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IMPACTS OF THUNDERSTORM ON FLIGHT OPERATIONS IN PORT-HARCOURT INTERNATIONAL AIRPORT OMAGWA, RIVER STATE, NIGERIA.

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ABSTRACT: *This research work evaluates the impacts of thunderstorms to flight operations in Port-Harcourt International Airport. This study focused on the monthly and annual occurrences of thunderstorms, trend/pattern of thunderstorm and its influence to the number of flight diversions, delays and cancellations. In other to evaluate this impact, six years data on thunderstorm frequency and the number of flight diversions, delays and cancellations were obtained. The statistical analyses employed were the Simple and Multiple bar charts and Pearson's product moment correlation. From the analysis, it was observed that thunderstorms occur mostly in the rainy season months (monsoon periods) with an increasing trend within the years due to the meridionial movement of the weather/ITD zones. The study revealed that thunderstorm accounted for 32% of flight cancellation with 218 occurrences, 0.2% of diversion with 291 occurrences and 24% of delays with 526 occurrences at the airport from 2008-2013. From the Analysis, thunderstorms have a greater influence on the number of flight cancellations and delays than on diversions with the correlation value of r=0.57, 0.49 and -0.04 respectively. The study concluded that thunderstorms occur in the study area during monsoon periods and it has more impact on delay and cancellations than on diversions.*

KEYWORDS: Impacts, Thunderstorm, Monsoon, Delay, Diversion, Cancellation.

INTRODUCTION.

One of the greatest dangers to aviation is thunderstorms. When evaluating accidents related with thunderstorms and other related impacts, it became apparent that the dangers associated were not always recognized by the aviators. Severe thunderstorm significantly influences the safety and operational efficiency of air traffic, particularly at the terminal areas. The unavoidable consequences of reduced efficiency are delays, diversions and cancellations of flights. Remi (1987) in analyzing factors of air crash in Port-Harcourt Airport in 1987 stated that the prevalent weather at the time of the crash was thunderstorm. This occurrence had some negative impacts on flight operations. Country of the size of United States or Australia experiences approximately 10,000 thunderstorms each year (Remi, 1987). Severe thunderstorm can be as destructive as a tropical cyclone or a tornado. A single severe thunderstorm unleashes its fury over an area of about 8km. Sometimes, especially along a weather front, thunderstorms come in company and line up for more than 150km.Annually, their destructive power results in economic losses of about $2 billion. In Australia, thunderstorms are more damaging than cyclones, floods or bushfires.

The International Air Transport Association (IATA) stated that 71% of air accidents in Nigeria are due to poor weather conditions (Punch, 2005). NOAA (2004) affirmed that weather affects flight operations in Nigeria. Even before these cases, there has been a decline on the efficiency of flight operation in the country which is traceable to weather phenomena and their antecedent hazards.

Therefore, a good knowledge of this subject matter becomes very important to Aircraft operators, pilots and flight crew members as safety of lives and properties should be ensured and risks reduced to the barest minimum. As such, the purpose of this study is to determine the influence of thunderstorm on flight operations in Port-Harcourt International Airport. In order to achieve this aim, the following objectives were pursued to;

1) Determine the annual and monthly occurrence of thunderstorms over Port-Harcourt.
2) Analyze the variability/ trend of thunderstorm occurrence in Port Harcourt.
3) Assess the number of flight cancellations, diversion or delays due to thunderstorms.

Study Area.

The Port Harcourt International Airport is located between latitude 04^{o} 00 -15^{0} 45 N and longitude 06^{o} 25` -7^{0} 30E. It is bounded by the following states Imo, Abia, Akwa-Ibom, Delta and Bayelsa State. Its shores form part of the West Africa Atlantic ocean coast line with two third of its landed space lying within the Niger Delta Basin. Port Harcourt International Airport (IATA: PHC, ICAO: DNPO) is an international airport located in Omagwa, a suburb of Port Harcourt city in Rivers State, Nigeria.

The Port Harcourt Airport features a tropical monsoon climate with lengthy and heavy rainy seasons and very short dry seasons. Only the months of December and January truly qualifies as dry season months in the city. The harmattan, which climatically influences many cities in West Africa, is less pronounced in Port Harcourt. Port Harcourt's heaviest precipitation occurs during September with an average of 370 mm of rain. Rainfall is seasonal, variable and energetic. Generally, south of latitude 05^{0}N, rain occurs on the average every month of the year but with varying duration circulation over the area. December on average is the driest month of the year; with an average rainfall of 20 mm. Temperatures throughout the year in the city is relatively constant, showing little variation throughout the course of the year. Average temperatures are typically between 25 °C-28 °C in the city.

CONCEPTUAL FRAMEWORK

Thunderstorm Processes

In some tropical regions, thunderstorms occur year round. In mid latitudes, they develop most frequently in spring, summer, and fall but Arctic regions occasionally experience thunderstorms during summer (Pilot Outlook, 2010). Individual thunderstorms measure from less than 5 miles to more than 30 miles in diameter. Cloud bases range from a few hundred feet in very moist climates to 10,000 feet or higher in drier regions. Tops generally range from 25,000 to 45,000 feet but occasionally extend above 65,000 feet. Forced upward motion creates an initial updraft, and cooling in the updraft results in condensation and the beginning of a cumulus cloud. Condensation releases latent heat which partially offsets cooling in the saturated updraft and increases buoyancy within the cloud. This increased buoyancy drives the updraft still faster, drawing more water vapor into the cloud; and, for awhile, the updraft becomes self-sustaining (Ayoade, 2001). Hence, an instability of air current and moisture formed in and around rain clouds generates electrical charges associated with thunderstorm. All thunderstorms progress through a life cycle from their initial development through maturity and into degeneration (Ayoade, 2001).

Climate data for Port Harcourt

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	32 (90)	33 (91)	33 (91)	32 (90)	31 (88)	30 (86)	30 (86)	29 (84)	29 (84)	30 (86)	31 (88)	32 (90)	31 (88)
Daily mean °C (°F)	26.5 (79.7)	28 (82)	28 (82)	27.5 (81.5)	27 (81)	26.5 (79.7)	25.5 (77.9)	25.5 (77.9)	25.5 (77.9)	26 (79)	26.5 (79.7)	26.5 (79.7)	27 (81)
Average low °C (°F)	21 (70)	23 (73)	23 (73)	23 (73)	23 (73)	23 (73)	22 (72)	22 (72)	22 (72)	22 (72)	22 (72)	21 (70)	22 (72)
Precipitation mm (inches)	29 (1.14)	62 (2.44)	136 (5.35)	188 (7.4)	235 (9.25)	288 (11.34)	345 (13.58)	302 (11.89)	367 (14.45)	246 (9.69)	76 (2.99)	20 (0.79)	2,294 (90.31)
Avg. precipitation days	2	5	9	12	14	17	20	20	21	16	6	2	144
Mean monthly sunshine hours	143	123	115	132	140	102	78	74	78	102	132	149	1,368

Source: The Weather Network

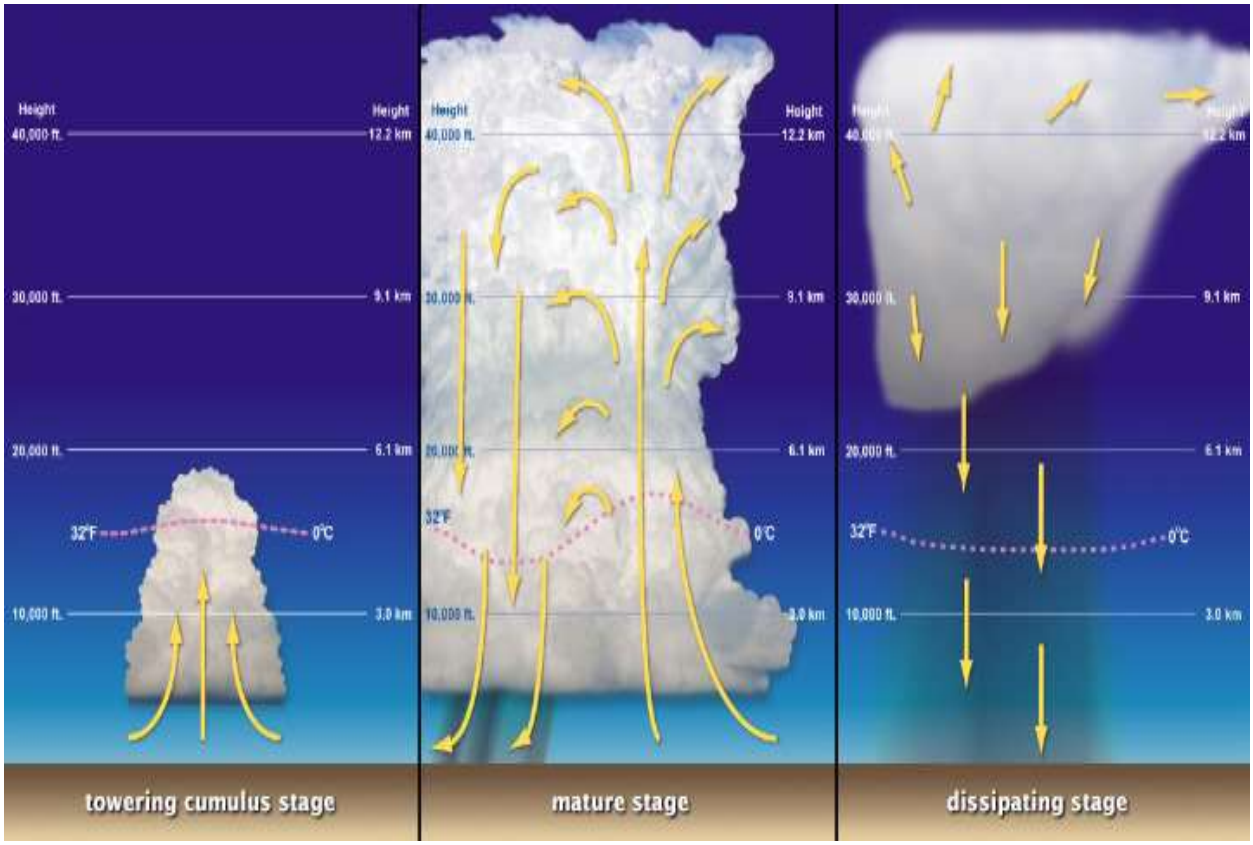

Figure 1: Stages of a Thunderstorm cell

It is a known fact that thunder occurred before lightning, it was caused by the collision of clouds, the sound was produced by resonance between high and low clouds, and by high clouds descending and colliding onto low clouds. And because of the built energy and intensity of thunderstorm, it becomes dangerous and unsafe for aircrafts wherever it is building.

Table 2.1: REPORTED AIR CRASHES ASSOCIATED WITH THUNDERSTORM HAZARDS

S/NO	AIRLINE	DATE	CAUSE	FATALITY	MET.INFORMATION
1.	British Oversees airport Corporation	24|06|1956	Weather	32 passengers	Strong downburst winds from a thunderstorm.
2.	Delta Airline Flight 191	2|08|1985	Weather(micro burst)	More than 130	Thunderstorm/Rain storm.
3.	Nigerian Airways, Port Harcourt.	15|10|1988	Weather	____	Heavy rain
4.	Nigerian Airways, Kaduna	13|11|1995	Weather	129 passengers destroyed	Dry thunderstorm with a 10-15 knots tailwind
5.	Sky Executive	21|05|2002	Weather	All passengers on board	Thunderstorm and turbulence in cloud
6.	Bell view Airlines, Lagos	22|10|2005	Weather	111 passengers and 6 crews.	Thunderstorm
7.	DHL	7|09|2006	Weather - aquaplaning	___	Squall and rain visibility of 600m and wind of 45knots, sky obscured with CB of several direction.
8.	ADC Airline, Abuja	29|10|2006	Weather(micro burst	96 passengers and crew	Heavy thunderstorms
9.	Arik Airlines, Enugu. Flight W3232	14|07|2012	Weather	153 passengers	Turbulence/ Heavy Rain
10.	Dana Airlines Lagos.	03|06|2012	Weather	All passengers on board	Thunderstorm

(Source: Accident investigation Bureau, Nigeria)

THUNDERSTORM TREND AND PATTERN IN NIGERIA

Weather is generally considered as the state of the atmosphere at a given time at any given location (Barry and Chorley, 1976). It may also be referred to as the aspects of the atmospheric state which

is visible and experienced and which affect human activities. The weather conditions of any given location is often described in terms of the meteorological elements which include the state of the sky, temperature, winds, pressure, precipitation, and humidity. These factors initiate and influence the atmospheric processes (Ayoade, 1973). Thunderstorm rainfall is a major form of convective rainfall over Nigeria. Its contribution to total wet season rainfall increases from about 18% in the south to 36% in the north. The importance of thunderstorms lies in the fact that they contribute significantly to flooding episodes and soil erosion processes due to their high intensity and torrential characteristics. (Adelekan, 1998).

The global climate has changed rapidly with the global mean temperature increasing by 0.7oC within the last century (IPCC 2007). However, the rates of change are significantly different among regions (IPCC 2007). This is primarily due to the varied types of land surfaces with different surface albedo, evapo-transpiration and carbon cycle affecting the climate in different ways (Meissner et al. 2003; Snyder et al. 2004). However, trend refers to the monotonic increase or decrease in average value between the beginning and the end of a time series (Giles and Flocas, 1984). The time series of frequency of thunderstorm occurrence at Abuja has been on the increase since the early 1980s. The long term anomaly of thunderstorm occurrence also indicates the same increasing trend in thunderstorm occurrence, being more pronounced from 2001 upwards. Therefore, an increase in thunderstorm frequency is a good indicator of changing extreme weather events due to climate change (Nigeria climate Review Bulletin, 2011).

Akinsanola and Ogunjobi (2014) in their study of analysis of rainfall and temperature in Nigeria, using observations of air temperature (^{o}C) and rainfall (mm) from 25 synoptic stations from 1971-2000 (30years). The data analyses of long time trends and decadal trends in the time series further suggest a sequence of alternately decreasing and increasing trends in mean annual precipitation and air temperature in Nigeria during the study period.

Adelekan (1998) examined the spatial and temporal variations in thunderstorm rainfall over Nigeria using daily rainfall data and associated weather information over a 30 year period (1960–1989) for 19 synoptic stations. Results show that the dry season distribution pattern of rainfall due to thunderstorms shows a general decrease from south to north similar to the total rainfall distribution pattern in the country. At the peak of the wet season (July–September) thunderstorm rainfall increases northwards up to around latitude 11°N when it begins to decrease. The effect of orography in enhancing thunderstorm rainfall across the country is also shown. Elementary linkage analysis was used to group the 19 synoptic stations into thunderstorm rainfall regions. Six regions were identified which showed internal coherence in terms of temporal fluctuations of thunderstorm rainfall.

Adefolalu (1986) studied the rainfall trends for periods of 1911–1980 over 28 meteorological stations in Nigeria with 40 years moving average showing appearance of declining rainfall. Eludoyin et al. (2009) studied monthly rainfall distribution in Nigeria between 1985-1994 and 1995-2004 and noticed some fluctuations in most months within the decades. Ayansina et al. (2009) also investigated the seasonal rainfall variability in Guinea savannah part of Nigeria and concluded that rainfall variability continues to be on the increase as an element of climate change.
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RESEARCH DESIGN

The research design was survey method. The data used in this research work includes; monthly totals of thunderstorm frequency ranging from 1999-2013,which was used in determining its trend and daily flight operation data indicating reasons for flight cancellation, delay and diversion from 2008-2013. The primary sources of data include interviews and the data for thunderstorm frequency and the number of cancellations, delays and diversions. The thunderstorm frequency data (1999-2013) was collected from the Nigerian Meteorological Agency (NIMET), while the data on flight cancellation, delays and diversion (2008-2013) was gotten from the Nigerian Airspace Management Agency (NAMA), both in Port Harcourt International Airport, Omagwa.

The data collected for the research consists of the monthly thunderstorm frequency for the period of 15 years (1999- 2013) ,which defines the number of thunder heard in each month of the specified years and the flight information data for the period of six years (2008-2013), which covers the cancellation, delay and diversion of flight for the station under investigation. This data were however, obtained through hourly and daily observations and recordings, which were later compiled and their monthly means computed in the station.

In analysing the required data, simple statistical techniques such as Arithmetic means and graphs were employed. The statistical technique employed to ascertain the relationship between thunderstorm frequency and flight cancellations, delays, and diversion was 'Pearson's Product Moment Correlation' method.

DATA PRESENTATION, ANALYSIS AND DISCUSSION

Data Presentation

Table 4.1 shows the total monthly frequency of thunderstorm occurrences during the fifteen year period over Port-Harcourt Station. The table reveals that the number of thunderstorms occurrences varies in each month, having the month of October with the highest frequency followed by the month of May while the month of December has the lowest frequency followed by the month of January.

Table 4.1: Monthly Frequency of Thunderstorm Occurrences (1999-2013)

Months	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct.	Nov	Dec
Thunderstorm Frequency	48	92	185	237	256	226	192	110	226	277	137	24

Source: Nigerian Meteorological Agency, Port-Harcourt

Thunderstorm occurrences show a steady rise from January to May, and then decreases from June to August. It displays another increase in the months of September and October and falls back again in November and December.

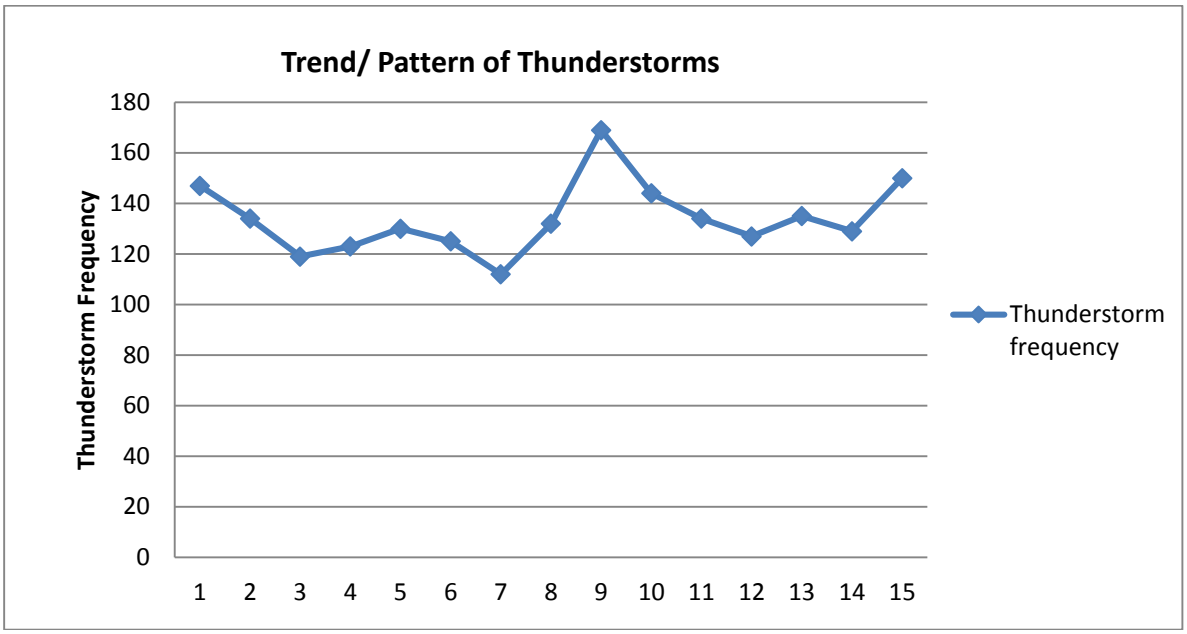

Figure 4.1: The trend/ pattern of thunderstorms (1999-2013)

Figure 4.3 reveals the annual trend of thunderstorm frequency in Port-Harcourt Airport Station for the period of 15 years. The trend tends to be fluctuating, having its highest occurrence in 2007 and 2013 and its lowest occurrence in 2005.

Table 4.2: Monthly Totals of Flight Diversions, Delays and Cancellations (2008-2013)

Months	No. of flight Diversion	No. of Flight Delay	No. of Flight cancellation	Thunderstorm Frequency
January	20	18	6	18
February	14	28	12	38
March	29	50	18	78
April	20	51	28	104
May	34	71	24	109
June	35	59	23	92
July	40	54	25	72
August	29	28	11	47
September	18	56	28	90
October	15	74	26	110
November	18	24	12	58
December	17	13	5	3
Total	291	526	218	819
Total (%)	35.5	64.2	26.6	100

Source: Nigerian Airspace Management Agency (NAMA), Port-Harcourt.

The Table 4.2 shows the monthly totals of flight diversions, delays and cancellations for a period of six years (2008-2013) as a result of thunderstorm occurrences. From the table, flight diversions

recorded a total number of 291 with the highest number of diversions in July, flight delays occurred 526 times, having its highest number of delay in October, and flight cancellations recorded 218 having its highest number of cancellations in both April and September. The highest number of diversions in the month of July could be as a result of heavy precipitation characterized in that month which can reduce visibility.

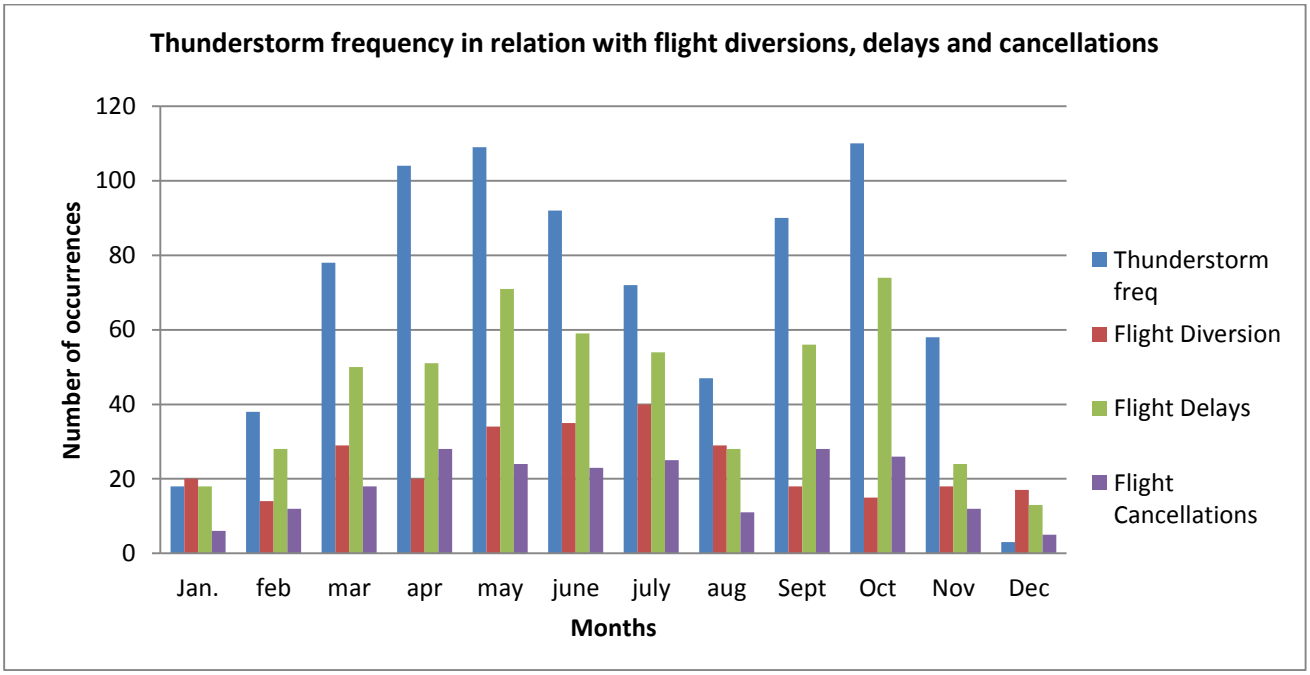

Figure 4.2: Thunderstorms frequency in relation with flight diversions, delays and cancellations (2008-2013)

From the illustration, the movement of thunderstorm frequency is in consonance with flight cancellations and delays but differs from the trend of flight diversion. It was observed that the month of October with the highest thunderstorm frequency shows a corresponding increase in the number of flight delays and cancellations but the reverse in the number of diverted flights.

DATA ANALYSIS

Flight Diversion

From the analysis carried out, the correlation coefficient between thunderstorm frequency and flight diversion is $r = -0.04$. This indicates that there is a weak inverse relationship between the number of thunderstorm occurrences and the number of flight diversions in Port-Harcourt station, where an increase in thunderstorm frequency gives rise to a decrease in the number of flight diversions, though the strength is weak.

In other words, flight diversions seem not to be pronounced in the station as a result of thunderstorm occurrences, which might be due to other factors antecedent to diversions such as technical, operational and human factors.

Flight Cancellation

The correlation coefficient between thunderstorm frequency and flight cancellation is r = 0.57. This means that the number of flight cancellation is positively associated with the number of thunderstorm occurrences. In other words, there is a general tendency for an increase in thunderstorm frequency to cause a greater number of flight cancellations in the Station.

The coefficient of determination (C/D) = r^2 =0.57^2=0.32 =32%. This means that with a correlation coefficient of 0.57 between thunderstorm frequency and flight cancellation, 32% of the number of flight cancellations in the station is determined by thunderstorms.

Flight Delay

The correlation coefficient between thunderstorm frequency and flight delay is r = 0.49. This indicates a moderate positive relationship between thunderstorm frequency and the number of flight delays in Port-Harcourt station. Therefore, an increase in thunderstorm frequency amounts to a considerable increase in the numbers of flight delays inherent in the Station. The coefficient of determination (C/D) = r^2 =0.49^2. =0.24 =24% .This means that with a correlation coefficient of 0.49 between thunderstorm frequency and flight cancellation, 24% of the number of flight delays in the station was determined by thunderstorms. Generally, from the analysis above, it can be deduced that there is a positive relationship between thunderstorm occurrences and flight cancellations and delays, which reveals that 32% and 24% of the number of flight cancellations and delays respectively are accounted for by thunderstorm occurrences. But, no percentage number was accrued to flight diversions as a result of thunderstorm occurrences. This may be likened to the weak relationship that exists between them.

DATA DISCUSSIONS

The findings in Figures 4.1 and 4.2 reveals that the frequency of thunderstorm varies within the months and years. The monthly frequency exhibited two maxima peaks, the first peak is seen in April and May with 237 and 256 respectively. The second peak occurred in September and October with 226 and 277 respectively. This indicates the two peaks of rainy season associated with thunderstorms.The finding is in agreement with Anne-Duncan (2010) who asserted that the months of May to October, which is the months of the rainy season are mostly characterized by thunderstorms and line squalls with its attendant turbulence, micro bursts and lighting. It also supports Maxwell (2008), who said that the monsoon period of the year is the worst for bad weather delays.

What is the pattern of thunderstorms occurrence in Port-Harcourt? The annual fluctuation shown in Figure 4.3 reveals that the frequency differs in occurrence from year to year. This explains why it does not show either an increasing or decreasing trend rather it fluctuates with its peak in 2007. It also exhibited two maxima peaks, the first peak in April and May, and then the second peak in September and October (see figure 4.1). This finding seems to be in disparity with Pilot Outlook (2010). Pilot Outlook (2010) found out that thunderstorms are most frequent during July and August and least frequent in December and January while our findings reveal that thunderstorm is most frequent in May and October and less frequent in December and January. How many cancellations, delays, or diversions occurred during the study period? From Table 4.2, it was discovered that flight delays due to thunderstorm Delays have a greater number with 526 occurrences while flight cancellations and diversions had 218 and 291 respectively. Therefore, it can be deduced that thunderstorm occurrence influences the number of flight delays, diversions

and cancellations in Port-Harcourt Station. This finding is in line with Jones (2004), Bazargen (2005) and Knecht (2008) that most of flight delays and cancellations were caused by poor weather conditions such as thunderstorm occurrence, poor visibility, wind shear and squall.

CONCLUSION

The findings of this study serve as the basis for making the following conclusion;Thunderstorms occurrences in Port-Harcourt are more frequent during the monsoon period having its highest peak in October and May but less frequent in December and January. It however depicts a fluctuation in its occurrence all year round with a rise in its occurrence in most of the years. Thunderstorms seem to have greater influence on flight delays and cancellations which is more pronounced in the station than as it has on diversions. This is as a result of the avoidance of the penetration of thunderstorms due to its excruciating impacts. Thus, thunderstorm activity in the airport has an increasing impact on flight operations.

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