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The responses of Climatic parameters and their Effects on solar indicators in Nigeria

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Abstract— This investigation focused on solar forcing on climatic parameters in Nigeria and their effects. The daily meteorological data for five climatic parameters; Minimum Temperature (MIT), Maximum Temperature (MAT), Relative Humidity (RH), Vapour Pressure (VP), and Rainfall (RNF) obtained from Nigeria Meteorological Agency (NIMET) and two solar parameters Total Solar Irradiance (TSI) and F10.7 cm solar radio flux (F10) from sorce™ were graphically represented and were modeled using a proposed linear multivariate model and the empirical coefficient determined by applying least square fittings. The validity of the model was tested using the statistical indicator; Mean Bias Error (MBE) and Root Mean Square Error (RMSE). The result shows that there is a considerable forcing on climatic parameters in Nigeria with relative humidity receiving the lowest percentage of forcing and rainfall having the greater percentage of solar forcing and that there is a direct forcing on temperature and an inverse force on precipitation.

Keywords- Sunspot Number, Solar Irradiance, Radiative forcing, Rainfall, Minimum, and Maximum Temperature, Relative Humidity

I. INTRODUCTION

The sun provides the Earth with the most efficient renewable energy, the sun's energy is also the most effective driving force for the earth's climatic system. The sun which comprises of different gases undergoes some set of activities called the solar activities.
Nigeria has been fortunate to experience heavy rainfall during the wet season when the Southwest trade wind – wind that blows from the Atlantic Ocean, engulfs the country. However, for the last 3 decades, there have been abnormalities in the amount of rainfall [1].

The reasons for these abnormalities are found to be caused by localized anthropogenic influences over the climate and environment, like the degradation of forest coverage, depletion of surface and subsurface water resources, industrial abuse of waste products in the atmosphere. Another possible reason is the periodicity in the occurrence of solar activities [1-3].
Solar activities most times increase solar energy that gets absorbed in the earth's atmospheric system and act as a basic driving force for the earth's climatic parameters. The Sun's energy is also varying due to spatial and temporal changes in its large-scale magnetic field structure. The most outstanding variation is the sunspot number which is the number of spots on the surface of the sun [4-8].

Radiative/Solar forcing, a keyword in this paper, is defined as the change in the net downward radiative flux at the troposphere resulting from any process that perturbs the climatic system. It is measured in W/m^2. An example of radiative forcing is the amount of solar radiation reaching the Earth, which is known as Total Solar Irradiance (TSI), the best-known proxy for sunspot on earth [9].

II. RELATED WORK

Period of low solar activity, for example, maunder minimum, have been related to the low temperature in Northern Europe in the 19th century, and a reduction of irradiance by up to 0.2 % have been established during the period [6].

The literature reviewed by [10] suggested that the surface temperature is negatively correlated with the TSI during the period 1880 – 1920 and positively correlated from 1920 to the present and a sign reversal was observed in the apparent dependence of water level at Lake Victoria around 1920.

[11], in their work on solar forcing on climate, performed two experiments, both of which show a wavelength-dependent reduction in TSI of ~75W/m^2 (0.55%). They observed that, though the climate responds to the variability of TSI, it will depend on the vertical profile of the Ozone changes imposed.

[12], carried out research on sunspots and rainfall in India, and the result from the analysis shows a strong linkage between the average number of sunspots and the annual Indian rainfall pattern. Their result further shows that the

10-years moving average of annual Indian rainfall and the 10-years moving average of mean sunspot number are falling since 1996. [13], in his study on solar radiative variability on climate change in Kenya, compared the data of climatic parameters to different solar indices using an empirical linear multivariate model and observed that there is either a negative or positive solar forcing on all the climatic parameters. [3] studied the effect of solar activities on the temperature ranges in Nigeria and found an occurring modal periodicity of 6 months and 12 months related to the occurrence of sunspot number.

Study Area

Nigeria is located approximately within latitude 9^0N and 14^0N of the Equator and between 2^0E and 14^0E of the Greenwich Meridian, Fig 1.

As in most West African countries, Nigeria's climate is characterized by strong latitudinal zones, becoming progressively drier as one moves Northward from the coast. Rainfall is the climatic variable that marked alternation of the wet and dry seasons in most areas. Two air masses control rainfall in Nigeria – Moist Northward moving maritime (Northwest Trade Wind) and the continental air masses coming South from the Atlantic (Southwest Trade Wind).

The four synoptic stations were chosen in this study cover the major climatic zones in the country. Port Harcourt (PH) (4.5^0N, 7.01^0E), Enugu (ENU) (6.28^0N, 7.33^0E) Ilorin (IRN) (8.29^0N, 4.35^0E) and Sokoto (SKT) (13.01^0N, 5.15^0E). The coordinates and locations of the different synoptic stations in Nigeria are shown in Fig 1.

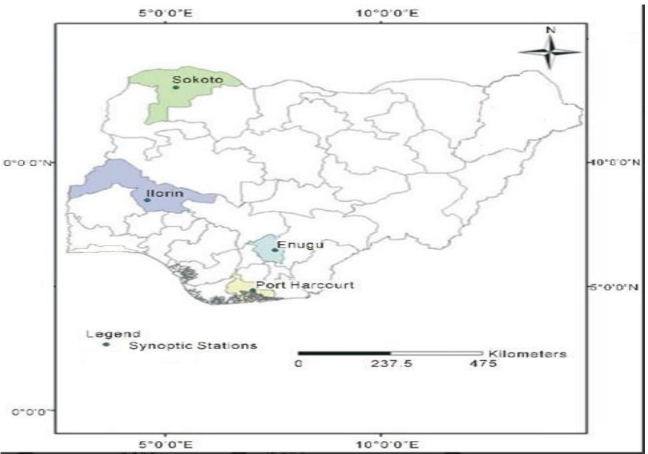


Figure 1. Map of Nigeria showing used for this study [17]

III. MATERIALS AND METHODS

DATA COLLECTION

The climatic parameters used in this study span through 1970 – 2014 covering 34years of meteorological reading which include Maximum Temperature (MAT), Minimum Temperature (MIT), Relative Humidity (RH), Vapour Pressure (VP), and Rainfall (RNF). The meteorological data were obtained from the archives of the Nigeria Meteorological Agency (Nimet), Oshodi Lagos Nigeria.

Solar Variability Data

The solar variables cover the same period as those of the climatic parameters (1970 – 2014). The two solar variables used in this study are the value of the daily Total Solar Irradiance and F10.7 cm solar radio flux from sorce^{TM}.

Data Reduction

The data reduction was done to get the monthly seasonal to decadal values by taking the mean of daily and monthly values of individual parameters. Data reduction was also necessary because it reduces the noise associated with the daily data. Equation 1 shows the formula used for reducing the collected data

$$Ag = \sum_{i=1}^{n} \frac{R_{1+R_2 \ldots\ldots\ldots R_n}}{n} \qquad 1$$

Where R is the monthly meteorological parameter data at each of the stations, n is the number of months or years in view and Ag is the annual meteorological parameter data.

Modeling the Meteorological and Solar Variable

Assuming the meteorological variable is expressible in terms of the solar indices TSI and F10 such that $y(TSI, F10\ )$, according to [13] an empirical linear multivariate model of the form can be proposed below.

$$y = A + BTSI + CF10 \qquad 2$$

Where y is any of the meteorological variables, TSI is total solar irradiance, F10.7 solar radio flux. A, B, and C are the empirical coefficients that are determined by least-square fitting, the values of these coefficients are presented in Tables 1 – 5.

(A= Intercept, B and C = Slopes, BTSI is the slope when TSI is plotted against y same as CF10)

Performance of Models

The validity of the model proposed in the previous section was tested by calculating the Mean Bias Error (MBE) and Root Mean Square Error (RMSE) equation 3 and 4 respected as used by [13], for the entire meteorological variable in the stations. The MBE (W/m^2) and RMSE (W/m^2) are commonly used in comparing the model of solar variability and climate predictions.

$$MBE = \frac{\sum(y_{pre} - y_{obs})}{N} \qquad 3$$

$$RMSE = \left[\sum\left[\frac{(y_{pre} - y_{obs})^2}{N}\right]\right]^{\frac{1}{2}} \qquad 4$$

Y_{pre} is the calculated value from the model, Y_{obs} is the observed value and N is the total number of observations. The test of RMSE provides information on the short-term performance of the studied model as it allows a term by term comparison of the actual deviation between the calculated value and the measured value, [14-15] have recommended that a low value of RMSE is ideal while a low MBE is desirable. The MBE and RMSE values obtained are represented in Tables 1 – 5

IV. RESULT AND DISCUSSION

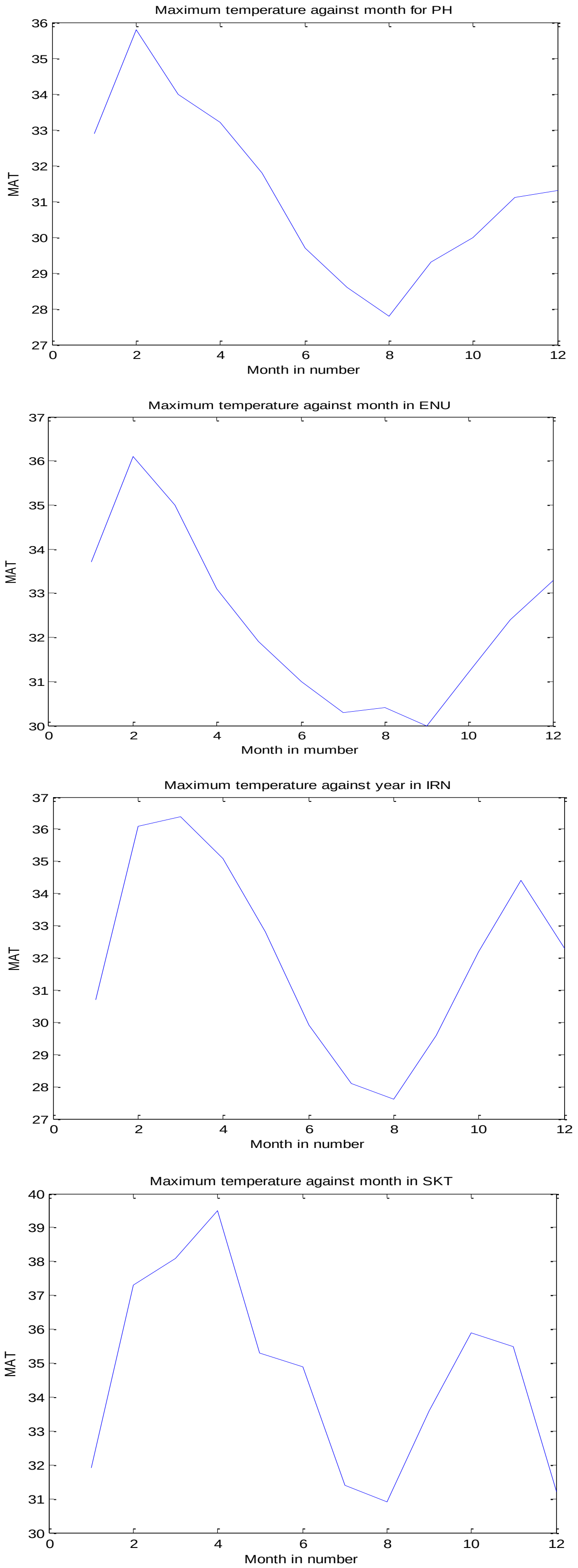


Figure 2: A graph of MAT against Year for

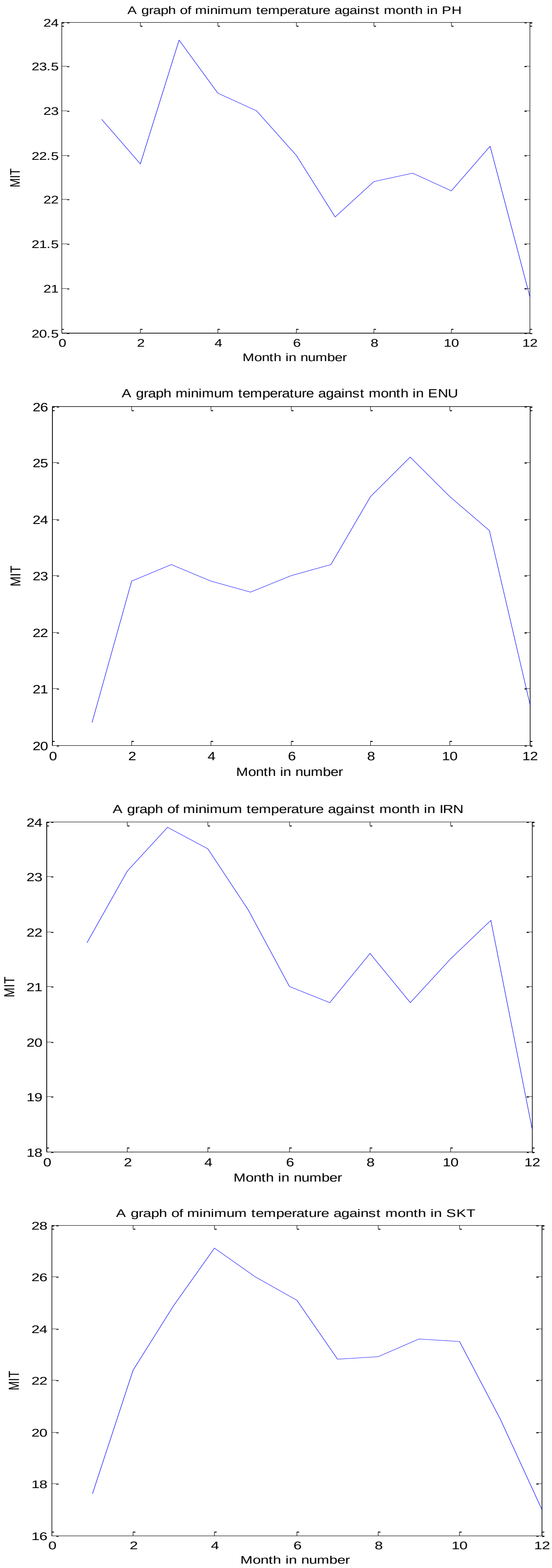


Figure 3: A graph of MIT against year

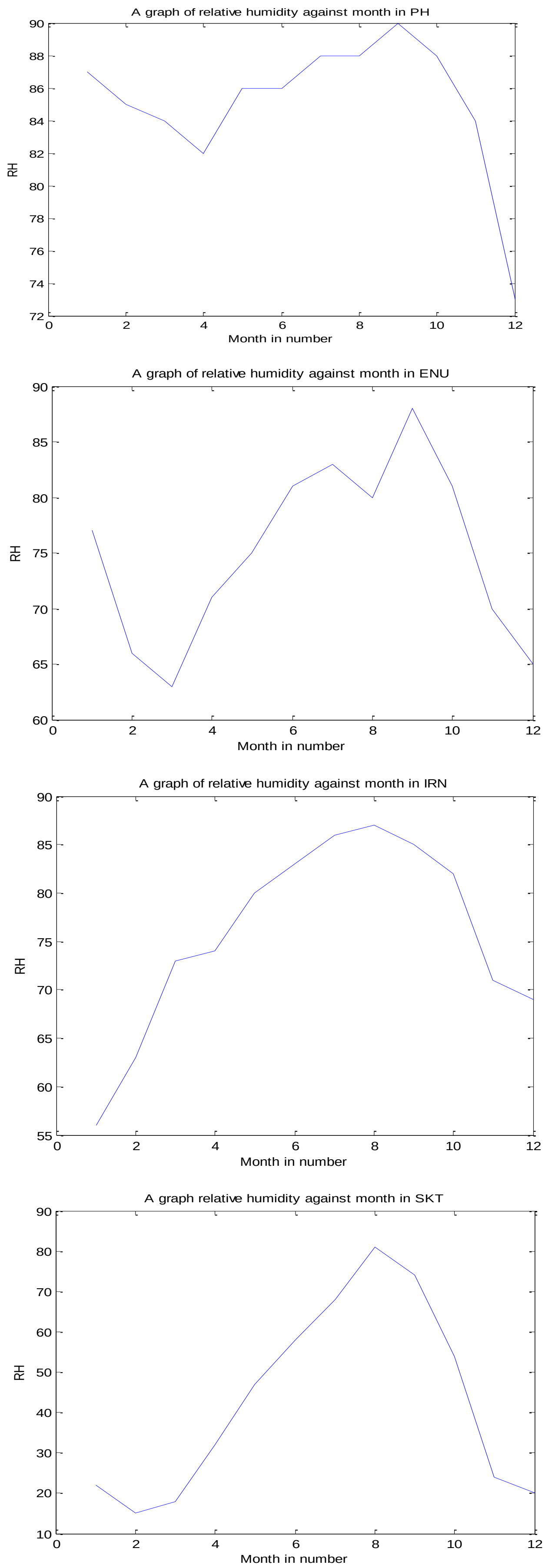


Figure 4: A graph of RH against year

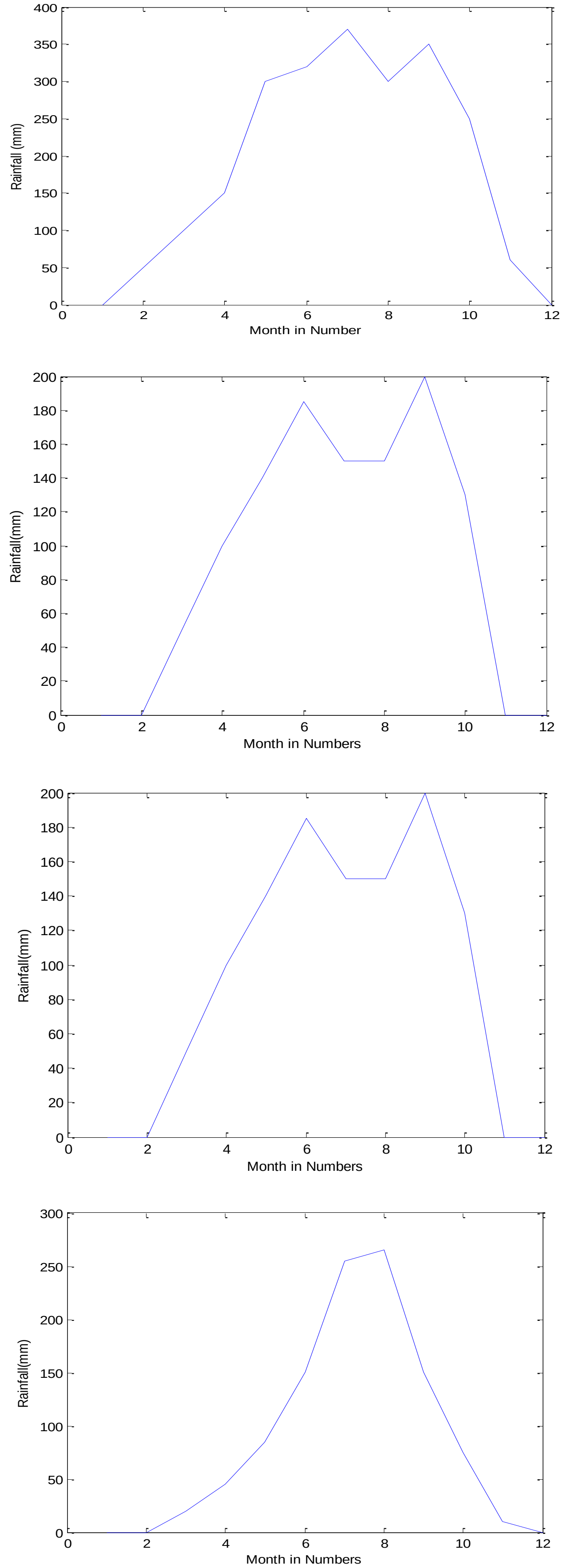


Figure 5: A graph of rainfall against year.

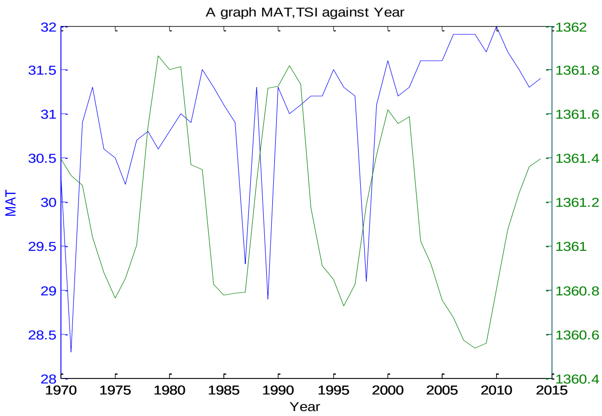
From the graph in figure 2, the highest value of MAT occurs in SKT in February with a value of 38.9°C this high temperature is as a result of the closeness of the city to the Sahara desert. The lowest value of MAT occurs in PH in August, this is the time when the South-east Trade wind engulfs the entire country.

The graph in figure 3, Shows MIT for the different cities used in this study, the highest value of MIT occurs in SKT with a value of 28.8 °C while the lowest occurs in the city PH with a value of 23.5 °C, the reason for the occurrence can be as result to the closeness of the city to the Sahara desert and the Atlantic Ocean

The graph of figure 4, shows the RH in the cities used in this paper, the pattern seems to follow those of the MAT and MIT the city with the highest water content is PH while the city with the lowest RH is that SKT, and the reason for this difference is because of their different locations as explained above.

Figure 5, Shows the distribution of rainfall in Nigeria, the pattern of rainfall follows the patterns of other climatic parameters where PH receives the highest amount of rainfall and SKT receives the lowest amount of rainfall, as discussed previously, the reason for this distribution is due to the geographical location of the cites

Result From the Graphical Relationship between TSI and Climatic Parameters



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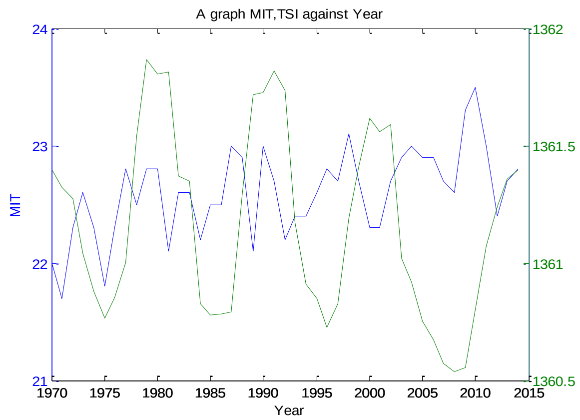

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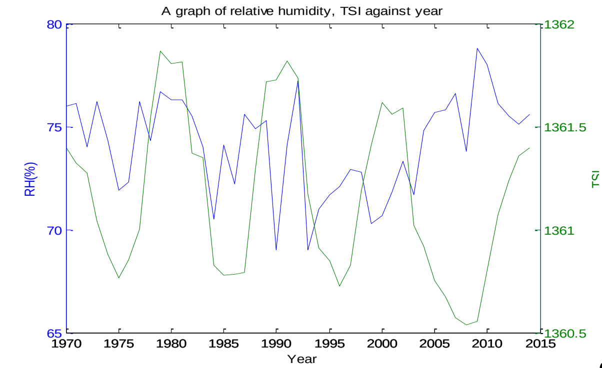

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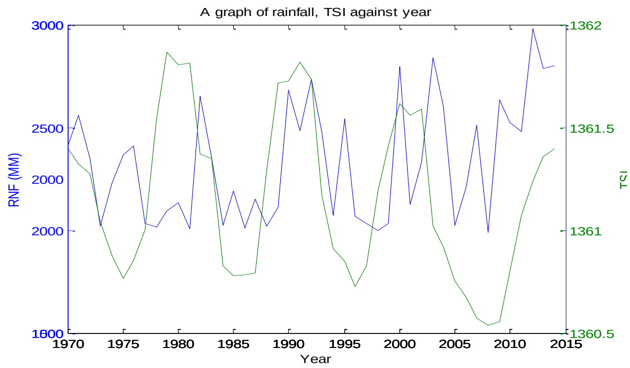

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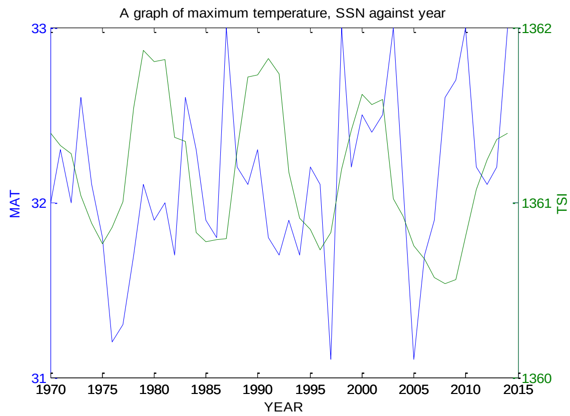
Figure 6: Graphs of (a) MAT (b) MIT (c) RH (d) RNF and TSI against year in PH



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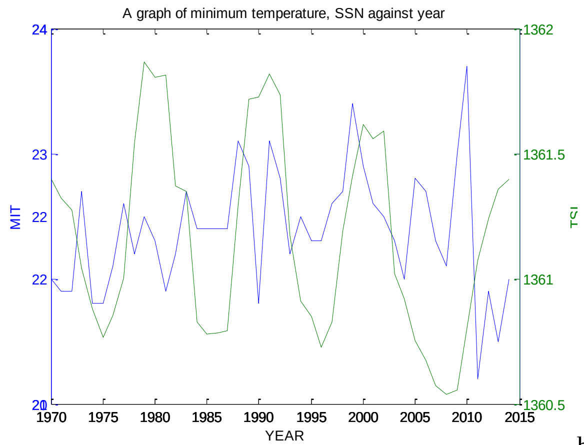

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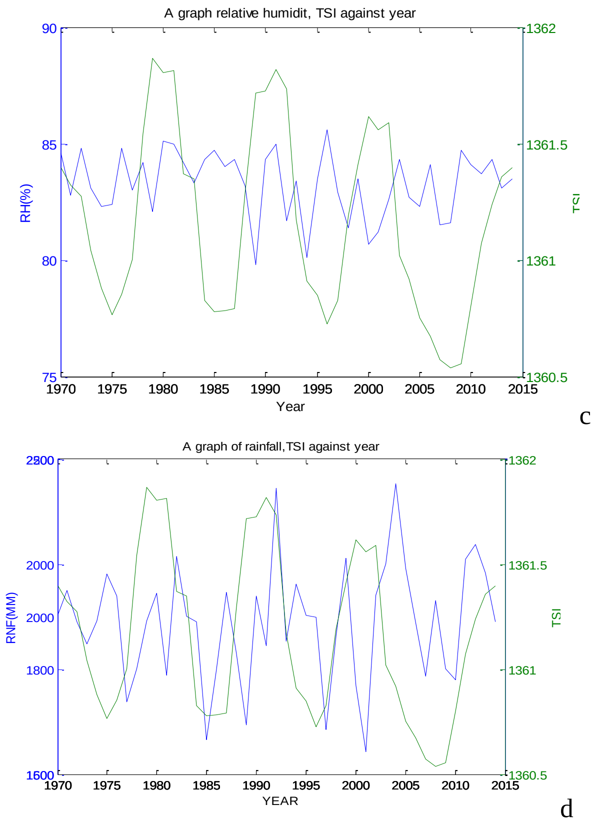


Figure 7: Graphs of (a) MAT (b) MIT (c) RH (d) RNF and TSI against year in ENU

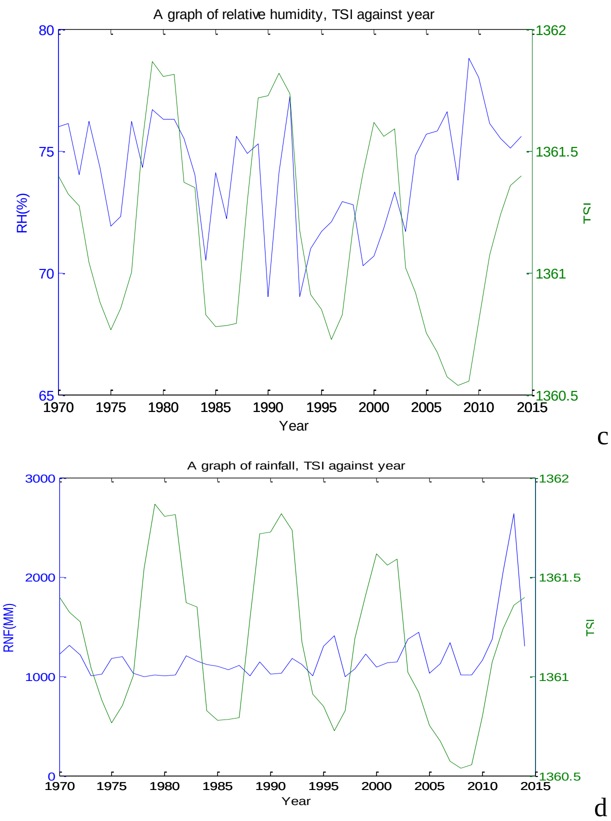
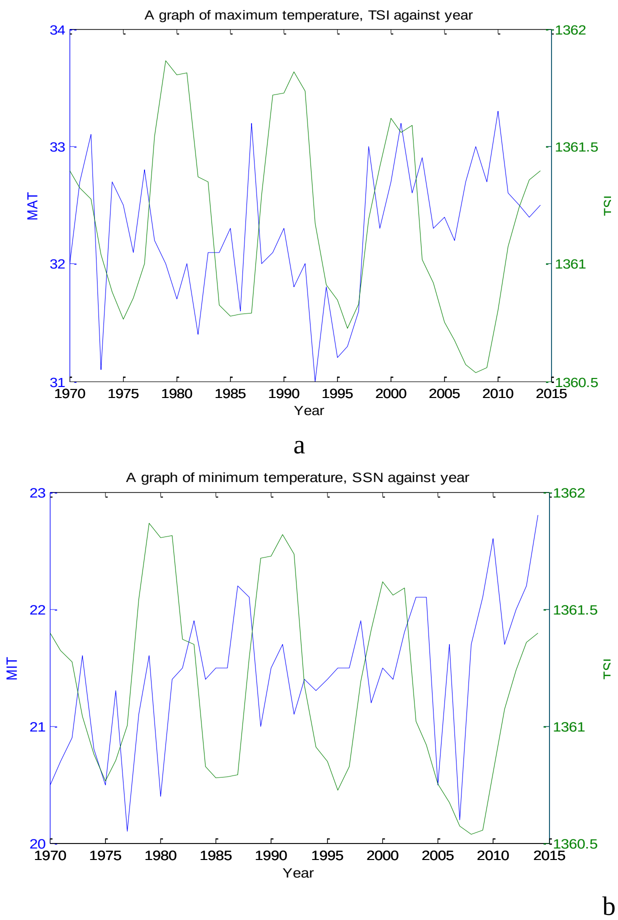
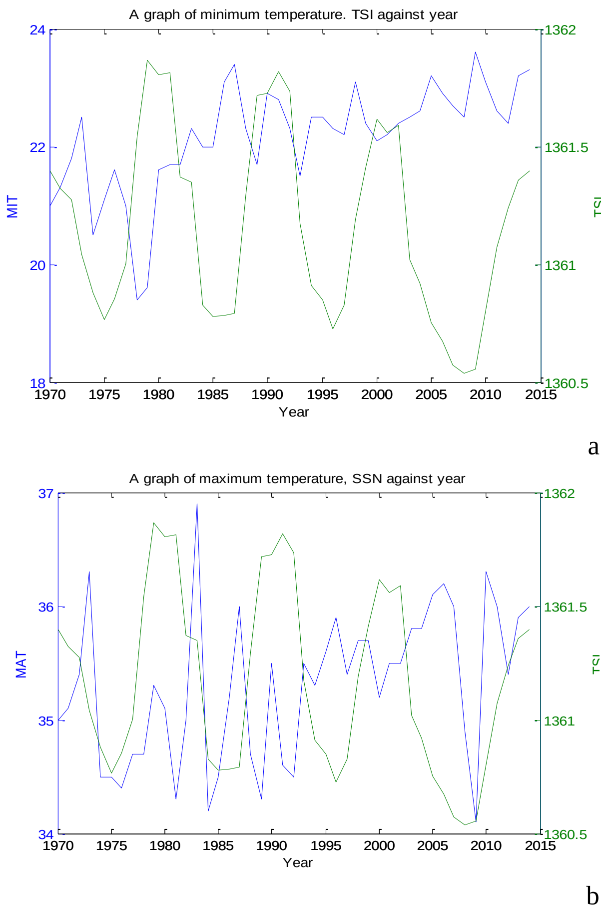
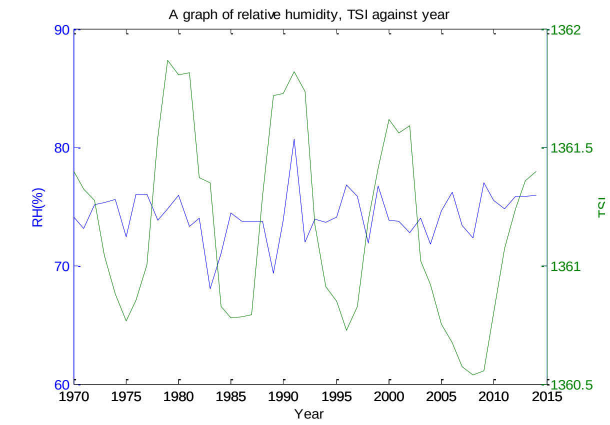


Figure 8: Graphs of (a) MAT (b) MIT (c) RH (d) RNF and TSI against year in IRN







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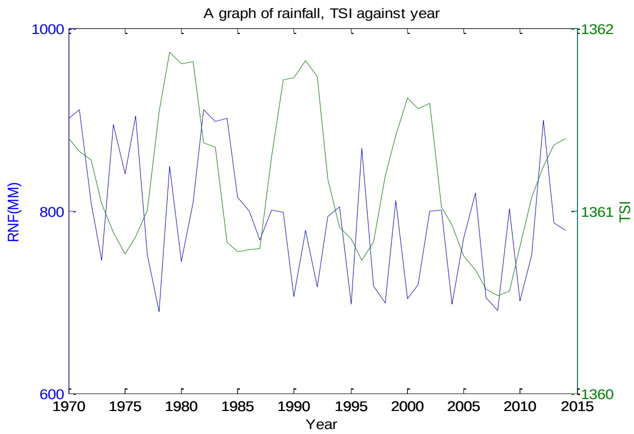

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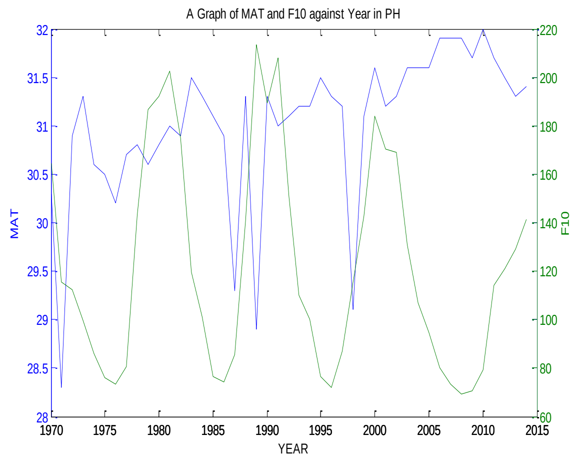
Figure 9: Graphs of (a) MAT (b) MIT (c) RH (d) RNF and TSI against year in SKT

From the graphs in figures 6 to figure 9, it can be seen that the temperature parameters are in a direct graphical relationship with TSI while RNF is an inverse relationship with the solar indicator for all the cities used in this research.

Result From the Graphical Relationship between F10 and Climatic Parameters



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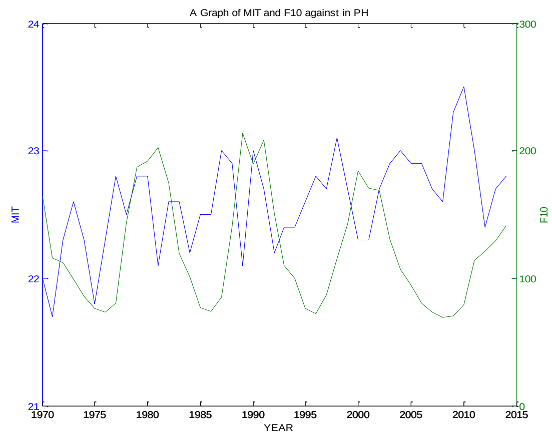

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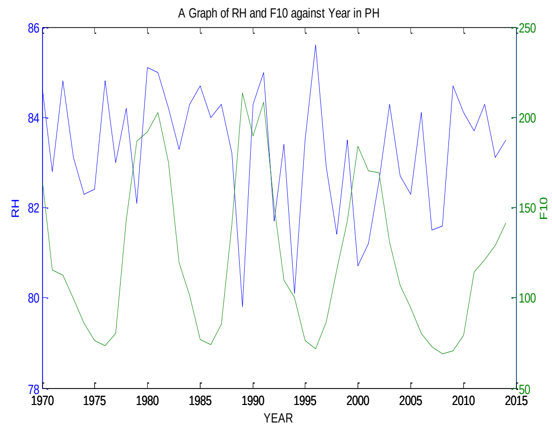

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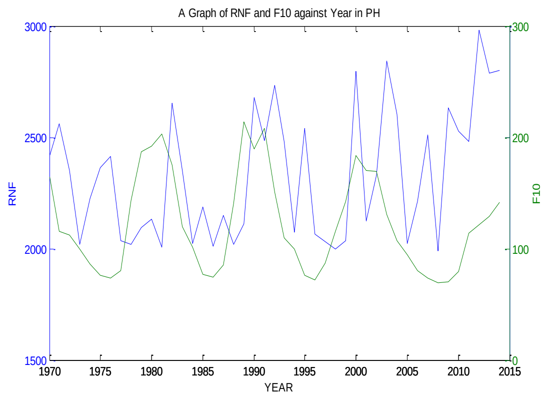
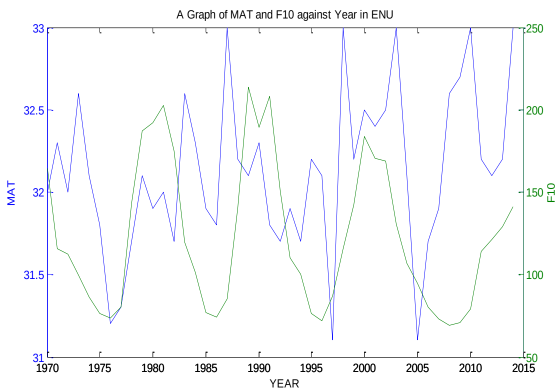


d.

Figure 10: Graphs of (a) MAT (b) MIT (c) RH (d) RNF and F10 against year in PH



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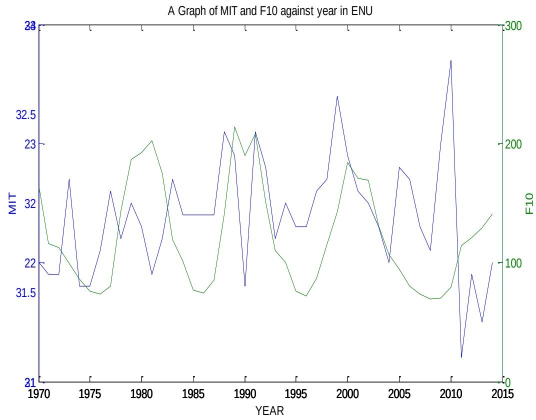

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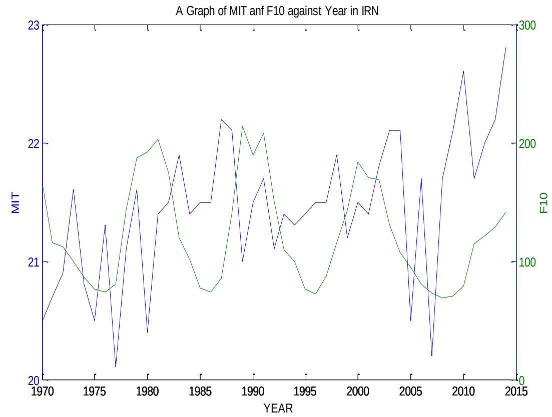

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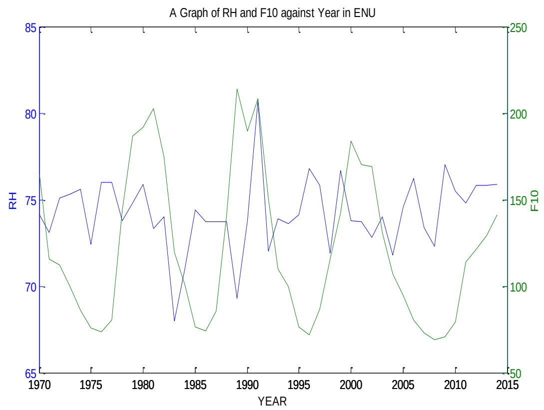

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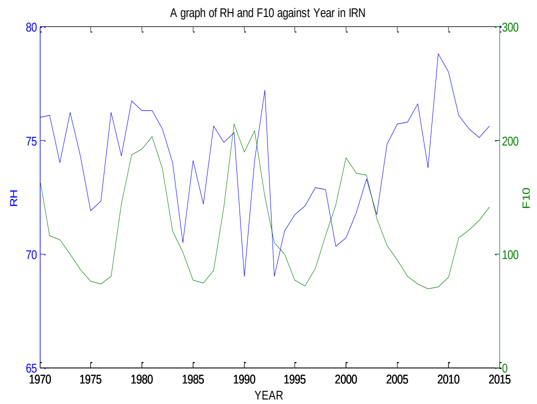

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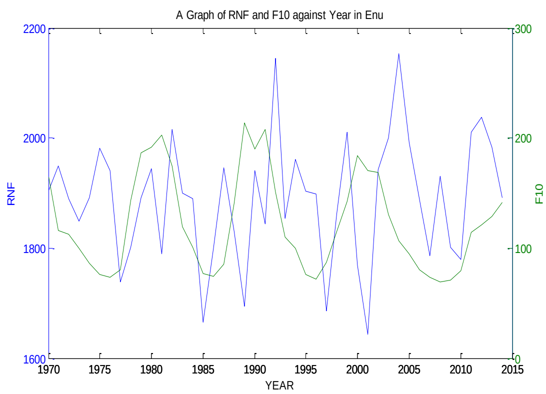
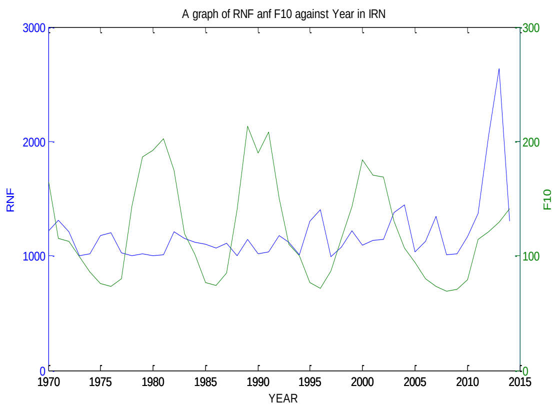


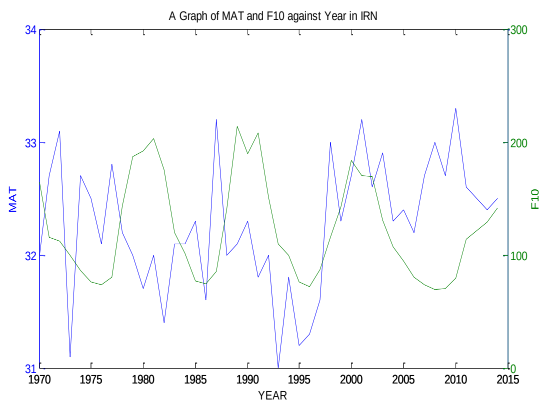
d.

Figure 11: Graphs of (a) MAT (b) MIT (c) RH (d) RNF and F10 against year in ENG

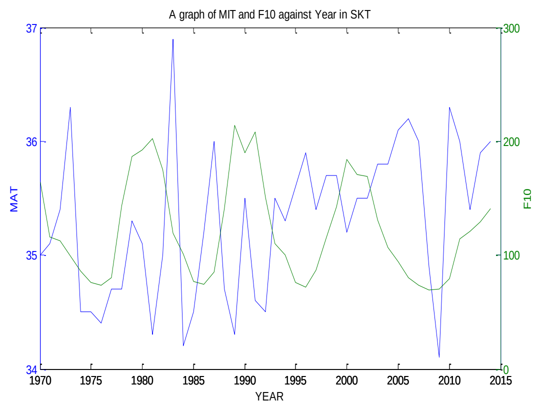


d.

Figure 12: Graphs of (a) MAT (b) MIT (c) RH (d) RNF and F10 against year in IRN



a.



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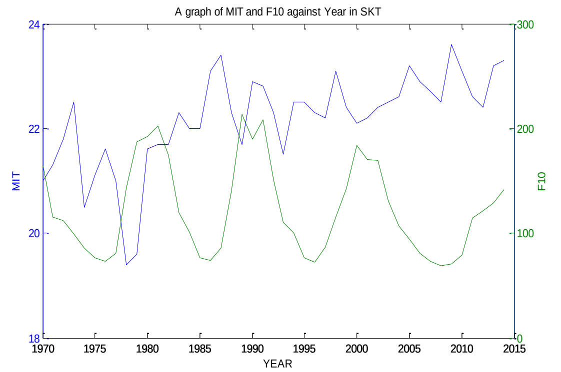

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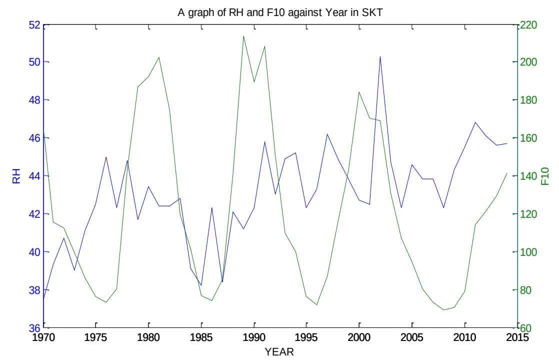

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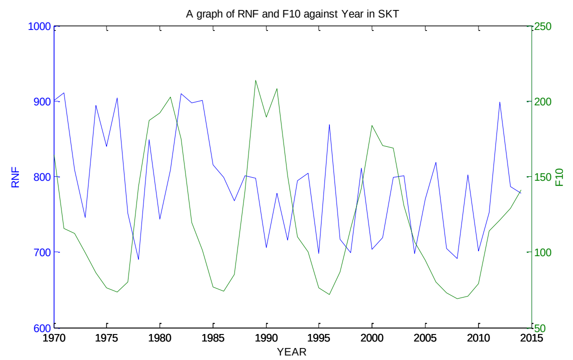

d

Figure 13: Graphs of (a) MAT (b) MIT (c) RH (d) RNF and F10 against year in SKT

The graphs in figure 10 to figure 13, shows the graphical relationship between the climatic parameters and those of the F10. From the figures, one can see that temperature parameters have a direct relationship with the solar indicator, while there is an inverse relationship between the RNF and F10.

The result from the Modelled Parameters

Table 1; Model parameters A, B, and C together with Performance Indicators MBE and RMSE from estimated Maximum Temperature (°C) using monthly means

	A	B	C	R^2	MBE	RMSE
PH	746.346	-1.261	0.007	0.081	-0.256	0.786
ENU	386.321	-0.260	0.003	0.010	0.267	0.496
IRN	321.956	-0.213	0.000	0.014	0.292	0.587
SKT	-438.961	0.349	-0.006	0.039	-0.477	0.668

Table 2; Model parameters A, B, and C together with Performance Indicators MBE and RMSE from estimated Minimum Temperature (°C) using monthly mean

	A	B	C	R^2	MBE	RMSE
PH	737.664	-0.526	0.003	0.069	-0.384	0.363
ENU	535.903	-0.378	0.004	0.014	0.110	0.496
IRN	489.169	-0.344	0.003	0.006	0.583	0.619
SKT	2937.029	-2.143	0.013	0.155	0.168	0.876

Table 3; Model parameters A, B, and C together with Performance Indicators MBE and RMSE from estimated Relative Humidity (%) using monthly mean

	A	B	C	R^2	MBE	RMSE
PH	-707.911	0.526	0.003	0.011	0.145	1.142
ENU	-380.953	0.335	-0.006	0.005	0.637	2.150
IRN	-470.289	0.400	0.003	0.001	0.464	2.412
SKT	-1294.775	0.983	-0.005	0.006	-0.119	2.506

Table 4; Model parameters A, B, and C together with Performance Indicators MBE and RMSE from estimated Vapour Pressure using monthly means

	A	B	C	R^2	MBE	RMSE
PH	1488.966	-1.073	0.008	0.055	-0.037	0.665
ENU	2973.346	-2.167	0.015	0.065	-0.672	1.264
IRN	2180.828	-1.585	0.010	0.062	-0.017	1.075
SKT	2773.947	-2.027	-0.018	0.065	0.194	1.083

Table 5; Model parameters A, B, and C together with Performance Indicators MBE and RMSE from estimated Rainfall (mm) using monthly means

	A	B	C	R^2	MBE	RMSE
PH	-111741.321	83.790	0.166	0.190	-0.503	289.216

ENU	-1115046.807	85.976	-0.750	0.011	-0.484	114.611
IRN	-392656.937	289.600	-2.807	0.021	0.289	280.149
SKT	-945.811	1.278	-0.030	0000	0.730	71.023

Models and Their Validity

The equations (models) that relate the various climatic parameters to the solar indices are obtained from Tables 1 to 5. The models represented in Equations 5a to 9d, show the solar forcing of MAT, MIT, RH, DP, VP, RNF respectively. The RMSE values for the equations seen in tables 1 to 5 are approximately zero and the MBE values are very low as recommended by [14-16]. This shows the good performance of the models and therefore validates them.

Maximum Temperature and Solar variables model

Equation 5a, shows the forcing of solar activities on MAT, the result shows a negative forcing of 1.261 TSI on MAT and a positive value of 0.007 F10 forcing on MAT in PH, the R^2 in table 1; for this region is 0.081 which means that only 8.1% of solar forcing can be accounted on MAT in PH.

Equation 5b, shows the forcing of solar activities on MAT for ENU, it can be observed that in this region there is a positive forcing of negative forcing of 0.26 for TSI and a positive forcing of just 0.003 for F10, the R^2 value in table 1 for this region 0.010 which means that just 1% of solar forcing can be account on MAT in this region.

Equation 5c shows the forcing of solar activities on MAT for IRN, a negative forcing of 0.213 is recorded for TSI, and the R^2 in table 1 for this region is 0.014 which means that a total of 1.4% solar forcing can be accounted on MAT in this region.

Equation 5d, shows the solar forcing on MAT in SKT, it can be observed that there is a positive forcing of 0.349 TSI and a negative forcing of 0.006 F10 on MAT, the R^2 value in table 1 for this region is 0.039 this means that about 3.9% of solar forcing can be accounted on MAT for this region. This agrees with the work of [13, 17, 18, 19] on semi-arid regions.

The intercept shown in the equations below indicates that the overall forcing for the parameter being discussed is negative.

$$[PH]\ MAT = 746.346 - 1.261TSI + 0.007F10 \quad 5a$$
$$[ENU]\ MAT = 386.321 - 0.260TSI + 0.003F10 \quad 5b$$
$$[IRN]\ MAT = 321.956 - 0.231TSI + 0.000F10 \quad 5c$$
$$[SKT]\ MAT = -438.961 + 0.349TSI - 0.006F10 \quad 5d$$

Minimum temperature and solar variables model

Equation 6a, shows the solar forcing on MIT for PH, it can be observed that there is a negative forcing of 0.526 TSI positive forcing of 0.003 F10 forcing on MIT in PH, the R^2 value in table 2 for this region is 0.069 which means that a total of 6.9% solar forcing can be accounted on MIT in this region

Equation 6b, shows the solar forcing on MIT IN ENU, there is a negative forcing of 0.378 TSI and a positive 0.004 F10 forcing on MIT for ENU, the R^2 for this region 0.014, which means that a total of 1.4% solar forcing can be accounted on MIT in this region.

Equation 6c, shows the solar forcing on MIT in IRN, it can be observed from the equation that there is a negative forcing of 0.344 TSI and a positive forcing of 0.003 F10 on MIT in IRN, R^2 value in table 2 for this region is 0.006 this means that only 0.6% of solar forcing can be accounted on MIT in this region.

Equation 6d, shows the solar forcing on MIT in SKT, it can be observed from the equation that there is a negative forcing of 2.143 TSI and a positive forcing of 0.013 F10 on MIT in this region, the R^2 value in table 2 for this region is 0.155 this means that only 15.5% of solar forcing can be accounted on MIT for this region.

The intercept shown in the equations below indicates that the overall forcing for the parameter being discussed is positive.

$$[PH]\ MIT = 737.664 - 0.526TSI + 0.003F10 \quad 6a$$
$$[ENU]\ MIT = 535.903 - 0.378TSI + 0.004F10 \quad 6b$$
$$[IRN]\ MIT = 489.169 - 0.344TSI + 0.003F10 \quad 6c$$
$$[SKT]\ MIT = 2937.029 - 2.143TSI + 0.013F10 \quad 6d$$

Relative Humidity (RH) and Solar variables Model

Equation 7a shows the solar forcing on RH in PH, it can be observed that there is a positive forcing for both solar variables on RH in PH. The R^2 value in table 3 for this region is 0.011 which implies that only 1.1% of solar forcing can be accounted on RH in this region.

Equation 7b, shows the solar forcing on RH in ENU, it can be observed from the equation that there is a positive forcing of 0.335 TSI and a negative forcing of 0.006 F10 on RH. The R^2 value in table 3, for this region, is 0.011 this means that only 1.1% of solar forcing can be accounted for on RH in this region.

Equation 7c shows the solar forcing on RH in IRN. It can be observed from the equation that there is a positive solar forcing on RH. The R^2 value in table 3, for this region, is 0.001 which implies that a total of 0.1% solar forcing can be accounted for on RH in this region.

Equation 7d shows the solar forcing on RH for SKT. It can be observed from the equation that there is a positive forcing of 0.983 TSI and a negative forcing of 0.005 F10. The R^2 value in table 3 for this region is 0.006 which means that 0.6% solar forcing can be accounted for RH in this region, thus, in consonance with the work of [13] on semi-arid desert climate.

The intercept shown in the equations below indicates that the overall forcing for the parameter being discussed is negative.

[PH] $\mathbf{RH = -707.911 + 0.526TSI + 0.003F10}$ **7a**

[ENU] $\mathbf{RH = -380.953 + 0.335TSI - 0.006F10}$ **7b**

[IRN] $\mathbf{RH = -470.289 + 0.400TSI + 0.003F10}$ **7c**

[SKT] $\mathbf{RH = -1249.775 + 0.983TSI - 0.005F10}$ **7d**

Vapour Pressure (VP) and Solar variables Model

Equation 8a shows the solar forcing model on VP in PH. It can be observed from the equation that there is a negative forcing of 1.073 TSI and a is positive forcing of 0.008 F10 on VP. R^2 value in table 4 for this region is 0.055 this implies that 5.5% of solar forcing can be accounted on VP in PH.

Equation 8b, shows the solar forcing model on VP in ENU. It can be observed from the equation that there is a negative forcing of 2.298 TSI and a positive forcing of 0.015 F10 on VP in ENU. R^2 value in table 4, for this region, is 0.065 this implies that 6.1% of solar forcing can be accounted for VP in ENU.

Equation 8c shows the solar forcing model on VP in IRN. It can be observed from the equation that there is a negative forcing of 1.585 TSI and a negative forcing of 0.015 F10 on VP in IRN. R^2 value in table 4, for this region, is 0.062 this implies that 6.2% solar forcing can be accounted on VP in IRN.

Equation 8d shows the solar forcing model on VP in SKT. As expected, there is a negative forcing of 2.027 TSI and a negative forcing of 0.018 F10 on VP. R^2 value in table 4, for this region is 0.021 which implies that only 2.1% solar forcing can be accounted on VP in SKT.
The intercept shown in the equations below indicates that the overall forcing for the parameter being discussed is positive.

[PH] $\mathbf{VP = 1488.966 - 1.073TSI + 0.008F10}$ **8a**

[ENU] $\mathbf{VP = 2973.346 - 2.167TSI + 0.015F10}$ **8b**

[IRN] $\mathbf{VP = 2180.828 - 1.585TSI + 0.010F10}$ **8c**

[SKT] $\mathbf{VP = 2773.947 - 2.027TSI + 0.018F10}$ **8d**

Rainfall (RNF) and Solar variables Model

Equation 9a shows the solar forcing model on RNF for PH. It can be observed from the equation that there is a positive forcing of 83.790 TSI and negative forcing of 0.116 F10 on RNF in PH. R^2 value on table 5, for this region, is 0.190 this implies that 19.0% solar forcing can be accounted on RNF in this region.

Equation 9b, shows the solar forcing model on RNF for ENU. It can be observed from the equation that there is a positive 85.976 TSI and a negative forcing of 0.750 F10 and on RNF in ENU. R^2 value on table 5, for this region, is only 0.011 which implies that 1.1% of solar forcing can be accounted on RNF in this region.

Equation 9c shows the solar forcing model on RNF for IRN. It can be observed from the equation that there is a positive forcing of 289.600 TSI and a negative forcing of 2.807 F10 on RNF in IRN. R^2 value on table 5, for this region, is 0.924 this implies that 92.4% of solar forcing can be accounted on RNF for this region.

Equation 9d shows the solar forcing model on RNF in SKT. It can be observed from the equation that there is a positive forcing of 1.287 TSI and a negative of 0.030 F10 on RNF in SKT. The R^2 value in table 5, for this region, is 0.001 which means that 0.1% solar forcing can be accounted on RNF for this region.
The intercept shown in the equations below indicates that the overall forcing for the parameter being discussed is negative.

[PH] $\mathbf{RNF = -111747.321 + 83.790TSI + 0.166F10}$ **9a**

[ENU] $\mathbf{RNF = -1115046.807 + 85.976TSI - 0.759F10}$ **9b**

[IRN] $\mathbf{RNF = -392656.937 + 289.600TSI - 2.807F10}$ **9c**

[SKT] $\mathbf{RNF = -945.811 + 1.278TSI - 0.030F10}$ **9d**

V. CONCLUSION

From the above-obtained results and discussions, it can be concluded that solar forcing is indeed affecting the climatic parameters in Nigeria – a negative forcing on relative humidity and rainfall, while a positive forcing on temperature, as can be seen from the graphical representation of the climatic parameters and solar indicators, and also from the modeled parameter in the above-discussed equations, consequently, it can be concluded that solar forcing affects the climate variability in Nigeria, hence, it can induce transient change in the variability of rainfall and temperature.

DEDICATION

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REFERENCES

[1] P.O. Ijila, O.A. Falaiye, O.J. Abimbola, "Study of Periodicity in Some Meteorological Parameters and Solar Indices over Some Station in Nigeria", JEES. **Vol. 6, Issue 5, pp. 2224-3216, 2016**.

[2] R. A. Obasi and C.O. Ikubuwaje, "Analytical Study of Rainfall and Temperature Trend in Catchment States and Stations of the

Benin- Owena RiverBasin", Nigeria, Journal of Environment and Earth Science, **Vol. 2. Issue 3, pp. 9-21, 2012**

[3] F.C. Olusegun, A.B. Rabiu, O.H. Ndeda, and E.C. Oleogbe, "Trend of Temperature and Signature of Solar Activity in Selected Station in Nigeria", Atm. and Climate Sci. **Vol. 4, Issue.3 pp. 171-178, 2014.**

[4] J. A. Eddy, "Climate and the changing sun", Clim. Change**, Vol. 1, pp. 173-190, 1977**.

[5] G. C. Reid, Solar Forcing And The Global Climate Change since The Mid-17th Century, Clim. Change, **Vol. 37, pp. 391–405, 1997**.

[6] S.K. Solanki, and N.A. Krivova,"Solar Irradiance Variation", Solar Physics Journal, **Vol. 224, pp. 197-206, 2004.**

[7] L. J. Gray, S. Crooks, C. Pascoe, S. Sparrow, and M. Palmer, "Solar and QBO Influences on the Timing of Stratospheric Sudden Warming", J. Atmos. Sci, **Vol. 61, pp. 2777–2796, 2004.**

[8] K. M. Hiremath and P. I. Mandi, "Influence of Solar Activity on the Indian Monsoon Rainfall", New Astronomy, **Vol. 9, pp. 651-662, 2004.**

[9] C.J. De. Jager and I. G. Usokin, "On the Possible Drivers of Sun-Induced Climate Change", Journal Atmosphere and Solar-Terrestrial Physics. J.Atmos. Sci, **Vol. 68, pp. 2053-2060, 2006.**

[10] D.V. Hoyt, and K.H. Schatten, "The Role of the Sun in Climate Change". Oxford University Press Oxford **pp. 30-37, 1997**.

[11] M.A. Palmer, L.J. Gray, M.R. Allen and Norton, W.A, "Solar Forcing of Climate: Model Results", Advances in Space Research, **Vol. 34, pp. 343-348, 2004.**

[12] D.K. Tripathi and A.B. Bhattacharya, "Sunspot activity over the Indian rainfall pattern", IJECT, **Vol. 2, pp. 43-45 2014.**

[13] J. O. H. Ndeda, A. B. Rabiu, L. H. M. Ngoo, and G. O. Ouma, "Inter-Relationships between Solar Radiation Intensity and Relative Humidity in Kenya". Abstract book of 2nd UN/NASA WORKSHOP on International Heliophysical Year and Basic Space Science, Bangalore India, **pp. 20-34, 2006**.

[14] J. O. Ndeda, "Solar Radiative Variability Forcing of Climatic Change on Seasonal to Decadal Scale in Kenya", **Ph.D. thesis** Jomo Kenyatta University of Agriculture and Technology, **pp. 90-120, 2008.**

[15] M. Iqbal, "An Introduction to Solar Radiation", Academic Press. New York, **pp. 59-67, 1993.**

[16] M. Halouani, C. T. Nguyem, and D. Ngoc, "Calculation of Monthly Average Global Solar Radiation on Horizontal Surface using Daily Hour of Bright Sunshine, Solar Energy", **Vol. 5, pp. 247-258, 1993.**

[17] I. U. Chibuogwu. T. N. Obiekezie. and H. I. Ikeri, "Solar Activities over the Rainfall Pattern and Temperature Ranges in Nigeria", The International Journal of Science and Technology, **Vol. 9, Issue 5, pp. 30 -39, 2021.**

[18] S. Kundu, S. Sasmal, S.K. Chakrabarti, "Long Term Ionospheric VTEC Variation During Solar Cycle 24 as Observed from India IGS GPS Station. IJSRPAS **Vol. 9, Issue 4, pp. 1-12, 2021.**

[19] I. U. Chibuogwu. T. N. Obiekezie, "Solar Forcing on Meteorological Parameter in Nigeria". IJMSAT, **Vol. 2, Issue. 11, pp. 15-23, 2001.**

