

## MANAGEMENT OF THE IMPACTS OF SUDDEN AND SLOW ONSET WEATHER EVENTS ON AVIATION OPERATIONS IN SOUTHEASTERN NIGERIA

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### Abstract

This study examined the impact of sudden and slow onset weather events on aviation operations in south-eastern Nigeria. The ex post facto and cross-sectional research designs were adopted for in this study. Data were sourced from both primary and secondary sources and the secondary data were hourly data on sudden weather parameters (wind, cloud cover, visibility, and precipitation) and slow weather parameters (minimum and maximum temperature) were collected from the archives of Nigerian Meteorological Agency (NiMet) for a period of 10 years. On the other hand, air traffic data were collected from the airliners while primary data were derived with the aid of distributed copies of questionnaire. Descriptive statistics, statistical diagrams and tables were used to present the data and analysis of variance (ANOVA) test, was used for analysis. The results showed that rainfall, temperature, wind and cloud cover established remarkable variation annually and monthly. Also, rainfall showed lack of consistency in most of the years, but 2013 had a similar pattern across the region whereas temperature ranged between 30°C and 35°C with Enugu recorded the highest maximum temperature. There was substantial evidence of slow and sudden weather events effects on flight operations which spatially varied across the cities investigated. The revealed effects of the sudden and slow events were delays, cancelation of flights and additional cost for travelers. There was a significant spatial variation in the sudden and slow weather events in the region at  $p < 0.05$ . The study recommended training and retraining programmes acquisition of automated instruments for real time and accurate data collection, replacement of aging aircraft and weather monitoring facilities and sensitization of passengers on coping techniques with sudden and slow weather events.

**Keywords:** Aviation, Weather, Visibility, Precipitation, Operations, Disruption

## 1. INTRODUCTION

Weather has a significant impact on airport operations and the performance of the whole aviation network. Delayed operations can be caused by airport capacity constraints due to severe weather conditions (Glass, Davis & Watkins-Lewis, 2022). The prediction of aircraft processes along their whole trajectories is required to achieve punctual operations (Montlaur, Delgado & Prats, 2023). Delays in departure at one airport can affect the network, resulting in system-wide far reaching effects. As documented in the year 2016, reactionary delays were the main cause of delays, followed by turn around delays which accounted for 46% of departure delays (Reitmann & Schultz, 2022). When transport systems are interrupted, delays emerge, introducing uncertainty regarding travelers' arrival time (Wang, Jin & Sun, 2022). Also, delays directly lead to extra travel time. Furthermore, in reaction to uncertain travel times, travelers may adjust their travelling schedule for potential delays leading to further cost on travel (Kumar & Khani, 2023). Generally, delays emerge when interactions between air transport players (i.e., carriers, airports and air traffic control entities) and external factors (i.e., adverse weather conditions, strikes and other incidents) lead to airport congestion (Lin, 2023). The empirical literature has analyzed two main determinants of airport congestion inherent to the air transport system - congestion externalities in general and how the structure of the airport network allows for diverse responses to these externalities. The congestion externality argument explains the emergence of delays as a consequence of airlines' failure to internalize the effect their scheduling decisions have on other airlines (Ren, 2023). At hub airports (i.e., airports with one or a few dominant carriers) two contrary forces affect delays. Thus, there is a tradeoff between providing additional connections and rising marginal congestion costs (i.e., increase in delays and connecting times) due to higher traffic numbers (Gnutzmann & Śpiewanowski, 2023). Again, hub airlines have leeway in their scheduling decisions, which allows to partially offset the increased congestion (Porter, 2023).

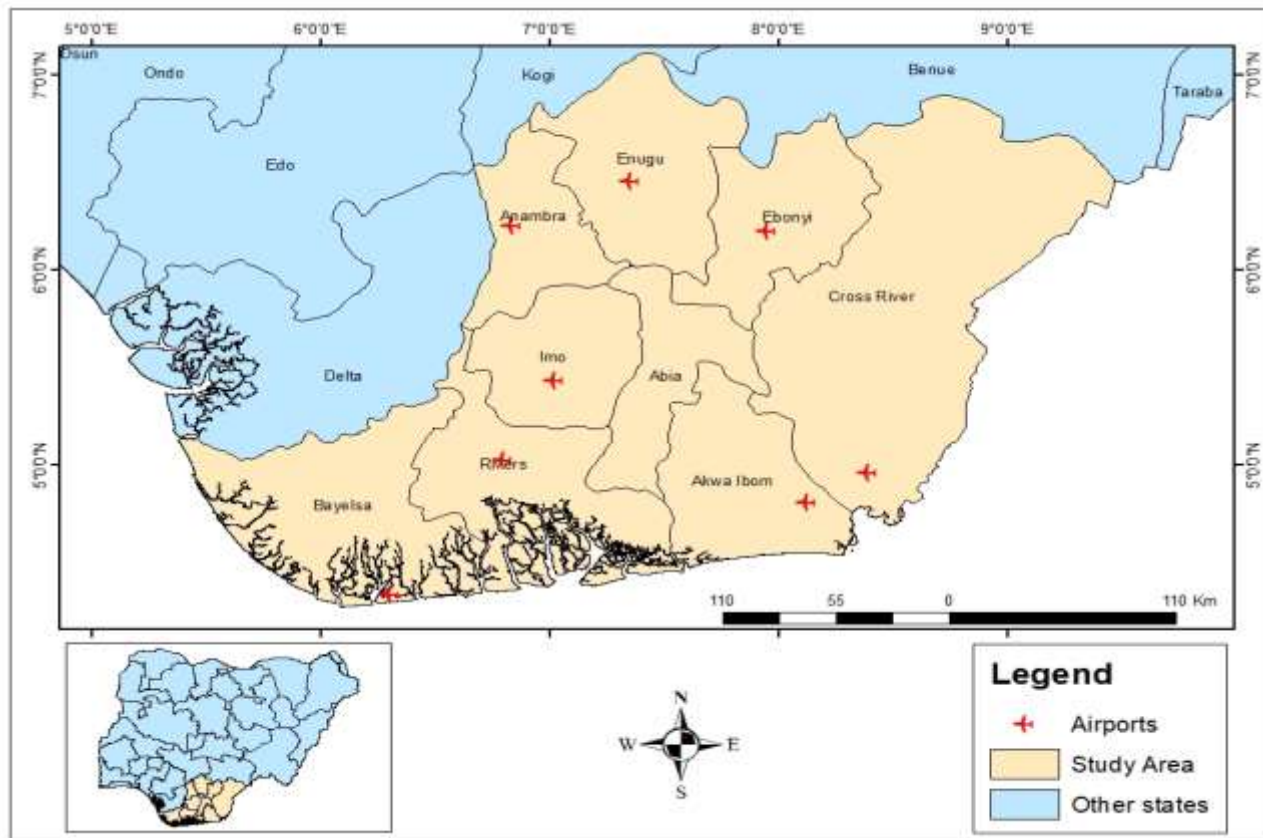
Modern societies are characterized by a high degree of mobility of goods, services and people. Supply chains are interlinked across countries and continents and people increasingly travel for business and private reasons (Sytych, Kim & Page, 2022). As population grows and income increases, the demand for mobility is growing as well (Ahmed, Le & Shahzad, 2022). Overall, the increasing demand for mobility leads to a high dependence on transport systems and their services, with high costs when mobility suddenly is restricted, delayed, or canceled (Deng *et al.*, 2023). Adverse weather conditions are an important external factor affecting delays in the air traffic system as well (Hutter & Pfennig, 2023). Depending on the year and month, they account for up to 50 percent of air traffic delays within the air space (Abdelghany, Guzhuva, & Abdelghany, 2023). The impact of weather-related extremes on delays in the aviation system are only scarcely covered in recent empirical literature, due in part to the acclaimed improvements in the aviation systems and fleets. Existing literature suggests that the general impact of adverse weather conditions on airport and airline operations is substantial and cannot be ignored (Voskaki, Budd, & Mason, 2023). Borsky & Unterberger, 2019) analyzed the impact of different weather shocks on airline operations at the Atlanta Hartsfield International Airport for one airline. He finds that annually over 165,000 min of delay are attributable to adverse weather conditions. Bertness,

(1980) shows that at the end of the 1970s, rainfall substantially increased the number of departures with a delay above 30minutes at Chicago O'Hare airport. Li, Jing & Dong, (2023) examined the impact of thunderstorms on delays at Frankfurt Airport during 1997 and 1998. They discover that thunderstorms significantly increase delays by a factor of 6.3 in 1997 and by 1.1 in 1998. From the forgoing, the aviation industry and associated operations are significantly influenced by weather. Aviation safety, efficiency and capacity are sensitive to weather, and adverse weather can have negative impacts on the sector (Dalal *et al.*, 2023). The increase in aviation demand can push airport's capacity to its limits, and even a small weather change can lead to a reduction of the airport capacity (Dönmez, 2023). Weather conditions affect all aspects of aerodrome operations such as aircraft fueling, cleaning, baggage handling, catering, aircraft maintenance, and the actual scheduled flights. The operational capacity of airports, and even a region's entire airspace, can be significantly reduced due to bad weather, resulting in delays, diversions and cancellations of flights (Dalmau & Gawinowski, 2023). 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 (Dempsey, 2002). It was reported by Diamond, (2017) 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. Delays are highly sensitive to the time of day affected by adverse weather, as the greatest amount of delays occur during the highest demand periods (Chen & Wang, 2019). It is against this background, that this study therefore seeks to examine the impact of sudden and slow onset weather events on flights' departure delays, overall operability and accidents in south-eastern Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Study area

Southeastern Nigeria is located within latitudes 4° 47' 35" N and 7° 7' 44" N, and longitudes 7° 54' 26" E and 8° 27' 10" E. The area comprises nine States namely; Abia, Anambra, Ebonyi, Enugu, Imo, Cross-River, Akwa-Ibom, Rivers and Bayelsa (Onyishi & Ofualagba, 2021). The area covers about 29095 km<sup>2</sup> which accounts for 3.19 % of the total area of Nigeria. The area is bounded to the North by Kogi and Benue States, to the east the area is bounded by Cross-River State and bounded to the south and west by Rivers and Delta States respectively (see figure 1).



**Figure 1: Southeastern Nigeria Showing the selected Airports**

The region has a tropical climate with humidity and rainfall decreasing from the coast inland, and characterized by uniformly high temperature and a seasonal distribution of bimodal rainfall (Ezemonye & Emeribe, 2012). The rainfall of southern Nigeria generally is heavy and ranges from over 2500 mm in the southern most region towards the Atlantic to about 1500 mm annually around River Benue in the northern borders. The vegetation stretches from the mangrove swamp in the coast through to the derived savanna in the interior (Ezemonye & Emeribe, 2012) but the region lies in the lowland rainforest natural vegetation belt with evergreen trees in the south and gradually gives way northward to rainfall-savanna forest characterized by trees interspersed with grass. The underlying geology consists of heterogeneous materials namely basement complex, beach sands, coastal plain sands, mangrove swamp deposits, sandstones, shale, sombrero Warri- deltaic deposits, recent and sub-recent alluvium (Okereke & Emeribeole, 2020). The soils of the southeastern Nigeria is heterogeneous in nature comprising of loose red-earth with sands, sandstones, clayey-loam with or without ferric properties underlain by shale formation (Okereke & Emeribeole, 2020). Also reported by Isagba *et al.* (2021) the soils are derived from shale and sandstone parent materials which are deep, porous, and acidic with low organic content as a result of leaching from rainfall activity.



## 2.2 Population/Sample size/Sampling Technique

The target population for this study includes airline managers for local airlines and passengers of the airports (Akwa-Ibom {Victor Attah International airport} Calabar {Margaret Ekpo International airport}, Imo {Sam Mbakwe} Rivers {Port Harcourt International airport} and Enugu (Akanu-Ibiam airport) that have existed in the area for up to 10 years. In all by consulting the manifest, the researcher found that the total annual passenger traffic for the listed airports were 489235, added to the managers of the airlines that ply the airports, it brings the population to 489247. The weather data for these states were collected for a period of 10 years on hourly scale (synoptic). The reason for sampling on hourly scale was to help the researcher knit an analysis between the days of interruption of flight operations with the prevailing weather circumstance at the time of interruption, whether sudden or slow events. Therefore, the period of sample is 10 years (2011-2020). The ten years' period was designed to eliminate hasty conclusions in the findings of the study. Secondly, the study was looking are the erraticism of sudden and slow weather events and how it affects aviation and Ayoade (2004), advised that using data from 2-10 years is sufficient for such inquiry. The researcher employed the Taro Yamane Equation to this population and a total of 400 respondents were derived. See equation 1:

$$n = \frac{N}{1 + N(e)^2} \dots \dots \dots (1)$$

Therefore, total sample size is 400.

## 2.3 Sources/Method of Data Collection/Analytical Technique

The data used for study was obtained mainly from secondary sources. Hourly data on sudden weather parameters (wind, cloud cover, visibility, precipitation) and slow weather parameters (minimum and maximum temperature) were collected from the Nigerian Meteorological Agency (NiMet) and for a period of 10 years (2011-2020). Similarly, air traffic data (such as delays and cancellation, accidents and reasons for delay and cancellation) were collected from the archives of airliners (Arik, Air peace, Aero contractors and Ibom Air). Data on the perception of passengers view of impacts of sudden and slow onset weather events on aviation were derived with the aid of a questionnaire. Descriptive statistics, statistical diagrams and tables were used for the presentation of data while means and standard deviation were used for description and summarization of data. On the other hand, Analysis of variance (ANOVA) test was used to analyze the hypothetical statement that the effects of sudden-slow weather events on flight operations in the south east is not significantly same. All analyses were done in the statistical package for the social sciences (SPSS) version 26 and Micro-soft Excel 2016 environment. ANOVA Equation is expressed as follows:

ANOVA Equation

$$TSS = \sum x^2 - \frac{(\sum x)^2}{N} \dots \dots \dots (2)$$

$$BSS = \frac{(\sum x_1)^2}{n_1} + \frac{(\sum x_2)^2}{n_2} + \frac{(\sum x_3)^2}{n_3} + \frac{(\sum x_4)^2}{n_4} - \frac{(\sum x)^2}{N} \dots \dots \dots (3)$$

$$WSS = TSS - BSS \quad \text{----} \quad \text{----} \quad \text{....} \quad \text{.....} \quad (4)$$

Where: TSS = Total Sum of Squares

BSS = Between Sample Sum of Squares

WSS = Within Sample Sum of Squares

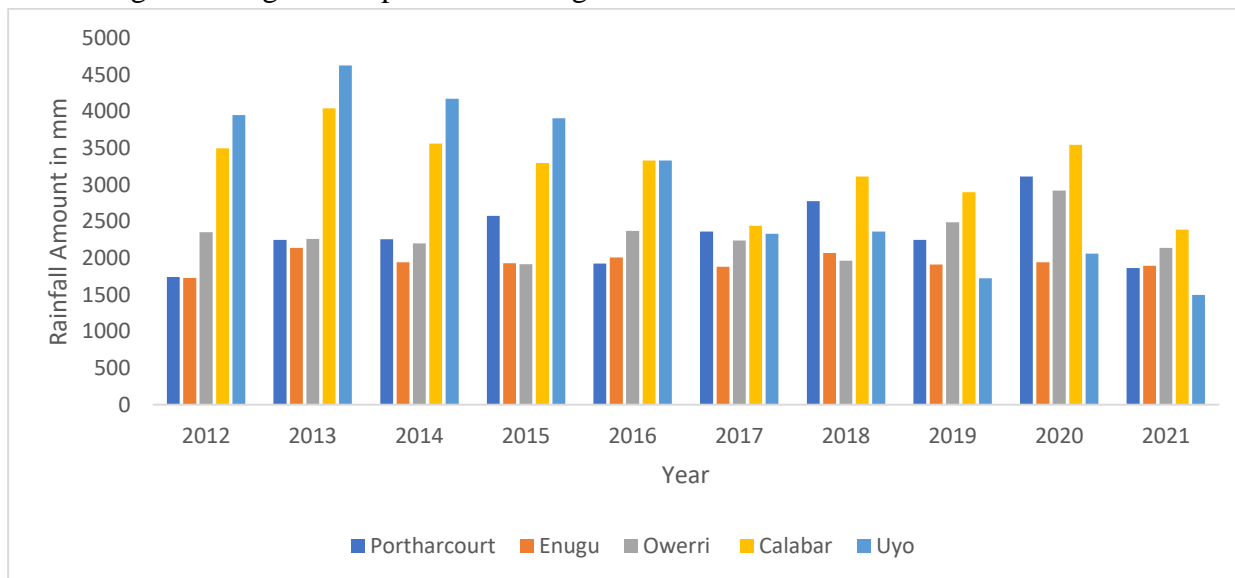
$n_1 \dots n_3$  = Number of Samples means being compared

N = Total items of all groups.

### 3. DATA PRESENTATION

#### 3.1 The sudden and slow weather event characteristics over the years in South Eastern Nigeria

The sudden and slow weather events are those weather events that come up suddenly in the day and can disrupt anthropogenic activities including aviation operations. These sudden and slow events were monitored within the data available in the data archive of the Nigerian meteorological agency. The weather characteristics in the south eastern region of Nigeria are presented in Figures 1-6.

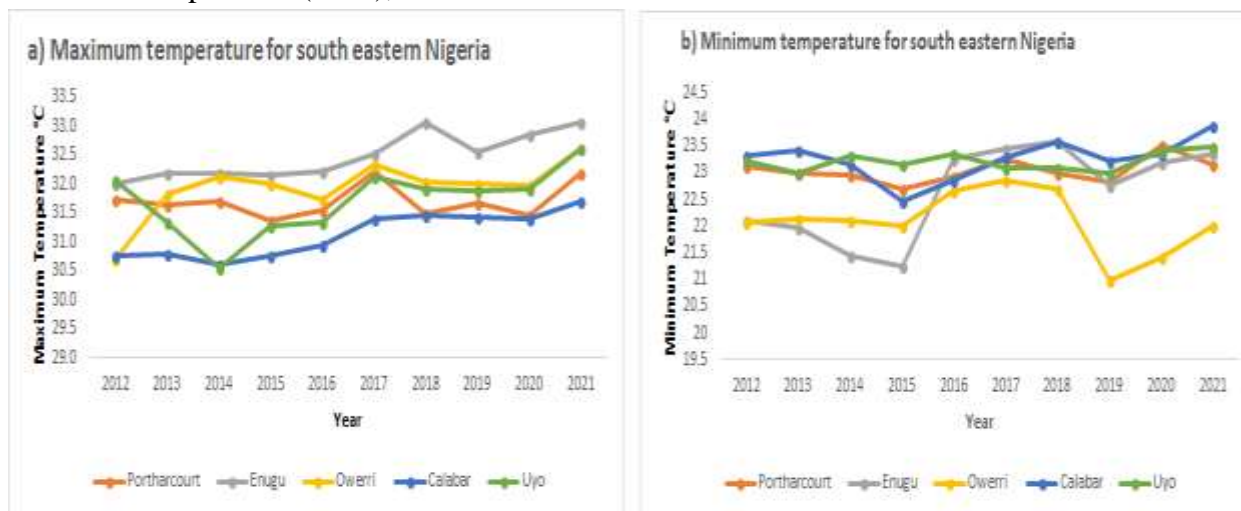


**Figure 2: Precipitation characteristics in South Eastern Nigeria (2012-2021)**

In figure2, the rainfall amounts and distribution for the whole region is displayed. In 2012, the highest rainfall amount for the region was recorded in Uyo with annual rainfall amount of 3585 mm of rainfall. The nearest to this amount of rainfall was recorded in Calabar (3495mm). These two locations are due to the fact that they are close to each other, having similar environmental and forcing factors. As such they are expected to have similar rainfall. Although, Enugu and Port Harcourt had similarity in rainfall amounts (1500mm and 1575mm respectively). Although the rainfall amount for Port Harcourt is fairly higher than that of Enugu with about 75mm of rainfall. In 2013 the pattern is similar, although the rainfall amount for all the locations were higher than that of the year 2012. For example, the rainfall amount for Uyo in 2013 was over 4500mm compared to the 3585mm posted in the

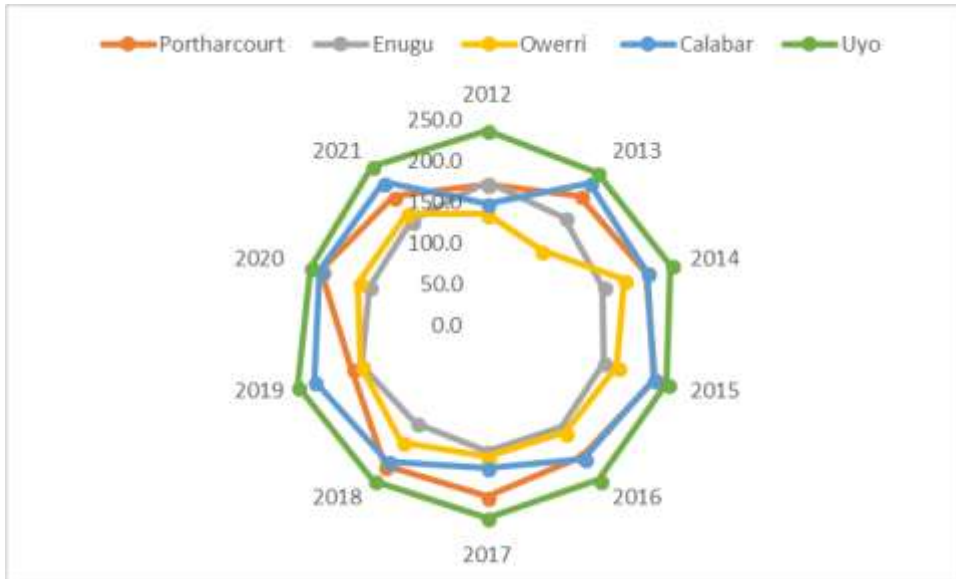
year 2012 for the same location. This same pattern can be reported therefrom. However, in 2020 whereas other locations were experiencing lowered amount in rainfall, Port Harcourt recorded about 3000mm of rainfall. In 2021, the general rainfall amount for the locations was low.

Figure 3 (a), presented the maximum temperature for the study area. The maximum temperature ranged between 30°C to 32.5°C. The maximum temperature for Enugu has been on the rise since 2012 and peaked at the year 2018 with a mean maximum temperature of 32.5°C. Maximum temperature in Enugu also represents the highest in the region. The reason for this is that the area is further hinterland compared to other states of the region. It is also common to see less water bodies around this part of the region. Consequently, the maximum temperature of this area appears to be the highest in the continuum. On the other hand, the Maximum temperature of Calabar revealed that it is the lowest in the study region and ranged between 30°C. The other locations within the region simply falls within these two extremes described above (figure 3a). For the minimum temperature, it is conspicuous that the mean temperature ranges between 20.5°C and 24°C (Figure 3b). Temperature for Owerri appears to be lower than that of other locations within the region. It is possible that the topography and the spatial extent of development in the region partly explains these minimum temperature characteristics. Other location just simply ranged minimum temperature between 21°C and 24°C accordingly. However, in Enugu the year 2015 had a remarkably low minimum temperature (21°C), same can be said of Owerri in 2019.



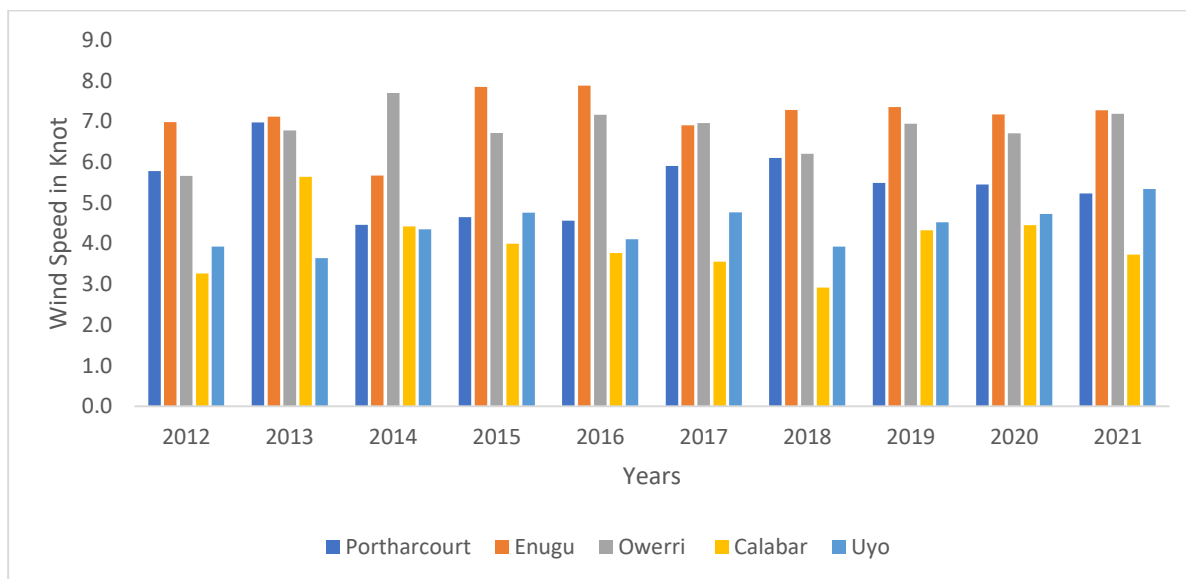
**Figure 3: Temperature characteristics in Eastern Nigeria (2012-2021)**

Wind characteristics is one weather element that is very essential for the operation of the aviation industry. The characteristics of which is very important to measure from time to time and the direction and buoyance determined. This will help determine the magnitude of the wind and adequate precautions taken. For the wind direction of the region showed that it is mostly south west winds in direction (Figure 4).



**Figure 4: Wind direction in south eastern Nigeria (2012-2021)**

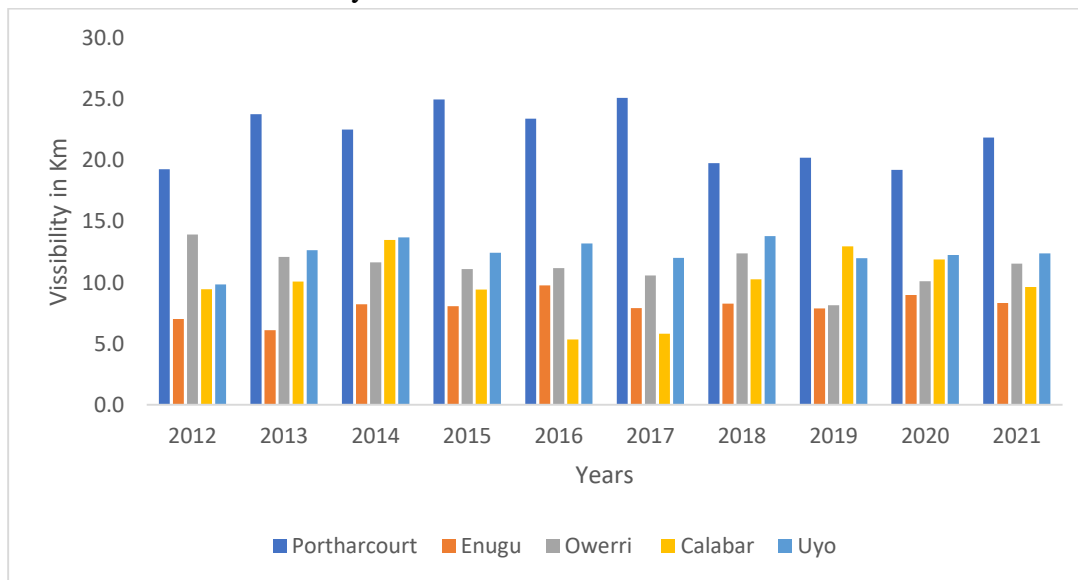
The speed of the wind is presented in figure 4. The wind appeared to have more speed in the Enugu axis of the region with an average of 7 Knot to 8 knots. This region is closer to the northern part of the country and the grass land vegetation is more rampant in this area, and so the buoyance of the wind in this region is expected to be higher.



**Figure 5: Wind Speed in south eastern Nigeria (2012-2021)**

Surprisingly, the wind speed in Calabar was lower than that of other regions even though it is a coastal town surrounded with a lot of water bodies. However, in this study our main aim is not to reveal with area has more wind speed or not, but to determine if there are departures from the norm and how such departures from the norms affects the aviation industry in the region.

The visibility characteristics of the study area is displayed in figure 6. Port Harcourt appears to be having better visibility than the other areas in the study area. Enugu is very poor with annual visibility that range from 5km to 10km. Calabar also presented a very weak visibility although it seems to have improved since 2019. The main reasons for the behavior of visibility in the study area is that to the north section of the region, there is the interference of the highlands and the intercontinental airmass which comes in from the north bearing dust and hazardous weather. To the Calabar section, the highlands of the Cameroons plays serious roles in the modification of the weather and visibility inclusive.



**Figure 6: Visibility characteristics in Eastern Nigeria (2012-2021)**

### 3.2 The changes in the sudden and slow weather events of south eastern Nigeria (2012-2021)

The annual extreme weather events between 2012 and 2021 is presented in Table 1. Rainfall data revealed a slight variation in occurrences of rainfall amongst the cities sampled. Port Harcourt, Calabar and Uyo recorded higher rainfall in 2012 with 28, 25 and 26 occurrences. This significant variation from Enugu (17 times) and Owerri (12 times) is attributable to the sub equatorial climate in the South South region of Nigeria. While the case of Enugu is adduced to the character of the hinterland climate, that of Owerri present evidence for critical investigation. There is evidence of lack of uniformity in rainfall occurrences and increase in 2016, but the most recent increase is recorded in Port Harcourt with 39 to times in 2016. What is very conspicuous is that Port Harcourt, Calabar and Uyo had high decadal mean rainfall with 227, 215 and 180 respectively.

**Table 1: Annual extreme weather (sudden) events in south-east Nigeria 2012-2021**

Rainfall												
Locations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Decadal	Mean
Port												
Harcourt	28	34	12	29	39	14	12	19	23	17	227	22.7
Enugu	17	19	11	16	18	14	9	15	12	10	141	14.1
Owerri	12	11	13	4	1	16	15	16	12	4	104	10.4
Calabar	25	23	22	14	22	15	18	31	11	34	215	21.5
Uyo	26	21	17	8	15	19	14	17	25	18	180	18
Cloud Oktas												
Port												
Harcourt	6	4	1	2	3	5	6	7	1	5	40	4
Enugu	4	2	5	1	5	6	1	3	5	5	37	3.7
Owerri	1	2	3	2	3	6	2	1	4	5	29	2.9
Calabar	3	2	1	1	1	2	3	2	1	3	19	1.9
Uyo	2	1	2	3	4	1	4	5	4	2	28	2.8
Visibility												
Port												
Harcourt	18.0	21.0	23.0	15.0	33.0	15.0	14.0	14.0	3.0	14.0	170	17.0
Enugu	45	39	38	47	32	28	34	32	8	22	325	32.5
Owerri	23	23	14	25	11	13	15	21	4	22	171	17.1
Calabar	3	1	5	3	6	7	2	6	1	12	46	4.6
Uyo	2	13	1	3	4	5	6	3	1	7	45	4.5

The obvious implication is that more flight delays caused by obscured weather conditions would be recorded in those three cities with spiraling effect in Enugu and Owerri. Table 1 also present annual and decadal cloud cover between 2012 and 2021. Remarkably, only Port Harcourt recorded 7 oktas in 2019 which is not full cloud and not sufficient to obscure visibility. There is prevalence of 1 oktas and mean decadal cloud cover of less than 3.0 given that the city with the highest decadal cloud cover is Uyo with 2.8 oktas. It can be generalized from the foregoing that airline operation in the decade under investigation was not significantly disrupted by poor visibility and cloud cover.

In Table 2, the extreme monthly weather events for 2012-2021 is shown. Port Harcourt recorded a remarkable exponential progression in rainfall occurrences from June to September with 52 and June 12 times respectively. The case of Port Harcourt is similar to Uyo and Calabar. However, all the sampled cities recorded a blip between

November and March. This is characteristic of the two seasons in Nigeria which are largely determined by the tropical continental and tropical maritime air masses. Only Port Harcourt recorded a full cloud in June with 8 and August with 9.

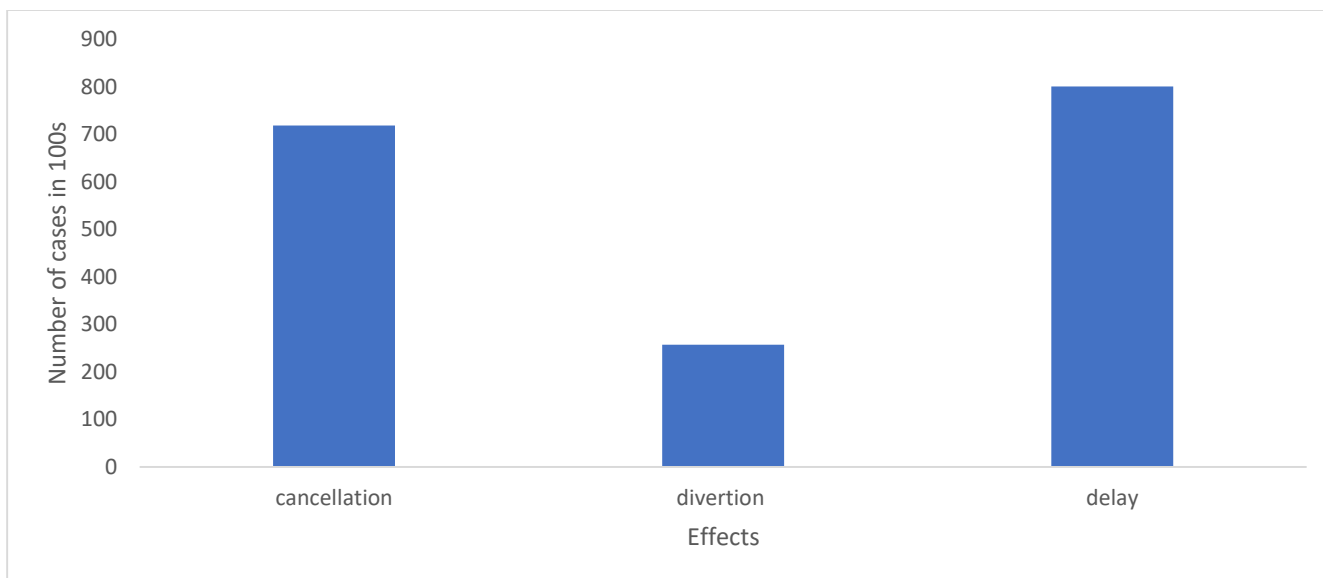
**Table 2: Monthly extreme weather (sudden) events in south-east Nigeria 2012-2021**

Rainfall												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	2	3	4	23	15	49	41	52	31	6	1	0
Enugu	4	7	9	12	9	26	23	26	19	5	1	0
Owerri	0	2	4	6	7	20	18	21	18	6	2	0
Calabar	5	7	9	11	9	41	33	38	31	23	5	3
Uyo	2	4	5	7	4	29	33	35	31	22	5	3
Cloud OKtas												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	1	2	3	3	2	8	6	9	3	2	1	0
Enugu	0	1	3	1	6	6	6	5	6	3	0	0
Owerri	1	2	3	3	4	5	2	4	1	4	0	0
Calabar	0	2	1	3	1	2	3	2	2	3	0	0
Uyo	0	1	2	3	4	1	4	5	4	4	0	0
Visibility												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	18	21	2	1	3	14	13	17	15	14	31	21
Enugu	45	19	14	11	14	12	10	32	34	38	52	44
Owerri	23	3	4	1	2	15	18	14	13	21	35	22
Calabar	1	0	1	0	4	1	1	1	0	3	19	15
Uyo	1	2	1	3	1	4	1	3	2	3	9	15

The implication of having a full cloud is that the sky was obscured in the two months which could cause disruption in flight operations. Enugu, Owerri, Calabar and Uyo recorded zero cloud cover in November and December which is highly supportive of flight operations.

### 3.3 Effects of sudden-slow weather events on airports operations in South Eastern Nigeria (2012-2021)

Figure 7 presents effects of sudden slow weather events on airports operations. Flight cancellation and delay are the dominant reactionary measures to slow weather events with 700 and 800 cases respectively. The data in figure 7 also demonstrated diversion of flight as a measure to surmount slow weather events. But this will have very little effect on passengers' satisfaction.



**Figure 7: Effects of sudden-slow weather events on airports operations in South Eastern Nigeria (2012-2021)**

**3. 4: Sudden-slow weather events that affects aviation most in the south eastern Nigeria (2012-2021)**

Table 3 present sudden weather events with more impacts on flight operations. The table reflects that cities in the sub equatorial climate recorded more occurrences of rainfall cumulatively. This is linked in extant literature to the tropical maritime air mass that causes rainy climate. But Owerri, though in the South East, recorded 104 rainfall occurrences, which is less than Enugu that is characteristic of hinterland climate. The case of Owerri can be adduced to the weather dynamics associated with the elevation of the state.

**Table 3: Sudden-slow weather events that affects aviation most in the south eastern Nigeria (2012-2021)**

Locations	Rainfall	Cloud	Visibility
Port Harcourt	227	40	170
Enugu	141	37	325
Owerri	104	29	171
Calabar	215	19	46
Uyo	180	28	45

Furthermore, the sudden-slow weather events that affects aviation most in the south eastern Nigeria (2012-2021) reflected in table 4.3 showed that Port Harcourt, Uyo and Calabar had more rainfall events that have affected aviation operations in the region. But the numbers of events in Owerri and Enugu is sufficient to disrupt flight operations. The figure show that visibility is not in sync with data on rainfall events. While Enugu and Owerri had less occurrences of rainfall, the two cities had more occurrences of when visibility disrupted flight operations, thus evident that poor visibility in the two cities is not a function of rainfall. Other climatic events could be responsible

for poor visibility. All the cities had cases of cloud effects on flight operations but Port Harcourt, Uyo and Owerri had more effects on cloud, this is because only the three cities had more oktas.

**3.4: Passengers’ perception of the effects of sudden or slow weather events on aviation (2012-2021)**

The perception of the passengers regarding the effects sudden slow weather events on the aviation industry was also considered and these passengers comprised of 72.3% of males and 27.2% females (see Table 4). Table 4 shows that more males (72.5%) boarded flight than females (27.7%) within the period under investigation. 19.8% of the passengers are less than 40 years of age while 36.2% are between 20 to 30 years. This is consistent with more volume of air travels for the economically active population in Nigeria that utilizes air travel for work, education, healthcare care, tourism, recreation and business.

**Table 4: Demographic characteristics of the passengers**

Sex	Frequency	Percentages (%)
Male	289	72.3
Female	111	27.7
Total	400	100
Age	Frequency	Percentages (%)
20-30	145	36.2
31-40	176	44
>40	79	19.8
Total	400	100
Education status	Frequency	Percentages (%)
Basic 1-9	27	6.8
SSCE	104	26
Tertiary education	269	67.2
Total	400	100
Frequency of air travel	Frequency	Percentages (%)
Weekly	156	39
Every fortnight	121	30.3
Monthly	89	22.2
> Monthly	34	8.5
Total	400	100

Data also showed that 67.2% of the passengers have tertiary education and 26% have SSCE. Only 6.8% possess basic education which is also consistent with studies that air travel is elitist. Frequency of air travel is recorded more in fortnight with 30.3% and weekly with 39%. This shows a high volume of the utility of air traffic in Nigeria.

Table 5 indicates that a good number of the passengers are aware of the effects of weather on aviation. High level of awareness can be added to high literacy rate of passengers. However, 5.3% of the passengers are skeptical.

**Table 5: Effects of sudden or slow weather events on aviation**

<b>Awareness of effects of weather on aviation</b>			
	Option	Frequency	Percentage
1	Yes	379	94.7
2	No	00	00
3	Undecided	21	5.3
<b>Weather element that has affected your flight</b>			
	Option	Frequency	Percentage
1	Temperature	00	00
2	Rainfall	103	25.8
3	Cloudiness	82	20.5
4	Visibility	192	48
5	Wind	00	00
6	Pressure	23	5.7
	Total	400	100
<b>Perceived effects of sudden slow weather events on aviation operations</b>			
	Option	Frequency	Percentage
1	Flight delays	193	48.3
2	Flight cancellations	134	33.5
3	Flight diversion	55	13.8
4	Near crash	18	4.5
	Total	400	100
<b>Perceived economic loss from sudden-slow weather events</b>			
	Option	Frequency	Percentage
1	Financial loss	178	44.5
2	Appointment cancelations	143	35.7
3	Loss of opportunities	79	19.8
	Total	400	100

In Table 5, passengers affirmed that visibility, rainfall, and cloudiness are more impactful on flight operations with 48%, 25.8% and 20.5% respectively. Though they did not see temperature and wind as impactful. 5.7% of the

passengers recognized pressure as a cause of air travel disruption. It is also clearly revealed in Table 5 that the main effects of sudden slow weather events on flights and aviation operation in the study area are flight delays (48.3%) and flight cancellations (33.5%). Other challenges of sudden slow weather events are flight diversion (13.8%) and near crash (4.5%). Overall, there appears to be a significant effect of sudden slow weather events on aviation operations in the south eastern part of Nigeria. The economic losses from sudden slow weather events are multidimensional. Passengers recognized financial losses, cancellation of appointments and loss of opportunities as major offshoots of sudden slow weather events. However, financial losses is more prevalent with 44.5%.

**Table 6A: ANOVA table showing the spatial difference in the effects of sudden weather events (rainfall) on aviation in the south east of Nigeria**

ANOVA					
Rainfall					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	8761.000	4	2190.250	12.684	.000
Within Groups	102747.500	595	172.685		
Total	111508.500	599			

**Table 6B: Duncan statistics showing the spatial difference in the effects of sudden weather events (rainfall) on aviation in the south east of Nigeria**

Rainfall					
Duncan					
Identifiers	N	Subset for alpha = 0.05			
		1	2	3	4
Owerri	120	8.6667			
Enugu	120	11.7500	11.7500		
Uyo	120		15.0000	15.0000	
Calabar	120			17.9167	17.9167
Port Harcourt	120				18.9167
Sig.		.070	.056	.086	.556

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 120.000.

Analysis of variance of the spatial variation in the effects of sudden weather events in rainfall for sampled cities in Table 4A (Port Harcourt, Uyo, Enugu, Owerri and Calabar) is significant at  $p < 0.05$  level,  $F = 12.684$ ,  $sig = 0.000$ . Since the significant level is below  $0.05$  ( $p$  value). It indicates that there is a statistically significant difference amongst the five states. Duncan statistics in Table 4B was further computed to decipher where the variation in rainfall is conspicuous. The analysis revealed that Owerri ( $M = 8.667$ ),  $Sig = 0.070$ ) is significantly varied from Uyo ( $M = 15.000$   $Sig = 0.86$ ) and varied from Port Harcourt ( $M = 18.9167$ ,  $Sig = 0.556$ ).

**Table 6C: ANOVA table showing the spatial difference in the effects of sudden weather events (Cloud-Oktas) on aviation in the south east of Nigeria**

ANOVA					
Cloud_Oktas					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	227.667	4	56.917	13.651	.000
Within Groups	2480.833	595	4.169		
Total	2708.500	599			

**Table 6D: Duncan statistics showing the spatial difference in the effects of sudden weather events (cloud-Oktas) on aviation in the south east of Nigeria**

Cloud-Oktas				
Duncan				
Identifiers	N	Subset for alpha = 0.05		
		1	2	3
Calabar	120	1.5833		
Uyo	120		2.3333	
Owerri	120		2.4167	
Enugu	120			3.0833
Port Harcourt	120			3.3333
Sig.		1.000	.752	.343

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 120.000.

Analysis of variance of the spatial variation in the effects of sudden weather events in cloud -oktas for sampled cities (Port Harcourt, Uyo, Enugu, Owerri and Calabar) is presented in Table 4C and it is significant at  $p < 0.05$  level,  $F 13.651$  sig  $0.000$ . Since the significant level is below  $0.05$  ( $p$  value). It indicates that there is a statistically significant difference amongst the five states. Duncan statistics was further computed to decipher where the variation in cloud oktas is conspicuous. Table 4D revealed that Calabar ( $M = 1.5833$ , Sig  $1.000$ ) is significantly varied from Uyo ( $M = 2.333$  Sig  $0.752$ ) and varied from Port Harcourt ( $M = 3.333$ , Sig  $0.343$ )

**Table 6E: ANOVA table showing the spatial difference in the effects of sudden weather events (Visibility) on aviation in the south east of Nigeria**

ANOVA					
Visibility					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	44414.333	4	11103.583	125.345	.000
Within Groups	52707.500	595	88.584		
Total	97121.833	599			

**Table 6F: Duncan Statistics showing the spatial difference in the effects of sudden weather events (Visibility) on aviation in the south east of Nigeria**

**Visibility**  
Duncana

Identifiers	N	Subset for alpha = 0.05		
		1	2	3
Uyo	120	3.7500		
Calabar	120	3.8333		
Port Harcourt	120		14.1667	
Owerri	120		14.2500	
Enugu	120			27.0833
Sig.		.945	.945	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 120.000.

Analysis of variance of the spatial variation in the effects of sudden weather events in visibility for sampled cities (Port Harcourt, Uyo, Enugu, Owerri and Calabar) is presented in Table 4E and it is significant at  $p < 0.05$  level,  $F = 125.345$  sig 0.000. Since the significant level is below 0.05 (p value). It indicates that there is a statistically significant difference amongst the five states. Duncan statistics was further computed to decipher where the variation in visibility is conspicuous. Table 4F revealed that Uyo ( $M = 3.7500$ , sig 0.945) is significantly varied from Port Harcourt ( $M = 14.1667$  Sig 0.45) and varied from Enugu ( $M = 27.0883$ , Sig 1.000)

#### 4: DISCUSSION OF RESULTS

The critical characteristics of sudden and slow weather events over the years in South Eastern Nigeria were evaluated. The character of weather and climate showed changes in frequency, intensity, blip, spatial coverage, number of occurrences and timing. Extremity of rainfall and cloud cover in Port Harcourt and Uyo can be linked to their geographic location and dominance of the south west trade wind. The implication is that the tropical maritime gives more potency for cloud and rainfall to reduce visibility, and affect flight operations given the ubiquity of thunderstorms. Enugu had higher wind speed, but its closeness to the northern part of the country would mean dominance of the tropical continental air-mass. Rainfall, temperature, cloud cover, wind and cloud cover showed remarkable variation annually and monthly. Rainfall showed lack of consistency in most of the years, but 2013 had a similar pattern, temperature ranged between 30 °C to 35°C with Enugu having the highest temperature maximum, and this is consistent with the dynamics of the various climate belts in Nigeria. These findings are consistent with those of Samson & Sumi, (2019). This study has identified the slow and sudden weather events characteristics in the South East. What was very conspicuous is the spatiality of weather characteristics and similarities amongst Port Harcourt, Uyo and Calabar. They showed near similarities in rainfall, cloudiness and visibility which is consistent with the character of the sub equatorial climate. However, this finding is not in tandem with the finding of Ogunrinde *et al.*, (2023). The weather characteristics of Enugu appeared

different and similar to that of the tropical hinterland climate, and have higher wind speed. However, all the sampled cities demonstrated that cloudiness is not very impactful on visibility. The study observed changes in weather characteristics in the decade under investigation, one deviation from the norm is that Calabar which is a coastal town has lower wind speed than other cities, and recorded the most recent increase occurrences in rainfall of 34 events in 2016. However, studies have shown that most of the disruption, delays and cancellations of flight are avoidable if human errors and negligence are tackled (Borsky & Unterberger, 2019).

The changes in the sudden and slow weather and climate events in the south eastern Nigeria is consistent with the environmental changes. But empirical evidences have shown that climate change is one of the defining contemporary issues that have been recognized as a major driver of change in the period under investigation. All the cities sampled showed remarkable differences in changes in precipitation, temperature, cloud cover and visibility. The wind in Enugu which shares the characteristics of the tropical hinterland climate had more speed than other cities but with marked variation across the years. Port Harcourt recorded remarkable shift with double maxima of high rainfall events in 2013 (34 occurrences) and 2016 (39 occurrences). Only 12 and 12 rainfall events recorded in port Harcourt in 2014 and 2018 are the only similarities, but the difference between rainfall events of 12 which is the lowest and that of 2016 (39 events which is the highest is significant. The case of Owerri where rainfall was recorded just ounces in 2016, 4 times 2015 and 2021 represent concrete evidence of climate. The only city that had one level of consistency in rainfall is Uyo, but there is abrupt reduction in 2018 with only 8 events. These findings are in line with those of Eludoyin & Akinbode (2009), although Ugochukwu, Emmanuel, & Lekia, (2023) reporter otherwise. Adverse weather and climate events are external factors that determines the operations of airports operations globally, but there is perceived over generalization of the climatic parameters that causes more disruptions in various climate regions. This study showed concrete evidence of slow and sudden weather events and potential effects on flight operations in the south east, but there is spatial variation among the cities investigated. As also reported by Uchechukwu *et al.* (2018). The effects of the sudden and slow events are multidimensional, one the one hand, it increases the cost of operations, and create a negative public perception for airlines that do not have the required expertise to be proactive, and minimize the effects on passengers. On the other hands, sudden weather events cause delays, flight cancelation and additional cost for travelers, it can also lead to fatalities. In most cases, delays occur when there is no accurate forecast of imminent sudden weather events, and when communication with passengers is poor. It has been established in the literature that weather events are not always controllable (Oriola, 2014), however, the onus is in airlines to minimize cost and losses of productive hours for passengers. Occurrences of heavy rainfall and strong wind are sudden, and occur at specific time of the day, but causes shift in disruption in logistics planning with economic cost for operators and passengers, but data on amount of departure delays in various airline companies is not availability for research (Balogun & Odjugo, 2020). The constancy of the effects of rainfall and cloud cover on visibility and airline operations in the decade under review is attributable to the dynamics in the sub equatorial and hinterland climate. Similar observation has been made by Borsky & Unterberger, (2019), they however, averred that being acquainted with the weather and

climate characteristics of the locale is key to ameliorating the sudden and slow weather events effects of aviation operations.

Passengers are largely aware of the effects of weather events on air travels. Over the years, financial losses, flight delays and cancellation and loss of opportunities have been recorded by passengers. But there is still no policy to compensate for poor service. Evidently, flight travels are still largely patronized by the elites as there seem to be a correlation between literacy and the utility of air transport. Only few passengers with basic education utilizes air transport in the sampled cities and they are obviously the respondents that are not aware of the effects of weather events on air travels (Adefolalu, 2007). Annual and decadal rainfall revealed steady increase from June to August and slight decrease from October to March. There is positive statistical relationship and variation in weather characteristics which also manifest in flight delays, cancellation and diversion. This is consistent with Mande (2019) where he reported that 71% of air travel disruption in Nigeria are due to the poor weather conditions, with the inclusion of human errors, aging aircraft and deficiency in safety management system. This case of full cloud in Port Harcourt also aligns with Mande (2019) where he reported flight disruption in the city with reduced horizontal visibility to between 200 to 800 for several days leading to spiraling flight disruption across the country.

## 5. CONCLUSION AND RECOMMENDATIONS

It is obvious as captured in several studies in the literature that knowledge on weather phenomena is very important for flight operations while others 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, available reports maintained that in aviation, weather has remained the important parameter in determining safety, regularity and efficiency of aviation operations. The plethora of studies in the literature that interrogate the effects of weather parameters on aviation have obviously failed to differentiate between slow and sudden weather events. Thus, there is perceived wrongful generalization and errors in responses to weather related problems in the aviation industry. This study has established the difference between slow and sudden weather events and disparity in weather characteristics amongst cities in the south east. It revealed that there are variations in cloudiness, rainfall and visibility amongst the cities and given the interconnectedness of aviation infrastructure and operations with weather parameters, disruption in one city leads to chain disruption in other cities resulting in flight disruptions. Noting that the economic cost of flight cancelation, diversion and delays are not quantified and duly compensated, the need to device various methods to address the peculiarities of problems in various cities are necessary. On the premise of the above, the following recommendations are made:

1. improvement in the expertise of aviation staff through training and retraining to keep pace with effects of weather variability and change in airline operations.
2. migrating from analog data collection methods to automated instruments to engender real time and accurate data collection for planning due to the dynamic nature of atmospheric parameters.
3. enactment and enforcement of stringent regulations on airline companies to engender global best practices.
4. replacement of aging aircraft and weather monitoring facilities.

5. improvement in maintenance culture.
6. synergy between all airport services providers is needed to activate proactive planning, anticipate climate change and design appropriate resilience and adaptation plan.as well measures to tackle flight disruption, damage of airport infrastructure given the progression of rainfall and changing wind.

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