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HISTORICAL EXTREME TEMPERATURE TRENDS IN A PART OF SUB-SAHARAN AFRICA

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ABSTRACT

The study examines the historical trends and changes in extreme temperature events in Nigeria using both observed (NIIMET) and simulated (Regional Climate Model) data over the study area. The spatiotemporal patterns, variability and trend analysis of the datasets were carried out. Fourteen (14) indices of the 27 climate indices were used to determine the trends and changes in extreme events across the region. Results showed an increase in trends of minimum and maximum temperature across the eco-climatic regions of Nigeria, and the RegCM replicated the observed data for most of the eco-climatic regions, except for the Sudan savanna. The study identified significant implications attributed to the temperature increase in humans, plants and animals.

Keywords: *Temperature events, warm spell duration index, cold days, sub-Saharan, model performance*

INTRODUCTION

Changes in environmental components influenced by either natural or anthropogenic activities often alter the ecological balance by influencing changes in other earth components. The anthropogenic activities and chemical change of the earth's components have recently become severe issues of the earth's climate mean change system (Houghton *et al.,* 2001; Solomon *et al.,* 2007). Climate is defined as the statistical synthesis of various weather events that persist in a specific area over a long period of time. The climate of an area/region can be easily investigated using its annual or seasonal mean temperature and precipitation (Akinsanola and Ogunjobi, 2014; Wu et al., 2023), though the climate is far from being average weather condition, but changes according to time scales (Venäläinen, 2020). Climate change is a complex biophysical process that does not make it easy to predict future climate conditions precisely, albeit the changes around the globe mainly result from agro-land use activities and fossil fuel combustion, which contributes to greenhouse gases. Another primary concern is that an increase in fertility rate and population growth due to migration poses dangers such as economic damage and extreme temperature events resulting in flooding into the environment. Weather and climate variability effects in terms of heat stress, harmattan (Idowu et al., 2022; Eludoyin et al., 2014) and disease outbreaks (Tonnang et al., 2015) are predominant in Sub-Saharan Africa (IPCC, 2007). For instance, in 2002, as documented by Ragatoa (2019), the northeastern part of Nigeria recorded temperatures above 50^{o} C as one of the hottest spells. Other research (Abiodun et al., 2013; Oguntunde et al., 2012) revealed that regions with severe atmospheric alterations due to anthropogenic activities such as mineral exploitation, gas flaring, land use change and mass movements are prone to heat stress.

Understanding the changes in extreme temperature events across Nigeria is imperative in assessing, predicting, and mitigating the socio-economic impacts of extreme temperature across the country and the world, especially in countries with similar characteristics. However, poor maintenance and lack of infrastructure to resist extreme weather conditions are major challenges faced in the Sub-Saharan African regions (Abiodun *et al.*, 2017; Idowu et al., 2022). Hence, a review of extreme events under changing climatic conditions is warranted. Therefore, this study examined the historical trends of extreme temperature events across the eco-climatic regions of Nigeria, with the specific objective of gaining insight into the impacts of a warming climate on humans and the environment.

STUDY AREA

The study area, Nigeria covered the seven eco-climatic regions for the study. Due to its large population, the country is described as the "Demographic Giant of the World Fastest Growing Region" (Sub-Saharan Africa). It is characterized by a tropical warm climate and a relatively high temperature throughout the year. Due to the latitudinal extent of Nigeria (1,100km) from south to north, its climate varies more than any other in West Africa. Nigeria's natural vegetation is characterized mainly by the savannas, forest zones and the montane land which anthropogenic activities and land use change have impacted.

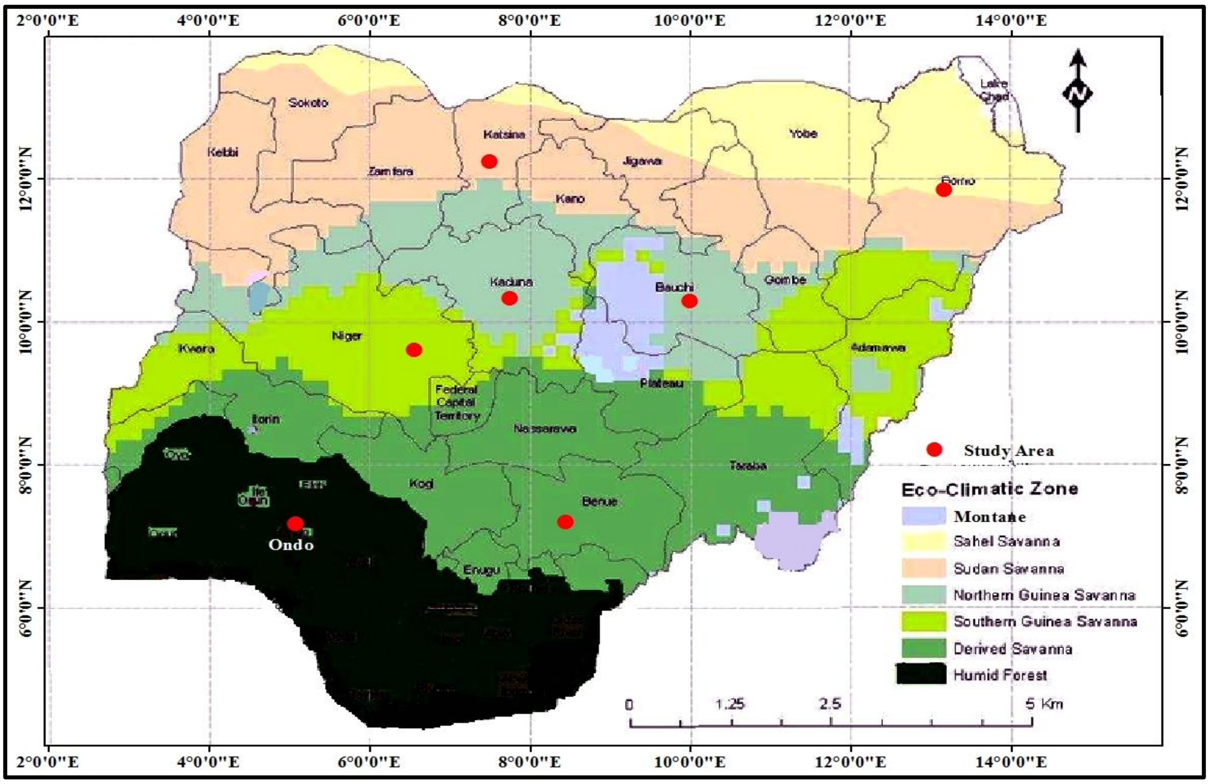

Figure 1: Map of Nigeria Showing the Eco-climatic Regions
Source: International Institute of Tropical Agriculture, (2005). Modified by Author (2018).

3. MATERIALS AND METHODS

3.1 Data

Thirty-five-year (1985-2015) ground station maximum and minimum daily temperature for the historical period were retrieved from the Nigerian Meteorological Agency (NIMET) archive. Similarly, the simulated region model dataset of daily temperatures for the study period (1985-2015) were obtained from the project data of the Coordinated Regional Climate Downscaling Experiment (CORDEX, www.cordex.org). The RegCMs are used to obtain higher spatial resolution over a specific region by downscaling the results of the General Models (GCMs). The model is a gridded model dataset with no missing values that has been validated over Nigeria (Abiodun et al., 2012) and is found to simulate Nigeria's eco-climatic regions at high resolutions. The study adopts the fourteen (14) of the twenty-seven (27) extreme indices developed by Expert Team on Climate Change Detection and Indices (ETCCDI) for assessing and monitoring extreme changes (Alexander et al., 2006; Peterson and Manton, 2008).

3.2 Data Analysis

The ground station and model maximum and minimum daily temperature data for the historical period were assessed for quality control using Rclimdex software developed and maintained by the Meteorological Service of Canada's Climate Research Division (CRD). The data were analyzed and the Mann Kendall test for trends (and significance level) was performed to examine the changes and trends in extreme events. The model simulations were then compared with the ground observations to evaluate the RegCM capability in reproducing extreme temperature characteristics over the country between 1981-2015.

To ensure a graphical overview of the model performance relative to each other for various temperature parameters, a metric approach was used to examine the model performance. The annual and monthly maximum and minimum temperature (Tmin and Tmax) analysis, the extreme parameters (Summer days (SMAD), Tropical night (TRPN), Cold Spell Duration Index (CSDI) and Warm Spell Duration Index (WSDI) computation were also carried out. The result suggests that the model performance varied across the different eco-climatic regions with potential overestimation of temperature data in all regions except northern guinea and humid forest while the Sahel, Sudan and Mid-altitude were underestimated by 0.55°C, 0.48°C and 0.24°C respectively.

RESULTS AND DISCUSSION

1. Temperature Trends

Figure 2 shows the annual trend of minimum temperatures across the eco-climatic regions of Nigeria for the period (1985-2015). The observed annual trend of minimum temperature increased across the regions between the range of 0.02°C and 0.07°C with only the Sudan savanna having a negative trend which is the least minimum temperature trend occurrence (i.e., 0.002°C (Sahel), -0.282°C (Sudan), 0.036°C (North guinea), 0.075°C (Montane), 0.028°C (South guinea), 0.042°C (Derived) and 0.033°C (Humid)).The simulated annual trend of minimum temperature showed an increase across the regions within the range of 0.005°C and 0.085°C (i.e., 0.026°C (Sahel), 0.085°C (Sudan), 0.005°C (North guinea), 0.172°C (Montane), 0.029°C (South guinea), 0.011°C (Derived) and 0.010°C (Humid)).

The annual maximum temperature trends across the eco-climatic regions (see figure 3) depict increasing temperature trends (i.e., 0.027°C (Sahel), 0.041°C (Sudan), 0.038°C (North Guinea), 0.044°C (Montane), 0.033°C (South Guinea), 0.053°C (Derived Savanna) and 0.071°C (Humid Forest) and the simulated temperature trend varies across regions with

0.036°C (Sahel), 0.024°C (Sudan), 0.006°C (North Guinea), 0.012°C (Montane), 0.011°C (South Guinea), 0.013°C (Derived) and 0.018°C (Humid)). In comparison, observed temperature values are generally higher than the simulated temperature values except for minimum temperature in the Sahel and Sudan Savanna (see Fig 2). The maximum temperature depicts increasing temperature trends over dry lands than the wetlands with a significant difference of about 4°C. This coincides with the IPCC Fourth Assessment Report (IPCC, 2007), which projects an increase in the earth's surface temperature between 2°C and 5°C if greenhouse gas emissions continue at their current rates for the next century.

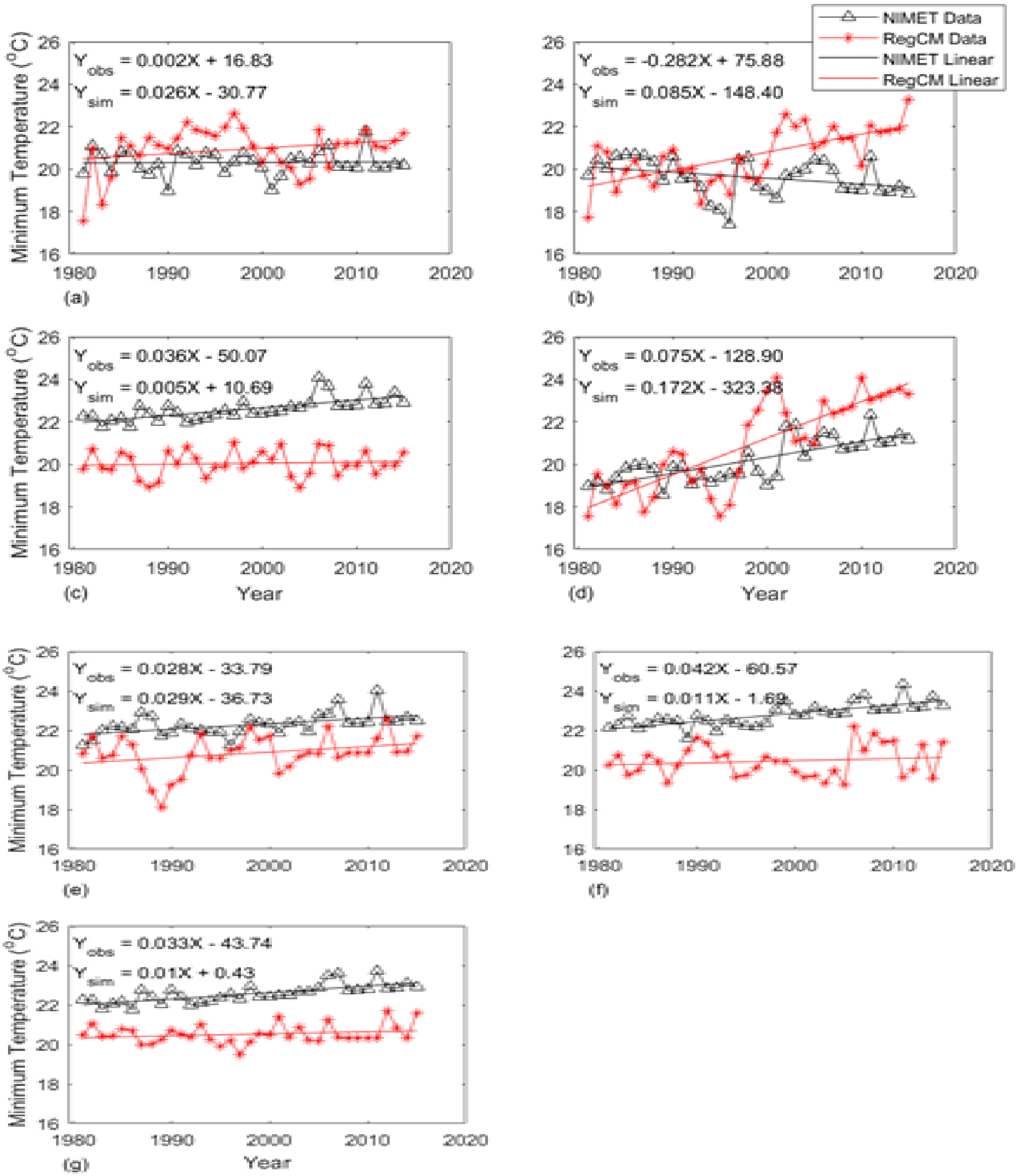

Figure 2: Annual Trend of Minimum Temperature between 1981 and 2015 in (a) Sahel, (b) Sudan, (c) North Guinea, (d) Montane, (e) South Guinea, (f) Derived Savanna and (g) Humid Forest

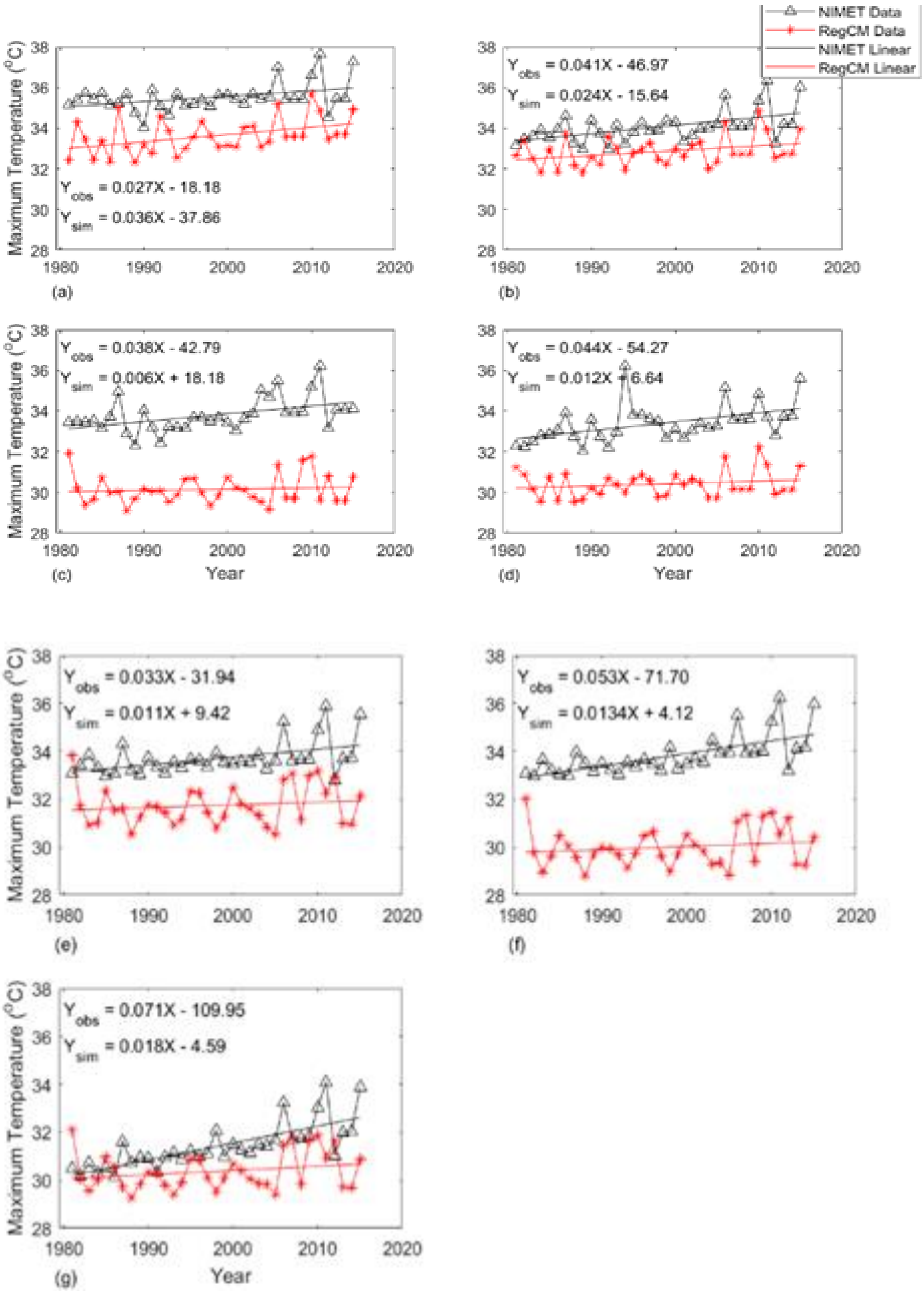

Figure 3: Annual Trend of Maximum Temperature between 1981 and 2015 in (a) Sahel, (b) Sudan, (c) North Guinea, (d) Montane, (e) South Guinea, (f) Derived Savanna and (g) Humid Forest

2. Extreme Temperature Events during Historical Period

Figures 4 to 6 illustrate the observed extreme temperature events (i.e., warm spell duration index (WSDI), cold spell duration index (CSDI), cool days (COOD), warm days (WAMD), cold nights (COON), warm nights (WAMN), diurnal and annual temperature range (DTR and ATR) across the eco-climatic regions of Nigeria during the historical period with their results computed in days per annum. The CSDI has the highest mean value of 2.8 days (Sahel) and a minimum of 0.7 days (Montane) (see figure 4), which can be attributed to variation in geographic location as the Northern regions tend to be warmer than the Southern regions of Nigeria. The WSDI depict a general decrease during the historical period with a maximum mean value of 1.4 days/annum (Sudan).

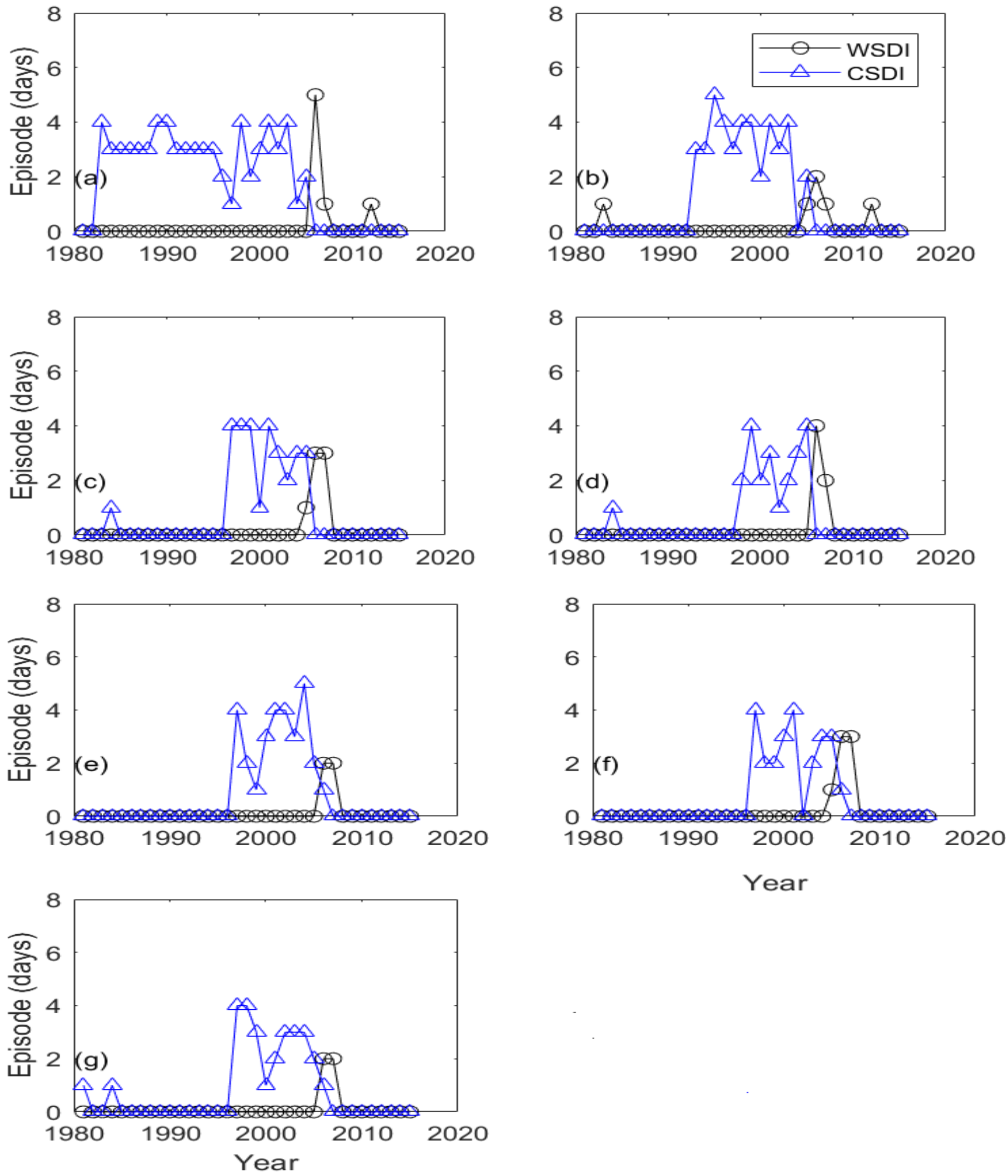

Figure 4: Number of Episodes of Warm Spell Duration Index (WSDI) and Cold Spell Duration Index (CSDI) between 1981 and 2015 in (a) Sahel, (b) Sudan, (c) North Guinea, (d) Montane, (e) South Guinea, (f) Derived savanna and (g) Humid Forest

Figure 5 represents the present-day extreme parameters of the eco-climatic regions of Nigeria; the warm days (WAMD), warm nights (WAMN), cool days (COOD) and cool nights (COON). An all-round fluctuation was observed in these parameters; extreme cases of WAMD showed an increasing trend, except over the derived Savanna; this concurs with the study of Abatan et al., (2016) and Idowu et al., (2022) that warm days and warm nights has increased over the historical periods. Although the temperature of COON and COOD have significantly decreased over time but the COON temperature is 0.72% higher than the COOD making it conspicuous with high rate of extreme events, which might be a result of intense warming at day time. This is consistent with the Annual Climate Summary (2014) report that observed and simulated cool night temperatures have increased more than cool day temperatures.

Above all, extreme events in Nigeria depict a significant decrease in the frequency of cold temperatures compared to warm temperatures, which has significantly increased across the country. This is consistent with the results of other studies in Africa (e.g., Fontaine et al., 2013; Kruger and Sekele, 2013).

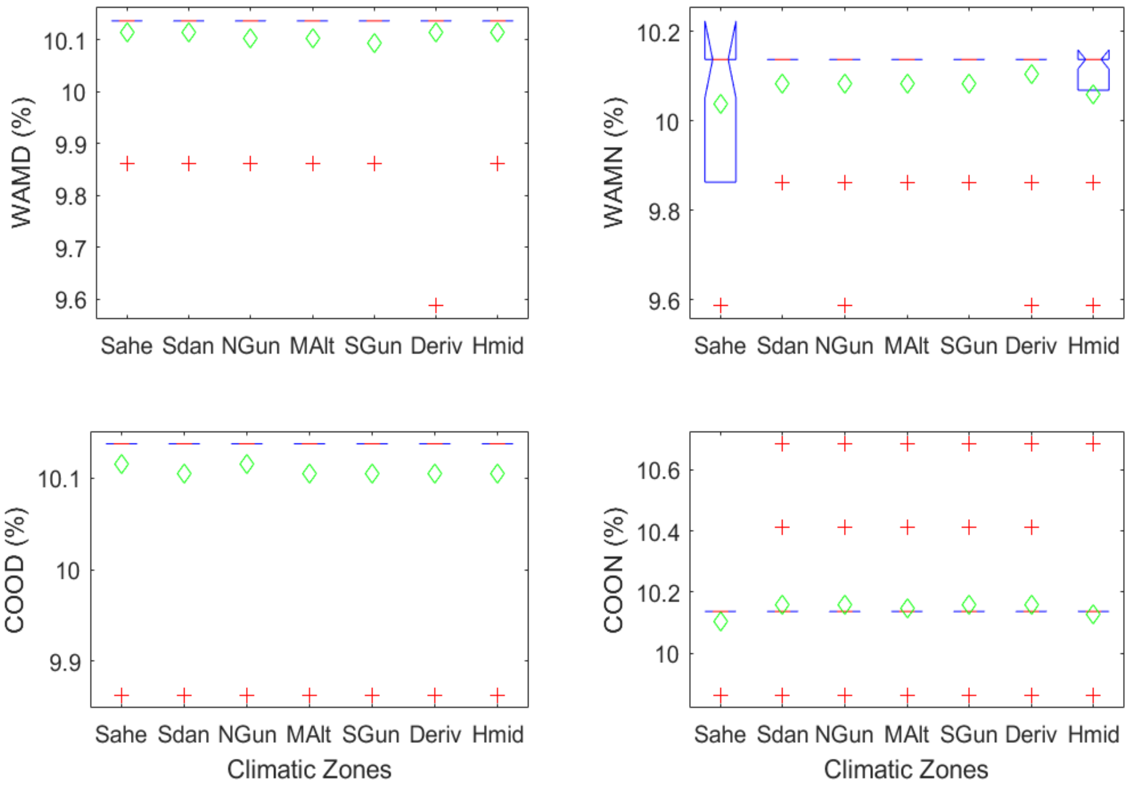

Figure 5: Historical Period Extreme Parameters WAMD = Warm days, WAMN = Warm nights, COOD = Cool days, COON = Cool nights.

Figure 6 shows the present-day diurnal temperature range (DTR) and the annual temperature range (ATR). The mean values for diurnal and annual temperature ranges are 14.02^{o}C and 12.80^{o}C respectively (Sahel savanna), with a maximum diurnal temperature value of 15.3^{o}C over the Sahel and a minimum of 9.6^{o} C (Humid forest). The humid region is characterized with extreme cases of DTR with a minimum value of 12^{o} C and a maximum value of 35 ^{o}C over the Sahel savanna. Extreme cases of ATR and DTR depict outward decreases which can be attributed to regional variations such as changes in precipitation and temperature, altitude, distance from the sea, relief and geographic location.

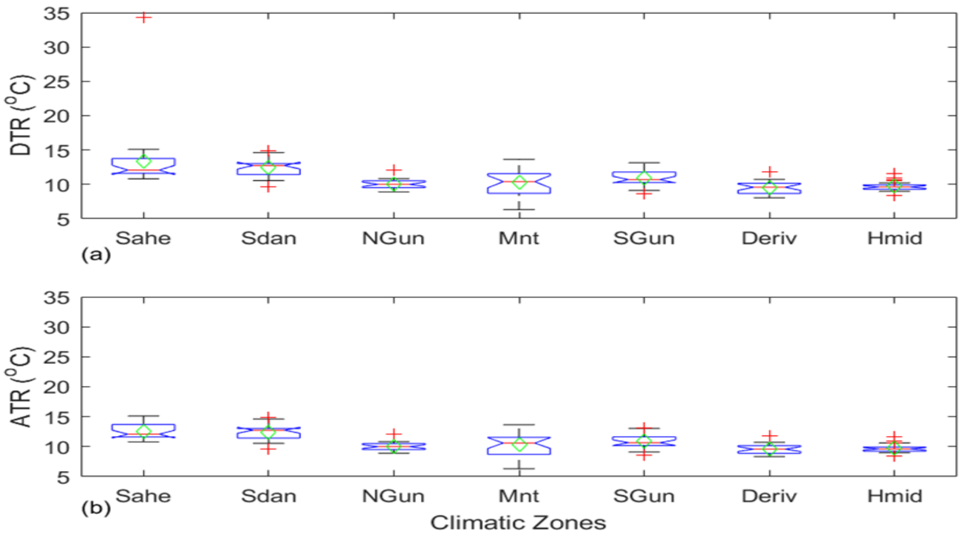

Figure 6: Diurnal Temperature Range (DTR) and Annual Temperature Range (ATR) between 1981 and 2015 over Eco-climatic Regions of Nigeria (Sahe=Sahel, Sdan= Sudan, NGun=Northern Guinea, Mnt=Montane, SGun=Southern Guinea, Deriv=Derived, Hmid=Humid).

CONCLUSION AND RECOMMENDATIONS

This study has investigated extreme temperature events across the eco-climatic regions (i.e., both dry lands and wetlands) of Nigeria. Observation datasets (NIMET) and model simulations (RegCM) which were analyzed to describe the temperature events of the regions reveals increase in extreme temperature events across the eco-climatic region of Nigeria. The results of the Mann-Kendall test for trends (and significance level) showed no significant difference between the observed and simulated datasets at p =0.05. Therefore, the trends of maximum and minimum temperature from both observed and simulated data depicts increase across the regions with ranging values between 0.02°C - 0.07 °C per annum.

Ostensibly, due to local perturbations, the results of the study depict that the rate of air temperature change tends to vary across the different eco-climatic regions of the country. A major implication identified in this study is that an increase in extreme temperature will continually be a driving force for the rate of disease outbreaks in humans (e.g., sunburn, meningitis, dehydration and respiratory disease); in animals (e.g., African horse, bluetongue); and in plant (e.g., barley yellow dwarf, rice blast, tomato mosaic and potato blight). This study recommends the development of strategies to serve as forewarnings on extreme conditions and mitigation efforts to improve and minimize the effects of extreme temperatures globally and especially in the Sub-Saharan countries (e.g., Nigeria).

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