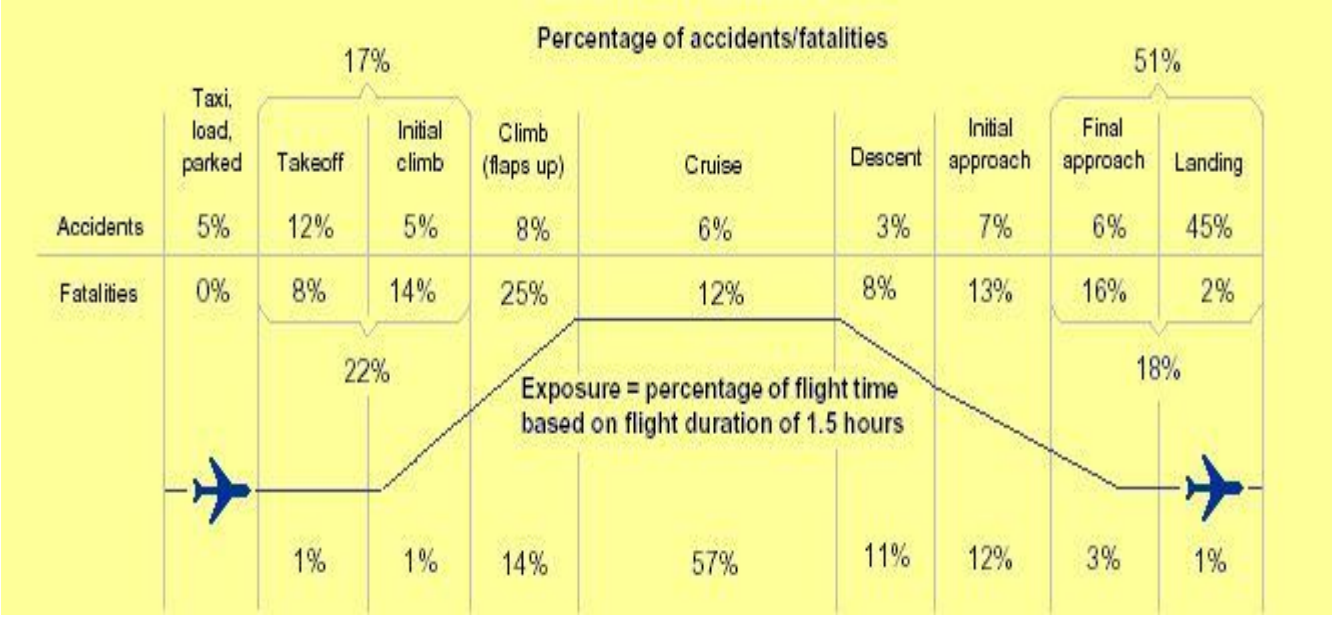
| Flight Phase | 2002 | 2001 | 2000 | 1999 |
|---|---|---|---|---|
| **Ground** | 0 | 1 | 0 | 0 |
| **Takeoff** | 2 | 3 | 3 | 2 |
| **Climb** | 4 | 7 | 11 | 7 |
| **Cruise** | 10 | 9 | 3 | 11 |
| **Approach** | 18 | 12 | 13 | 16 |
| **Landing** | 2 | 1 | 3 | 8 |
| **Total** | **36** | **33** | **33** | **44** |

***Source: Ranter, 2003(modified)***

Table 2.7 shows high number of accidents in approach/landing and takeoff/climb, which are the most problematic phases in aircraft flight (Wikipedia, 2008).Ground flight phase caused the least

number of accidents. In related development, Kebabjian (2009) in looking at the causes of fatal accidents by decade, revealed the percentage of accidents and fatalities by approach/landing and takeoff/climb phases of flight. The approach/landing phase accounted for 51% accidents and 18% of fatalities while Takeoff/climb phase accounted for 17% of accidents and 22% of fatalities (fig. 2.8). However, he did not indicate the study period.

**Table 2.8: Accidents and Fatalities by phase of Flight**




***Source: Kebabjian, 2009***

## 2.5 Weather Parameters and Flight Operations in Nigeria

There has been an increasing awareness, concern and studies on weather as one of the causes of air disaster over the years. The importance of such studies cannot be overemphasized if air safety must be achieved. However, there is still low level of recognition and research attention on some weather parameters in Nigeria. In some cases weather is completely neglected. For instance Arizona-Ogwu (2008), in a study on safety of air transport in Nigeria reported that experts

attributed the causes of air disaster to Pilot Error (human related), Pilot Error (weather related), Pilot Error (mechanical related), Other Human Error, Weather, Mechanical Failure, Sabotage plus Other Cause. Nevertheless, he attributed it to outdated Aircrafts being flown everywhere in Nigeria rather than what the experts revealed.

He also reported that between 1965 and 2002 (37 years) when the Nigeria Airways was in operation it recorded six crashes in which 219 persons died. Between 1965 and 1983 (18 years), Nigeria Airways recorded two air crashes while for another 18 years, 1984 to 2002, it recorded another three crashes out of which the last two, in 1996 and 2002 recorded no casualties. Besides, between 1988 and 2005 (17 years), the private airlines recorded 12 crashes, of which only one had no casualties, while the total deaths recorded was 762. He added that the worst plane crash took place on 02/05/1955 in Calabar courtesy of West African Air System Company, seconded by the 11/07/1996 in Lagos through Aviation Dev. Corp. (ADC Airline) and that of 06/26/1991 in Sokoto, courtesy of Okada Air. He attributed all these accidents to outdated aircraft problem.

Okwusogu (1999) carried out a geographical study on the problems and prospects of aviation industry in Nigeria and identified only human and economical factors such as cost of maintenance, aircraft rental, insurance premium, spare parts and maintenance bills, salaries of expatriates engineering corps, and administrative policy as the problems of the aviation industry in Nigeria, while neglecting the weather factor. On the other hand, Bature (2002) identified two factors that generally affect the operation of the aviation industry in Nigeria to include the human and the natural factors in a study ‘‘Factors affecting international flight operations in Nigeria’’. He reported that administrative, pilot`s competence level, ground crew, type and model of

aircrafts in use and condition of fuel used are human factors, while the natural factor includes weather condition such as cloud, temperature, fog, wind, precipitation, among others. He emphasized that this climatic factor has for time immemorial been disrupting not only international flight operations but also every flight operation in the aviation industry. However, he concluded that the natural factor causes only little inconveniences, for the fact that there were responsive knowledgeable ways of dealing with the natural phenomena with respect to the aviation industry. This is considered an underestimation of the real fact. With the incessant plane crash, flight delay, cancellation and diversion in Nigeria and all over the world as a result of weather as one of the causative factors suggests that weather phenomena is not done with yet.

The study carried out by Jerome (1999) within Kano International Airport environment in 1999 was on the assessment of the variation of climate parameters (temperature, pressure, humidity and evaporation) within the airport environment for the period 1968-1997. The study revealed that there was no significant variation in the climate of the airport environment. The objective of the study was just to assess the variation in the microclimate of the airport with no link to flight operations. Abdulazeez (2009) carried out a study on the effect of weather on air transport; a case study of Abuja International Airport. The study revealed that rainfall parameter was the most critical parameter influencing air transport services. Therefore, flight delay and cancellation becomes very frequent, serious and regular during the period of rainfall (March-October or early November) in Nigeria. Olagunju (1999) studied the effect of weather on military operations. He took a case study of ECOMOG peace keeping in Liberia and came up with a result that, among the factors that militated against the smooth operations of the military in Liberia, weather stood high. Strong wind restricted the use of aircrafts for the operation. Therefore, recommended for

intensive training of the military in the aspects of climatology and meteorology irrespective of field of specialization. Mohammad (2009), in his study ‘‘weathering the weather factor,” revealed that one of the greatest challenges in aviation safety in Nigeria is the weather-induced aviation disasters. These types of disasters usually occur as result of wind shear, storms, and heavy rainfall. He further revealed that wind shear, which is a hazardous meteorological phenomenon caused by sudden changes in the wind speed and, or direction over a short distance and, or short period, is particularly hazardous when it occurs at lower altitudes. Low level wind shear has therefore been recognized as a potential hazard to the aircraft, especially during landing and take-off phases of aircraft. In addition, weather imposes some dangers in aviation as convective weather systems are usually very severe in nature and pose very serious threat to both life and property especially in aircraft operations. They are particularly hazardous to aircraft operations because of the down and updraft (wind systems) and lightning associated with such convective systems. In general, weather is a significant factor affecting safety in the skies as statistics indicate that weather contributes up to 30% of civil aviation accidents worldwide, either as a sole factor or among the causative factors.

According to Mohammad (2009), one of the strategies adopted by the Federal Government towards achieving safer skies over Nigeria is the strengthening of the operational capacity of our national weather service provider: the Nigerian Meteorological Agency (NIMET). Many stakeholders in the aviation industry have applauded this step. The Federal Government supported NIMET to embark on some safety-critical projects, which has recorded substantial accomplishments since May 2007. Some stakeholders believed that with some of the initiatives being implemented by NIMET, Nigeria’s skies would surely be among the world’s best in the

next few years. Other initiatives that are being implemented by NIMET towards achieving safer skies over Nigeria include the establishment of a National Weather Forecasting and Research Centre in Abuja. In addition, the installation of new conventional meteorological instruments in the NIMET's weather observatories nationwide to replace the obsolete ones, establishment of marine meteorological stations along the country's coastal belt and human capacity development, particularly for the professional cadre of NIMET (Mohammad, 2009).

### 2.5.1 Wind and Flight Operations

Wind has for long disrupting flight operations both locally and internationally. Lankford (2001) study has shown that wind direction and speed is crucial for determining flight safeties. Tailwind, headwind and crosswind vary in direction and influence both landing and takeoff phases of aircraft flight. Smith (1975) in his findings reported that during the summer months, the breeze often attains a mean speed of over 7.5m/s, with gusts up to 15m/s. These conditions made landing hazardous. Roberts (1971) in Smith (1975) have shown that a runway is considered unsafe when the wind component at right angles to it exceeds a certain value depending on aircraft type. Therefore, in an effort to ensure successful landing, the Pilot is provided with detailed information on wind behaviour in the last 30 meters of descent. The Air Traffic Controller usually apprises the Pilot of surface conditions about 10 minutes before touchdown. On the other hand, Keddie (1971) in Smith (1975) carried out a research that revealed that a mean speed measured over 4½ minutes period provided a reasonable estimate of speed 10 minutes later. Crossley (1966) in Smith (1975) revealed that a mean headwind of 4m/s on the trans-atlantics crossing would increase the flight time by one minute and it consequently became less profitable to deviate from great circle routes in other to seek the least-time track for fear of anticipated strong winds (jet streams).

In general terms Smith (1975) concluded that, forecast wind conditions has the most important role in determining the selection of the fastest and the most economical flight path, for the fact that favourable tailwinds can produce the most significant improvements in air speed, fuel consumption, and estimated arrival times. Griffiths (1976) supports this fact by recommending that, the routing of a flight should take full cognizance of tailwinds and headwind and optimum levels in order to obtain the most economical route. This helps to avoid areas of turbulence. It is apparent from the findings that wind is both a hazard and a resource for flight operations.

### 2.5.2 Visibility and Flight Operations

The accurate forecasting of visibility, fog clearance and fog formation at most airports according to Maunder (1970) is in many cases difficult. Nevertheless, accurate visibility and fog forecasts are important especially if flight delay or diversion most be controlled at low latitudes (at approach/landing).Smith (1975) has shown that even with the increasing sophistication of automatic landing equipment poor visibility from fog and low cloud ceilings is still the major impediment to flight operations throughout the world. Ehigiator (2007) reported that poor visibility due to harmattan haze disrupted flight operations from Lagos to Owerri. While some airlines delayed flights to the northern part of the country for some hours, others cancelled their flights out rightly because the visibility was worse. Ehigiator and Orakpo (2010) reported that poor visibility resulted in the cancellation of flights from Lagos to Benin, Owerri and the northern part of the country. This was because NIMET forecasted that there was a significant build up of surface pressure systems over the Sahara Desert and the Sahel regions in the past few days, which resulted in the lifting of considerable quantity of dust particles into the atmosphere in those regions. The raised dust particles were transported southwards and caused significant reduction in the horizontal visibility over the extreme northeastern part of the country. Places

around Maiduguri, Potiskum, Nguru and Kano experienced severe harmattan dust haze with the associated reduction in horizontal visibility to less than 800m, and in some days, horizontal visibility was reduced in Maiduguri and Yola to less than 300m. Base on this weather condition, Nigeria Civil Aviation Authority (NCAA) set weather minima for most airports in the North to less than 1000m and at 800m and set a fine of N50, 000.00 for erring pilots and N500, 000.00 for the airlines. Abubakar and Nurudeen (2011) also reported the cases of flight delay and cancellation because of poor visibility. They reported that flights from Kano, Abuja, Yola and other parts of the North especially, were delayed for 2 hours and above due to poor visibility.

NIMET (2011) reported that the year 2010 witnessed a few instances of disruptions due to severe weather conditions. However, the month of March recorded a severe dust hazy spell, which reduced horizontal visibility to between 200m-800m for several days and this caused many disruptions in flight operations across the country. These disruption affected flight operations in Lagos, Abuja, Kano, Kaduna, Minna, Maiduguri, Sokoto, and Enugu. Others were Owerri, Port Harcourt and Calabar airports. There were also cases of outright cancellations. In January and December, early morning fog was reported in Lagos, Port Harcourt and Jos, which reduced horizontal visibility to between 200m-800m. This resulted in flight delays at these airports. In addition, thousands of Europe-bound Nigerians were stranded at the Murtala Mohammed International Airport Lagos, as heavy snow pounded European airports in December. These harsh weather conditions affected the number of inbound and outbound flights at the Murtala Mohammed International Airport during the period. See table 2.9.

**Table 2.9: Summary of Weather Effect on Flight Operations at Lagos Airport in 2010**

| Date | Weather | Effects |
|---|---|---|
| January-March | Dust haze and fog | Rescheduling and delays of most local flights which lasted for several days |
| April-September | Volcanic eruption of Mt | Most international flights were cancelled due to the closure of Europe airports |
| | Severe thunderstorm and squalls | Flight delays were experienced in severe thunderstorms and squalls |
| December | Snow in America and Europe | Most international flights were cancelled due to the closure of European airports |
| | Fog in Nigeria | Local flight delays |

***Source: NIMET 2011, pp. 29-31***

NIMET (2011) also reported flight delays, cancellations and diversions due to adverse weather conditions during the year 2010. Preliminary analysis of air traffic at the Nnamdi Azikiwe International Airport Abuja shows March with the highest number of flight disruptions largely due to the harmattan dust haze. The prevailing dust haze during the period (March) resulted in very low horizontal visibility at most of the nation's airports. In addition, flight disruptions were reported during the wet season mainly due to heavy downpours, severe thunderstorms and squally weather. Table 2.10 is the analysis of air traffic at the Abuja airport, which suggests a sharp increase of flight delays and cancellations in 2010 when compared with the previous two years.

**Table 2.10: Comparison of flight disruptions at Abuja Airport in 2008, 2009 and 2010**

| Month | 2008 | 2009 | 2010 |
|---|---|---|---|
| **January** | 2 | 5 | 13 |
| **February** | 0 | 9 | 12 |
| **March** | 0 | 8 | 55 |
| **April** | 0 | 3 | 3 |
| **May** | 0 | 2 | 6 |
| **June** | 6 | 0 | 0 |
| **July** | 1 | 1 | 0 |
| **August** | 1 | 0 | 5 |
| **September** | 5 | 1 | 1 |
| **October** | 2 | 1 | 1 |
| **November** | 0 | 5 | 3 |
| **December** | 12 | 5 | 12 |
| **Total** | **27** | **40** | **113** |

***Source: NIMET 2011, pp. 29-31***

### 2.5.3 Cloud and Flight Operations

The convective turbulence found within some of the large cumulonimbus clouds of tropical and subtropical latitudes is perhaps the greatest single atmospheric threat to aircraft safety. Smith (1975) has shown that almost all losses of large civil jets planes directly attributable to turbulence occur in or near thunderstorms. Up draughts and downdraughts of 30m/s and above have been recorded within cumulus clouds in the United State. Flight within a well-developed cumulonimbus cloud is usually difficult if not dangerous. This is because the turbulence nature of precipitation associated with it affects aircraft and the response of the aircraft to the turbulence condition is one of the major causes of accidents. It is on this note that Powell (1981) in Abdulazeez (2009) recommended that the takeoff of an aircraft should be postponed when there

is any risk of flying into the area of an active thunderstorm from cloud. Similarly, on arrival in such a condition, the approach and landing should be delayed if possible until the storm has cleared. However, Abdulazeez (2009) made it clear that not all clouds are dangerous to flight operations because there are some clouds that are very safe for flying. These include clouds of the cirrus, stratus, and even some types of the cumulus family.

## CHAPTER THREE: THE STUDY AREA AND RESEARCH METHODOLOGY

### 3.1: Introduction

This chapter describes the study areas, the type of data used, source of data, and the various methods used to analyze the data for this study.

### 3.2: The Study Area

Abuja International Airport in the Federal Capital Territory (FCT) Abuja and Kano International Airport in the commercial city of Kano State of Nigeria are the two study areas of this research work.

#### 3.2.1 Nnamdi Azikiwe International Airport Abuja

##### 3.2.1.1: Location, Position and Size

The airport is located on latitude 09°00`N and longitude 07°15`E and at altitude 314.98m. It is about 49km away from the main town. The airport type is public, elevation is AMLS 1,123ft/342m, runways direction is 04/22 and length is 3,609m/11,842ft (Wikipedia online version, 2009 & Abdulazeez, 2009). See figures. 3.1 and 3.2.

Geographically, Abuja main town is located in the centre of Nigeria, within the Federal Capital Territory (FCT). It is a well planned city, and was built mainly in the 1980s. It officially became Nigeria's capital on 12 December 1991, replacing Lagos. Abuja lies between latitude 8°25` and 9°20`N of the equator and longitude 6°45` and 7°39`E of the Greenwich meridian (Coordinates:9.066667°N and 7.483333°E). It occupies a total area of 713 $km^2$ (275.3 sq ml) of land. It has a density of 1,088.8/ $km^2$ (2,819.9/sq mi).Time zone is WAT (UTC+1) and Website is fct.gov.ng/fcta. At the 2006 census, the city of Abuja had a population of 776,298 (Wikipedia online version, 2009 & Abdulazeez, 2009).

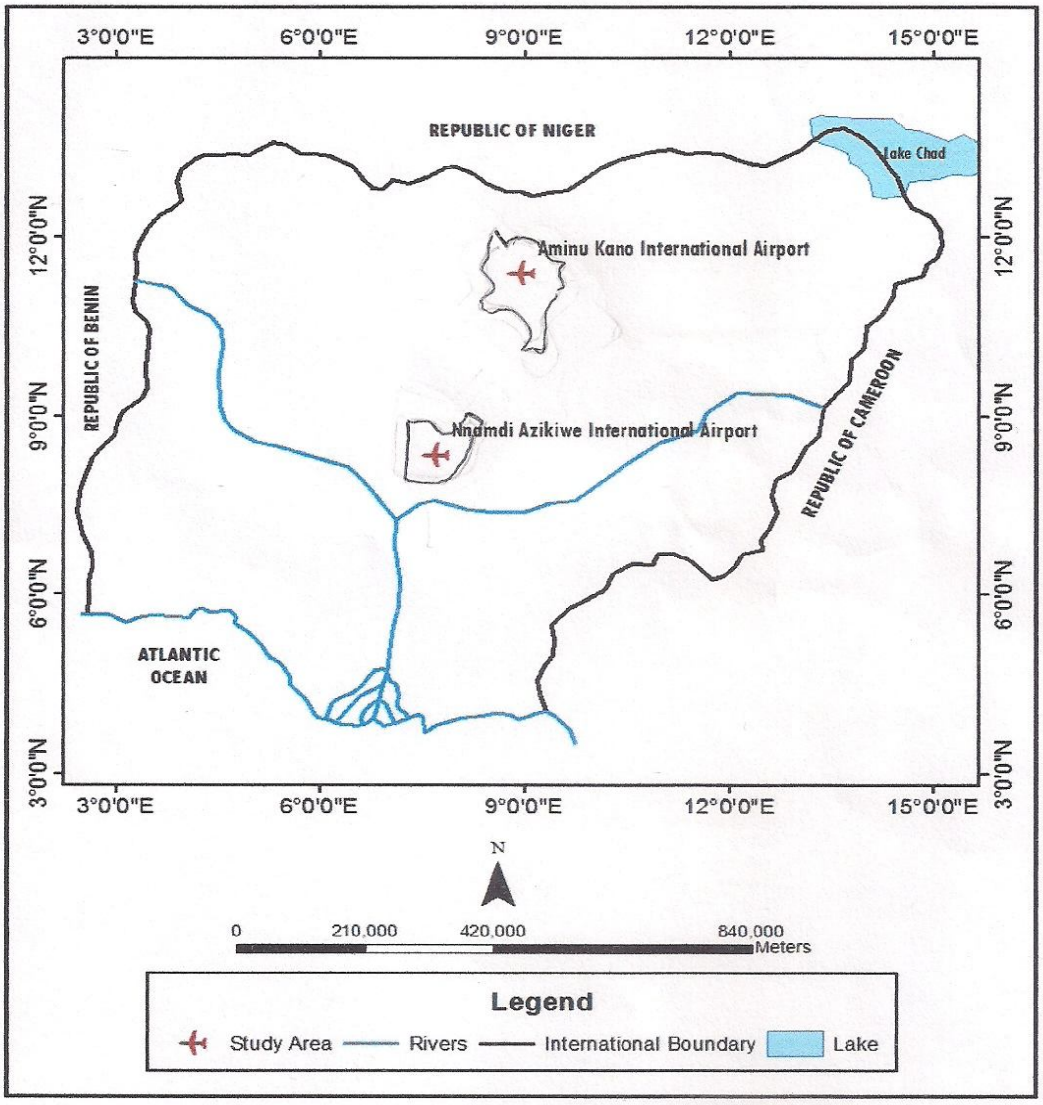



**Figure 3.1: The Map of Nigeria showing Abuja and Kano Airports.**

***Source: Paul, 2014***

### 3.2.1.2 History of Abuja International Airport

Nnamdi Azikiwe International Airport (**IATA**:ABV, **ICAO:** DNAA) Abuja is located some 40 kilometers from the city centre of Abuja on the highway from Abuja to Gwagwalada in the Federal Capital Territory (FCT), Nigeria, and is the main airport serving the Nigerian capital city. It was named after Nigeria's first President, Dr Nnamdi Azikiwe. It consists of an

international and a domestic terminal. Both terminals share the same runway. The Airport is coded ABV by the International Air Transport Association (IATA) and DNAA by the International Civil Aviation Organization (ICAO), meaning an IATA location identifier and ICAO location indicator around the world. The IATA codes are used by the general public for airline timetables, reservations, and baggage handling (the characters prominently displayed on baggage tags attached at airport check-in desks are an example of a way these codes are used), while the ICOA codes are used by air traffic control and airline operations such as flight planning. Abuja International Airport provides excellent flight services both to destinations in Nigeria and elsewhere. It is a public airport operated by the Federal Airports Authority of Nigeria (FAAN) but managed by the Abuja Gateway Consortium. (Wikipedia online version, 2009).

#### 3.2.1.3 Facilities

Although the Airport is the most modern in Nigeria with many world class facilities such as state of the art radar systems, watch towers, hangars, well laid runways and two terminals one for domestic flights and the other for international flight services it is yet to be completed as work is on going with its second phase. The length of its asphalt surface runway is 3,609m and has an elevation of 3,609.4m. It has a presidential wing made up of a taxiway linking the runway, Presidential Hanger, guest chalet and the Presidential Lounge, which is fully developed. However, with its first phase, the Airport has excellent facilities. The second Phase of the airport is ongoing construction and renovations, when completed will have a parallel taxiway, the first module of the international terminal building, fire fighting station, protocol lounge, access roads and the linking of the international and presidential wings with water lines from water scheme services (Wikipedia online version, 2009).

### 3.2.1.4 Climate

Abuja under Koppen's climate classification (AW) features a tropical wet and dry climate. The FCT experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a break of harmattan occasioned by the northeast trade wind, with the main feature of dust haze, intensified coldness and dryness. The rainy season begins from April and ends in October, daytime temperatures reach 28 °C (82.4 °F) to 30 °C (86.0 °F) and nighttime lows hover around 22 °C (71.6 °F) to 23 °C (73.4 °F). In the dry season, daytime temperatures can soar as high as 40 °C (104.0 °F) and nighttime temperatures can dip to 12 °C (53.6 °F). Even the coldest nights can be followed by daytime temperatures well above 30 °C (86.0 °F). The high altitudes and undulating terrain of the FCT act as a moderating influence on the weather of the territory. Rainfall in the FCT reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses. Due to the hilly and mountainous nature of Abuja city, Orographic activities bring heavy and frequent rainfall of about 1,500 mm (59.1 in) during the rainy season. Beginning in March to November, the rainy season peaks in September, during which abundant rainfall is received in the form of heavy downpours (Wikipedia online version, 2009).

### 3.2.1.5 Vegetation

The major types of vegetation in the Federal Territory are the forests and savanna. The forest constitutes the rainforest and the riparian vegetation complex, while the savanna constitutes the savanna woodland, park savanna and shrub savanna. The vegetation is distributed as follows:

i. Rainforest: this covers about 592 sq km (about 7.9%) of the territory. They are more common on the Gwagwa plains in the rugged southwest part and the golith landscape of the sedimentary rock area of the southwest. In these areas, the forest vegetation

type occurs in three different positions- on or at the rocky hills, in deep George-like river and rock valley bottoms.

ii. The riparian vegetation complex: this covers some 1000 sq km (12.5%) of the territory. These are found mostly along the lowland level channels and banks of rivers.

iii. The savanna woodland: this occurs most exclusively in the less accessible part of the territory. They are associated with ridges and hill ranges and are found on the south of Kwali and the Sukuku hills fringing the Iku plains. The savanna woodland covers some 1026 sq km (about 12.8%) of the Federal Capital Territory.

iv. The park savanna covers greater proportion of the Federal Capital Territory. It covers some 4231 sq km, about 53% of the land area.

v. The shrub savanna covers 1032 sq km, about 12.9% of the Federal Capital Territory and occurs close to valley complexes usually below wooded ridges and hills (Abdulazeez, 2009).

**3.2.1.6 Geology**

There are two broad geological regions in the Federal Capital Territory: the basement complex and the sedimentary rocks. The basement complex covers more than 8% of the territory and are classified into three groups, which are the granite and granitic, gneiss, quartzoze metamorphic rocks and more basic igneous and metamorphic rocks. The sedimentary formation consists mainly of fine grain sandstone including silt, stones and clay. Apart from the basement complex and the sedimentary rocks, alluvial deposit also occurs in the Gurara flood plain (Abdulazeez, 2009).

### 3.2.1.7 Soils

The soils of the Federal Capital Territory are well drained and deep soils. These soils are derived from the granite ores and migmatites underlying the Gwagwa plains. Their stability for various urban land uses varies with depth, occurrence of iron pan, texture, erodibility, fun off potential and drainage (Abdulazeez, 2009).

### 3.2.1.8 Drainage

There are network of streams, valley and depressions covering the Federal Capital Territory an d are fan-shaped. The concentration of rainfall shows the need for drainage systems that can handle large volume of water and dispatch it quickly. The primary river drainage in the territory is the Gurara and its west and north flowing tributaries. Seven major drainage basins can be recognized within the territory. These are from north to south the upper rivers Tapa, the river Itau, the river Usman, the river Mangol, the river Rob, the river Afara-bokwi and the river Yewu (Abdulazeez, 2009).

### 3.2.1.9 People and Human Activities

There are many ethnic groups in Abuja comprising the Gwari, Koro, Gade and Ganagana being the dominant groups and a few Guandara, Bassa, Fulani and the Habe people. The Gwaris alone comprise more than half of the total population of the whole area. With the status of the city as the federal capital, ethnic groups from all over the country have dominated the administrative sector. Prior to the movement of the seat of government from Lagos to Abuja, the majority of the inhabitants of the region were engaged in primary activities such as farming, fishing, weaving, poultry and black smiting, with a few engaged in trading activities. however, following the shift in the seat of government, people working in the federal capital territory engage mostly in the

territory service sector of the economy with more people engage in administrative and white collar jobs (Abdulazeez, 2009).

### 3.2.2 Mallam Aminu Kano International Airport Kano

#### 3.2.2.1 Location, Position and Size

Kano international airport is located within latitude 12° 03`N and longitude 08° 32` E in Dala Local Government Area with an altitude of 475.8m (Jerome, 1999). Geographically, Kano town is located approximately between longitudes 7° 45`E and 10° 35`E, and between latitudes 10° 30`N and 13° 02`N (figure 3.1) and as such is a part of the Sudano-Sahelian zone of Nigeria. Kano region has a land area of 43,284 $km^2$ (about 4.69 percent) of Nigeria's total land area. It has a total population of 17 million and a population density of 649 people per $km^2$ compared to a national average of 235 $km^2$ and world average of 442 per $km^2$. Kano is characterized by a high population growth rate of 2.9% from 1992 to 2006 based on the provisional census figure of 2006. Within the Kano closed settled zone population density is well above 1000 per $km^2$ (Nabegu, 2009).

#### 3.2.2.2 History

Mallam Aminu Kano International Airport **(IATA**: KAN, **ICAO**: DNKN) is located in Kano, a city in the Kano State of Nigeria (figure 3.1). It is the main airport serving northern Nigeria and was named after a Nigerian politician, Mallam Aminu Kano. The airport consists of an international and a domestic terminal. Both terminals share the same runway. Construction started on a new domestic terminal, and is expected to be commissioned soon. In 2009, the airport handled 323,482 passengers. The Airport is coded KAN by the International Air Transport Association (IATA) and DNKN by the International Civil Aviation Organization (ICAO), meaning an IATA location identifier and ICAO location indicator around the world.

The IATA codes are used by the general public for airline timetables, reservations, and baggage handling (the characters prominently displayed on baggage tags attached at airport check-in desks are an example of a way these codes are used), while the ICOA codes are used by air traffic control and airline operations such as flight planning. The airport is the oldest in Nigeria, with operation started in 1936. In the first decade of operation, the airport became an important fuel stop for airlines flying long-haul services between Europe and Africa. Newer aircraft however did not need such fuel stops any longer, and with the demise of the economy of Kano in the late 20th century, many international airlines stopped serving the airport. KLM is the only European airline currently serving Kano, which they have done without interruption since 1947. This makes KLM the longest-serving foreign airline in Nigeria. Currently the bulk of international flights cater for the large Lebanese community in Kano and Muslim pilgrimages to Mecca (Wikipedia online, 2009).

**3.2.2.3 Facilities**

The airport both serves civilian and military flights. Runway 06/24 is mainly used for civilian flights, while runway 05/23 primarily serves the Nigerian Air Force base at the south side of the airport. However, runway 05/23 was in use for all operations, when the main runway was rehabilitated in the beginning of the 21st century. Between the two runways lie the terminal facilities. The main terminal with the control tower serves international flights and domestic services operated by Arik Air and Nigerian Eagle Airlines. Facilities in the departure lounge are minimal, with a newsstand near the check-in counter, and a small bar at airside. There is a small VIP Lounge for business class passengers. Duty Free shops are currently closed. In the arrivals hall there is a small bar and a post office. On the south side of the airport, along runway 06/24, is

the domestic terminal currently serving operations of Bellview Airlines and IRS Airlines. Facilities include a newsstand and small bar (Wikipedia online version, 2009).

### 3.2.2.4 Climate

Kano is located at 481 metres (about 1580 feet) above sea level. The region features savannah vegetation and a hot, semi-arid climate of the ‘‘AW’’ Koppen’s classification. Kano receives on average about 873 mm of precipitation per year, the bulk of which falls from June through September. Kano is typically very hot throughout the year, though from December through February, the city is noticeably cooler. Nighttime temperatures are cool during the months of December, January and February, with average low temperatures ranging from 11°-14°C (Wikipedia online version, 2009). The area is one of the most fragile ecosystems in Nigeria because of the frequent drought and unreliable rainfall regimes. The agriculture is described as complex, diverse and risk-prone. It is the area worst heated by desertification and land degradation (Nabegu, 2009). The climate is determined by the movement of two air masses, a moist rather cool southerly mass known as south-westerlies and a hot and dry northern air called the north-easterlies. The moist southern air forms a wedge under the lighter dry air and the region where the two air masses meet is primarily an area of pronounced moisture gradient. The humidity gradient is called the intertropical discontinuity (ITD). The annual motion of the ITD is northwards between February and August and southwards between September and January. The north-south movement of the ITD influences weather pattern (Ahmed, 2011).

### 3.2.2.5 Vegetation

The natural vegetation of this area is the Sudan type composed of a variety of trees scattered over an expanse of grassland. Trees with broad canopies usually taller than twenty metres (20m) are

common (the baobab tree features). The locust bean tree and Shea butter tree are very common and the acacias of varied species. However, it is noted that most of these trees have paved way to open cropping lands, thus creating an extensive open space devoid of large trees. Many of the original species have completely disappeared, while others occur at distances apart. This is attributed to the fact that the people are mostly cultivators and besides, the construction work in the area requires the clearing of trees (Jerome, 1999).

### 3.2.2.6 Geology

There are three major rock formations namely the basement complex rocks comprising of crystalline igneous and metamorphic rocks dating back to the Precambrian age (4,500 million years). Younger granite rocks were intruded later in the Jurassic (180 million years). The youngest formation is the Chad sediment deposited from the quaternary (0.01 to 2 million years) including recent deposits. Rocks of the basement complex underline over 70% of the Kano environment. The rock types in the area are older granites, meta-sediments and older basement. The older basement is composed of migmatite, biotite gnciss, and blanded gneiss. Migmalite is composite gneiss produced by injection of granite magma into schist host. Gneiss is metamorphosed granite and is granitic in composition while biotite gneiss is a foliated crystalline rock with high biotite content. Banded gneiss has light and dark bands with a light fraction of quartz while the dark fraction or band consists of biotite, plagioclase and quartz minerals. The ancient meta-sedimentary rocks result from the weak metamorphism of sedimentary rock. Rock types include Phyllite which is derived from metamorphism of clayey sediments. It is intermediate in metamorphism between slate and schist. Quartzite meta-sediments results from cementation or fussion of quartz grains of sandstone. Older granites are commonly biotite granite and granordiorite. Biotite granite is an acid igneous rock with high content of biotite mineral

while a granordiorite has a composition which is intermediate between a diorite (an intermediate igneous rock) and granite. Joints and fractures in the Basement complex rocks are better developed in the granites and quartzites and less in the gneisses, and migmatites, Joints rarely extend to depths greater than 90 metres (Ahmed, 2011).

Occurrence of Younger Granite corresponds to basement joints and fracture system. The systems guided volcanic eruptions and the granite intruded as high level magma chambers beneath volcanic centers. It is for this reason that the younger granite ring-complex structure formed. Large quantities of volcanic rhyolite lava are still preserved in southern part of Kano state. Rhyolite has the same mineral composition as granite (quartz, feldspar, and mica) but it has minute crystals due to rapid cooling of magma. Besides rhyollite extrusive there are also intrusions of granite-porphyry and biotite granite. The intrusions form the ring-complex and are more resistant to erosion than most of the rocks of the basement complex. This is the reason they form a series of hill massifs rising over 1000 meters above sea level. The younger granites have low magnesium content and this facilitated the crystallization of iron bearing minerals such as fayalite and olivine, hedenbergite as pyroxene and riebeckite and amphibole. Cassiterite or tin is abundant and associated with the biotite-granite. Erosion concentrated the tin in colluvial deposits to provide sources for the tin mining industry. The younger granites are strongly jointed arising from regional compression with the stress producing fractures which break outcrops into blocks. These vertical or near vertical joints are usually independent of the local intrusive structure.

The Chad sediments rocks are freshwater sediments of lacustive and fluviatile clays, sandy clays and silts with beds and lenses of sand and gravel at various levels. These are overlain by more

recent sand drift and alluvium. Chad sediments are found in the northeast where unconsolidated aelolian sand form a drift plain. The alluvial sediment is related to the channel of the Rivers Hadejia, Jakara, Thomas and Gari. In the former causes of these rivers the ancient alluvium is almost overlain by drift material while recent alluvium occurs along the existing water causes (Ahmed, 2011).

**3.2.2.7 Soils**

The soils of Kano region are mainly formed by two parent materials: weathered rock debris and sandy drift, which give rise in different conditions to two distinct types of soil. Seasonally flooded valley floors are normally associated with grey soils of partly alluvial origin, possessing a relatively high clay fraction and a fine grain structure. Such lowland or fadama soils are distinct from those occurring on the interfluves and less eroded valley sides which may be described in general terms as brown and orange loose sands with a small proportion of fine grain silt. Amongst these upland soils, the principal variable is the depth of the lateritic horizon, which gives rise to a red lateritic soil where it is closest to the surface and least obscured by the drift. With increasing depth of this horizon, progressively lighter soils occurs, culminating in a light brown sandy soil where it is either completely obscured or non-existent.

Soil erosion is most serious along valley sides where the steepest slopes occur, gullies frequently working back from the river banks and along footpaths and cultivated furrows aligned at right angle to the banks. This sandy nature of the drift cover facilitates erosion, not only by easing the removal of the soil by surface run-off, but also in providing a minimum of resistance to under cutting of stream banks. This has accelerated along certain rivers by the removal of sand from the bed for construction purposes. These soils have however been modified, altered and far from possessing their natural characteristics, through construction, continuous tillage, condition of

household refuse and other activities. These practices have changed the profile, texture, structure and chemical properties original to these soils (Jerome, 1999).

### 3.2.2.8 Drainage

There is considerable relation between geology and drainage pattern with the highest network of rivers in the basement complex area. The small areas of Chad Sediments in Danbatta and Gaya Local Government Areas have groundwater potential with limited channel development. The drainage systems are the rivers Kano, Challawa, Iggi and Gaya in the South while Rivers Gari, Thomas, and Jakara are located in the north. These rivers are dammed to store water in surface reservoirs for multi-purpose use including irrigation, domestic supply, fisheries and recreation. Irrigation development is well advanced along the Rivers Gari, Thomas, Jakara and Kano. Groundwater potential is higher in the limited areas of sedimentary rock and it occurs in perched aquifers as well as in confined and semi confined aquifers. The potential is low in the basement complex area and the success ratio of boreholes is lower because of the limited depth of regolith, its clay content, and the localized occurrences of factures and joints. However, the basement area has higher surface runoff potential. The streams are seasonal and have flash flows with flow rising and falling in response to rainfall occurrences. The high flash flows exceeded 10% of the times are recorded mainly in July and August in response to rainfall events of 30mm or more. Such heavy rainfall storms are capable of generating high flash flows even at the beginning of the hydrological year (Ahmed. 2011).

### 3.2.2.9 People and Human Activities

The area known as Kano state was created in July 1967 out of the defunct Northern region. The area had and still has a location advantage as the centre of commerce and terminus of trade with some African regions as well as the Arab world. Despite changes in the administrative structure

and size of the Kano State due to the creation of Jigawa State out of it in 1991, the importance of Kano as commercial center has not been eroded. There is still a concentration of middle men and agents in the famous Kurmi, Kwari and Muhammed Abubakar Rimi (Sabongari) markets who distribute finished goods of manufactured in different parts of Nigeria and the rest of the world. Apart from its striving commerce, Kano economy consist of a booming agricultural sector established since the groundnut Pyramids or the colonial era, and an industrial sector that is yet to regain its status since it was destroyed by the effects or SAP in the late 1980's and early 1990's. According to the 1991 census figures, Kano state is the second largest state in Nigeria in terms of population. The population was then put at 5,633,040 people with the growth rate of 2.8%. The state is predominantly peopled by the Hausa-Fulani ethnic groups. Other ethnic groups include Nupe, Kanuri, Yoruba, Igbo Tir, Idoma and Igala. There are also foreigners from neighboring African nations. Like Niger Republic, Ghana and Cameroon, a sizeable number of Sudanese, Lebanese and Turkish people. The teeming population of Kano drives the economy as it provides readily available cheap labor and a ready market for most of the produced goods (Sani and Suleiman, 2011).

### 3.3 Methodology

#### 3.3.1 Types of Data used

In order to achieve the stated aim and objectives of this study, the following data were collected:

i. Hourly records of wind speed (WNSPD) for two locations (WNSPD-09 and WNSPD-15) each for Abuja and Kano Airports from 1986-2005

ii. Daily records of low horizontal visibilities due to weather for the selected months of November, December, January, February and March (months of high visibility

occurrence) each year for Abuja and Kano Airports in the range of 0-99, 100-199, 200-388 and 300-999 from 1986-2005

iii. Hourly amount of cloud cover for Kano and Abuja airports from 1986-2005

iv. Total number of air crashes in Nigeria from 1986-2005

These four types of data were used to compute trends of the weather parameters, air crashes and casualties in Nigeria, relationships between the weather parameters and air crash, significance of the relationship and determination of the most critical of the three weather parameters to flight operations.

### 3.3.2 Source of Data used

Data for this study was collected from secondary sources. The data on weather parameters (wind, cloud cover and visibility) were collected from the Nigerian Meteorological Agency (NIMET) Headquarters in Abuja, and traffic data (plane crash) from authorized published secondary material; a Conference Proceedings on Climatic Change and the Nigerian Environment, of the Department of Geography, University of Nigeria Nsukka (Anyadike, Madu and Ajaero, 2010). The online materials were from both Kano-History of Aircraft Accidents and Nigerian Elites Forum-Brief History of Air Disaster/Crashes in Nigeria (Kano Online, 2002 and Kano, 2009).

### 3.3.3 Data Analysis

Descriptive, relationships and significance in correlation statistical methods were applied for both analyses and presentation of the data using Microsoft excel statistical package. The descriptive methods include the mean ($\bar{x}$), standard deviation (б) and co-variance. The relationship method includes Product moment correlation coefficient or Pearson correlation coefficient (r), and the significance in correlation methods includes the students' `t' test and `r'

values. The measures of average deviations (mean and standard deviation) are both necessary for a complete description of the data set to present an overall picture in one measure of both the average and the deviation. Co-variance was calculated to see if the two data sets under correlation were related or not. In this case, weather parameters were the independent variables (x) while traffic data the dependent variables (y). Comparison between the two variables leads to an inference of cause and effect. Co-variance was used to calculate the mean value of each data set and then measured the deviation of each away from the mean of each set. This is to measure the extents to which the data sets co-vary in terms of their mean values and their deviations. Where the relationship between the data sets, x and y is in the same direction, co-variance is positive (+). Where it is in the opposite direction, co-variance is negative (-) or inverse. Relationship in the same direction (+) mean increase in y is associated with increase in x and relationship in the opposite direction (-) or inverse mean when y decreases, x increases. Product moment correlation coefficient or Pearson correlation coefficient (r) indicates the extent of correlation of data sets, x and y. This is done by calculating the co-variance of the two data sets together and at the same time; and standard deviation, which measured the deviations irrespective of the other. If the values of the two measures are the same when compared, it means the correlation is high, and vice versa. The value of `r' will occur in the range of +1 or -1. The sign positive or negative indicates whether the relationship is in the same direction or in an inverse direction (Toyne & Newby, 1976).

The following critical values by Toyne and Newby (1976), Akuezuilo, and Agu (2002) were taken to evaluate the different degrees of correlation:

Values of ± 0.70 – 1.00 shows a high degree of relationship

± 0.40 – 0.70 shows a substantial (moderate) relationship

± 0.20 – 0.40 shows a low degree of correlation

± < 0.20 shows a negligible relationship

The students' `t' test, is a test for the significance of the correlation coefficient (r).The `t' value is read off against the ``degrees of freedom'' to ascertain the level of percentage probability of the correlation occurring by chance. At 99.9% probability, it shows the correlation is a significant one because it means there is only one chance in 1000 that the correlation would have occurred by chance. So correlation is described as highly significant (Toyne & Newby, 1976). The same `t' value will show the weather parameter most critical to flight operations.

# CHAPTER FOUR: RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter consists of data analysis, results and discussion of the results obtained.

## 4.2 Tends

This section revealed the trends of weather parameters and the related air crash for the period under review (1986-2005). The annual mean wind speed, annual average cases of disruptions by month of horizontal visibility, annual totals cloud cover amount (Tables 4.4 and 4.5) and annual totals of air crashes (Table 4.3) were computed and used to determine trends represented by the graphs in figures 4.1 to 4.10 below.

### 4.2.1 Trends of Weather Parameters

Figures 4.1and 4.2 show the linear relationship trends of average wind speed for Kano and Abuja airports at two wind speed locations (WNSPD-09 and WNSPD-15). The straight lines (regression line) show the average trends of the relationship. In Figure 4.1below, the regression line is described by y=0.0253x + 10.979 for location 09, and y=0.0256x + 7.6458 for location 15. Location 09 shows a steadily increase of wind speed from 11 knots to 11.2 knots, and location 15 from 7.6 knots to 8.2 knots in Kano over the years, because of the stability of weather parameters in Kano.

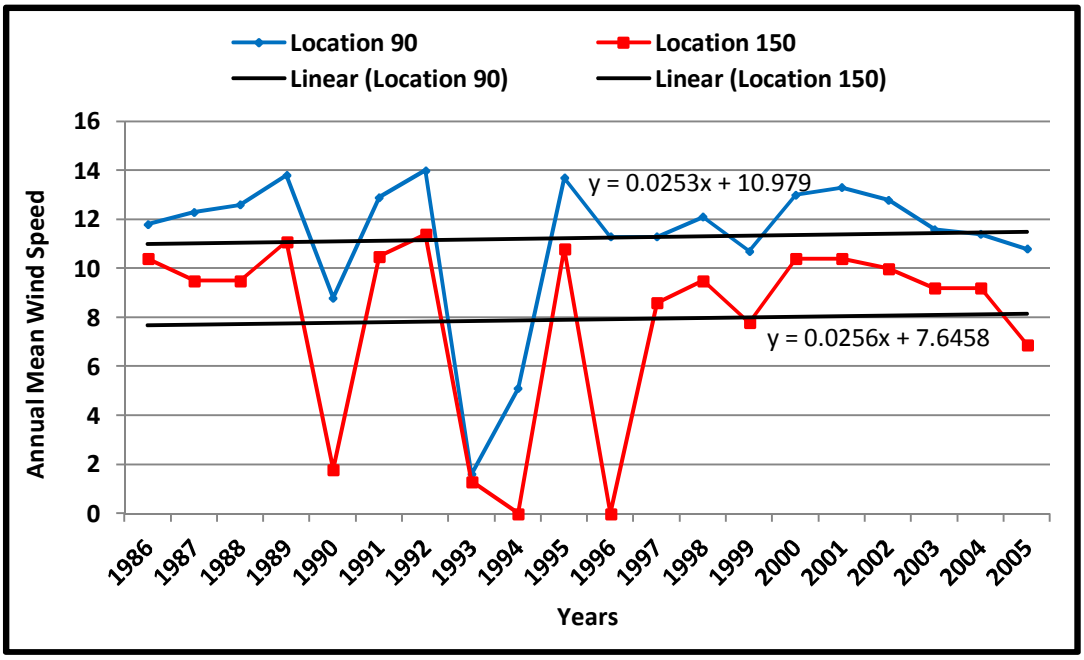



**Figure 4.1: Annual Mean Wind Speed for Kano Airport (Location WNSPD-09 and WNSPD-15) from 1986-2005**

***Source: Data Analysis, 2011***

In Figure 4.2 below, the regression line is described by y=0.0898x + 5.2774 for location 09, and y=0.1656x + 3.3158 for location 15. Location 09 shows a steadily increasing rate of wind speed from 3.3 knots to 6.6 knots, and location 15 from 5.3 knots to 7.1 knots in Abuja over the years. The Abuja station shows higher wind speed compared to Kano Station, because of high instability of the weather parameters over Abuja.

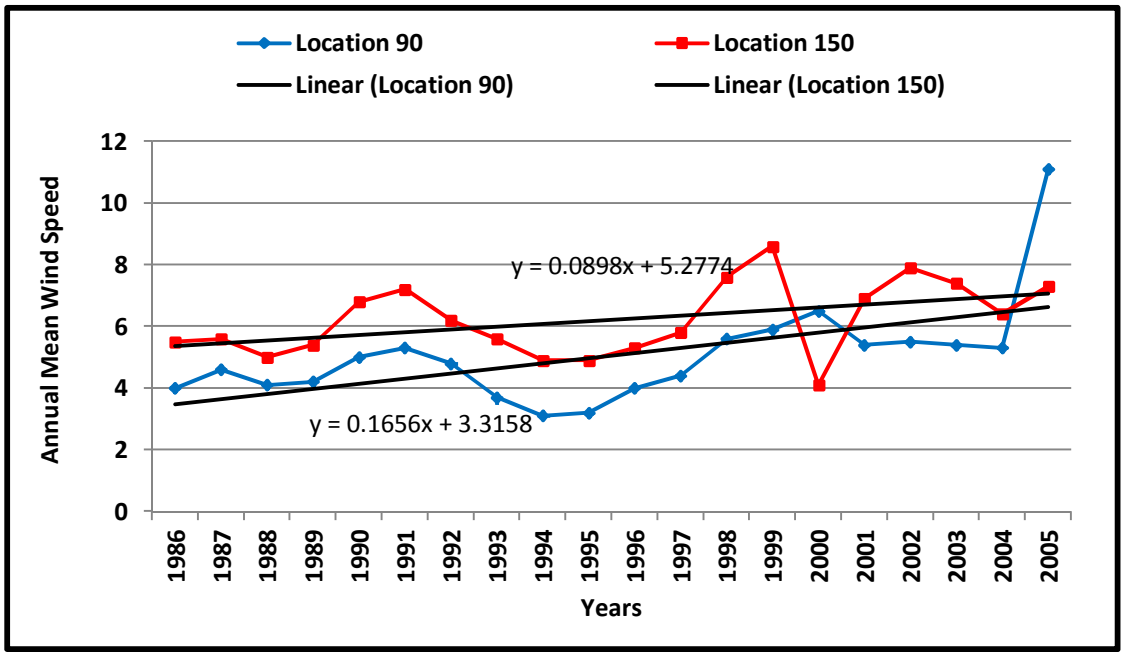



**Figure 4.2: Annual Mean Wind Speed for Abuja Airport (Locations WNSPD-09 and WNSPD-15) from 1986-2005**

***Source: Data Analysis, 2011***

Figure 4.3 shows trends of flight disruptions due to horizontal visibility caused by dust haze over Kano airport. The month of January shows high peak of disruptions over the years with over 300 cases of disruption. The month of March recorded the least cases of disruption, slightly above 100 cases. In Abuja airport the month of January recorded the highest cases of disruption of above 100 and the month of November is least with just 10 cases of disruption. (See figure 4.4). From the data used for this work, both airports show that visibility range of 300-999m, which is the highest visibility range has the highest frequencies of disruptions due to weather condition with larger disruptions in Kano airport. The reason for the substantial level of disruptions is that the airports visibility minima are 750m respectively, which is below the highest range of 999m.

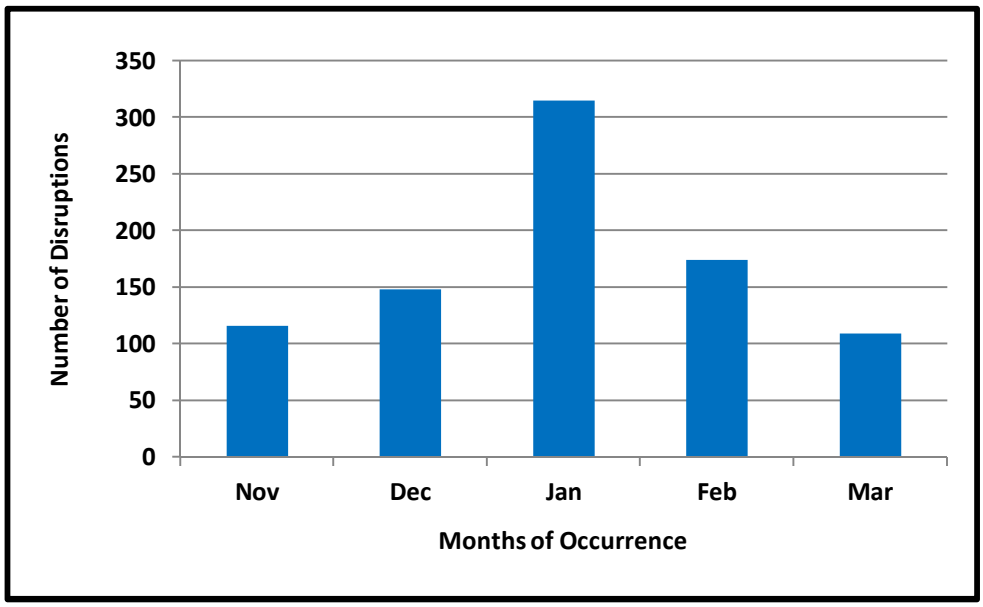



**Figure 4.3: Annual Average Cases of Disruptions by Month of Horizontal Visibility for Kano Airport (1986-2005)**

***Source: Data Analysis, 2011***

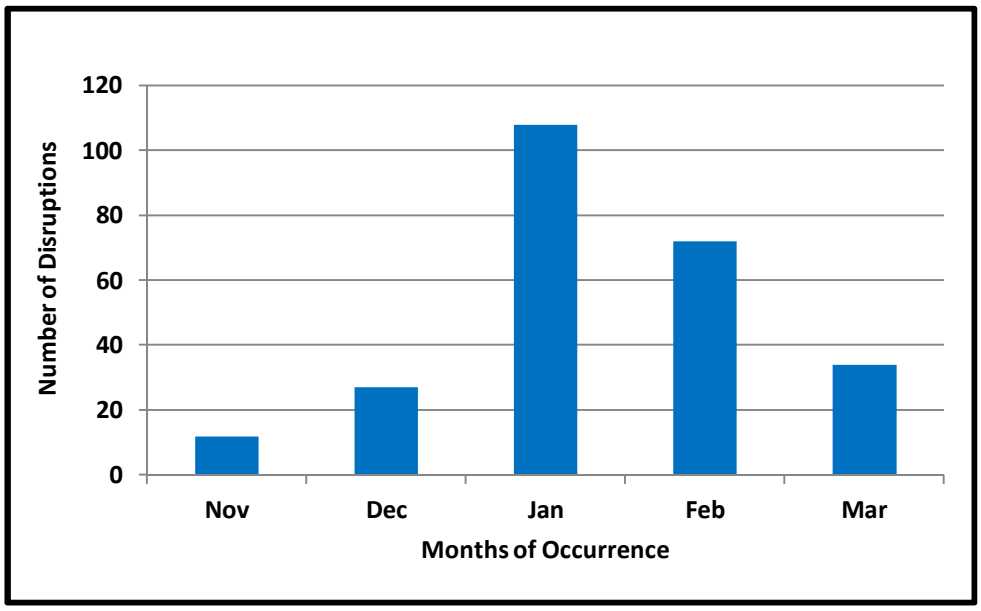



**Figure 4.4: Annual Average Cases of Disruptions by Month of Horizontal Visibility for Abuja Airport (1986-2005)**

***Source: Data Analysis, 2011***

The amount of cloud (high, medium or low) generally accepted as 7 oktas all over Nigeria shows steady uniform increase trends in Kano and Abuja airports over the years. See figures 4.5 and 4.6.

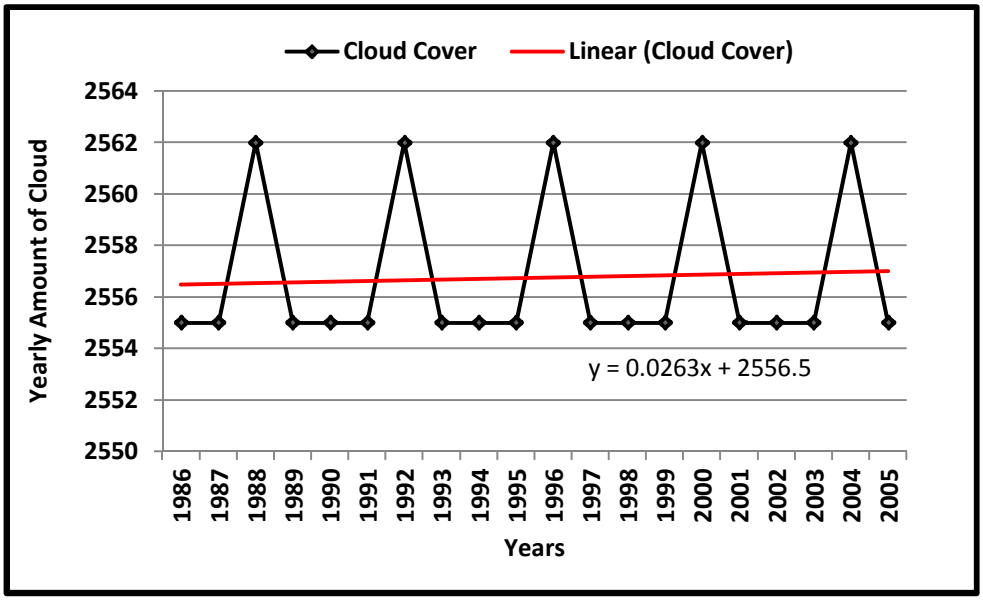



**Figure 4.5: Annual Totals Amount of Cloud Cover for Kano Airport (1986-2005)**

***Source: Data Analysis, 2011***

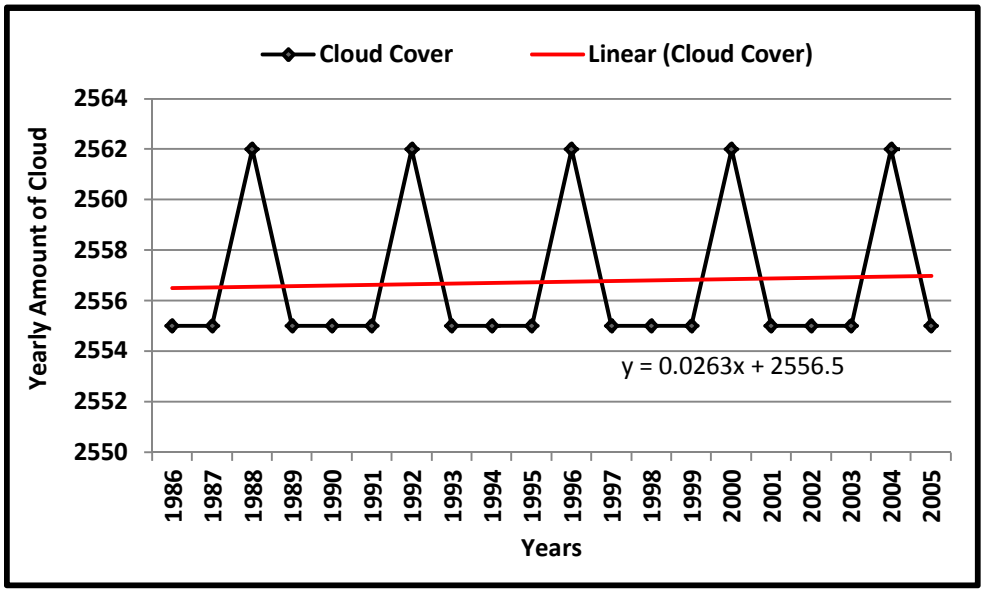



**Figure 4.6: Annual Totals Amount of Cloud Cover for Abuja Airport (1986-2005)**
***Source: Data Analysis, 2011.***

The regression lines of the annual totals amount of cloud in both Kano and Abuja airports (Figures 4.5 and 4.6) are described by y=0.0263x + 2556.5. The trends show slight increase of annual totals amount of cloud from 2556.6in 1986 to 2557 in 2005.

### 4.2.2 Trends of Weather-related Aircraft Fatal Accidents

The trends of weather-related aircraft fatal accidents are presented in figures 4.7 to 4.10. In figure 4.7 below the regression line is described by y=0.2707x + 0.4579. The trend shows high increase number of air crashes from about 01 in 1986 to about 06 in 2005 in Nigeria. The air crashes casualties regression line described by y=2.1271x + 46.316 in figure 4.8 below shows increase number of casualties from about 50 to about 100 from 1986-2005 in Nigeria.

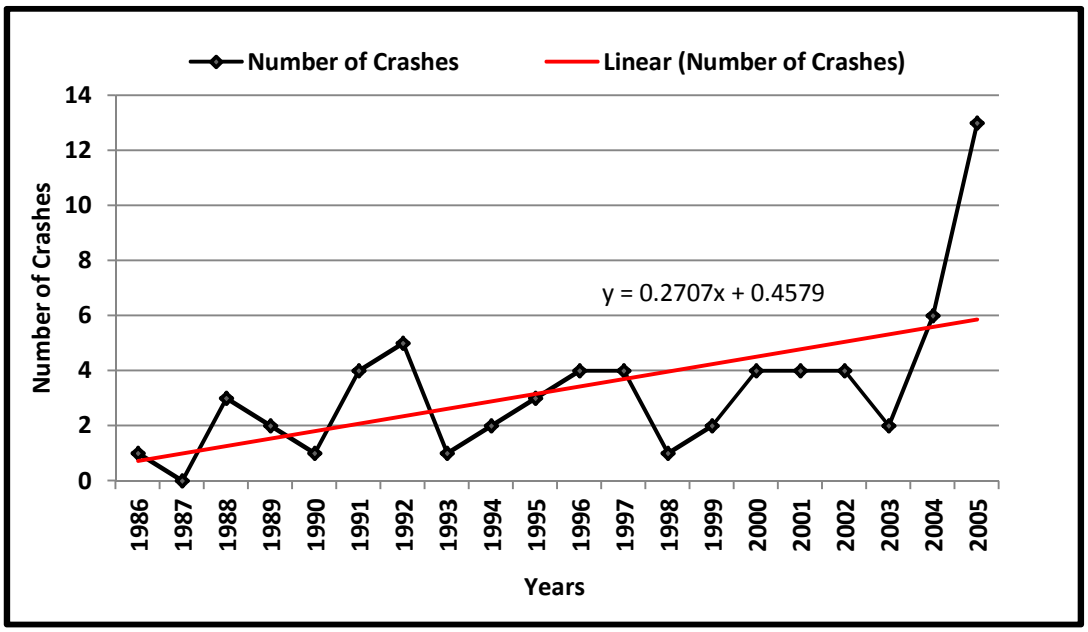



**Figure 4.7: Air Crashes in Nigeria Associated with Extreme Weather Events (1986-2005)**

***Source: Data Analysis, 2011***

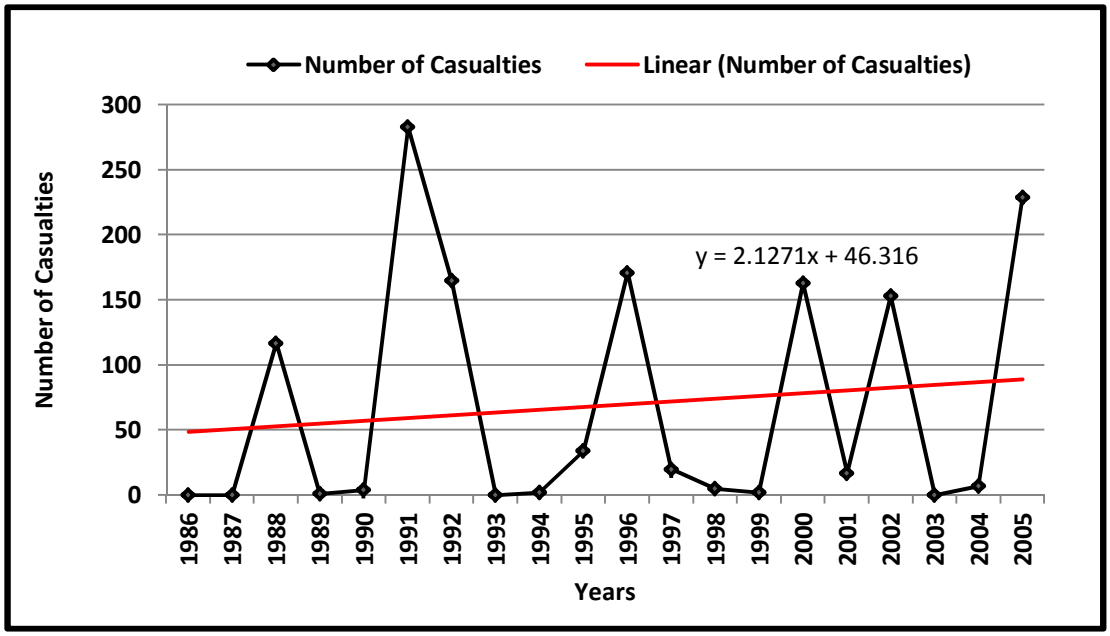



**Figure 4.8: Air Crashes Casualties in Nigeria Associated with Extreme Weather Events (1986-2005)**

***Source: Data Analysis, 2011***

The trends show that extreme weather condition in Nigeria is still on the increase and may have contributed to the increase in air crashes and casualties in Nigeria as indicated in figures 4.7 and 4.8.

Figure 4.9 below shows world fatal crashes associated with extreme weather events. The regression line is described by y= -3.0364 + 57, which indicate decrease in number of air fatal crashes from 57 in 1996 to 24 in 2005. The world crashes casualties (figure 4.10) is described by the regression line y= - 91.8x + 1528.8, which also indicate decrease in number of air crash casualties from 1,528 in 1996 to about 500 in 2005.

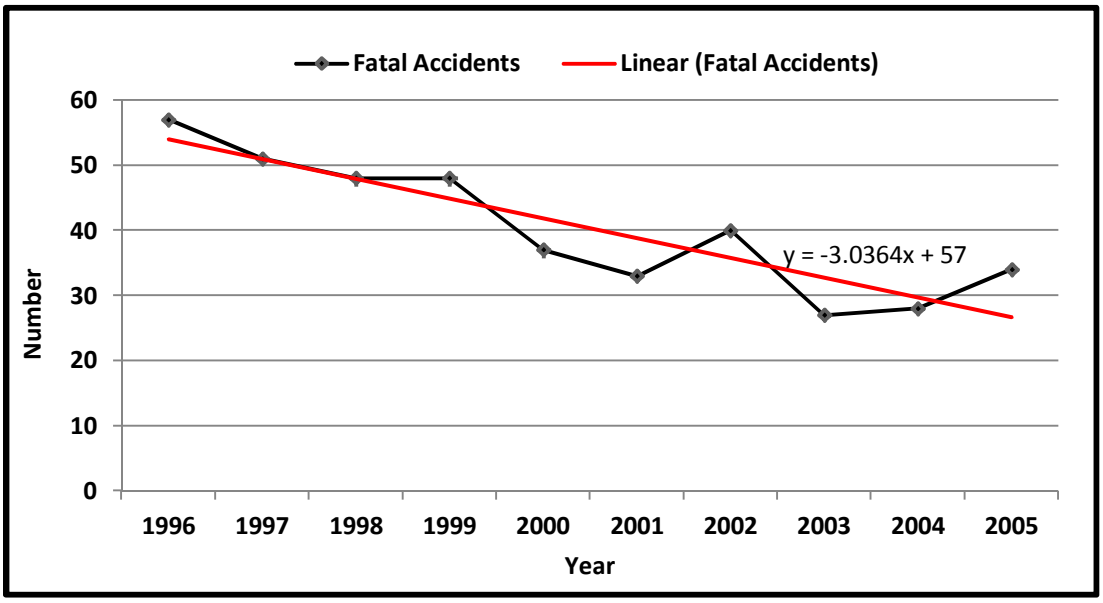



**Figure 4.9: World Air Fatal Crashes Associated with Extreme Weather Events (1986-2005)**

***Source: Data Analysis, 2011***

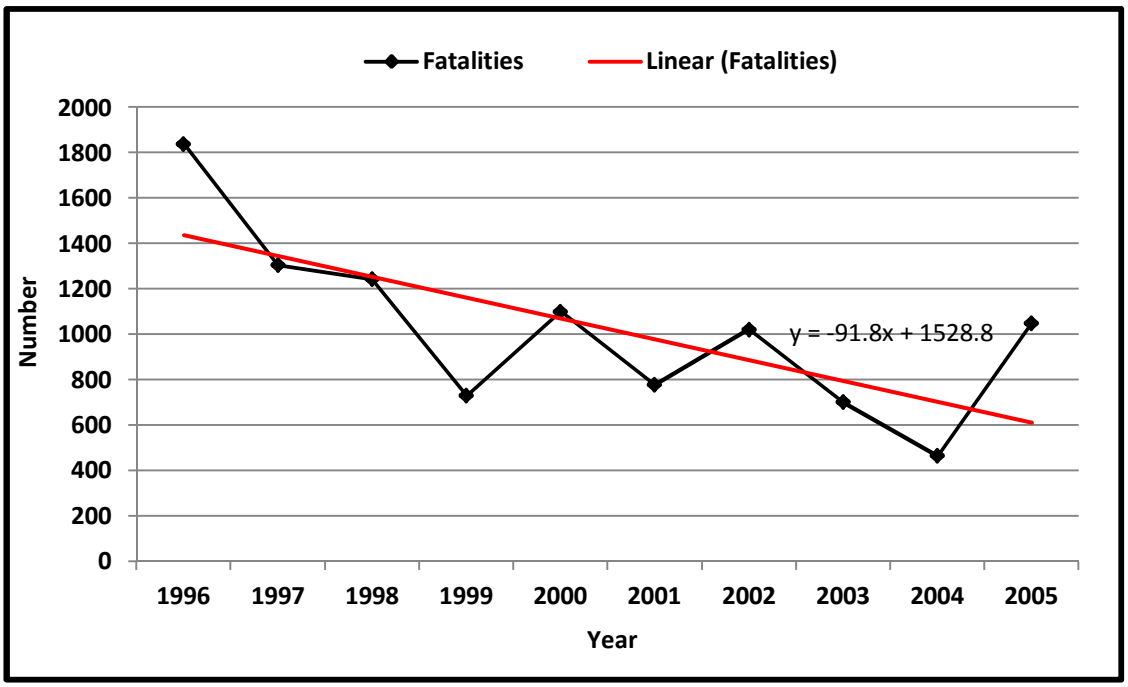



**Figure 4.10: World Air Crashes Casualties Associated with Extreme Weather Events (1986-2005)**

***Source: Data Analysis, 2011***

The period under review 1986-2005, shows that air crashes and casualties in Nigeria are generally on the increase over the period as shown in figures 4.7 and 4.8. In contrast, the world weather-related airline fatal accidents and fatalities are decreasing. The general decrease trends in the world number of crashes and casualties over the years is possibly due to improved knowledge of weather forecast, weather modification, introduction of new automation of aeronautical meteorological observation, sophisticated infrastructural facilities at airports, radio aids and navigational techniques. These find relevance in the works of Ranter (2003) and Joseph (2005), who reported that Europe, North America, South America, and Central America recorded a steadily decreasing accident rate in a moving 10-year average trend over eleven years (1992-2002). While Africa still remain the most unsafe continent with nearly 27% of all fatal airliner accidents, while she only accounted for approximately 3 percent of all world aircraft departures, and that Nigeria occupies position 21on the list of world's 25 most dangerous skies with 33 numbers of accidents and 1,070 fatalities from 1945-2005.Table 2.6 shows this increase trend of fatal airliner accidents in Africa against decrease in other continents of the world.

### 4.3 Weather Parameters

The hourly records of wind, monthly records of horizontal visibility, daily records of cloud cover and total number of air crashes were computed to obtain annual totals from 1986-2005. See tables 4.1, 4.2 and 4.3. Kano airport statistics shows that wind speed at location 09 is higher than at location 15 and flight disruption shows peak in the month of January than the rest of the months (Table 4.1). The situation is quite similar in Abuja airport to the one in Kano airport except that location 15 shows high wind speed than location 09and the figures are larger in Kano than Abuja (Table 4.2). Cloud situation is the same over the two Airports.

**Table 4.1: Annual Totals of Climatic Parameters for Kano Airport (1986-2005)**

| Year | Wind Speed (kt) 09 | 15 | Visibility (m) Nov | Dec | Jan | Feb | Mar | Cloud Cover (oks) |
|---|---|---|---|---|---|---|---|---|
| 1986 | 4301 | 3812 | 8 | 31 | 9 | 1 | 4 | 2555 |
| 1987 | 4494 | 3467 | 0 | 4 | 13 | 9 | 10 | 2555 |
| 1988 | 4620 | 3489 | 0 | 14 | 15 | 5 | 10 | 2562 |
| 1989 | 5032 | 4042 | 3 | 2 | 27 | 20 | 2 | 2555 |
| 1990 | 3201 | 666 | | | 23 | 3 | 5 | 2555 |
| 1991 | 4726 | 3833 | 4 | 5 | 10 | 1 | 2 | 2555 |
| 1992 | 5123 | 4171 | 24 | 5 | 38 | 11 | 1 | 2562 |
| 1993 | 591 | 486 | | | 17 | | | 2555 |
| 1994 | 1860 | 0 | 10 | 23 | | | | 2555 |
| 1995 | 5001 | 3931 | 13 | | 15 | | | 2555 |
| 1996 | 4123 | 0 | 3 | | 1 | 8 | | 2562 |
| 1997 | 4117 | 3123 | 4 | 4 | 13 | 33 | 26 | 2555 |
| 1998 | 4426 | 3461 | 10 | 16 | 17 | 16 | 16 | 2555 |
| 1999 | 3915 | 2841 | 22 | 21 | | | | 2555 |
| 2000 | 4772 | 3791 | 1 | 1 | 19 | 16 | 1 | 2562 |
| 2001 | 4841 | 3798 | 1 | 1 | 6 | 25 | 1 | 2555 |
| 2002 | 4686 | 3632 | | 3 | 37 | 4 | 8 | 2555 |
| 2003 | 4250 | 3367 | | 13 | 6 | 3 | 8 | 2555 |
| 2004 | 4170 | 3355 | 10 | 4 | 10 | 15 | 15 | 2562 |
| 2005 | 3956 | 2508 | 3 | 1 | 39 | 4 | | 2555 |
| **TOTAL** | **82205** | **57773** | **116** | **148** | **315** | **174** | **109** | **51135** |

***Source: Data Analysis, 2011***

**Table 4.2: Annual Totals of Climatic Parameters for Abuja Airport (1986-2005)**

| | Wind Speed (kt) | | Visibility (m) | | | | | Cloud Cover |
|---|---|---|---|---|---|---|---|---|
| **Year** | **09** | **15** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **(oks)** |
| 1986 | 1456 | 2021 | | 13 | 4 | | | 2555 |
| 1987 | 1668 | 2040 | 0 | | 16 | 2 | 1 | 2555 |
| 1988 | 1513 | 1822 | 11 | | 10 | | 6 | 2562 |
| 1989 | 1522 | 1988 | | | 9 | 3 | | 2555 |
| 1990 | 1825 | 2477 | | 1 | 20 | | | 2555 |
| 1991 | 1930 | 2611 | | | 13 | 1 | 2 | 2555 |
| 1992 | 1763 | 2262 | | | 7 | 3 | 1 | 2562 |
| 1993 | 1368 | 2041 | | | 2 | | 2 | 2555 |
| 1994 | 1125 | 1801 | | 3 | | 31 | | 2555 |
| 1995 | 1180 | 1779 | | | 1 | | | 2555 |
| 1996 | 1451 | 1922 | | | | | | 2562 |
| 1997 | 1616 | 2107 | | | 7 | 10 | 6 | 2555 |
| 1998 | 2041 | 2758 | | 6 | 8 | 1 | 4 | 2555 |
| 1999 | 2141 | 3146 | 1 | 4 | | | | 2555 |
| 2000 | 2366 | 1501 | | | 1 | 3 | 1 | 2562 |
| 2001 | 1966 | 2536 | | | | 6 | 1 | 2555 |
| 2002 | 2020 | 2898 | | | | 6 | 1 | 2555 |
| 2003 | 1974 | 2686 | | | | | 3 | 2555 |
| 2004 | 1934 | 2329 | | | 10 | | 6 | 2562 |
| 2005 | 2047 | 2650 | | | | 6 | | 2555 |
| **Total** | **34906** | **45375** | **12** | **27** | **108** | **72** | **34** | **51135** |

***Source: Data Analysis, 2011***

**Table 4.3: Annual Totals of Air crashes and Casualties in Nigeria (1986-2005)**

| Years | Number of Crashes | Number of Casualties |
|---|---|---|
| 1986 | 1 | Nil |
| 1987 | NA | NA |
| 1988 | 3 | 117 |
| 1989 | 2 | 1 |
| 1990 | 1 | 4 |
| 1991 | 4 | 283 |
| 1992 | 5 | 165 |
| 1993 | 1 | Nil |
| 1994 | 2 | 2 |
| 1995 | 3 | 34 |
| 1996 | 4 | 171 |
| 1997 | 4 | 20 |
| 1998 | 1 | 5 |
| 1999 | 2 | 2 |
| 2000 | 4 | 163 |
| 2001 | 4 | 17 |
| 2002 | 4 | 153 |
| 2003 | 2 | NA |
| 2004 | 6 | 7 |
| 2005 | 13 | 229 |
| **Total** | **66** | **1373** |

***NA-not available, Nil-no casualty**

***Source: Data Analysis, 2011***

The total air crashes and casualties in twenty years (1986-2005) are 66 and 1,373 respectively. These doubled the figures earlier reported by Joseph (2005) that in sixty years (1945-2005) there were 33 numbers of accidents, which resulted to 1,070 fatalities over Nigeria, although the report excluded military accidents, corporate jets, hijackings and other criminal occurrences. However,

the figures are still on the high side. The annual totals of the air crashes show high figures in 2004 and 2005 and least in 1986. The casualties show high figures in 1991 and 2005 and least in 1989 (Table 4.3).

A close observation of the annual average wind speed and annual average cases of disruptions due to horizontal visibility by dust haze shows high inclement weather over Kano airport than Abuja airport (Tables 4.4 and 4.5).

**Table 4.4: Annual Mean Wind Speed (1986-2005)**

| | Kano Airport | | Abuja Airport | |
|---|---|---|---|---|
| **Year** | **Location 09** | **Location 15** | **Location 09** | **Location 15** |
| 1986 | 11.8 | 10.0 | 4.0 | 5.5 |
| 1987 | 12.3 | 9.5 | 4.6 | 5.6 |
| 1988 | 12.6 | 9.5 | 4.1 | 5.0 |
| 1989 | 13.8 | 11.1 | 4.2 | 5.4 |
| 1990 | 8.8 | 1.8 | 5.0 | 6.8 |
| 1991 | 12.9 | 10.5 | 5.3 | 7.2 |
| 1992 | 14.0 | 11.4 | 4.8 | 6.2 |
| 1993 | 1.6 | 1.3 | 3.7 | 5.6 |
| 1994 | 5.1 | 0.0 | 3.1 | 4.9 |
| 1995 | 13.7 | 10.8 | 3.2 | 4.9 |
| 1996 | 11.3 | 0.0 | 4.0 | 5.3 |
| 1997 | 11.3 | 8.6 | 4.4 | 5.8 |
| 1998 | 12.1 | 9.5 | 5.6 | 7.6 |
| 1999 | 10.7 | 7.8 | 5.9 | 8.6 |
| 2000 | 13.0 | 10.4 | 6.5 | 4.1 |
| 2001 | 13.3 | 10.4 | 5.4 | 6.9 |
| 2002 | 12.8 | 10.0 | 5.5 | 7.9 |
| 2003 | 11.6 | 9.2 | 5.4 | 7.1 |
| 2004 | 11.4 | 9.2 | 5.3 | 6.4 |
| 2005 | 10.8 | 6.9 | 11.1 | 7.3 |

***Source: Data Analysis, 2011***

**Table 4.5: Annual Average Cases of Disruptions by Month of Horizontal Visibility (1986-2005)**

| Month | Kano Airport | Abuja Airport |
|---|---|---|
| November | 116 | 12 |
| December | 148 | 27 |
| January | 315 | 108 |
| February | 174 | 72 |
| March | 109 | 34 |

***Source: Data Analysis, 2011***

### 4.4 Result of the analysis

In order to determine the statistical relationship between weather parameters and air crash co-variance was computed. Product moment correlation coefficient (r) computed to determine the extent of the correlation through multiple regression analysis was taken at 99% confidence level. To ascertain the level of percentage probability of the correlation occurring by chance (significance of the correlation) the `Students' `t' test' was computed. The `t' value indicates the probability level of the correlation and the weather parameter critical to flight operations. Results of data analysis are presented in Tables 4.6 to 4.10.

### 4.4.1 Relationship between Weather Parameters and Air Crash

From Table 4.6, it is clear that there is statistical relationship between weather parameters and flight operations (air crash).The weather parameters show positive relationships with air crash, except horizontal visibility over Abuja airport that shows inverse relationship. The positive relationships mean increase in the weather parameters is associated with increase in air crash. While the negative relationships mean decrease in visibility is associated with increase, in air crash. Wind shows higher relationship followed by cloud cover, and visibility is least in Kano airport. While cloud cover shows higher relationship followed by wind, and visibility is least

(below average) in Abuja airport. This answers the second research question that seeks to know the relationship between weather and flight operations.

**Table 4.6: Relationship of Weather Parameters and Air Crash**

| Co-variance | Wind | Visibility | Cloud Cover |
|---|---|---|---|
| **Kano Airport** | 2.37 | 1.50 | 2.05 |
| **Abuja Airport** | 1.96 | -0.65 | 2.05 |

***Source: Data Analysis, 2011***

### 4.4.2 Extent or Degree of Relationship

The correlation coefficient for the two airports shows that weather parameters exhibit positive relationship, meaning increase in weather is associated with increase in air crash, however the degree of the relationship is not significant. In Kano airport, the correlation coefficient (r) of wind is 0.17, visibility is 0.15 and cloud cover is 0.23 (Table 4.7). Based on the critical values by Toyne and Newby (1976), Akuezuilo and Agu (2002), the degree of relationship between wind, visibility and air crash is negligible while cloud cover shows a low degree of relationship. This reveals that the degree or extent of the effect of these weather parameters on flight operations is insignificant. On the contrary, wind shows a substantial (moderate) degree of relationship of 0.60 with air crash while visibility and cloud cover shows low degree of relationships of 0.25 and 0.23 respectively in Abuja airport (Table 4.8). This reveals that only wind shows moderate effect on flight operations, while visibility and cloud cover shows insignificant effect on flight operations in Abuja airport. Based on this result, there is no significant relationship between weather and flight operations in Nigeria.

**Table 4.7: Correlation Metric of Weather Parameters and Air Crashes for Kano Airport**

| Parameters | Correlation Coefficient |
|---|---|
| **Wind** | 0.171082 |
| **Visibility** | 0.147684 |
| **Cloud Cover** | 0.234895 |

***correlation was taken at 99 % confidence level***

***Source: Data Analysis, 2011***

**Table 4.8: Correlation Metric of Weather Parameters and Air Crashes for Abuja Airport**

| Parameters | Correlation Coefficient |
|---|---|
| **Wind** | 0.602970 |
| **Visibility** | 0.245966 |
| **Cloud Cover** | 0.234898 |

***correlation was taken at 99 % confidence level***

***Source: Data Analysis, 2011***

### 4.4.3 Significance of Correlation Coefficient (r)

The significance of the correlations is shown in Tables 4.9 and 4.10 for Kano and Abuja airports respectively. For Kano, the result shows that wind with t-value 0.73, the correlation is well within the 0.25% probability level, visibility with t-value 0.64, the correlation is also within 0.25% probability level and cloud with t-value 1.01, the correlation is within 0.1% probability level. This means that there are only one to two chances in 1000 that these correlations would have occurred by chance. Therefore, the correlations are 99.8% - 99.9% significantly high. The result for Abuja airport shows that wind with t-value 3.18, the correlation is well within the 0.0005% probability level, visibility with t-value1.09, the correlation is well within the 0.1%

probability level and cloud with t-value 1.01, the correlation is within 0.1% probability level. This means that there is only one chance in 1000 that these correlations would have occurred by chance in each case. Therefore, the correlations are 99.9 % significantly high.

**Table 4.9: Significance of Correlation Coefficient (r) for Kano Airport**

| Parameters | t-cal value | Significance Level |
|---|---|---|
| **Wind** | 0.73 | 0.25% |
| **Visibility** | 0.64 | 0.25% |
| **Cloud Cover** | 1.01 | 0.1 % |

***Significance level is one-tailed***

***Source: Data Analysis, 2011***

**Table 4.10: Significance of Correlation Coefficient (r) for Abuja Airport**

| Parameters | t-cal value | Significance Level |
|---|---|---|
| **Wind** | 3.18 | 0.0005% |
| **Visibility** | 1.09 | 0.1 % |
| **Cloud Cover** | 1.01 | 0.1 % |

***Significance level is one-tailed***

***Source: Data Analysis, 2011***

The t-value in Table 4.9 indicates cloud cover as the weather parameter most critical to air crash in Kano airport because it has the highest t-value and highly significant. While for Abuja airport, wind is the most critical weather parameter to air crash because of its highest t-value and significance (Table 4.10). This result of the multiple regression analysis shows that cloud and wind are the most critical weather parameters to flight operations in Kano and Abuja airports respectively. However, the degree of the effects is generally low.

## 4.5 Discussion

This study sought to find the extent or degree of the effects of wind, horizontal visibility, and cloud cover on plane crash in Nigeria. Since aviators cry everyday that the weather is one of the major problems of flight operations responsible for the countless plane crashes in recent years believed to be the factor that placed Nigeria in position four (4) in the world with worst safety record in air traffic disaster. The result shows clear statistical relationship between the weather parameters and flight operations (Table 4.6), which accord well with relevant studies by Olagunju (1999), Lankfort (2001), NASDAC (2003), Abdulazeez and Mohammed (2009), Ehigiator (2009), NIMET (2011) and many others. However, the extent or degree of the relationship between the weather parameters and flight operations (plane crash) is insignificant, except wind that shows substantial degree of relationship in Abuja airport. The low and even the negligible degree of relationship between the weather parameters and air crash over Kano airport (Table 4.7) compared to Abuja airport (Table 4.8) is not surprising. This may be due to the stability of the weather parameters in Kano. Figures 4.1, 4.3 and 4.5 revealed steady annual increase of the weather parameters over the years. This confirmed the study by Jerome (1999) that there were no variations in climate parameters within Kano airport environment. Therefore, their effects on flight operations are minimal. For Abuja airport, only wind shows a moderate degree of relationship. This is due to the sharp annual increase of wind speed over the years (figure 4.2). Abdulazeez (2009) revealed high atmospheric pressure condition over Abuja airport, which connotes wind instability and consequently high wind speed.

The t-value in Tables 4.9 and 4.10 indicates that cloud cover and wind are the weather parameters most critical to flight operations in Kano and Abuja airports respectively. This implies that the two parameters are most threatening to flight operations in Kano and Abuja

airports. In the field, aviators, particularly the Traffic Controllers generally confessed that cloud cover no longer pose any problem to flight operations like wind and visibility. This might be due to the improved knowledge of weather forecast, weather modification, and introduction of new automation of aeronautical meteorological observation, sophisticated infrastructural facilities at airports, radio aids and navigational techniques. Therefore, the introduction of the earth weather equipment to ensure safety compliance of major airports in the country especially the Total Radar Coverage for Nigeria (TRACON) and the building of website for Nigerian Meteorological Agency (NIMET), to make it possible for travelers to check weather forecast before embarking on trips, reported by Olayinka (2009) is yielding positive results. What aviators need is more knowledge on the nature of wind and visibility.

The result of the relationship of these three weather parameters revealed by the study is not by chance, because the significance of the correlations is 99.9 %. This implies that the effects on causing air crash are insignificant, therefore, find relevance in the work of Bature (2002) that the natural factors causes only little inconveniences for aviation operations in Nigeria, because of responsive knowledgeable ways of dealing with the natural phenomena. The result of this study is unexpected because according to Mohammad (2009), weather contributes up to 30% of civil aviation accidents worldwide, either as a sole factor or among the causative factors, and the cry against weather by aviators was alarming. However, this achievement is owed to the responsive knowledgeable ways of weather modification in place now, which NIMET and other organizations in the aviation sector responsible for air safety have achieved with the help of the Federal Government of Nigeria. Therefore, flight operations could possibly be more affected by human, economic and mechanical factors as earlier reported by Gabriel (2005), Bature (2002), and others.

Dangana (2009) classified human factor in air accidents into Pilots, Passengers, Aircraft Engineers and Traffic Controllers. For example, air accident can occur if a pilot insists on landing against the air traffic control services instruction. In addition, air traffic controller who is either under the influence of alcohol or not attentive may issue conflicting information to pilots about landing. Air Passengers may carry materials or equipment that can cause fire or distort radio signals. He revealed that 70% of all air accidents in Nigerian airspace involved human factors.

### 4.6 Implication of the study

The results of this study have relevant implication that would be useful to the airport authorities and aviators that can be of help in mitigating the menace of air crash in Nigeria. These are:

i. Trend in weather revealed steady annual increase of the weather parameters over the years in Nigeria. This implies that their effects on flight operations is minimal or can be mitigated.

ii. Analysis in figures 4.9 and 4.10 show that the world trend of weather-related aircraft fatal accidents and casualties are decreasing and this could be because of improvement in weather forecast coupled with aircraft design and human factor training for cabin crew members. This would make people have confidence in foreign airlines. In contrast, in figures 4.7 and 4.8, the average number of crashes and casualties in Nigeria are on the increase of which could impact negatively on both the socio and economic condition of the country. The negative impact will be that people will loose confidence in air transport which will results to reduction in passenger movement and invariably reflect on the economy of the nation.

iii. The study revealed clear statistical relationship between weather parameters and flight operations (Table 4.6). However, the degree of relationship is insignificant, implying that weather is not the cause of air crash in Nigeria.

iv. The result also indicates that cloud cover and wind are the weather parameters most critical to flight operations in Kano and Abuja airports respectively (Tables 4.9 and 4.10). This implies that the two parameters are most threatening to flight operations in the two airports. However, they do no longer pose any problems base on the results of this study, and aviators, particularly the Traffic Controllers have confessed it. The improved knowledge of weather forecast, weather modification, and the introduction of the state of the art equipment for safety compliance of major airports in the country by the authorities concerned has yielded positive results.

v. The study revealed human, economic and mechanical factors such as conflicting weather reports to pilots, refusal to comply to air traffic controller's instructions by pilots, influence of alcohol, laisser faire attitude to aviation regulation, the bid to make more money, going along with equipment that can cause fire or distort radio signals in aircrafts, among others are the major problems of flight operations in Nigeria. Hence, the disciplinary measures on erring aviators and airlines, and the recommendations for maintenance culture, pilot's exposure to more training and refresher courses are right actions taken to mitigate these problems.

vi. Nigeria's plan of diversifying her economy from oil-dependent one to other sectors such as agriculture, tourism, solid minerals, information technology, among others is feasible only if the human, economic and mechanical factors are addressed.

vii. Base on the positive result because of the measures taken to contain weather factor, fear is done with. However, there is still need to mark the weather tied because of the present concept of climate change and its resultant effects, which African continent is predicted to be the hardest hit by the Intergovernmental Panel on Climate Change (IPCC). This can change the trend of atmospheric processes as weather can evolve at rapid rates over a wide spatial extent.

# CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATION

## 5.1 Introduction

This chapter consists of summary of results, conclusion and recommendation.

## 5.2 Summary of Results

This research work was carried out to assess the degree or extent of effects of wind, horizontal visibility and cloud cover on flight operations (air crash). The findings of the study are as follows:

To achieve the stated aim and objectives of this study, hourly records of wind speed, daily records of low horizontal visibility, hourly amount of cloud cover, for both Kano and Abuja airports, and total number of air crashes in Nigeria from 1986-2005 were computed. The annual mean wind speed, annual cases of disruptions by month of horizontal visibility, annual totals of cloud cover amount (Tables 4.4 and 4.5) and annual totals of air crashes (Table 4.3) were obtained from the computation and used to determine trends represented by the graphs in figures 4.1 to 4.10. Descriptive, relationships, and significance in correlation statistical methods were applied for both analysis and presentation of the data using Microsoft excel statistical package. Trends revealed that the weather parameters over Kano airport were stable and show steady increase over the years, while less stable over Abuja airport, and show higher increase over the years. It also revealed linear relationship of average wind speed for Kano and Abuja airports at two locations (WNSPD-09 and WNSPD-15). The straight lines (average trends) show a steadily increasing rate of wind speed in Nigeria over the years. It also show general increase trends of flight disruptions due to horizontal visibility caused by dust haze over Kano and Abuja airports. The month of January shows high peak of disruptions over the years. However, the month of March recorded a slight decrease below the rest of the months in Kano airport. The amount of

cloud (high, medium or low) generally accepted as 7 oktas all over Nigeria shows steady uniform increase trends in Kano and Abuja airports over the years.

The world weather-related airline fatal accidents and fatalities show general decrease trends in the number of crashes and casualties over the years. In contrast, air crashes and casualties in Nigeria are generally on the increase over the period. The study reveals that there is statistical relationship between weather parameters and flight operations (air crash). All the weather parameters show positive relationships with air crash, except horizontal visibility in Abuja airport that show inverse relationship. The positive relationships mean increase in the weather parameters is associated with increase in air crash. While the negative relationships mean decrease in visibility is associated with increase, in air crash. Wind shows higher relationship followed by cloud cover, and visibility is least in Kano airport. While cloud cover shows higher relationship followed by wind, and visibility is least (below average) in Abuja airport. However, the degree of the relationships are not significant based on the critical values by Toyne and Newby (1976), Akuezuilo and Agu (2002). Only wind shows a substantial (moderate) degree of relationship with air crash in Abuja airport.

The study also shows that significance of correlations is 99.8 % - 99.9 %, meaning that there is only one to two chances in 1000 that these correlations would have occurred by chance in each case. The multiple regression analysis shows cloud and wind to be the most critical weather parameters to flight operations in Kano and Abuja airports respectively. However, the degree of the effects is generally low.

## 5.3 Conclusion

Three weather parameters: hourly records of wind speed for two locations (WNSPD-09 and WNSPD-15), daily records of low horizontal visibility and daily amount of cloud cover for both Kano and Abuja Airports from 1986-2005 were collected from Nigerian Meteorological Agency (NIMET) Headquarters, Abuja, and total number of air crashes in Nigeria from authorized published secondary material; a Conference Proceedings on Climatic Change and the Nigerian Environment, of the Department of Geography, University of Nigeria Nsukka. The online materials were from both Kano-History of Aircraft Accidents and Nigerian Elites Forum-Brief History of Air Disaster/Crashes in Nigeria. The four types of data were in good condition, except for some very few cases of missing records. Data on low horizontal visibility only captured records in the months of November, December, January, February and March, being the months of visibility occurrence.

In this study, annual total number of plane crash in Nigeria was correlated with data on the three weather parameters to explore degrees of relationships. It was found that there were relationships but the degrees of the relationships were insignificant owed to good weather modification practices. This implies that the effects these weather parameters have on flight operations is insignificant, hence not solely responsible for plane accidents recorded in Nigeria in recent years. Therefore, other causative factors such as human, economic and mechanical are the major problems to flight operations in Nigeria. Hence, the suspension of pilots, other aviation operators and airlines by aviation authorities concerned on misbehaviours, and the recommendations for maintenance of aircrafts, routine check of the planes, Pilot's exposure to more training and refresher courses and lightening of the runway were actions taken in the right direction.

## 5.4 Recommendation/Suggestion

Emanating from the study, the following recommendations/suggestions are made. They are:

i. This study is limited to one parameter of air traffic (plane crash) because of insufficient data on other parameters such as flight delay, flight cancellations and flight diversion due to inadequate record keeping. Therefore, there is need for all aviation organizations concerned to develop grassroots information database and keep proper records of every flight operations activities.

ii. There is also need for baseline studies on flight operations with a view to raising data for more researches. Security bottleneck on data acquisitions in the aviation industry should be relaxed to give room for more researches.

iii. The aviation bodies concerned with safety rules should ensure the accuracy of weather reports and strict compliance to weather reports and safety regulations to avoid or minimize air disaster. Since it was reported that Nigerian Pilots often ignored weather reports and safety rules in a bid to make more money, as they are paid according to the number of flights and hours they logged.

iv. The laisser–faire attitude to aviation regulation in Nigerian Airspace by aircraft operators and airlines should be sanctions and prosecuted by appropriate authority or regulatory body.

v. Refresher courses for personnel is a powerful and effective tool in air disaster management and should be enforced for aviators particularly Pilots and Air Traffic Controllers for effective management of weather, technical and economic reports

to mitigate problems encountered by Pilots on landing and takeoff phases of aircraft flight.

vi. Maintenance culture should be imbibed by all and sundry in the aviation industry to ensure the up to date function of the state of the art equipment in the airports and to mitigate the problems of mechanical failures of aircraft, bad fuel condition (contamination), and outdated aircrafts.

vii. The need to accurately understand the trends and causes of air disasters is very important towards eliminating, if not, minimizing the risk of air disasters in Nigerian Airspace. Most of the causes of air disasters are within rational ability to mitigate if the right attention is given.

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## Appendix I: Table 1.1

**Table1.1: Airliner Accident Statistics Released by the Aviation Safety Network in 2006**

| Total no. of accidents | Total no. of fatalities | Breakdown of air crashes | Causes of crashes given | Percentage of the breakdown |
|---|---|---|---|---|
| 27 | 888 | 17 | Because of loss of control, either on takeoff or landing and in-flight | 63.0% |
| | | 10 | Mid-air collision, loss of situational awareness, weather and mechanical problems | 37.0% |

***Source: Extract moderated from a statistic data in Punch Newspaper, January 3, 2007, p. 24 by Bisiriyu, 2006***

## Appendix II: Sample of Hourly Wind Data for Abuja Airport for the Year 1986

| STN-NAME | YEAR | MON | DAY | WNDIR-09 | WDSPD-09 | WNDIR-15 | WNSPD-15 |
|---|---|---|---|---|---|---|---|
| Abuja | 1986 | 1 | 1 | 80 | **4** | 330 | **9** |
| Abuja | 1986 | 1 | 2 | 300 | **4** | 0 | **0** |
| Abuja | 1986 | 1 | 3 | 180 | **2** | 290 | **7** |
| Abuja | 1986 | 1 | 4 | 0 | **0** | 270 | **3** |
| Abuja | 1986 | 1 | 5 | 270 | **9** | 210 | **7** |
| Abuja | 1986 | 1 | 6 | 0 | **0** | 0 | **0** |
| Abuja | 1986 | 1 | 7 | 80 | **5** | 160 | **3** |
| Abuja | 1986 | 1 | 8 | 0 | **0** | 270 | **6** |
| Abuja | 1986 | 1 | 9 | 0 | **0** | 250 | **9** |
| Abuja | 1986 | 1 | 10 | 180 | **6** | 270 | **6** |
| Abuja | 1986 | 1 | 11 | 220 | **3** | 260 | **5** |
| Abuja | 1986 | 1 | 12 | 0 | **0** | 240 | **4** |
| Abuja | 1986 | 1 | 13 | 0 | **0** | 200 | **5** |
| Abuja | 1986 | 1 | 14 | 90 | **5** | 0 | **0** |
| Abuja | 1986 | 1 | 15 | 90 | **5** | 90 | **5** |
| Abuja | 1986 | 1 | 16 | 30 | **4** | 0 | **0** |
| Abuja | 1986 | 1 | 17 | 0 | **0** | 300 | **4** |
| Abuja | 1986 | 1 | 18 | 80 | **4** | 0 | **0** |
| Abuja | 1986 | 1 | 19 | 0 | **0** | 0 | **0** |
| Abuja | 1986 | 1 | 20 | 110 | **2** | 290 | **2** |
| Abuja | 1986 | 1 | 21 | 0 | **0** | 0 | **0** |
| Abuja | 1986 | 1 | 22 | 20 | **2** | 240 | **2** |
| Abuja | 1986 | 1 | 23 | 0 | **0** | 300 | **6** |
| Abuja | 1986 | 1 | 24 | 40 | **2** | 260 | **2** |
| Abuja | 1986 | 1 | 25 | 120 | **4** | 0 | **0** |
| Abuja | 1986 | 1 | 26 | 90 | **2** | 330 | **2** |
| Abuja | 1986 | 1 | 27 | 0 | **0** | 0 | **0** |
| Abuja | 1986 | 1 | 28 | 120 | **2** | 280 | **3** |
| Abuja | 1986 | 1 | 29 | 0 | **0** | 90 | **5** |
| Abuja | 1986 | 1 | 30 | 170 | **2** | 280 | **2** |
| Abuja | 1986 | 1 | 31 | 0 | **0** | 270 | **4** |
| Abuja | 1986 | 2 | 1 | 200 | **2** | 180 | **2** |
| Abuja | 1986 | 2 | 2 | 0 | **0** | 0 | **0** |
| Abuja | 1986 | 2 | 3 | 270 | **2** | 300 | **2** |

***Source: NIMET Abuja, 2011***

**Appendix III: Sample of Hourly Wind Data for Kano Airport for the Year 1986**

| STN-NAME | YEAR | MN | DAY | WDSPD-09 | WNDIR-09 | WNSPD15 | WNDIR15 |
|---|---|---|---|---|---|---|---|
| Kano | 1986 | 1 | 1 | 90 | **8** | 80 | **5** |
| Kano | 1986 | 1 | 2 | 80 | **13** | 60 | **10** |
| Kano | 1986 | 1 | 3 | 110 | **10** | 120 | **10** |
| Kano | 1986 | 1 | 4 | 110 | **10** | 50 | **9** |
| Kano | 1986 | 1 | 5 | 0 | **0** | 20 | **7** |
| Kano | 1986 | 1 | 6 | 0 | **0** | 50 | **5** |
| Kano | 1986 | 1 | 7 | 101 | **11** | 90 | **15** |
| Kano | 1986 | 1 | 8 | 80 | **12** | 100 | **7** |
| Kano | 1986 | 1 | 9 | 90 | **10** | 80 | **12** |
| Kano | 1986 | 1 | 10 | 90 | **15** | 60 | **10** |
| Kano | 1986 | 1 | 11 | 90 | **16** | 70 | **12** |
| Kano | 1986 | 1 | 12 | 120 | **16** | 120 | **4** |
| Kano | 1986 | 1 | 13 | 80 | **21** | 80 | **16** |
| Kano | 1986 | 1 | 14 | 90 | **25** | 100 | **22** |
| Kano | 1986 | 1 | 15 | 90 | **27** | 80 | **18** |
| Kano | 1986 | 1 | 16 | 90 | **20** | 90 | **14** |
| Kano | 1986 | 1 | 17 | 120 | **12** | 60 | **15** |
| Kano | 1986 | 1 | 18 | 110 | **10** | 100 | **10** |
| Kano | 1986 | 1 | 19 | 90 | **11** | 100 | **10** |
| Kano | 1986 | 1 | 20 | 100 | **18** | 90 | **9** |
| Kano | 1986 | 1 | 21 | 120 | **16** | 70 | **12** |
| Kano | 1986 | 1 | 22 | 80 | **16** | 80 | **12** |
| Kano | 1986 | 1 | 23 | 80 | **10** | 80 | **10** |
| Kano | 1986 | 1 | 24 | 80 | **15** | 60 | **17** |
| Kano | 1986 | 1 | 25 | 90 | **16** | 50 | **8** |
| Kano | 1986 | 1 | 26 | 90 | **10** | 60 | **10** |
| Kano | 1986 | 1 | 27 | 120 | **14** | 60 | **10** |
| Kano | 1986 | 1 | 28 | 100 | **10** | 80 | **16** |
| Kano | 1986 | 1 | 29 | 60 | **12** | 110 | **16** |
| Kano | 1986 | 1 | 30 | 90 | **10** | 90 | **5** |
| Kano | 1986 | 1 | 31 | 90 | **8** | 80 | **10** |
| Kano | 1986 | 2 | 1 | 120 | **5** | 50 | **8** |
| Kano | 1986 | 2 | 2 | 140 | **6** | 80 | **14** |
| Kano | 1986 | 2 | 3 | 90 | **8** | 100 | **4** |
| Kano | 1986 | 2 | 4 | 30 | **10** | 50 | **5** |
| Kano | 1986 | 2 | 5 | 0 | **0** | 40 | **9** |

***Source: NIMET Abuja, 2011***

**Appendix IV: Sample of Daily Records of Horizontal Visibilities Data for Abuja Airport (2005-2010)**

**NIGERIAN METEOROLOGICAL AGENCY**

Statistics of Low Horizontal Visibilities caused by Weather

Pls note visibility ranges are in metres

| Year | Vis. Range | Months Jan | Months Feb | Months Mar | Months Nov | Months Dec | |
|---|---|---|---|---|---|---|---|
| 2010 | 0 - 99 | | | | | | |
| | 100 - 199 | | | | | | |
| | 200 - 388 | | | | | | |
| | 300 - 999 | | | 10 | | | 10 |
| 2009 | 0 - 99 | | | | | | |
| | 100 - 199 | | | | | | |
| | 200 - 388 | | | | | | |
| | 300 - 999 | 1 | | | | | 1 |
| 2008 | 0 - 99 | | | | | | |
| | 100 - 199 | | | | | | |
| | 200 - 388 | | | | | | |
| | 300 - 999 | | | | | | |
| 2007 | 0 - 99 | | | | | | |
| | 100 - 199 | | | | | | |
| | 200 - 388 | | | | | | |
| | 300 - 999 | 2 | | | | | 2 |
| 2006 | 0 - 99 | | | | | | |
| | 100 - 199 | | | | | | |
| | 200 - 388 | | | | | | |
| | 300 - 999 | | | 4 | | | 4 |
| 2005 | 0 - 99 | | | | | | |
| | 100 - 199 | | | | | | |
| | 200 - 388 | | | | | | |
| | 300 - 999 | | 6 | | | | 6 |

***Source: NIMET Abuja, 2011***

**Appendix V: Sample of Daily Records of Horizontal Visibilities Data for Kano Airport (2005-2010)**

**NIGERIAN METEOROLOGICAL AGENCY**

Statistics of Low Horizontal Visibilities caused by Weather

Pls note visibility ranges are in metres

| Year | Vis. Range | Months Jan | Months Feb | Months Mar | Months Nov | Months Dec | |
|---|---|---|---|---|---|---|---|
| 2010 | 0 - 99 | | | 2 | | | 2 |
| | 100 - 199 | | | | | | |
| | 200 - 388 | | | 9 | | | 9 |
| | 300 - 999 | 2 | 7 | 20 | | | 29 |
| | | | | | | | 0 |
| 2009 | 0 - 99 | | | | | | |
| | 100 - 199 | | 1 | | | | 1 |
| | 200 - 388 | | 8 | 2 | | | 10 |
| | 300 - 999 | | 19 | 16 | 12 | 2 | 49 |
| | | | | | | | |
| 2008 | 0 - 99 | | | | | | 0 |
| | 100 - 199 | | | | | | 0 |
| | 200 - 388 | | | 2 | 3 | | 5 |
| | 300 - 999 | 11 | 28 | 2 | | | 41 |
| | | | | | | | 0 |
| 2007 | 0 - 99 | | | | | | 0 |
| | 100 - 199 | 5 | | 2 | | | 7 |
| | 200 - 388 | 16 | | 5 | | 3 | 24 |
| | 300 - 999 | 39 | | 11 | | 15 | 65 |
| | | | | | | | 0 |
| 2006 | 0 - 99 | | | | | | 0 |
| | 100 - 199 | | | | | | |
| | 200 - 388 | | | | | | 0 |
| | 300 - 999 | | | 20 | 11 | 21 | 52 |
| | | | | | | | 0 |
| 2005 | 0 - 99 | | | | | | |
| | 100 - 199 | 4 | | | | | 4 |
| | 200 - 388 | 5 | | | | | 5 |
| | 300 - 999 | 30 | 4 | | 3 | 1 | 38 |

***Source: NIMET Abuja, 2011***