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Daily air temperature variation in Makurdi metropolis using analysis of variance model

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Abstract

This paper revealed the variations observed in the daily air temperature in Makurdi Metropolis, Benue State, Nigeria. The data used here is a 37years (1984-2021) on daily air temperature sourced from National Aeronautics and Space Administration (NASA). Two way Analysis of Variance (ANOVA) model was used and the results revealed that both months, years and interaction were all significance (0.000 < 0.05). This means that the daily air temperature of Makurdi metropolis are statistically significance across the Months (January – December) and the Years as well as the interaction between them. It was observed that month of March has the highest mean value of daily air temperature of 28.11 ^{0}C whereas December has the least mean value of 23.65 ^{0}C (Figure 1). Furthermore, 1984 has the least mean air temperature and 2021 has the highest though stochasticity is observed (Figure 2). The multiple means comparison was carried out using Turkey Honestly Significant Difference (HSD). The multiple means comparison for the months revealed ten (10) different subsets with July and September in subset 4, September and November in subset 5 shows no significant difference. Significance differences were observed with comparison across different subsets. For example, December and January are significantly different from each other (subset 1 and subset 2) and so on. The HSD result of the year shows eighteen (18) different subsets with 2021 significantly differ from any other year (subset 18 and any other subset), 2019 in subset 17 differ significantly from any other year exception of 2014 in the same subset.

Keyword: ANOVA; Turkey HSD; Significance difference; Daily air temperature

1. Introduction

Analysis of Variance (ANOVA) is based on the law of total variance, where the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether two or more population means are equal or not, and therefore it is a generalization of the t-test beyond two means. The essence of ANOVA is the breaking down of total variations into two types. That is, the variation that is attributed to chance and the variation that is attributed to treatments. Climatic variables such as temperature can be analyzed using ANOVA for differences (climatic change) across zones and time [1].

Climate change stands to alter the structure of the natural ecosystem and function through numerous and diverse ways. In addition to this changes, the fundamental abiotic qualities of ecosystems (temperature, water availability, CO_2 concentration), also alter the behavioral life cycle of an organisms [9]

The impacts of change in temperature include global warming, changes in precipitation, increases in the frequency or intensity of some extreme weather condition such as rainfall and rising sea levels. These impacts has a threat on our health in a sense that it affect the food and the water we consume as well as the weather we experience [4]. The impacts

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of variability of temperature varies and sometimes serve as an enabling ground for outbreak of epidemic within a geographical location.

In climate change, variability in temperature is one of the major variable that is paramount. It is one of the most serious environmental threat to the fight against hunger, malnutrition, disease and poverty in the world today, Nigeria inclusive. Its impact on agriculture and human health cannot be over emphasized [8]. Temperature plays a vital role in the life of every living organisms. Hence, the need to determine if variability exist or not in mean air temperature from 1984 – 2021 within Makurdi metropolis.

Temperature has been described to be the degree of hotness or coldness of a body. The degree to which the temperature of a body reaches, is largely dependent on the outdoor temperature. The natural causes of change in temperature include elevation, flow of surface winds and vorticity, changes in waves and ocean currents etc. while Manmade causes range from deforestation and other combustive engines and activities that emits greenhouse gases into the atmosphere [5].

The consequences of global temperature changes since the industrial revolution era is alarming; this has caused climate change that is gradually moving the earth to an inhabitable zone for living organism [2]. [6] revealed that climatic parameters such as air temperature, relative humidity and rainfall are affected by global warming resulting to variability in weather patterns. Furthermore, the increase in these greenhouse gases has led to the increase in global air temperature.

Rainfall amount depends on the maximum amount of water vapour that the air can hold and this in turn depends on the air temperature. In addition, warm air is capable of holding more water vapour than cold air [7]

Extreme weather condition can be trace to rising global temperatures, increase in water vapour in the atmosphere and change in atmospheric circulation. It has also been established that warmer temperatures directly influence heat waves and increase the atmosphere to supply extreme precipitation events [3].

2. Material and methods

2.1. Study Area and Source of Data

Nigeria lies between 4^0N and 14^0N latitude and longitude 4^0E to 14^0E. It is located in West Africa, sharing border with the Republic of Niger to the North; Cameroon to the East; Benin Republic to the West and to the south is the Gulf of Guinea which is an arm of the Atlantic Ocean.

Benue State is one of the North Central state in Nigeria with a population of 4,253,641 as at 2006 census. The state borders Nassarawa State to the North; Taraba State to the East; Kogi State to the West; Enugu State to the South-West; Ebonyi and Cross-Rivers to the South; and has an international border with Cameroon to the South-East. The daily air temperature was obtained from National Aeronautics and Space Administration (NASA) (Modern Era Retrospective Analysis Version 2 (MERRA-2)) for the period of thirty-seven (37) years (1984-2021).

2.2. Analysis of Variance Model

Two-way ANOVA is one of the methods used to examine the effect of two factors on a dependent variables. The two way analysis of variance model are as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \epsilon_{ijk} \begin{cases} i = 1,2,\dots,a \\ j = 1,2,\dots,b \\ n = 1,2,\dots,n \end{cases} \dots\dots\dots\dots\dots(1)$$

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk} \begin{cases} i = 1,2,\dots,a \\ j = 1,2,\dots,b \\ n = 1,2,\dots,n \end{cases} \dots\dots\dots\dots(2)$$

Note that $\Sigma\alpha_i = \Sigma\beta_j = \Sigma(\alpha\beta)_{ij} = 0$ and $\varepsilon_{ij} \sim IIDN(0,\sigma^2)$

Where;

Y_{ijk} are independent observations of the i-th treatments of the j-th blocks and the k-th replications, μ is the true mean value of the dependent variable, α_i is the effect due to the i-th level of the treatment effect and β_j is the effect due to the j-th level of the block effect, $(\alpha\beta)_{ij}$ is the effect due to the interaction between the i-th level of the treatment and the j-th level of the block and ε is the random error in the response attributed to the dependent variable.

Equations (1) and (2) above are two way analysis of variance without and with interaction respectively.

Table 1 General ANOVA Layout

Factors	**Factor B**			
Factor A	**1**	**2**	**...**	**b**
1	$Y_{111,}Y_{112},\ldots,Y_{11n}$	$Y_{121,}Y_{122},\ldots,Y_{12n}$	...	$Y_{1b1,}Y_{1b2},\ldots,Y_{1bn}$
2	$Y_{211},Y_{212},\ldots,Y_{21n}$	$Y_{221},Y_{222},\ldots,Y_{22n}$	...	$Y_{2b1,}Y_{2b2},\ldots,Y_{2bn}$
3	$Y_{311,}Y_{312},\ldots,Y_{31n}$	$Y_{321},Y_{322},\ldots,Y_{32n}$	...	$Y_{3b1,}Y_{3b2},\ldots,Y_{3bn}$
.	.	.		.
.	.	.	...	.
.	.	.		.
a	$Y_{a11},Y_{a12},\ldots,Y_{a1n}$	$Y_{a21},Y_{a22},\ldots,Y_{a2n}$	...	$Y_{ab1,}Y_{ab2},\ldots,Y_{abn}$

In estimating the model parameters, the following formula are needed.

The Sum of squares total (SS_T)

$$SS_T = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{n} y_{ij}^2 - \frac{y_{\ldots}^2}{\text{abn}} \quad \ldots\ldots\ldots\ldots(3)$$

The sum of squares for the treatment effects (SS_A)

$$SS_A = \frac{1}{\text{bn}}\sum_{i=1}^{a} y_{i..}^2 - \frac{y_{\ldots}^2}{\text{abn}} \quad \ldots\ldots\ldots(4)$$

The sum of squares for the block effects (SS_B)

$$SS_B = \frac{1}{\text{an}}\sum_{j=1}^{b} y_{.j.}^2 - \frac{y_{\ldots}^2}{\text{abn}} \ldots\ldots\ldots\ldots(5)$$

The convenient way of estimating the sum of squares due to interactions (SS_{AB}) is as follows

$$SS_{AB} = \frac{1}{\text{n}}\sum_{i=1}^{a}\sum_{j=1}^{b} y_{ij.}^2 - \frac{y_{\ldots}^2}{\text{abn}} - SS_A - SS_B \quad \ldots\ldots\ldots\ldots(6)$$

Where

$$SS_{Subtotal} = \frac{1}{\text{n}}\sum_{i=1}^{a}\sum_{j=1}^{b} y_{ij.}^2 - \frac{y_{\ldots}^2}{\text{abn}}$$

The error sum of squares (SS_E)

$$SS_E = SS_T - SS_A - SS_B - SS_{AB} \ldots\ldots\ldots\ldots(7)$$

The test statistic for nullify the null hypothesis is as summarized in the ANOVA Table below.

In order to carryout multiple means comparison, this paper makes used of honestly significant difference (HSD) and is as given below. $q = \frac{\bar{y}_i - \bar{y}_j}{\sqrt{\frac{MS_E}{n}}}$ where n is the number of observation, MS_E is the mean square error, $\bar{y}_i$ is the mean of the i-th treatment and $\bar{y}_j$ is the mean of the j-th block to be compared.

Table 2 Analysis of Variance Table (ANOVA)

Source of Variation	**Sum of squares**	**Degree of Freedom**	**Mean square**	**F-Ratio**
Factor A	SS_A	(a - 1)	$\frac{SS_A}{(a-1)}$	$F = \frac{MS_A}{MS_E}$
Factor B	SS_B	(b - 1)	$\frac{SS_B}{(b-1)}$	$F = \frac{MS_B}{MS_E}$
Interaction	SS_{AB}	(a - 1)(b - 1)	$\frac{SS_{AB}}{(a-1)(b-1)}$	$F = \frac{MS_{AB}}{MS_E}$
Error	SS_E	(N - ab)	$\frac{SS_E}{N-ab}$	
Total	SS_T	(N - 1)		

3. Results and discussion

This section presents the results and the interpretation of the analysis of the daily air temperature of Makurdi metropolis from 1984 - 2021 using two way analysis of variance model and Statistical Package for Social Sciences Software (SPSS) version 22.

Table 3 shows the descriptive statistics of Makurdi daily air temperature from 1984 to 2021. The result showed that the temperature for year 1984 is the least with mean value of 24.66 ^{0}C follow by 1989 with mean value of 24.73 ^{0}C as well as a standard deviation of 1.94 and 2.31 respectively. Year 2021 has the highest mean of 28.11 ^{0}C and the standard deviation of 1.16. Looking at the mean of Table 3 critically, you will observe gradual increases as you move down from 1984 to 2021; though stochasticity is observed (plot 1 and 2). Observe that the mean of the air temperature across the year is purely stochastics but increase gradually year after year (Figure 2). Furthermore, a unique characteristics of this air temperature is that, from 1984 down to 2005, the perturbation occurs three (3) years on the average and then continue to fluctuate with 2008 and 2005 having the maximum variations of seven (7) and six (6) years respectively (Figure 2). From the graph (Figure 2), the air temperature that is down in 1984 will move up and return down in 1988 (four years later). It then now follows by 1991, 1994, 1997 etc which were all three (3) years interval.

Table 3 Descriptive Statistics

Years	**Mean**	**Std. Error**	**N**
1984	24.66	1.94	366
1985	24.94	1.44	365
1986	25.21	1.88	365
1987	25.96	1.59	365
1988	25.71	1.67	366
1989	24.73	2.31	365
1990	25.67	1.37	365
1991	25.47	1.92	365
1992	25.00	2.24	366
1993	25.10	1.95	365

1994	24.91	2.21	365
1995	25.02	1.94	365
1996	25.08	1.78	366
1997	24.96	1.66	365
1998	25.69	2.09	365
1999	26.22	1.47	365
2000	25.83	2.42	366
2001	24.90	1.97	365
2002	25.42	2.00	365
2003	25.69	1.51	365
2004	26.18	1.44	366
2005	26.59	1.73	365
2006	26.15	1.94	365
2007	25.55	2.14	365
2008	25.39	1.72	366
2009	26.12	1.54	365
2010	26.28	1.86	365
2011	25.83	1.89	365
2012	25.96	1.92	366
2013	26.43	1.51	365
2014	26.84	1.45	365
2015	26.81	2.03	365
2016	26.57	2.01	366
2017	26.32	1.54	365
2018	26.51	1.81	365
2019	27.20	2.21	365
2020	26.49	1.78	366
2021	28.11	1.16	151

Table 4 presents the analysis of variance for the mean air temperatures from year 1984 to 2021 across the months of the years at 5% level of significance. The result showed that the overall model is significant with a p_value of 0.000 which is less than 0.05 alpha level of significance. Both the months, years and the interaction between the months and the years were all significant at the same alpha level (0.05) and the p_value of 0.000 for all (0.000<0.05, Table 4). The implication of the significance in the interactions between the months and the years is that, changes occur across the months as one moves from one month to the other at any given year.

As the result of significance difference observed between the months and the years, as well as the interaction, we then now move to multiple mean comparison using Tukey Honestly Significant Difference (HSD) test.

The result of the homogenous test in Table 5 using Tukey HSD shows ten (10) different homogeneous subsets. July and September has the same mean air temperature as in subset 4 (No significance differences observed across these months). Also in subset 5, September and November has the same mean air temperature. Lastly, April and March has the same mean air temperature in subset 10 (No significance differences observed between these months). Any other comparison across subset(s) has different mean air temperature (Significantly different from each other). The implication of these results is that any epidemic/pandemic that strive base on air temperature in July will definitely do same in September, the same apply to September and November, April and March. Note that July and November are significantly different from each other in term of the mean air temperature. The variability in the mean air temperature across the months is less compared to that of the years. The multiple means comparison for the year has over eighteen (18) different subsets (Table 6). The year 1989, 2001, 1994, 1985, 1997, 1992 and 1995 in subsets one (1) and two (2) has the same mean air temperature (No significant differences observed among them). Similarly, 2001, 1994, 1985, 1997, 1992 and 1995 in subsets one (1), two (2) and three (3) are not significantly different from each other. It then now follow for other years across other subset. 2019 in subset seventeen (17) is significantly different from every other years across all the subsets (Table 6).

Table 4 Analysis of variance

Source of Variation	Type III Sum of Squares	Df	Mean Square	F	Sig.
Model	9130991.51	449	20336.28	19150.84	.000
Months	24131.19	11	2193.74	2065.90	.000
Years	6340.70	37	171.37	161.38	.000
Months * Years	8358.19	400	20.90	19.68	.000
Error	14035.14	13217	1.06		
Total	9145026.66	13666			
a. R Squared = .998 (Adjusted R Squared = .998)					

Table 5 Homogeneous Test across the Months (January – December)

Months	N	Subset									
		1	2	3	4	5	6	7	8	9	10
11 December	1147	23.65									
0 January	1178		24.16								
7 August	1147			24.93							
6 July	1147				25.12						
8 September	1110				25.17	25.17					
10 November	1110					25.32					
9 October	1147						25.54				
5 June	1110							25.99			
1 February	1074								26.49		
4 May	1178									27.06	
3 April	1140										27.98
2 March	1178										28.09
Sig.		1.000	1.000	1.000	.996	.274	1.000	1.000	1.000	1.000	.78

Means for groups in homogeneous subsets are displayed based on observed means.

Table 6 Homogeneous Test across the Years (1984 – 2021)

Years	N	Subset																	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1984	366	24.66																	
1989	365	24.73	24.73																
2001	365	24.90	24.90	24.90															
1994	365	24.91	24.91	24.91															
1985	365	24.94	24.94	24.94															
1997	365	24.96	24.96	24.96															
1992	366	25.00	25.00	25.00															
1995	365	25.02	25.02	25.02	25.02														
1996	366		25.08	25.08	25.08	25.08													
1993	365		25.10	25.10	25.10	25.10													
1986	365			25.21	25.21	25.21	25.21												
2008	366				25.39	25.39	25.39	25.39											
2002	365					25.42	25.42	25.42											
1991	365						25.47	25.47	25.47										
2007	365						25.55	25.55	25.55										
1990	365							25.67	25.67	25.67									
1998	365							25.69	25.69	25.69									
2003	365							25.69	25.69	25.69									
1988	366							25.71	25.71	25.71									
2011	365								25.83	25.83	25.83								
2000	366								25.83	25.83	25.83								
2012	366									25.96	25.96	25.96							
1987	365									25.96	25.96	25.96							

2009	365										26.12	26.12	26.12						
2006	365										26.15	26.15	26.15	26.15					
2004	366										26.18	26.18	26.18	26.18					
1999	365											26.21	26.22	26.22	26.22				
2010	365											26.28	26.28	26.28	26.28	26.28			
2017	365											26.32	26.32	26.32	26.32	26.32			
2013	365												26.43	26.43	26.43	26.43			
2020	366												26.49	26.49	26.49	26.49	26.49		
2018	365													26.51	26.51	26.51	26.51		
2016	366														26.57	26.57	26.57		
2005	365															26.59	26.59		
2015	365																26.81		
2014	365																26.84	26.84	
2019	365																	27.20	
2021	151																		28.11
Sig.		.078	.055	.327	.061	.183	.173	.250	.075	.447	.107	.086	.065	.070	.092	.302	.120	.083	1.000

Means for groups in homogeneous subsets are displayed based on observed means.

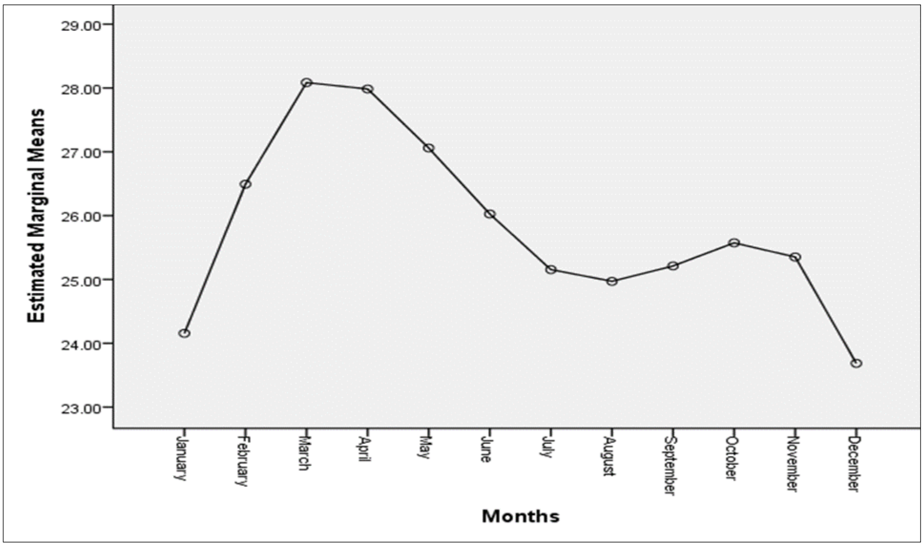

Figure 1 The Plot of the Distributions of the Daily Air Temperature across the Months

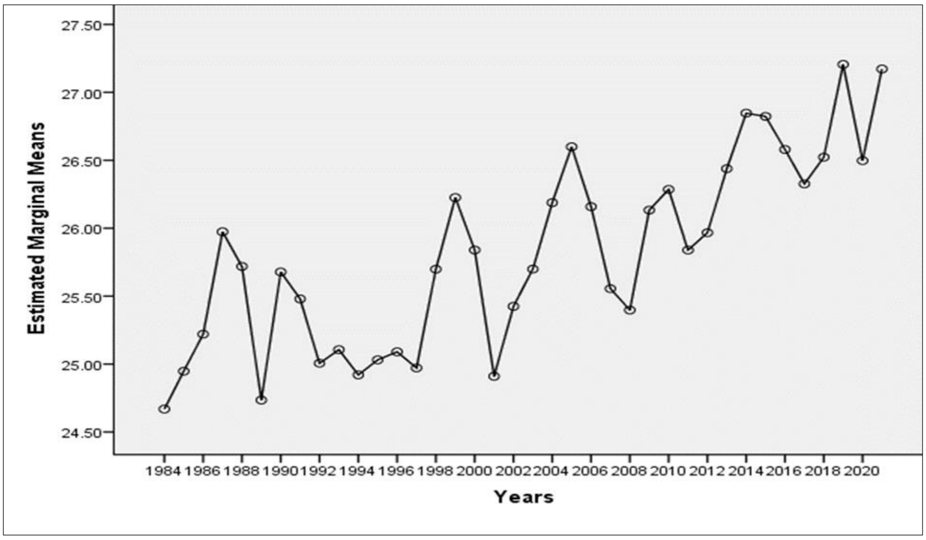

Figure 2 The Plot of the Distributions of the Daily Air Temperature across the Years

4. Conclusion

This Study analyzed Makurdi daily air temperature data of 37 years (1984 to 2021) using Analysis of Variance (ANOVA) and SPSS version 22. The variation of daily air temperature in Makurdi metropolis was checked across the years in order to draw inference base on the effect of temperature. Furthermore interaction between the years and the month were also checked in order to determine if there are changes among them. This study revealed the existence of significant differences in the daily air temperature of Makurdi metropolis within the year under study. The daily air temperature showed that there is significant difference across the months of the years under study with March having the highest maximum mean air temperature of 28.09 ^{0}C from 1984 to 2021 (Figure 1).

Analysis of variance of the daily air temperature of Makurdi was carried out and the result have shown that there is significant difference across the years (1984 to 2021). Year 2021 had the highest mean maximum temperature of 28.11 ^{0}C across the years under consideration. The monthly daily air temperature showed that the month of March have the highest temperature across the months of the years. However, the month of September and November are not significantly different from each other (subset 5, Table 5), the month of September and July are not significantly different from each other as well in subset 4, Table 5. Also the month of March and April are not significantly different from each other as shown in Table 5, subset 10. Any other pairs across subsets are all significance at alpha level of 0.05. This is to say that most of the months have peculiar air temperature different from every other months. However, the results showed that the highest air temperature was recorded in the month of March which has the value of 28.11 ^{0}C closely followed by the month of April with the value of 27.98 ^{0}C. This is to say that in Makurdi, the month of March and April have the highest temperature with December having a minimum of 23.65 ^{0}C.

This finding agrees with the study of Karyn (2010) though in different locations; that the month of April appears to be the hottest month at Yobe, Bauchi, Gombe and Adamawa states, while the month of March was the hottest month in Borno and Taraba. According to Bergstrom *et al.* (2011) the desertification, flood plain and basement nature of Nigeria could be the reason for changes in monthly rise in temperature.

This paper has successfully revealed that there are variation in monthly daily air temperature in Makurdi metropolis. This variability observed could be an evidence of climate change resulting from increase in population and industrialization. This observation is in line with the observations of Varis (2004) which indicate an increase in mean air temperatures over time in the last century. According to Varis (2004), temperature in Northern Nigeria is significantly higher in April followed by March, May, June and October as compared to all the other months of the year.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest concerning this work.

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