# Time Series Analysis of Rainfall and Temperature in South West Nigeria.

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## ABSTRACT

In other to give an objective explanation to the effect of some natural phenomenon in the study of climate change, especially global warming, monthly recorded agro-meteorological data was collected from the Forestry Research Institute of Nigeria's (FRIN) agro-meteorological station. Least square method was used to estimate the trend in the series and the trend equation for rainfall and temperature. Time series method using additive model for the deterministic approach was employed in estimating the seasonal variation/index and also to make elementary forecast of the future values of temperature and rainfall. However, before the analysis was carried out, the time plots were plotted for the two variables.

The plots of the AC and PAC neither decay exponentially to zero or cut off which is a characteristic of autoregressive (AR) model. The reverse does not suggest moving average (MA) also. The two corellograms exhibit characteristics of autoregressive moving average (ARMA) based on the inability to display a characteristic pattern, which suggests it to be a mixed model of AR and MA. The minimum AIC value is 10.90464 which is less than the initial one (10.95916). There is no serial correlation in the residuals as indicated by the Durbin Watson statistic (DW=2.034172) and Breusch-Godfrey Serial correlation test and the model parameters are significant at 1% and 5% level.

(Keywords: agro-meteorological data, rainfall, temperature, least square method, climate change, moving average, corellogram)

## INTRODUCTION

Climate change refers to a change in climate that is attributable directly or indirectly to human activities, that affects the atmospheric conditions of the Earth leading to global warming. It can also be referred to as any long-term change in the statistics of weather over durations ranging from decades to millions of years. It can be manifest in changes to averages, extremes, or other statistical measures, and may occur in a specific region or for the Earth as a whole.

Climate change has the potential to affect all natural systems thereby becoming a threat to human development and survival socially, politically, and economically. According to a report published by the Federal Ministry of Environment, Nigeria with a population of about 140 million and with an area of 923.000 square kilometers, the various activities being carried out by this vast population coupled with variability in elements of climate such as rainfall and temperature, exposes the country to the impact of climate change.

Nigeria's vulnerability occurs in two ways according to the reports; the first results from the impacts of climate change and second relates to the impact of response measures. This is because Nigeria's economy is highly dependent on income generated from the production, export, and consumption of fossil fuels and associated energy-intensive products.

The negative impact of climate change such as temperature rise, erratic rainfall, sand storms, desertification, low agricultural yield, drying up of water bodies, and sea level rise are real in the desert prone eleven front line states of Nigeria. Environmental degradation and the attendant desertification are major threats to the livelihood of the inhabitants of the frontline states of Nigeria. These lead to increasing population pressures, intensive agricultural land use, overgrazing, bush burning, and extraction of fuel wood and other biotic resources.

Today, the entire global community has started suffering from the unfriendly climatic condition, the gradual disappearance of rain forest in the tropics, the loss of plant and animal species, changes in rainfall patterns, and global warming resulting from climate change (Akinyemi, 2008). Babalola et al., 2008, opined that climate change will have significant effects on the energy sector in Nigeria. The most significant impact of climate change on energy will include (i) higher electricity demand for heating, cooling, water pumping, etc., (b) reduced availability of hydroelectricity and fuel wood, and (c) extensive damage to petrochemical industrial installations presented concentrated in the coastal belt. In particular, rising temperatures, changes in the amount of precipitation, and variation in humidity, wind patterns and the number of sunny days per year, could affect both consumption and production of energy.

Women and children are particularly the most vulnerable to the impact of climate change. The report advised governments at all levels to improve the financial status towards these issues. Inadequate funds hamper progress in achieving Nigeria's objectives on Climate Change. So far, very little has been dedicated to this issue of climate change in the National Budget, the report stated. It calls for increased public awareness, research, the building of strong climate change institutions, and the provision of appropriate institutional and legal frameworks with full government support. Minister of Environment, Mr. John Odey, at a press briefing during the World Environment Day (WED), declared that the Federal Government, while addressing the threat of climate change in Nigeria, both in terms of mitigation and adaptation, is currently focusing on the implementation of the Clean Development Mechanism (CDM) projects and other climate friendly projects in the country. These projects are being executed on a public-private partnership basis with many investors, including some big banking institutions, indicating interest in some of the CDM projects ranging from afforestation and forest degradation programs to capturing of associated gas in the course of petroleum exploration.

## RESULTS AND DISCUSSION

The monthly time plot for rainfall and temperature in Figure 1 revealed that the trends are varying and the series are stationary. Hence, the forecast generated for temperature and rainfall using probability forecast show that temperature increases slowly with time and rainfall decreases averagely with time. The time series analysis of Rainfall and temperature was carried out using E-views 5.0.

## DISCUSSIONS AND CONCLUSION

Time plots for rainfall display series of cyclical behavior and this is due to seasonal changes from month to month across the year. Fairly seasonal behavior is also experienced in the temperature series.

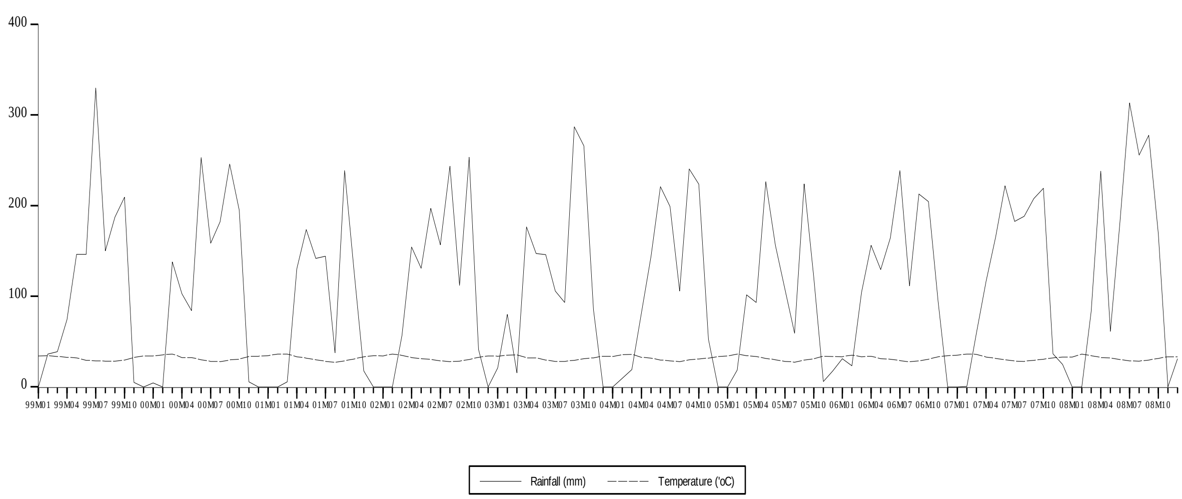


**Figure 1:** Time Plots of Rainfall (mm) and Temperature ($^oC$).

The two series appear to be stationary and this is justified based on unit root (nonstationarity) tests presented in Table 1.

The results was computed up to lag 10 for Dickey and Fuller (1979) test otherwise known as Augmented Dickey Fuller (ADF) test and the Phillips-Perron (1988) test was computed based on automatic selection using the Eviews 5.0 software.

For the two tests (ADF and PP), Null hypothesis is Unit Root (nonstationary) and the results in the table indicate significance of the stationarity regression coefficients at 1%, 5%, and 10% level of significance which implies the rejection of the null hypotheses of Unit Roots for rainfall and temperature series. Hence, stationarity is confirmed in the rainfall and temperature data used in this research work.

The model is identified based on the shape of sample autocorrelation (AC) and partial autocorrelation (PA) plots. Following Figure 2 below, the autocorrelations are all significant indication that the series generating them are not noise process but sequence of random values, $X_t$.

The plots of the AC and PAC neither decay exponentially to zero or cut off which is a characteristic of autoregressive (AR) model. The reverse, does not suggest moving average (MA) also. The two corellograms exhibit characteristics of autoregressive moving average (ARMA) based on the inability to display a characteristic pattern, which suggests it to be a mixed model of AR and MA.

For the Temperature series, the computed values of the sample autocorrelations are high in compared to that of Rainfall given in Figure 1 above. This is confirmed based on the probability values (*$p$ <0.05, $p$<0.01*).

Based on the pattern of the AC and PA, there is strong indication that the model is mixed that is ARMA model.

For the Temperature series, the autocorrelation plot is sinusoidal and the PAC shows some significant spikes. The model as well cannot be pure AR or MA but there is a suggestion for ARMA model.

## RAINFALL SERIES

Model order is determined based on the minimum value of Akaike Information (AIC) criterion. For each of the series, a grid search over all possible values of ($p,q$), (that is the order of autoregression and moving average) was set up and the corresponding model orders that give minimum Information values (AIC) are picked.

The grid search detects the full ARMA model to be of order ($p$, $q$) = (9, 6) and this is too large as a model. The non-significant parameters will then be removed starting from the least significant in order to avoid this problem of over-parameterization.

The final model showing subset of significant parameters (after removing the insignificant ones) is presented above in Table 3.

**Table 1:** Series Unit Root (Nonstationarity) Tests

| | Rainfall (mm) Series | | | | Temperature (oC) Series | | | |
|---|---|---|---|---|---|---|---|---|
| Test | ADF | | PP | | ADF | | PP | KPSS |
| *Statistic* | *-6.216551* | | *-5.577007* | | *-6.255662* | | *-4.795606* | |
| *1%* | -3.486064 | (0.0000) | -3.486064 | (0.0000) | -3.486551 | (0.0000) | -3.486064 | (0.0001) |
| *5%* | -2.885063 | | -2.885863 | | -2.886074 | | -2.885863 | |
| *10%* | -2.571818 | | -2.571818 | | -2.579931 | | -2.579818 | |

**Figure 2:** Sample Autocorrelation (AC) and Partial Autocorrelation (PAC) Plots (Corellograms) of the Rainfall (mm) Series.

<table>
<tr><th>Autocorrelation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>.|**** |</td><td>.|**** |</td><td>1</td><td>0.494</td><td>0.494</td><td>30.022</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>2</td><td>0.210</td><td>-0.045</td><td>35.478</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>*|. |</td><td>3</td><td>-0.019</td><td>-0.138</td><td>35.521</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>**|. |</td><td>4</td><td>-0.267</td><td>-0.263</td><td>44.533</td><td>0.000</td></tr>
<tr><td>****|. |</td><td>**|. |</td><td>5</td><td>-0.468</td><td>-0.305</td><td>72.405</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>*|. |</td><td>6</td><td>-0.421</td><td>-0.085</td><td>95.161</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>**|. |</td><td>7</td><td>-0.380</td><td>-0.189</td><td>113.92</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>.|. |</td><td>8</td><td>-0.200</td><td>-0.041</td><td>119.13</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>*|. |</td><td>9</td><td>-0.049</td><td>-0.124</td><td>119.45</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>10</td><td>0.137</td><td>-0.021</td><td>121.94</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>.|** |</td><td>11</td><td>0.421</td><td>0.276</td><td>145.74</td><td>0.000</td></tr>
<tr><td>.|**** |</td><td>.|* |</td><td>12</td><td>0.513</td><td>0.165</td><td>181.35</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>.|. |</td><td>13</td><td>0.376</td><td>0.012</td><td>200.66</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>**|. |</td><td>14</td><td>0.114</td><td>-0.207</td><td>202.46</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>15</td><td>-0.023</td><td>0.052</td><td>202.54</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>.|. |</td><td>16</td><td>-0.207</td><td>0.063</td><td>208.56</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>.|. |</td><td>17</td><td>-0.326</td><td>0.014</td><td>223.64</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>.|. |</td><td>18</td><td>-0.305</td><td>0.035</td><td>237.02</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>*|. |</td><td>19</td><td>-0.260</td><td>-0.118</td><td>246.84</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>.|. |</td><td>20</td><td>-0.176</td><td>-0.009</td><td>251.38</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>21</td><td>-0.027</td><td>0.028</td><td>251.49</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>22</td><td>0.110</td><td>-0.011</td><td>253.31</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>23</td><td>0.300</td><td>0.055</td><td>266.86</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>.|* |</td><td>24</td><td>0.425</td><td>0.096</td><td>294.36</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>*|. |</td><td>25</td><td>0.242</td><td>-0.095</td><td>303.36</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>26</td><td>0.089</td><td>-0.040</td><td>304.60</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>.|. |</td><td>27</td><td>-0.062</td><td>-0.046</td><td>305.21</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>.|* |</td><td>28</td><td>-0.150</td><td>0.109</td><td>308.79</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>.|* |</td><td>29</td><td>-0.204</td><td>0.087</td><td>315.52</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>*|. |</td><td>30</td><td>-0.228</td><td>-0.083</td><td>323.95</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>.|. |</td><td>31</td><td>-0.157</td><td>0.034</td><td>328.02</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>*|. |</td><td>32</td><td>-0.134</td><td>-0.111</td><td>331.02</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|* |</td><td>33</td><td>-0.027</td><td>0.113</td><td>331.14</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>34</td><td>0.063</td><td>-0.044</td><td>331.81</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>*|. |</td><td>35</td><td>0.193</td><td>-0.058</td><td>338.21</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>36</td><td>0.265</td><td>0.038</td><td>350.45</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>37</td><td>0.223</td><td>0.024</td><td>359.18</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|* |</td><td>38</td><td>0.065</td><td>0.073</td><td>359.94</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>39</td><td>0.024</td><td>0.018</td><td>360.05</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>.|. |</td><td>40</td><td>-0.091</td><td>-0.048</td><td>361.55</td><td>0.000</td></tr>
</table>

**Figure 3:** Sample Autocorrelation (AC) and Partial Autocorrelation (PAC) Plots (Corellograms) of the Temperature ($^{o}C$) Series.

<table>
<tr><th>Autocorrelation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>.|****** |</td><td>.|****** |</td><td>1</td><td>0.793</td><td>0.793</td><td>77.270</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>****|. |</td><td>2</td><td>0.443</td><td>-0.498</td><td>101.61</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>****|. |</td><td>3</td><td>0.002</td><td>-0.463</td><td>101.61</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>****|. |</td><td>4</td><td>-0.450</td><td>-0.488</td><td>127.13</td><td>0.000</td></tr>
<tr><td>******|. |</td><td>**|. |</td><td>5</td><td>-0.757</td><td>-0.262</td><td>200.14</td><td>0.000</td></tr>
<tr><td>*******|. |</td><td>*|. |</td><td>6</td><td>-0.854</td><td>-0.151</td><td>293.81</td><td>0.000</td></tr>
<tr><td>******|. |</td><td>*|. |</td><td>7</td><td>-0.728</td><td>-0.090</td><td>362.50</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>*|. |</td><td>8</td><td>-0.428</td><td>-0.148</td><td>386.48</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>9</td><td>-0.007</td><td>0.042</td><td>386.48</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>*|. |</td><td>10</td><td>0.384</td><td>-0.091</td><td>406.11</td><td>0.000</td></tr>
<tr><td>.|***** |</td><td>.|. |</td><td>11</td><td>0.660</td><td>-0.051</td><td>464.53</td><td>0.000</td></tr>
<tr><td>.|****** |</td><td>.|* |</td><td>12</td><td>0.781</td><td>0.105</td><td>547.12</td><td>0.000</td></tr>
<tr><td>.|***** |</td><td>**|. |</td><td>13</td><td>0.645</td><td>-0.237</td><td>604.03</td><td>0.000</td></tr>
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<tr><td>.|. |</td><td>.|. |</td><td>15</td><td>-0.005</td><td>-0.046</td><td>621.83</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>.|. |</td><td>16</td><td>-0.360</td><td>-0.002</td><td>640.02</td><td>0.000</td></tr>
<tr><td>*****|. |</td><td>*|. |</td><td>17</td><td>-0.616</td><td>-0.115</td><td>693.99</td><td>0.000</td></tr>
<tr><td>*****|. |</td><td>.|. |</td><td>18</td><td>-0.680</td><td>0.022</td><td>760.42</td><td>0.000</td></tr>
<tr><td>****|. |</td><td>*|. |</td><td>19</td><td>-0.574</td><td>-0.106</td><td>808.24</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>.|. |</td><td>20</td><td>-0.322</td><td>-0.013</td><td>823.43</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>21</td><td>0.019</td><td>-0.054</td><td>823.49</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>*|. |</td><td>22</td><td>0.316</td><td>-0.175</td><td>838.38</td><td>0.000</td></tr>
<tr><td>.|**** |</td><td>*|. |</td><td>23</td><td>0.522</td><td>-0.098</td><td>879.43</td><td>0.000</td></tr>
<tr><td>.|**** |</td><td>**|. |</td><td>24</td><td>0.578</td><td>-0.196</td><td>930.32</td><td>0.000</td></tr>
<tr><td>.|**** |</td><td>.|. |</td><td>25</td><td>0.482</td><td>-0.025</td><td>966.18</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>26</td><td>0.268</td><td>-0.055</td><td>977.36</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>*|. |</td><td>27</td><td>-0.004</td><td>-0.090</td><td>977.36</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>*|. |</td><td>28</td><td>-0.266</td><td>-0.186</td><td>988.64</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>.|. |</td><td>29</td><td>-0.434</td><td>0.017</td><td>1019.0</td><td>0.000</td></tr>
<tr><td>****|. |</td><td>.|. |</td><td>30</td><td>-0.464</td><td>-0.032</td><td>1054.1</td><td>0.000</td></tr>
<tr><td>***|. |</td><td>*|. |</td><td>31</td><td>-0.395</td><td>-0.160</td><td>1079.8</td><td>0.000</td></tr>
<tr><td>**|. |</td><td>**|. |</td><td>32</td><td>-0.224</td><td>-0.207</td><td>1088.1</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>*|. |</td><td>33</td><td>0.014</td><td>-0.071</td><td>1088.2</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>*|. |</td><td>34</td><td>0.216</td><td>-0.132</td><td>1096.1</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>*|. |</td><td>35</td><td>0.351</td><td>-0.164</td><td>1117.3</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>*|. |</td><td>36</td><td>0.401</td><td>-0.084</td><td>1145.3</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>***|. |</td><td>37</td><td>0.317</td><td>-0.384</td><td>1163.0</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>*|. |</td><td>38</td><td>0.180</td><td>-0.127</td><td>1168.8</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>**|. |</td><td>39</td><td>0.008</td><td>-0.297</td><td>1168.8</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>***|. |</td><td>40</td><td>-0.164</td><td>-0.332</td><td>1173.7</td><td>0.000</td></tr>
</table>

**Table 2:** Grid Search for Minimum AIC for Rainfall Modeling.

| ***p/q*** | ***q=0*** | ***q=1*** | ***q=2*** | ***q=3*** | ***q=4*** | ***q=5*** | ***q=6*** |
|---|---|---|---|---|---|---|---|
| ***p=0*** | - | | | | | | |
| ***p=1*** | 11.57006 | 11.58207 | - | - | - | - | - |
| ***p=2*** | 11.58769 | - | - | - | - | - | - |
| ***p=3*** | 11.59324 | - | - | - | - | - | - |
| ***p=4*** | 11.51045 | - | - | - | - | - | - |
| ***p=5*** | 11.44118 | - | - | - | - | - | - |
| ***p=6*** | 11.42979 | - | - | - | - | - | - |
| ***p=7*** | 11.27094 | - | - | - | - | - | - |
| ***p=8*** | 11.26383 | - | - | - | - | - | - |
| ***p=9*** | 11.23565 | 11.24834 | 10.99661 | 11.00657 | 11.00686 | 11.00085 | **10.95916** |

**Table 3**: Model Estimation for Rainfall Series.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 111.9920 | 3.732385 | 30.00548 | 0.0000 |
| AR(1) | 0.419639 | 0.088286 | 4.753151 | 0.0000 |
| AR(2) | -0.516563 | 0.084797 | -6.091739 | 0.0000 |
| AR(4) | -0.229900 | 0.047391 | -4.851180 | 0.0000 |
| AR(6) | -0.638237 | 0.052858 | -12.07446 | 0.0000 |
| AR(7) | -0.164504 | 0.086446 | -1.902964 | 0.0600 |
| AR(9) | -0.375157 | 0.072038 | -5.207738 | 0.0000 |
| MA(1) | -0.337022 | 0.041259 | -8.168418 | 0.0000 |
| MA(2) | 0.307364 | 0.036109 | 8.512074 | 0.0000 |
| MA(4) | 0.190890 | 0.042570 | 4.484115 | 0.0000 |
| MA(5) | -0.208449 | 0.053325 | -3.909034 | 0.0002 |
| MA(6) | 0.883006 | 0.045663 | 19.33749 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.680575 | Mean dependent var | 110.7459 |
| Adjusted R-squared | 0.645084 | S.D. dependent var | 90.05453 |
| S.E. of regression | 53.64986 | Akaike info criterion | 10.90464 |
| Sum squared resid | 284952.4 | Schwarz criterion | 11.19756 |
| Log likelihood | -593.2075 | F-statistic | 19.17565 |
| Durbin-Watson stat | 2.034172 | Prob(F-statistic) | 0.000000 |

The minimum AIC value is 10.90464 which is less than the initial one (10.95916).

There is no serial correlation in the residuals as indicated by the Durbin Watson statistic (DW=2.034172) and Breusch-Godfrey Serial correlation test in Table 4 and the model parameters are significant at 1% and 5% level.

The minimum AIC occurs at (p, q)=(12, 6) with value 1.10087. This is also a large model with many parameters and the insignificant parameters cannot be removed due to sub-setting. This instead makes nearly all the parameters to be insignificant. So, the full ARMA (12, 6) is modeled for Temperature series. The model is presented in Table 7.

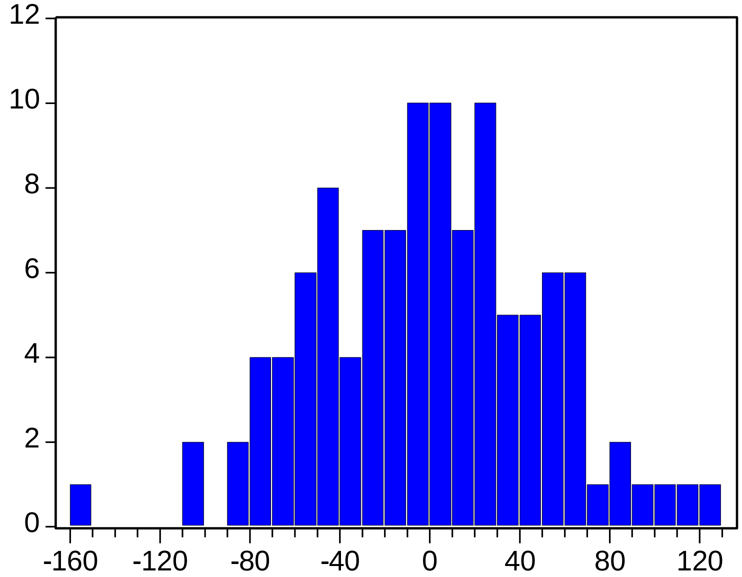
**Table 4:** Test for Serial Correlation.

| Breusch-Godfrey Serial Correlation LM Test: | | | |
|---|---|---|---|
| F-statistic | 0.215230 | Probability | 0.806740 |
| Obs*R-squared | 0.470342 | Probability | 0.790436 |

**Figure 4:** Correlograms of Residuals (Q- Statistics)

<table>
<tr><th>Autocorrelation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>. |. |</td><td>. |. |</td><td>1</td><td>-0.028</td><td>-0.028</td><td>0.0897</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>2</td><td>0.043</td><td>0.043</td><td>0.3057</td><td></td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>3</td><td>0.072</td><td>0.075</td><td>0.9141</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>4</td><td>-0.016</td><td>-0.014</td><td>0.9441</td><td></td></tr>
<tr><td>. |. |</td><td>.*|. |</td><td>5</td><td>-0.050</td><td>-0.058</td><td>1.2361</td><td></td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>6</td><td>0.078</td><td>0.071</td><td>1.9561</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>7</td><td>0.048</td><td>0.061</td><td>2.2355</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>8</td><td>-0.032</td><td>-0.029</td><td>2.3572</td><td></td></tr>
<tr><td>. |* |</td><td>. |. |</td><td>9</td><td>0.082</td><td>0.063</td><td>3.1861</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>10</td><td>-0.019</td><td>-0.020</td><td>3.2317</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>11</td><td>-0.057</td><td>-0.052</td><td>3.6333</td><td></td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>12</td><td>0.128</td><td>0.120</td><td>5.7205</td><td>0.017</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>13</td><td>-0.038</td><td>-0.034</td><td>5.9058</td><td>0.052</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>14</td><td>-0.168</td><td>-0.175</td><td>9.5445</td><td>0.023</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>15</td><td>-0.015</td><td>-0.047</td><td>9.5747</td><td>0.048</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>16</td><td>-0.135</td><td>-0.127</td><td>11.968</td><td>0.035</td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>17</td><td>0.067</td><td>0.118</td><td>12.574</td><td>0.050</td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>18</td><td>0.123</td><td>0.136</td><td>14.599</td><td>0.041</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>19</td><td>0.063</td><td>0.052</td><td>15.135</td><td>0.057</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>20</td><td>-0.029</td><td>-0.022</td><td>15.252</td><td>0.084</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>21</td><td>-0.062</td><td>-0.112</td><td>15.794</td><td>0.106</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>22</td><td>-0.092</td><td>-0.087</td><td>16.986</td><td>0.108</td></tr>
<tr><td>.*|. |</td><td>. |. |</td><td>23</td><td>-0.093</td><td>-0.037</td><td>18.208</td><td>0.110</td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>24</td><td>0.133</td><td>0.126</td><td>20.773</td><td>0.078</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>25</td><td>-0.021</td><td>0.005</td><td>20.840</td><td>0.106</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>26</td><td>-0.075</td><td>-0.082</td><td>21.668</td><td>0.117</td></tr>
<tr><td>. |. |</td><td>.*|. |</td><td>27</td><td>-0.022</td><td>-0.089</td><td>21.741</td><td>0.152</td></tr>
<tr><td>. |. |</td><td>. |* |</td><td>28</td><td>0.051</td><td>0.084</td><td>22.138</td><td>0.179</td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>29</td><td>0.073</td><td>0.135</td><td>22.964</td><td>0.192</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>30</td><td>0.029</td><td>-0.016</td><td>23.090</td><td>0.233</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>31</td><td>0.029</td><td>-0.012</td><td>23.226</td><td>0.278</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>32</td><td>-0.081</td><td>-0.089</td><td>24.262</td><td>0.281</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>33</td><td>-0.010</td><td>0.044</td><td>24.277</td><td>0.333</td></tr>
<tr><td>.*|. |</td><td>. |. |</td><td>34</td><td>-0.089</td><td>-0.020</td><td>25.555</td><td>0.322</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>35</td><td>-0.073</td><td>-0.093</td><td>26.433</td><td>0.332</td></tr>
<tr><td>. |* |</td><td>. |. |</td><td>36</td><td>0.078</td><td>-0.035</td><td>27.455</td><td>0.334</td></tr>
</table>

**Figure 5:** Residual Normality Test




| | |
|---|---|
| Series: Residuals | |
| Sample 1999M10 2008M12 | |
| Observations 111 | |
| Mean | -0.682736 |
| Median | 0.045312 |
| Maximum | 121.8275 |
| Minimum | -154.1665 |
| Std. Dev. | 50.89210 |
| Skewness | -0.082636 |
| Kurtosis | 3.003105 |
| Jarque-Bera | 0.126375 |
| Probability | 0.938767 |

Skewness, Kurtosis and Jarque-Bera test indicate the normality of the residuals.

**Table 5:** Testing for Autoregressive Conditional Heteroscedasticity (ARCH)

| ARCH Test: | | | |
|---|---|---|---|
| F-statistic | 0.060348 | Probability | 0.941469 |
| Obs*R-squared | 0.123971 | Probability | 0.939897 |

The ARCH effect is not significant.

The ARMA (9, 6) model presented in Table 3 is then the optimal and best model for the Rainfall series.

**TEMPERATURE SERIES**

**Table 6:** Grid Search for Minimum AIC for Temperature Modeling.

| *p/q* | *q=0* | *q=1* | *q=2* | *q=3* | *q=4* | *q=5* | *q=6* | *q=7* |
|---|---|---|---|---|---|---|---|---|
| ***p=0*** | - | - | - | - | - | - | - | - |
| ***p=1*** | 3.732291 | - | - | - | - | - | - | - |
| ***p=2*** | 3.414987 | - | - | - | - | - | - | - |
| ***p=3*** | 3.183246 | - | - | - | - | - | - | - |
| ***p=4*** | 2.875848 | - | - | - | - | - | - | - |
| ***p=5*** | 2.725953 | - | - | - | - | - | - | - |
| ***p=6*** | 2.586201 | - | - | - | - | - | - | - |
| ***p=7*** | 2.587355 | - | - | - | - | - | - | - |
| ***p=8*** | 2.572432 | - | - | - | - | - | - | - |
| ***p=9*** | 2.583390 | - | - | - | - | - | - | - |
| ***p=10*** | 2.548846 | - | - | - | - | - | - | - |
| ***p=11*** | 2.547900 | - | - | - | - | - | - | - |
| ***p=12*** | 2.346501 | 2.361736 | 2.308087 | 2.295500 | 2.190798 | 2.115490 | **1.910087** | 2.009491 |
| ***p=13*** | 2.360398 | - | - | - | - | - | - | - |
| ***p=14*** | 2.373942 | - | - | - | - | - | - | - |

**Table 7:** Model Estimation for Temperature Series.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(1) | 31.71648 | 0.059881 | 529.6608 | 0.0000 |
| AR(1) | 0.778313 | 0.106489 | 7.308827 | 0.0000 |
| AR(2) | -1.041089 | 0.135304 | -7.694434 | 0.0000 |
| AR(3) | 1.009745 | 0.175532 | 5.752475 | 0.0000 |
| AR(4) | -1.064337 | 0.207735 | -5.123532 | 0.0000 |
| AR(5) | 0.532631 | 0.236418 | 2.252920 | 0.0268 |
| AR(6) | -0.837960 | 0.241492 | -3.469928 | 0.0008 |
| AR(7) | 0.298453 | 0.241713 | 1.234742 | 0.2202 |
| AR(8) | -0.328170 | 0.234753 | -1.397940 | 0.1656 |
| AR(9) | 0.255779 | 0.205249 | 1.246191 | 0.2160 |
| AR(10) | -0.481755 | 0.172091 | -2.799413 | 0.0063 |
| AR(11) | 0.281946 | 0.130244 | 2.164750 | 0.0331 |
| AR(12) | 0.021502 | 0.103577 | 0.207592 | 0.8360 |
| MA(1) | -0.682133 | 0.024226 | -28.15720 | 0.0000 |
| MA(2) | 1.213672 | 0.027125 | 44.74318 | 0.0000 |
| MA(3) | -1.344577 | 0.039220 | -34.28291 | 0.0000 |
| MA(4) | 1.203769 | 0.037267 | 32.30094 | 0.0000 |
| MA(5) | -0.680475 | 0.040516 | -16.79533 | 0.0000 |
| MA(6) | 0.958375 | 0.024343 | 39.37014 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.958235 | Mean dependent var | 31.70748 |
| Adjusted R-squared | 0.949692 | S.D. dependent var | 2.588498 |
| S.E. of regression | 0.580585 | Akaike info criterion | 1.910087 |
| Sum squared resid | 29.66294 | Schwarz criterion | 2.384701 |
| Log likelihood | -83.18965 | Durbin-Watson stat | 1.841262 |

Durbin Watson fairly indicates serial correlation but this can be confirmed by Breusch –Pagan Serial Correlation test.

**Table 8:** Serial Correlation Test.

| Breusch-Godfrey Serial Correlation LM Test: | | | |
|---|---|---|---|
| F-statistic | 1.992202 | Probability | 0.142640 |
| Obs*R-squared | 4.736678 | Probability | 0.093636 |

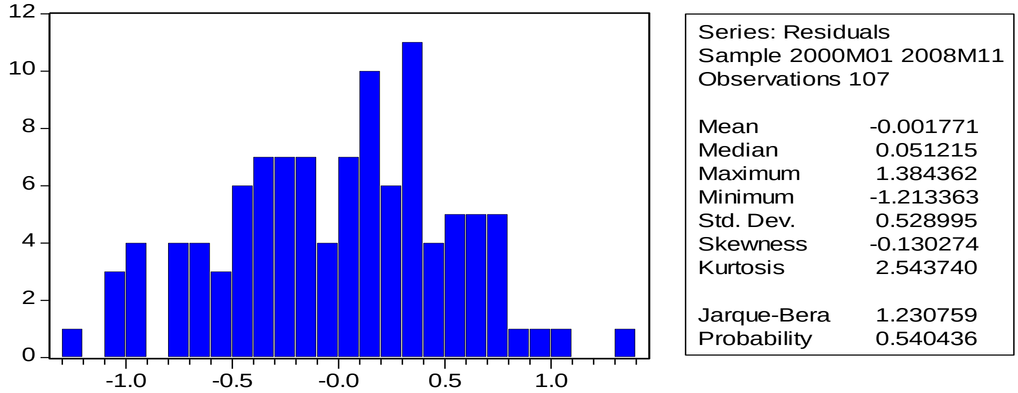
Serial correlation is not significant in the Temperature series.

**Figure 6:** Correlograms of Residuals (Q- Statistics).

<table>
<tr><th>Autocorrelation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>. |* |</td><td>. |* |</td><td>1</td><td>0.067</td><td>0.067</td><td>0.4903</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>2</td><td>-0.045</td><td>-0.050</td><td>0.7159</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>3</td><td>0.019</td><td>0.025</td><td>0.7556</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>4</td><td>0.064</td><td>0.059</td><td>1.2248</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>5</td><td>0.039</td><td>0.033</td><td>1.4019</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>6</td><td>0.002</td><td>0.003</td><td>1.4024</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>7</td><td>0.024</td><td>0.025</td><td>1.4708</td><td></td></tr>
<tr><td>. |. |</td><td>.*|. |</td><td>8</td><td>-0.055</td><td>-0.064</td><td>1.8252</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>9</td><td>-0.053</td><td>-0.048</td><td>2.1550</td><td></td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>10</td><td>-0.074</td><td>-0.077</td><td>2.8121</td><td></td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>11</td><td>-0.138</td><td>-0.137</td><td>5.1196</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>12</td><td>-0.039</td><td>-0.024</td><td>5.3034</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>13</td><td>-0.023</td><td>-0.022</td><td>5.3707</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>14</td><td>-0.015</td><td>0.001</td><td>5.4008</td><td></td></tr>
<tr><td>.*|. |</td><td>. |. |</td><td>15</td><td>-0.071</td><td>-0.046</td><td>6.0388</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>16</td><td>0.012</td><td>0.035</td><td>6.0575</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>17</td><td>0.007</td><td>0.004</td><td>6.0637</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>18</td><td>0.039</td><td>0.046</td><td>6.2665</td><td></td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>19</td><td>0.018</td><td>0.002</td><td>6.3099</td><td>0.012</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>20</td><td>-0.101</td><td>-0.122</td><td>7.6851</td><td>0.021</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>21</td><td>-0.002</td><td>-0.019</td><td>7.6857</td><td>0.053</td></tr>
<tr><td>. |. |</td><td>.*|. |</td><td>22</td><td>-0.014</td><td>-0.058</td><td>7.7109</td><td>0.103</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>23</td><td>-0.003</td><td>-0.026</td><td>7.7125</td><td>0.173</td></tr>
<tr><td>.*|. |</td><td>**|. |</td><td>24</td><td>-0.180</td><td>-0.196</td><td>12.248</td><td>0.057</td></tr>
<tr><td>. |. |</td><td>. |* |</td><td>25</td><td>0.063</td><td>0.085</td><td>12.813</td><td>0.077</td></tr>
<tr><td>. |* |</td><td>. |. |</td><td>26</td><td>0.070</td><td>0.039</td><td>13.510</td><td>0.095</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>27</td><td>-0.049</td><td>-0.020</td><td>13.864</td><td>0.127</td></tr>
<tr><td>.*|. |</td><td>. |. |</td><td>28</td><td>-0.060</td><td>-0.035</td><td>14.389</td><td>0.156</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>29</td><td>-0.054</td><td>-0.048</td><td>14.832</td><td>0.190</td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>30</td><td>0.100</td><td>0.088</td><td>16.341</td><td>0.176</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>31</td><td>0.032</td><td>-0.007</td><td>16.498</td><td>0.223</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>32</td><td>-0.010</td><td>-0.037</td><td>16.514</td><td>0.283</td></tr>
<tr><td>.*|. |</td><td>.*|. |</td><td>33</td><td>-0.087</td><td>-0.128</td><td>17.695</td><td>0.279</td></tr>
<tr><td>. |. |</td><td>. |. |</td><td>34</td><td>-0.014</td><td>-0.030</td><td>17.726</td><td>0.340</td></tr>
<tr><td>. |* |</td><td>. |. |</td><td>35</td><td>0.086</td><td>0.018</td><td>18.920</td><td>0.333</td></tr>
<tr><td>. |* |</td><td>. |* |</td><td>36</td><td>0.073</td><td>0.084</td><td>19.790</td><td>0.345</td></tr>
</table>

The errors are white noise based on the results of Q-statistic above.

**Figure 7:** Residual Normality Test




The residuals are normally distributed as indicated by the normality V test in Figure. 7.

**Table 9:** Testing for Autoregressive Conditional Heteroscedasticity (ARCH).

| ARCH Test: | | | |
|---|---|---|---|
| F-statistic | 0.112624 | Probability | 0.893598 |
| Obs*R-squared | 0.231361 | Probability | 0.890760 |

No heteroscedastic effect in the Temperature series.

## MODEL FORECAST

**Forecast Values for Rainfall Series**

| Months/Year | Rainfall (mm) |
|---|---|
| 2009M01 | -3.8 |
| 2009M02 | -33.0 |
| 2009M03 | -23.3 |
| 2009M04 | 22.9 |
| 2009M05 | 92.5 |
| 2009M06 | 166.8 |
| 2009M07 | 227.2 |
| 2009M08 | 257.9 |
| 2009M09 | 249.7 |
| 2009M10 | 204.3 |
| 2009M11 | 134.5 |
| 2009M12 | 59.1 |
| 2010M01 | -2.6 |
| 2010M02 | -34.9 |
| 2010M03 | -28.1 |
| 2010M04 | 16.3 |
| 2010M05 | 86.2 |
| 2010M06 | 162.6 |
| 2010M07 | 226.0 |
| 2010M08 | 259.7 |
| 2010M09 | 254.4 |
| 2010M10 | 210.8 |
| 2010M11 | 140.9 |
| 2010M12 | 63.5 |
| 2011M01 | -1.2 |
| 2011M02 | -36.6 |
| 2011M03 | -32.7 |
| 2011M04 | 9.8 |
| 2011M05 | 79.7 |
| 2011M06 | 158.1 |
| 2011M07 | 224.4 |
| 2011M08 | 261.4 |
| 2011M09 | 259.0 |
| 2011M10 | 217.3 |
| 2011M11 | 147.5 |
| 2011M12 | 68.2 |

**Forecast Values for Temperature Series**

| Months/Year | Temperature ($^oC$) |
|---|---|
| 2009M01 | - |
| 2009M02 | - |
| 2009M03 | - |
| 2009M04 | - |
| 2009M05 | - |
| 2009M06 | - |
| 2009M07 | - |
| 2009M08 | - |
| 2009M09 | - |
| 2009M10 | - |
| 2009M11 | - |
| 2009M12 | - |
| 2010M01 | - |
| 2010M02 | - |
| 2010M03 | - |
| 2010M04 | - |
| 2010M05 | - |
| 2010M06 | - |
| 2010M07 | - |
| 2010M08 | - |
| 2010M09 | - |
| 2010M10 | - |
| 2010M11 | - |
| 2010M12 | - |
| 2011M01 | - |
| 2011M02 | - |
| 2011M03 | - |
| 2011M04 | - |
| 2011M05 | - |
| 2011M06 | - |
| 2011M07 | - |
| 2011M08 | - |
| 2011M09 | - |
| 2011M10 | - |
| 2011M11 | - |
| 2011M12 | - |

Eviews 5.0 reports spurious forecasts of unexpected values for temperature forecast. This is then left for future research using another software.

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1. Adegbulugbe, A.O. 1991. "Energy Demand and $CO_2$ Emissions Reduction Options in Nigeria". *Energy Policy*. December 1991: 940-945.

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