DYNAMIC MAPPING VARIABILITY OF CLIMATE PARAMETERS ACROSS NIGER STATE

BY

MOHAMMED, ABDULLAHI
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DEPARTMENT OF SURVEY AND GEOINFORMATICS
FEDERAL UNIVERSITY OF TECHNOLOGY,
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ABSTRACT

In recent times across the globe, the concept of climate variability has gained more relevance due to its dynamics or fluctuations, complex nature and significant influence it has on the environment and its increasing threat on global climate change. Hence, the need to examine the spatiotemporal dynamics of some meteorological parameters in the context of climate change. The aim of this work is to study and analyze the trend of five climate parameters: Wind Speed, Surface Pressure, Relative Humidity, Precipitation, and Temperature in the twenty-five local government areas of Niger State using Merra2 dataset. The L.G.As were classified into three geopolitical zones considering their proximity (locations) and ethnic connectivity. The total average of the Merra2 datasets was computed for each L.G.A of Niger state. Merra2 datasets was extracted from National Aeronautical and Space Agency in alliance with Global Modeling Assimilation

Office. Using statistical template such as Bar chat, Mann-Kandel, Sen's slope estimator and correlation analyses index to examine and analyze the trend of the above-mentioned climate variables and to measure their levels of correlation when compared with a primary data (Nimet dataset). The data analysis covers a span of ten (10) years, from 2010-2019. The annual temperature (T) indicated an (upward movement) increasing trend of Sen.'s slope (32.42502), correlation index R of 0.61 and by 2040, the predicted temperature will increase by 6.7% at 95% confident level. The annual rainfall (RF) trend depicts a (downward movement) decrease of Sen.'s slope 2.36554, correlation index R of 0.67 and a predicted decreasing rate in the years 2040 to 10.59% at 95% confident limit. The annual Relative humidity (RH) shows a downward or a decreasing trend of Sen.'s slope -43.8309, correlation index R of 0.31 and a predicted decreasing rate in the years at 2040 to be 18.42% at 95% confident limit, the annual surface pressure (PS) showed an upward or increasing trend of Sen.'s slope 99.20, correlation index R of 0.58 and a predicted increasing rate by 2040 to be 0.09% at 95% confident limit, while the annual wind speed (WS) also showed an upward or increasing trend of Sen.'s slope 3.30133, correlation index R of -0.3 and predicted increasing rate in the years 2040 to be 18.43% at 95% confident limit. The study therefore, recommend continues monitoring of climatic meteorological parameters as they are useful in Dynamic maps production.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Variability is an important inherent characteristic of climate and it varies on all time scales. There has been much recent public and scientific interest in climate variability and the possible role of human activity in observed climate change (Braganza *et al.*, 2003). Global scale assessments of climate change impact on livelihood and economic factors are commonly based on averages assumption, rather than on the analysis of the variability or extremes (Adams *et al.*, 1990)

Observations, however, suggest that climate change impact on society results primarily from extreme events and their variability (Bernstein et al., 2007). This is because, in addition to changes in climate means, climate variability is expected to increase in some regions in future, including the frequency and intensity of extreme events (Bernstein et al, 2007). Climate changes when its extremes will have more adverse impact on crop production and the social lives of human (Tubiello *et al.*, 2007).

Climate science or climatology investigates the structure and dynamics of Earth's climate system. This science seeks to understand how local, regional and global climates are maintained, processes through which they change with time. Climate variation can be described as the mean weather conditions over a period of time. It is a branch of study within atmospheric sciences and also takes into account the variables and averages of short-term and long-term weather conditions (Cordero *et al.*, 2020).

Climate on the Earth's surface involves variations in a complex system in which the atmosphere interfaces with many other parts including the sea ice, oceans, land and its features. Climatic condition of a place is influenced by forces outside the climate system, such as Earth's rotation, the geometry bounding the Earth and Sun, the Earth's orbital gradual perturbation and radiation from the Sun (Kevin *et al.,* 2000). This notation implies that, depending on the associating elements, the climate constitutes of different parameters.

Awad *et al.,* (2013) stated that climate includes patterns of temperature, precipitation (rain or snow), humidity, wind and seasons. On a broader sense, World Meteorological Organization (2020) regarded essential climate variables (ECV) or parameters as physical, chemical or biological variables or a group of linked variables that critically contributes to the characterization of Earth's climate. They identified climate elements

(variable) to be dependent on Earth's region; atmosphere, land and ocean. ECVAtmosphere matrix was further classified as surface and upper atmosphere (Awad *et al.,* 2013).

Climate constituents in the surface atmosphere include Precipitation (Rainfall), Surface pressure, Surface Radiation Budget, Surface Wind Speed and Direction, Temperature and Water vapor. Earth Radiation Budget, Lightning, Temperature (upper-air), cloud properties and Wind speed and direction (upper-air) were identified as elements of the upper-atmosphere ECV. ECV-Land matrix was associated with river discharge, lakes, groundwater, and soil moisture. While Ocean related essential climate, parameters include ocean surface heat flux, sea ice, sea surface salinity, sea surface temperature, subsurface currents, subsurface temperature and surface stress (Tubiello *et al.,* 2007). This study however is concerned with the atmospheric (surface) climatic parameters specifically temperature, rainfall, pressure, relative humidity and wind speed. Need for measurement and assessment of climatic parameters either for its diverse applicability or their spatio-temporal variation cannot be overemphasized. Humanity depends largely on weather conditions of an area for their existence.

Understanding and predicting what the coming winter might bring, or predicting how climate will change over the next century is of great importance, both for our economy and society. The need for understanding and assessment of climatic parameters is on the rise. Impact of climatic change on food production has recently been of global concerns.

Agriculture is always vulnerable to unfavorable weather events and climate conditions. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are still key factors in agriculture productivity (Jayanta *et al.,* 2010). Often the linkage between these key factors and production losses are obvious, but sometimes the linkages are less direct (Jayanta *et al.,* 2010).

Meteorological (climate) measurements are required, either jointly or independently and locally or globally for input to numerical weather models for hydrological and agricultural purposes as indicators for climatic variability (Odessa, 2015). Positioning and navigation are largely affected by the understanding of climatic parameters. Global Navigation Satellite Systems (GNSS), one of the technological amazements of the modern world which provides global access to precision location and timing services have stimulated advances in industry and environmental developments including all forms of transport, synchronization of power grids, telecommunication. Unfortunately, this system is largely affected by natural phenomena in the form of space weather, Ionospheric, tropospheric and other space-related errors are forces combating the optimum performance of GNSS. Yet, accurate functioning (for positioning and other applications) of GNSS is needful for navigation especially in aircraft and ships (Rowhani *et al.,* 2011).

Narrowed down, in ship navigation, weather simulation is of utmost importance for safe landing and precise navigation. Sea states such as waves, tidal currents and wind are important factors for safe and economic navigation of ships (Chen *et al.,* 2013). Global warming and the greenhouse effects, environmental hazards, evaluation of wildfire growth, study of terrestrial ecosystems, tourism, modeling of land surface processes, and so on are other aspects of science that needs the input of climatology.

Climatic variations in Africa, characterized by widespread rainfall fluctuations, are an identifiable feature of the climate of the continent. The effects of these climatic variations are multifarious and affect the environmental, economic and social safety of the societies concerned. Studies have revealed that no nation of Africa and even the entire world is spared from the negative impact of variations in climatic parameters (this variation as explained by Adekunle *et al.* (2011) refers to some anomalies in the climate system that is as a result of human activities and which is measured of an area over a period of time) but poor and under-developed countries like Nigeria suffer heavily from this effect due to less attention paid to understanding of such scientific studies. Assessment of variation in climatic parameters is highly needful.

Climate change and global warming if not studied will cause adverse effects on livelihoods in the country such as reduction in crop production, fisheries, forestry and post-harvest activities. This is so because climatic parameter in this region varies with time. Rainfall season and patterns are continuously altered, floods which devastate farmlands do occur, increase in temperature and humidity which increase pest and disease are prevalent, wind-induced ocean surge and all these will not only affect

Nigerians' livelihood but also cause harm to life and property (Lobell, & Field, 2007). Niger state, a central region of the country will not be exempted.

Niger state is one of the states in Nigeria that experiences unstable and varied climate year-in-year-out. The state can be classified as part of states with dynamic weather and climate condition and some of the settlements in the state are gradually transiting to desert region. Jude *et al.,* (2018) research on climate study over Niger state recommends that measures should be taken to integrate climate change (prompted by variation in climatic parameters) adaptation measures into Niger state development process. This is only possible when there is a comprehensive understanding of the parameters over the area. This necessity is also supported by Adekunle *et al.,* (2011) who also suggested that there is a need for better monitoring systems to measure the impacts of variation in climatic parameters.

The conventional approach of measuring and the Spatio-temporal analysis of variation in climatic parameters is a specialization in meteorology. Acwadam, (2010) stated that various climatic parameters are measured with different equipment; temperature with thermometer, rainfall with rain gauge, wind speed with wind anemometer, solar radiation with pyranometer, humidity with humidity sensor or wet and dry thermometer, evaporation with evaporimeter and pressure with barometer or pressure sensor. Awareness however, of the implications of climatic variations imposes the need for better monitoring systems to measure the impacts of climatic variations. In meteorology, advancement in technology has brought about key developments in observation, numerical modeling and data assimilation. Before now, there has been series of approaches to the measurement, recording and analysis of climatic parameters. These methods and models however, have their relative advantages. Operations of the Meteorologists who monitored the conditions of the atmosphere that impact the weather had greatly transited from the crude approach to a more sophisticated system of observing and analyzing climatic parameters. These weather experts now make use of more efficient equipment to collect and use climatic data. These advancements in turn allow them to make better predictions faster than ever before. Doppler radar, satellite data, radiosondes, automated surface-observing systems. Advanced Weather Information Processing Systems (AWIPs) are many of the recent developments that have transited the field of climate science from its analog mode of operation to the modernized approach. Known for its versatile use and relevance, the applicability of satellite data (a product of remote sensing) has brought about a remarkable aid to geospatial assessment of climatic parameters. Richard *et al.* (2019) expressed that the field of remote sensing has brought about large developments to the observation of the atmosphere and surface; local and global climatic parameters can now be measured many times per day which brings about increase in the reliability of forecasted climatic parameters across an area. Geospatial techniques which include

Remote Sensing, Geographic Information System (GIS), Global Navigational Satellite Systems and integration of these now have direct and large contribution in the observation, processing and analysis of climatic parameters.

Remote Sensing, the process of observing and recording the physical characteristics of an area by measuring its reflected and emitted radiation at a distance from satellites or air-borne objects, now offers a new way of observing the Earth's climate system with continuous and high-resolution spatial coverage through satellite-based, aircraft-based, or drone-based sensor technologies.

This has significantly improved the understanding of variation in climatic parameters which depict climate change and its potential impacts at global, regional and local scales (Takara *et al.*, 2009). Relevance of remote sensing and its associated geospatial technique is traceable to the availability of climatic-parameters-observing satellites in space. Since 1960 when the first meteorological satellite known as TIROS (Television Infrared

Observation Satellite) till date, satellites data have been used to estimate climatic parameters and has sufficed as an appropriate alternative for non-availability of point-based weather stations. GOES-R series, Nimbus-3, Meteor series, EUMETSAT, RADARSAT, and so on are other satellites launched across countries for the purpose of climate science. NigeriaSat-2 and NigeriaSat-X were launched in Nigeria with weather as one of their recording parameters.

This study aims to perform spatio-temporal assessment of variation in climatic parameters across Niger State by processing and analyzing climatic data from the Modern-Era Retrospective analysis for Research and Applications, version 2 (MERRA-

2) which is a global atmospheric reanalysis product by the NASA's Global Modeling and Assimilation Office (GMAO). This data spans the satellite observing era since 1980 to the present.

1.2 Problem Statement

Scarcity of point-based Climate observations impedes the understanding of the Earth's changing climate. This affects the advancement in our knowledge of the Earth's climate system and our capability to develop well-suited climate models to simulate future climate change, which further results in considerable uncertainties associated with future climate projections. However, to quantify and minimize these uncertainties it is thus becoming one of the most challenging issues to be addressed in climate change impact assessment and adaptation studies (Takara *et al.*, 2009).

Operation of climate satellites now adequately suffice for these imposed challenges. Niger State located in the central region of Nigeria is known for seasonal unpredictable weather condition which is a function of climate parameters and which continuously influence the socio-economic wellbeing of the state. This predicament however is worsened by the non-availability of weather stations across the state, hence impeding the understanding, modeling and forecasting of future weather condition of the study area. These therefore necessitate the investigation into applicability of geospatial technique in climatology across Niger State.

1.3 Aim and Objectives

The aim of this study is to estimate the rate of change in climatic parameters as an overview to mitigate the variation of weather estimation in Niger State. In-view of the above, the following are the objectives of the study:

i. To examine the Spatio-temporal relationship of pattern of changes in climate parameters across the twenty-five-local government of Niger State.

ii. To generate dynamic map of the climate parameters across the twenty local government areas of Niger state iii. To estimate the rate of change (Dynamics) of the climatic parameters as an indicator of climate change using the Mann-kandel trend analysis.

1.4 Scope of the Study

The research study trenches across the twenty-five local government areas of Niger state including the state capital. The dataset used was from National Aeronautical and Space Agency in affiliation with global modelling and assimilation office (NASA_GMAO). Merra2 dataset is an upgrade of Merra1. The climate parameters generated were

Temperature (T), Surface pressure (SP), wind speed (WS), precipitation (RF), and Relative humidity (RH). The relationship between the geopolitical zones relatively to the climate parameter was examined, dynamic mapping was created for each parameter for the twenty-five local government areas at an epoch of ten years, such that the map automatedly change with change in the climate parameters. The estimation of each climate parameter was computed using Mann-Kandel and Sen's slope estimator in order to compute the trend pattern for each climate parameter with the aim to determine whether there is upward or downward (movement) trend over time. Datasets from the Nigeria meteorological agency (NIMET) were used to validate the secondary data, although due to the difficulty in retrieving NIMET data, only one local government area was validated

1.5 Justification of the Study

The climate parameters which make-up the weather condition of place is relevant in the prediction of climate activities which have some extended influence in various socialeconomical and the financial wellbeing of a country. In fact, most sectors of the state or country economy is influenced one way or the other by the climate information. Agriculture, which happens to be the main source of livelihood for the indigenes of the state needs much information on climate in order to plan and strategies so as to attain maximum yield of crops. Power generation is another aspect that justifies the need for this research exercise. In-fact, the enormous used of power cannot be overemphasis, information on temperature for solar energy, rainfall information for hydro-power, and wind for wind power generation etc.

Secondly, Niger state experience high volume of precipitation especially in the southern part of the state. There are areas that are prone to flooding and river/dam surge whenever there is high rainfall. In such case, future climate information is important in such areas in order to re-settle or advise occupants to relocate in such prone areas or provide adaptive measures to drastically reduce the danger ahead.

Lastly, due to the dynamic nature of climate and weather condition of places which are mainly influenced by the activities of the developed world such as burning of fossil fuel, exposes of dangerous element which has negative reaction to the ozone layer of the atmosphere etc. there is need to continuously check the climate parameter and estimate future change to examine the effect of these changes which will help in making strategic planning in order to avert unforeseen climate danger ahead.

1.6 Study Area

The State lies on latitude 08^0 to 11^0 30' North and Longitude 03^0 30' to 07^0 40' East. The State is bordered to the North by Zamfara State, West by Kebbi State, South by Kogi State, South West by Kwara State, North-East by Kaduna State and South East by FCT. The State also has an International Boundary with the Republic of Benin along Agwara and Borgu LGAs to the North West. Niger State possesses fertile land as a cherished asset and the potentials are yet to be fully explored. The Climate and availability of wide variety of mineral and agricultural resources attest to the economic potentials of the State. Niger State experiences harsh, distinct dry and wet seasons with annual rain fall varying from 1,100mm in the northern parts to 1,600mm in the southern parts. The maximum temperature (usually not more than 94^oc) is recorded between March and June, while the minimum is usually between December and January.

The rainy seasons last for about 150 days in the northern parts to about 120 days in the southern parts of the State. Generally, the fertile soil and hydrology of the State permits the cultivation of most of Nigeria's staple crops and still allows sufficient opportunities for grazing, fresh water fishing and forestry development. Figure 1.1 shows the map of the state as extracted from map of Nigeria.

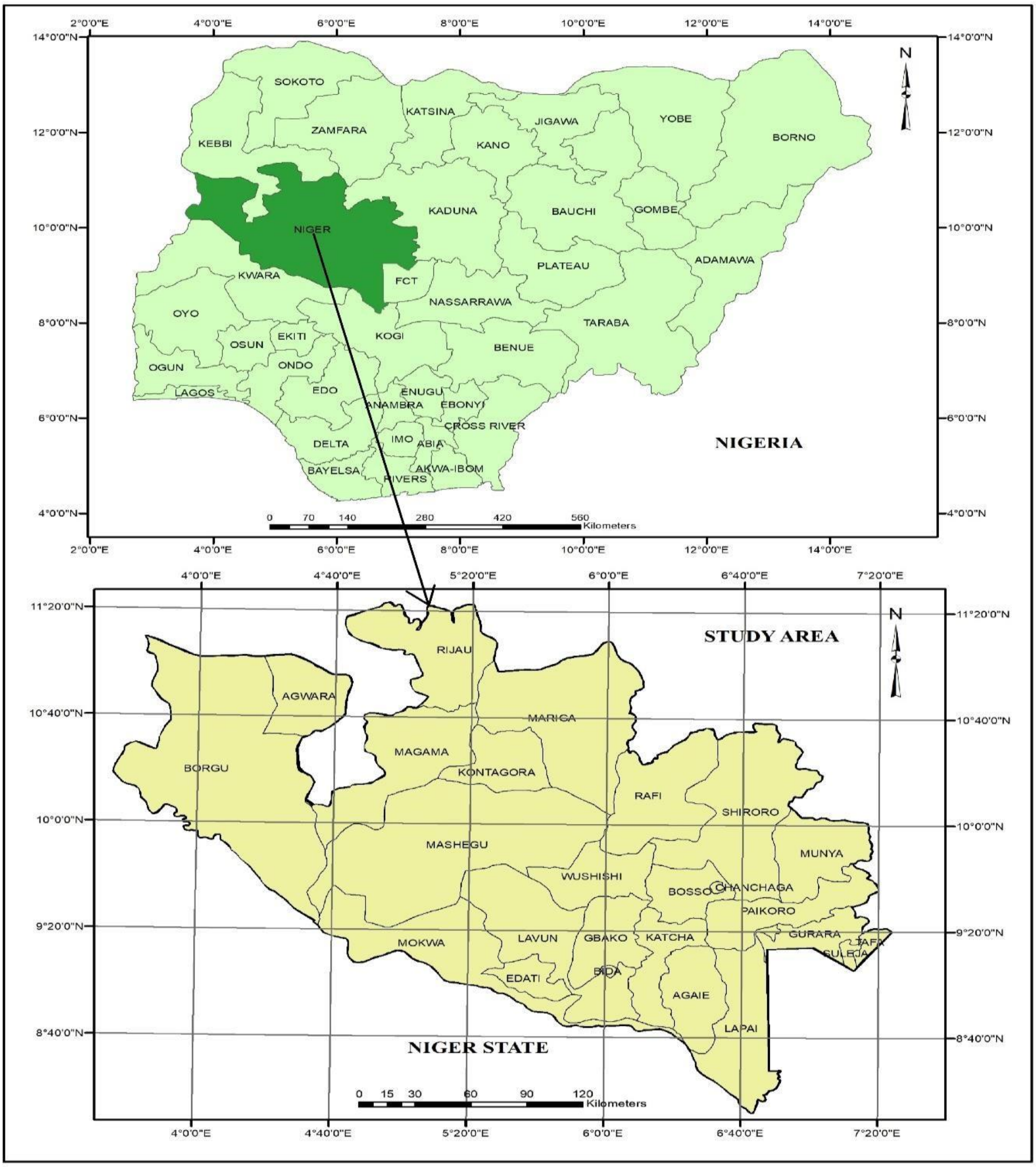


Figure 1.1: Map of Niger State as extracted from map of Nigeria
Source: (Office of the Surveyor-General of Niger State, 2021)

CHAPTER TWO

2.0 LITERATURE REVIEW

“Climate” refers to the average weather in terms of the mean and its variability over a certain time-span and a certain area. Classical climatology provides a classification and description of the various climate regimes found on Earth. Climate varies from place to place, depending on latitude, distance to the sea (Baede et al 2005) Climate variability is defined as “a change of climate which is attributed directly or indirectly to human activity (anthropogenic) that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”, according to United Nation Frame Convention on Climate Change (UNFCCC) 1992.

This phenomenon is caused by so-called greenhouse gases in the Earth’s atmosphere. Emissions of greenhouse gases have been increasing since industrialization in the 1900s, due to increased fossil fuel burning. These gases allow solar radiation to reach the Earth’s surface, but prevent radiation from the surface travelling back into space. This causes the Earth’s temperature to rise gradually (Takara *et al.,* 2009).

It is expected that climate change will strongly affect the hydrological cycle in future decades (Gedney *et al.,* 2006). It will also have significant impacts on the availability, as well as the quality and quantity of water. Among the climatic variables, precipitation (P) and potential evapotranspiration (ET) have the greatest importance in long-term changes of water resources (Richard *et al.,* 2019). Many researchers have predicted that climate change will accelerate water cycles, with higher ET and increased precipitation in some parts of the globe (Betts *et al.,* 2007). But increased precipitation does not necessarily lead to sustainable water resources because less frequent but heavier precipitation may lead to extreme flood or drought occurrences (Lettenmaier *et al.,* 2006). Therefore, it should be emphasized that in order to monitor and assess the impact of climate change on drought occurrence, ET and P should be considered together as two major climatic variables.

Trenberth *et al.,* (2008) evaluated the impacts of climate change and variability on heavy precipitation, floods and drought, and concluded that there is likely to be increased runoff and risk of flooding in early spring but increased risk of drought in high summer, especially over continental areas. Karamouz *et al.*(2009) simulated flood flows under climate change scenarios using GCM models for the Kajoo River basin, located in the arid and semi-arid regions of southeast Iran, and estimated the magnitude of floods that would occur in the future due to the impacts of climate change.

Abbaspour *et al.*, (2009) studied the impact of climate change on water resources in Iran. They used the SWAT model for analysis of daily river discharge and annual wheat yield data at the sub-basin level for the period 1980–2002. They also used CGCM 3.1 with scenarios A1, B1 and A2 for simulation of the water resource situation for 2010– 2040 and 2070–2100. Their results indicated that daily rainfall intensities will be greater in the future, causing larger floods in the humid regions and more prolonged droughts in the dry regions.

Harmsen *et al.,* (2009) estimated precipitation (P), reference evapotranspiration (ET_0), precipitation deficit PD= P- ET_0 and relative crop yield reduction (YR) for generic crop under climate change conditions for three locations in Puerto Rico. Results from their analysis indicated that the rainy season will become wetter and the dry season will become drier. The 20-year average September precipitation excess increased for all scenarios and locations, from 121 to 321 mm between 2000 and 2090. Conversely, the

20-year average February precipitation deficit changed from 27mm to 77 mm between 2000 and 2090.

Rosenberg *et al.,* (2010) evaluated the impacts of climate change on precipitation extremes and storm-water infrastructure in Washington State, USA. Although their simulations generally predicted increases in extreme rainfall magnitudes, the range of these projections is too large at present to provide a basis for engineering design, and can only be narrowed through consideration of a larger sample of simulated climate data. Nonetheless, the evidence suggests that drainage infrastructure designed using mid-20th-century rainfall records may be subject to a future rainfall regime that differs from current design standards. Dastorani & Mohammadi (2011) studied the effects of climate change on drought indices for Yazd station in Iran. This research employed the HadCM3 model based on the IPCC-SRES scenarios A2 and B2. The results indicated that the values of SPI (standardized precipitation index) and RDI (reconnaissance drought index) for scenario A2 have a negative trend along the projected years, while these indicators tended to have a positive trend when scenario B2 was applied. SPI and RDI are the most important indices for evaluation of drought characteristics (Kousari et al. 2014). Azaranfar *et al.*, (2009) studied variations of precipitation and temperature in the Zayanderud basin in Iran using statistical methods. Their results suggested that temperature and precipitation will increase in 2010–2039. (Massah-Bavani & Morid, 2006) studied the effects of uncertainty on runoff probability distributions under climate change in the same basin. Their probability distributions were most effective in estimating runoff for 2070–2099.

Trenberth *et al.,* (2008) studied changes in precipitation due to climate change and concluded that global warming has a direct influence on precipitation. Increased heating leads to greater evaporation and thus surface drying, thereby increasing the intensity and duration of drought. However, the water-holding capacity of air increases by about 7% per 1°C warming, which leads to increased water vapour in the atmosphere. Hence storms, whether individual thunderstorms, extratropical rain or snow storms, or tropical cyclones, are supplied with increased moisture, and produce more intense precipitation events. Such events are now occurring widely, even where total precipitation is decreasing, and this increases the risk of flooding.

Acharya *et al.,* (2013) investigated the impacts of climate change on extreme precipitation events over the Flamingo Tropicana watershed in Nevada, USA. According to their results, the predicted cumulative annual precipitation for each 30year period shows a continuous decrease from 2011 to 2099. However, the summer convective storms, which are considered as extreme storms for the study area, are expected to be more intense in future. Extreme storm events show larger changes in streamflow under different climate scenarios and time periods. The simulated peak streamflow and total runoff volume both showed an increase from 40% to more than 150% (during 2011–2099) for different climate scenarios.

Khalil *et al.,* (2013) analyzed the effects of climate change on evapotranspiration in Egypt. In this study, agrometeorological data were collected from 20 stations in the Nile Valley and Nile Delta to determine the variation of evapotranspiration under current and future climate conditions. The Penman-Monteith equation was used to calculate reference evapotranspiration according to the agrometeorological data. Results showed that under the current climate the Aswan region shows the highest and Damietta shows the lowest rates of evapotranspiration. However, under climate change,

evapotranspiration will increase at all 20 stations, especially using scenarios A2 and B1. These results reveal that water requirements will increase under climate change conditions due to increased evapotranspiration.

Tanasijevic *et al.,* (2014) evaluated the impacts of climate change on the evapotranspiration and irrigation requirements of the olive crop in the Mediterranean region, focusing on olive growth and possible alterations to cultivable areas under changing climate. The results showed that olive flowering is likely to be advanced by 11 ± 3 days and crop evapotranspiration is expected to increase by 8% (51 ± 17 mm season^{-1}). Net irrigation requirements were predicted to increase by 18.5% (70 ± 28 mm season^{-1}). In addition, effective evapotranspiration of rainfed olives could decrease in most areas due to the expected reduction of precipitation and increase of evapotranspiration demand, thus making it impossible to maintain rainfed production as it is at present. The phenomenon of global warming and climate change is the most important challenge of the 21st century. However, climate change impacts on rainfall and evapotranspiration have not been determined conclusively. Decrease in rainfall and increase in temperature would result in increase in evapotranspiration (Abtew & Melesse, 2013).

According to Sandberg et al. (2008), the effects of climate change could be different in different parts of the world, therefore, regional research projects are necessary to enable results to be combined to build a comprehensive understanding of the impacts on hydrology and water resources for the whole planet. This research was carried out to provide some of the knowledge required on regional impacts of climate change on three main parameters of hydrology. The purpose was the evaluation and mapping of the impacts of climate change on precipitation, temperature and potential evapotranspiration in Iran under scenarios A2 and B2 for the time periods 2010–2039, 2040–2069 and 2070–2099. Awareness of the type and the size of changes in such important parameters would help the authorities and planners to adopt better optimized and effective management strategies for water resources to be able to cope with the conditions expected in the future.

2.1 Altitude Effect of Climate

Global warming is occurring at an accelerated pace in many high-altitude regions around the world and among the consequences could be water shortages, according to a new study co-authored by Rutgers climate scientist Jim Miller. A professor in the

Department of Marine and Coastal Sciences in the School of Environmental and Biological Sciences, Miller collaborated with an international team of scientists on a new study published in the journal Nature Climate Change. The researchers say evidence is showing that global warming often occurs more rapidly in high mountains and that further study is needed to fully grasp the true impact of the phenomenon. "Somewhere on the order of 1 billion people a day don't have access to good clean water," Miller said. "Climate change will exacerbate that and what happens in mountains is going to be a major part of that." Rutgers climate scientist Jim Miller has found faster warming in many mountainous regions, and this could have serious implications for agriculture and cities (Lobell, & Field, 2007).

Globally, the team of researchers found that as altitude rises, the rate of temperature change often accelerates. In the past 20 years, temperatures above 4,000 meters (13,120 feet) have warmed 75 percent faster than at altitudes below 2,000 meters (6,560 feet). Miller explained that the snow line on a mountain, rather than specific altitude, is what matters in the rate of warming. "Snow reflects a lot of solar radiation so, if that snow melts, radiation gets absorbed by the ground which heats the ground and warms the air," he said. "Right at the snow line, as the snow melts, it gets significantly warmer. And that's the same sort of thing that happens in the Arctic when the sea ice melts." In the United States, areas such as southern California and Arizona, which rely on water brought from the mountains, stand to be most adversely impacted, Miller said. As snow accumulates later in the fall and melts faster in the spring, less fresh water will emerge from the mountains during the late spring and through the summer. For both agriculture and the water supplies of major cities, that could spell trouble. “Water is going to be a major problem over the next few decades anyway and climate change is going to exacerbate it," Miller said. "Who gets the water? Are you going to use the water to grow crops or are you going to use the water to fill swimming pools in LA? Those are ultimately social and political decisions. With climate change, those changes could be more dramatic. “Beyond water supply issues, the "elevation-dependent warming"

phenomenon has implications for tourism, in terms of shorter ski and whitewater rafting seasons, as well as forestry. In Colorado, for example, a spruce beetle infestation has been devastating forests. “Some people would argue that because the climate is warming, it makes it more favorable for spruce beetles to exist," Miller said. "Also, drought conditions make trees less resilient to the beetle. “The report by the international scientific team calls for improved observations, satellite-based remote sensing and climate model simulations to better understand elevation-dependent warming. In addition, existing observational data from around the world needs to be collated and evaluated. The lead author is Nick Pepin, of the University of Portsmouth

(UK).

2.2 Geography Effect

Earth is a dynamic planet, constantly undergoing change driven by internal and external forces. Currents of magma within our planet move the plates that form the continental crust in a constant process that builds mountains and creates valleys. These valleys may eventually become lakes, seas, and oceans. On the surface, the greatest factor affecting Earth is sunlight. Sun provides energy for living organisms, and it drives our planet's weather and climate by creating temperature gradients in the atmosphere and oceans.

It is widely recognized that climate change poses a grave threat to biodiversity, exacerbating existing threats because of land use change, fragmentation, and environmental degradation. In the past century, mean global surface temperature has increased almost 1°C (Meehl *et al.*, 2007). The impacts of climate change are broadly detectable in many taxa, including shifts in phenology, distribution, and demography

(Moritz *et al.*, 2008). In the next century, mean global temperature could increase by 4°C or more, with an associated increase in the frequency of extreme events (heat waves, storms) and in the frequency and extent of wildfire (Krawchuk *et al.*, 2009). If the rate of change exceeds the pace of biological response, especially the capacity of populations to migrate or undergo adaptive evolutionary change, impacts on species distributions, community structure and ecosystem function may be profound.

Enhanced conservation efforts, including expanded reserve systems, intensive management, and the more controversial idea of managed translocation, will play a critical role in efforts to reduce the impacts of climate change on biodiversity and ecosystem services (Lawler *et al.*, 2010). One of the most important tools in conservation planning with respect to climate change is the deployment of species distribution models to evaluate present and potential future species ranges in relation to climate, soils and other predictive variables. These models can highlight individual species that may be at risk because of climate change, and geographic areas that may face substantial shifts in diversity and species composition (Loarie *et al.*, 2008).

In some cases, models suggest that protected areas may no longer maintain populations of key species, possibly the very ones that the reserves were created to protect (Araujo *et al.*, 2004). Conversely, shrinking distributions and range shifts could create new refugia - areas where threatened species would be concentrated in the future

(Loarie *et al.*, 2008).
The use of climate and species modelling to inform conservation faces (at least) two fundamental challenges. First, different species are expected to exhibit distinct, individualistic responses. Even if it were possible to accurately project climate change and to precisely model the biological responses, it is extremely difficult to analyze and

integrate projections for hundreds or thousands of species and discern how this information should be used to inform current conservation strategies.

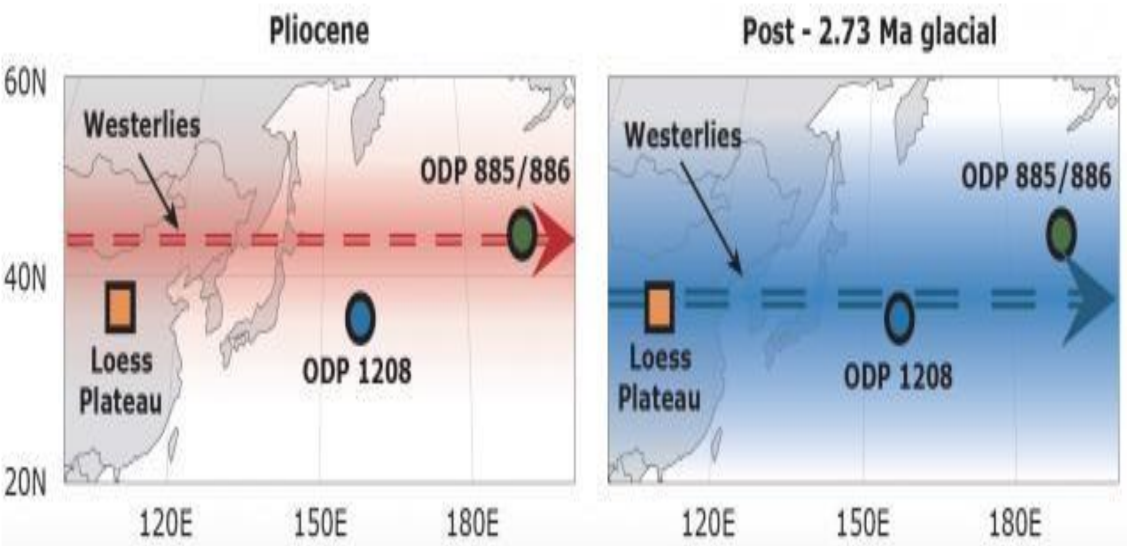
The second issue is that the models are intrinsically uncertain, and the application of modelling to conservation is frequently overshadowed by the specter of uncertainty in model projections. Uncertainty arises at each step in the species modelling process, because of imperfect knowledge or modelling of current distributions and climates, mechanisms underlying species distributions, trajectories of future climate change, and the challenge of extrapolating species responses to novel climates, beyond the range of conditions used for model parameterization (Leathwick *et al.,* 2009). Despite these limitations, species distribution models remain a critical tool, and they can be surprisingly effective at predicting observed range shifts, at least for mobile taxa like birds and butterflies.

2.3 Global Wind

The westerlies or westerly winds play an important role in weather and climate both locally and on a global scale, by influencing precipitation patterns, impacting ocean circulation and steering tropical cyclones. So, finding a way to assess how they will change as the climate warms is crucial. Typically, the westerlies blow from west to east across the planet's middle latitudes. But scientists have noticed that over the last several decades, these winds are changing, migrating poleward. Research suggests this is because of climate change. But scientists have been debating whether the poleward movement of the westerlies will continue as temperatures and atmospheric carbon dioxide (CO2) increase further under future warming scenarios. It's been difficult to resolve this scientific question because our knowledge of the westerlies in past warm climates has until now been limited.

Climate researchers from Columbia University's Lamont-Doherty Earth Observatory describe a new method of tracking the ancient history of the westerly winds a proxy for what we may experience in a future warming world. Jordan *et al.,* (2015) developed a way to apply paleoclimatology, the study of past climate to the question of the behavior of the westerly winds, and found evidence suggesting that atmospheric circulation patterns will change with climate warming.

The finding represents a breakthrough in our understanding of how the winds changed in the past, and how they may continue to change in the future. By using dust in ancient, deep-sea sediments as an indirect tracer of wind, the researchers were able to reconstruct wind patterns that occurred three to five million years ago. Knowing that winds in this case, the westerlies transport dust from desert regions to faraway locations, the authors examined cores from the North Pacific Ocean. This area is downwind from Eastern Asia, one of the largest dust sources today and a known dust-generating region for the past several million years. By measuring the dust in cores from two different sites thousands of kilometers apart, the researchers were able to map changes in dust, and in turn the westerly winds. This is shown in plate I below as correlation of wind pattern.



PlPlate I: Correlation of Wind Pattern to Climate Change (Abell *et al.*, 2021) They found that during the warm parts of the Pliocene (a period three to five million years ago, when the Earth was about two to four degrees Celsius warmer than today but had approximately the same concentration of CO2 in the air as we do now), the westerlies, globally, were located closer towards the poles than during the colder intervals afterwards (Abell *et al.,* 2021). By using the Pliocene as an analogue for modern global warming, it seems likely that the movement of the westerlies towards the poles observed in the modern era will continue with further human-induced warming, (Winckler *et al.,* 2016).

The movement of these winds has huge implications for storm systems and precipitation patterns. And while this research does not indicate exactly where it will rain more or less, it confirms that the wind and precipitation patterns will change with climate warming.

2.4 Map Projection

Projection of map is usually from the real Earth, celestial body or imagined world to a plane representation on a piece of paper or on a digital display such as a computer monitor. Maps are created by transforming data from the real world to a spherical or ellipsoidal surface and then to a plane. The characteristics of this generating globe are that angles, distances or surfaces measured on it are proportional to those measured on the real Earth. The conversion from the curved surface into a plane is known as map projection and can take a variety of forms, all of which involve distortion of areas, angles, and/or distances. The nature of distortion can be controlled to preserve specific characteristics, but map projections must distort other characteristics of the object represented. One of the measure challenge in cartography is that it is difficult to project a spherical or ellipsoidal surface into a plane without distortions. Only a spherical or ellipsoidal shaped globe can portray all round Earth or celestial body characteristics in their true perspective (Miljenko et al., 2006).

According to Miljenko et al. (2006), the process of map projection is accomplished in three specifics Steps:

i. Computing the size and shape of the Earth by a mathematical figure that is by a sphere or an ellipsoid; ii. Adjusting the scale of the mathematical representation to a generating globe.

iii. Transforming/Converting the generating globe into the map using a map projection

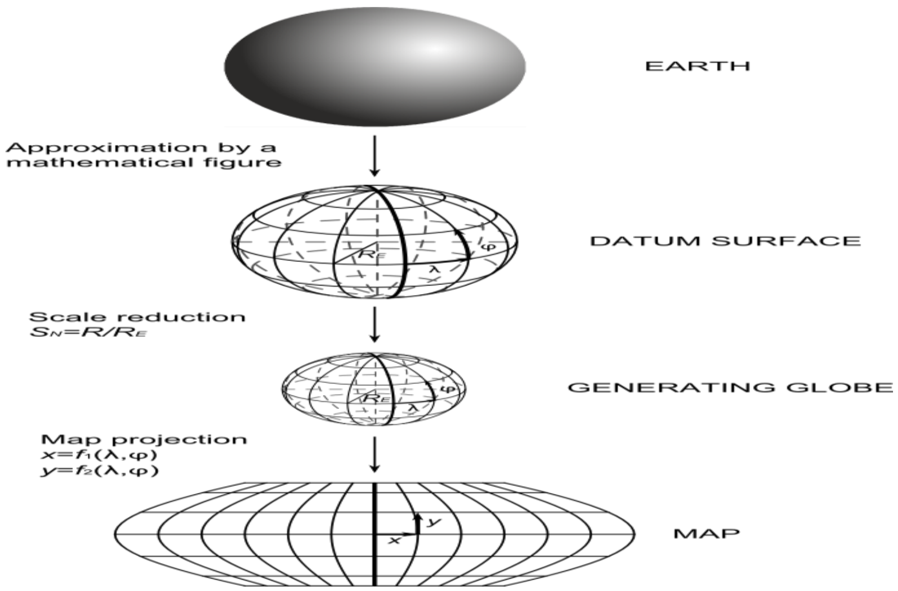


Figure 2.1: Projections from the Earth through a Generating Globe to the Final Map).

Map projections depend first on an assumption of specific geodetic variables of the object (Earth) itself, such as spherical or ellipsoidal shape, radius of the sphere (or lengths of the semi-major and semi-minor axes of the ellipsoid), and a specific datum or starting point for a coordinate system representation. These assumptions form the rudiments of the science of Geodesy and are accomplished using satellite measurements usually from the Global navigation satellite system (GNSS), Glonass, or Galileo (Once these measurements are accepted, an ellipsoidal representation of coordinates is generated as latitude and longitude coordinates. Those coordinates can then be projected through map projection formulae to a plane system of x and y coordinates. The general equations of this transformations have the following form $x = f_1(\varphi,\lambda)$, $y = f_2(\varphi,\lambda)$ Where:

x; the plane coordinate in the east_west direction y:

the plane coordinate in the north_south direction φ:

is the latitude coordinate λ: is the longitude

coordinate

The form of the functions f_1 and f_2 determines the exact transformation and the characteristics of the ellipsoidal or spherical representation that will be preserved. Before addressing the specific types of transformations and the characteristics preserved, it is necessary to understand the geodetic characteristics of the ellipsoidal coordinates and how these are generated with modern satellite positioning systems.

2.4.1 Geodetic Latitude

This is a parameter which determines the position of parallels on the Earth's ellipsoid and is defined by the angle from the equatorial plane to the normal one (or line perpendicular) to the ellipsoid at a given point. It is usually from the interval [–90°, 90°] and is marked with Greek letter φ. An increase in geodetic latitude marks the direction of North, while its decrease marks the direction South. Geodetic longitude is a parameter which determines the position of the meridian on the Earth's ellipsoid and is defined by the angle from the prime meridian (that is the meridian of the Greenwich observatory near London) plane to the given point on the meridian plane. It is most often from the interval [–180°, 180°] and is marked with Greek letter λ. An increase in geodetic longitudes determines the direction of East, while a decrease determines the direction of West

A geodetic datum should define the relation of geodetic coordinates to the Earth.

Geodetic coordinates φ, λ and height *h* may be transformed to an Earth-centred, Cartesian three dimensional system using the following equations:

$X = (N + h)cos\varphi cos\lambda$

$Y = (N + h)\cos\varphi\, sin\lambda$

$Z = Y = \mathrm{R}\, sin\varphi$

where

$$N = \frac{a}{\sqrt{1-e^2 sin^2}}$$

$$e^2 = \frac{a^2-b^2}{a^2}$$

If we wish to represent a large part of the Earth, a continent or even the whole world, the flattening of the Earth can be neglected. In that case, we speak about a geographic coordinate system instead of a geodetic (Miljenko *et al.*, 2006).

Geographic coordinates are geographic latitude and geographic longitude, with or without height. They are also referred to as spherical coordinates. Geographic latitude is a parameter which determines the position of parallels on the Earth's sphere and is defined by the angle from the equatorial plane to the normal on the sphere at a given point. It is usually from the interval [–90°, 90°] and is marked with Greek letter φ. An increase in geographic latitude marks the direction of North, while its decrease marks the direction south. Geographic longitude is a parameter which determines the position of the meridian on the Earth's sphere and is defined by the angle from the prime meridian plane to the given point on the meridian plane. It is most often from the interval [–180°, 180°] and is marked with Greek letter λ. An increase in geographic longitudes determines the direction of East, while a decrease determines the direction of West

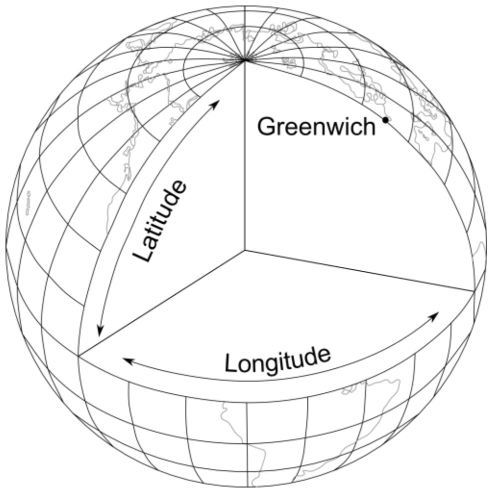


Figure 2.2: Spherical Coordinate System: Geographic Latitude Φ, Geographic Longitude Λ.

Geographic coordinates φ, λ and height h=0 may be transformed to an Earth centred, Cartesian three-dimensional system using the following equations:

$X = Rcos\varphi cos\lambda$

$Y = R\cos\varphi\ sin\lambda$

$Z = \mathrm{R}\ sin\varphi$

Where R is a radius of the spherical Earth.

A spherical coordinate system can be obtained as a special case of an ellipsoidal coordinate system taking into account that flattening equals zero, f = 0, or equivalently stating that the second eccentricity equals zero, e = 0.

Sometimes, in geodetic and cartographic practice, it is necessary to transform Cartesian three_dimensional coordinates to spherical or even ellipsoidal coordinates. Furthermore, sometimes there is a need to make a transformation from one three_dimensional coordinate system to another one (Miljenko et al., 2006).

2.5 Classes of Map Projections

Projections may be classified on the basis of geometry, shape, special properties, projection parameters, and nomenclature. The geometric classification is based on the patterns of the network (the network of parallels of latitude and meridians of longitude).

According to this classification, map projections are usually referred to as cylindrical, conical, and azimuthal, but there are also others (Miljenko et al., 2022).

An azimuthal projection also projects the image of the Earth on a plane. A map produced in cylindrical projection can be folded in a cylinder, while a map produced in conical projection can be folded into a cone. Firstly, let us accept that almost all map projections in use are derived by using mathematics, especially its part known as differential calculus. This process allows for the preservation of specific characteristics and minimizing distortion, such as angular relationships (shape) or area (Anoni *et al.,*

2003).

2.5.1 Cylindrical Projections

Cylindrical projections are those that provide the appearance of a rectangle. The rectangle can be seen as a developed cylindrical surface that can be rolled into a cylinder. Whereas these projections are created mathematically rather than from the cylinder, the final appearance may suggest a cylindrical construction. A cylindrical map projection can have one line or two lines of no scale distortion (Spilhaus, 1991). Classic examples of cylindrical projections include the conformal Mercator and Lambert's original cylindrical equal area.

Cylindrical projections are often used for world maps with the latitude limited to a reasonable range of degrees south and north to avoid the great distortion of the polar areas by this projection method. The normal aspect Mercator projection is used for nautical charts throughout the world, while its transverse aspect is regularly used for topographic maps and is the projection used for the UTM coordinate system described above

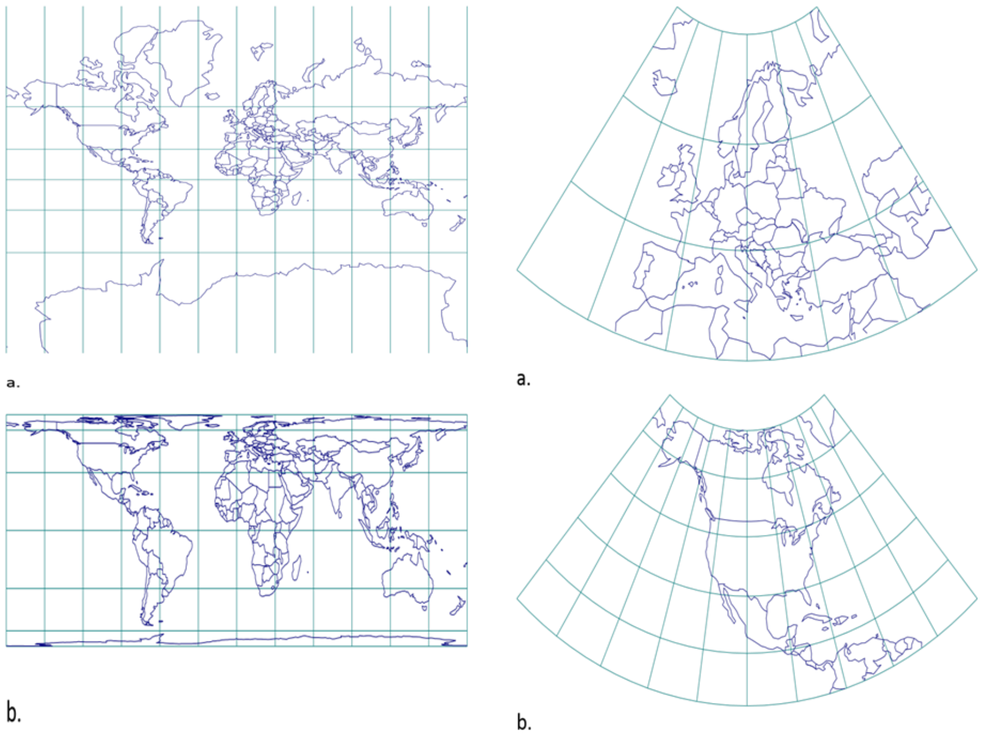


Figure 2.3: The conformal cylindrical Mercator projection (a) and Lambert's cylindrical equal area projection (b). Lambert's conformal conic (a) and the Albers conical equal area projection (b)

2.5.2 Conical Projections

Conical projections give the appearance of a developed cone surface that can be furled into a cone. These projections are usually created mathematically and not from the cone. Classic examples of conical projections are Lambert's conformal conic and the Albers conical equal area projection. Conical projections are inappropriate for maps of the entire Earth and work best in areas with a long axis in the east-west direction (Anoni et al., 2003). This makes them ideal for representations of land masses in the northern hemisphere, such as the United States of America, Europe, or Russia.

2.5.3 Azimuthal Projections

Azimuthal projections are those preserving azimuths (*i.e.*, directions related to north in its normal aspect). A single point or a circle may exist with no scale distortion. Classic examples of azimuthal projections include the stereographic and Lambert’s azimuthal equal area (Anoni *et al.*, 2003).

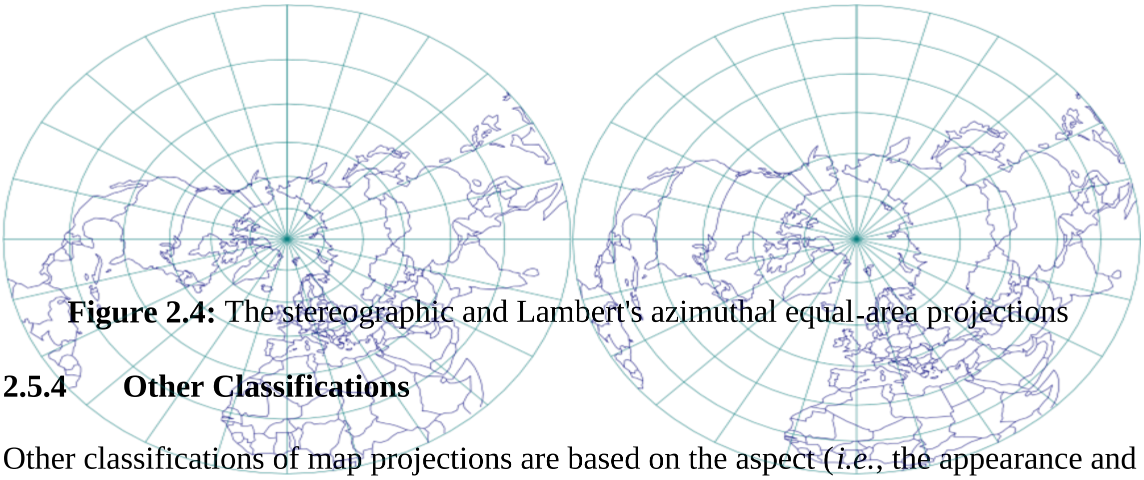


Figure 2.4: The stereographic and Lambert's azimuthal equal-area projections

2.5.4 Other Classifications

Other classifications of map projections are based on the aspect (*i.e.*, the appearance and position of the graticule, poles or the equator in the projection) or oblique. Accordingly, there are polar projections, normal projections, equatorial projections, transverse projections and oblique map projections. These are names of individual sets of map projections and not a systematic categorization because, for example, a projection can be polar and normal at the same time. In theory, each projection almost always used in certain aspects in order to express their characteristics as well as possible (Hager et al.,

1989).

For example, many factors such as temperature, contamination breakout and biodiversity depend on the climate (*i.e.*, the latitude). For projections with a constant distance between parallels, the latitude in the equatorial aspect can be directly converted into vertical distance, facilitating comparison. Certain projections with graticules in normal aspect appearing as simple curves were originally defined by geometric constructions. Considering most transverse and oblique projections have graticules consisting of

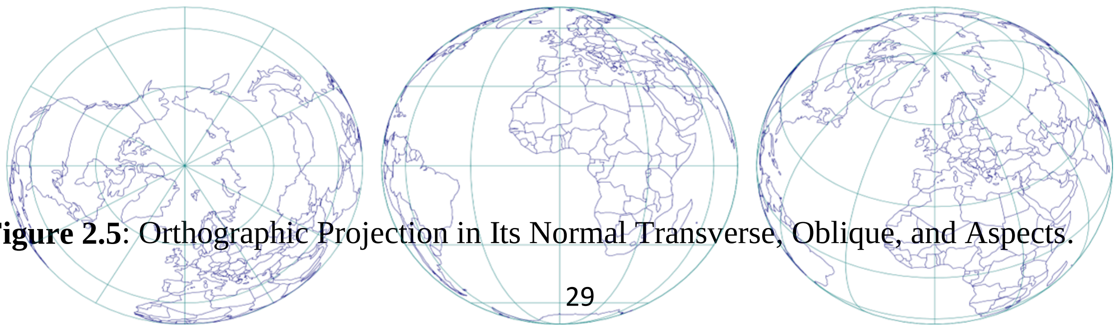


Figure 2.5: Orthographic Projection in Its Normal Transverse, Oblique, and Aspects.

complex curves, such projections were not systematically analysed prior to the computer era. In general, calculating oblique projections for a particular ellipsoid is very complex and is not developed for all projections. Nevertheless, oblique projections have applications.

A map projection is a normal projection or it is in normal aspect if the appearance and position of the graticule, poles and the equator in the projection are the most natural and are usually determined by geometrical conditions. It is often determined by the simplest calculations or the simplest appearance of the graticule. The polar aspect is normal for azimuthal projections, while the equatorial aspect is normal for cylindrical projections

2.6 Digital Mapping

Beginning in the early 1960s and concurrent with research in cartographic communication, cartography was greatly influenced by computer technology. The adaptation to this new technology occurred very quickly, even though early methods of graphic output produced crude depictions. But until recently, the computer has been used primarily to automate the production of maps on paper, therefore it was mainly viewed as a tool to make the creation of maps easier for the cartographer. This view of the computer changed around 1980. Computer mapping software begins to incorporate an interactive, in some case animated form of cartography – a type of map use that is not possible with the printed map. The computer is being used not only as a tool to help make maps on paper but as a medium of communication. Digital Mapping is a computer technology that generates, stores, and process maps in terms of two states: positive (1) and non-positive (0) in order to display them visually on an electronic medium like a monitor,

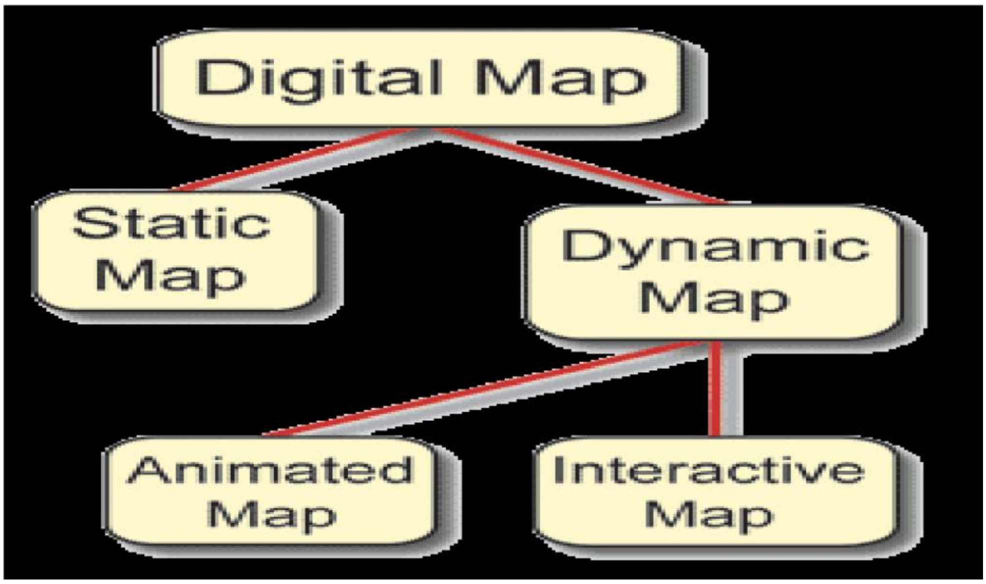


Plate II. Divisions of digital mapping (Freeman 1982)

Digital map processing (or simply map processing), refers to computational procedures aimed at automatic or semi-automatic extraction and/or recognition of geographic features contained in images (usually scanned) of maps. Digital map processing is a relatively young research field that grew out of image processing, document analysis, graphics recognition, and digital cartography. Over the past 40 years, researchers have become increasingly interested in the methodological aspect of computational map processing (mostly in scanned maps) for the purposes of retrieval, extraction, and integration of geographic data (Freeman *et al.*, 1982). This increasing attention results not only from the parallel advances in technologies (e.g., digital image analysis, recognition, and Geographic Information Systems (GIS) but also can certainly be linked to the fact that computational map processing methods enable the preservation of unique (historical) maps and the utilization of the contained geographic information in modern analytical environments (e.g., in a GIS).

Maps can cover large areas over long periods of time for many regions in the world. This makes maps unique documents witnessing places, human activities, and natural features in the past for which no or only limited alternative information sources exist. Processing map images to extract and recognize geographic information results in spatially referenced data (i.e., map data) that can then be accessed, processed, and maintained in a GIS environment (in other words, “unlocking” geographic information from map documents). Incorporating map data into a GIS environment (i.e., map data can be used for spatial analyses and overlaid with other spatial data) creates unprecedented opportunities for multi temporal and multi-contextual spatial analyses, such as analyzing the changes in built-up areas over large regions across long time periods, and investigating how these changes interact with other geographic features, such as vegetation or wetland areas. In addition, digital map processing can expedite the processes of comparing map contents from different map series/editions (e.g., contemporary maps vs historical maps), to update current map series, and to create thematic maps or new map series.

The need for computational solutions with higher degrees of automation for map processing becomes evident if one considers that millions of map documents have already been scanned and stored in digital archives. For example, the U.S. Geological Survey (USGS) continues to scan and release all editions of more than 200,000 historic topographic map pages of the United States that cover the time period from 1884 to 2006. The GIS Center in Academia Sinica, Taiwan, has scanned and archived more than160, 000 historical maps. Such digital archives can only be fully used after the archived maps have been converted to a GIS usable format. However, manually processing these maps not only generates nonreproducible data that can suffer from a high degree of inaccuracy and introduced subjectivity but also does not scale well for handling large numbers of maps. For example, manually digitizing one sounding label on a nautical chart includes two steps: drawing a minimum bounding box to label the sounding location and typing in the sounding value. If these two steps take a total of 6 seconds per sounding label, for a typical nautical chart that has more than 4,000 sounding labels, the digitization process takes more than 6 hours.

In contrast, using digital map processing techniques can dramatically reduce the time (and cost) to fully utilize the geographic information locked in these maps. For example, Knoblock *et al.*, (2011) developed a map processing package, Strabo, which only requires 1 minute of the user's time for operating the software to recognize 1,253 labels from an area in a nautical chart with 83% precision and 80% recall. For this particular area in the nautical chart, the amount of user time for verifying and correcting the recognition results from Strabo is less than 1 hour, which is around 30% of the time that would be needed when performing the entire text recognition task manually. Without such computational solutions for map processing, large portions of the spatial data in maps remain inaccessible unless they are manually converting to spatial datasets.

General techniques for document analysis and graphics recognition cannot be directly applied to map processing because maps often pose particular difficulties for recognition due to various graphical quality issues and the complexity of the map contents. The graphical quality of scanned maps can be affected by scanning or image compression processes. In addition, the stored and archived map materials suffer from aging and bleaching effects, whereas original reproduction materials (e.g., copper plates) have often been destroyed or lost. The final scanned images inherit these graphical properties.

2.7 Dynamic Mapping

Dynamic mapping is a cartographic concept used to depict dynamic spatial phenomena or to present spatial information in a dynamic way. It summarizes various cartographic presentation methods which incorporate the dimension of time into a map. These methods are time-series maps, time-composite maps, environmental change maps, maps with time-related charts, and vector and flow maps, all of which are used for static presentation (static maps), and cartographic film and computer animation, both of which are applied in dynamic presentation (dynamic maps).

Dynamic mapping originally served the purpose of showing spatial processes on maps, but since the 1990s computer animation has expanded this concept to include, for example, the dynamic presentation of spatial data, such as the successive display of map objects. Computer animation, especially interactive animation, has improved dynamic visualization of spatial data for demonstration purposes as well as for exploration tasks. Future developments in the early twenty-first century may be in the area of virtual reality, which will add more vividness and interactivity to dynamic mapping.

Maps are constructed from visual variables which could be static or dynamic. Primary static visual variables include shape, size, orientation and color, while dynamic visual variables include duration, rate of change and order (DiBiase *et al.,* 1992). According to DiBiase *et al.,* (1992), static maps are constructed from static visual variables within two or three spatial dimensions. Time is required to perceive static maps but their forms are essentially temporal. Unlike static maps, dynamic maps are constructed from static and dynamic visual variables within two or three spatial dimensions and the temporal dimension. Time is intrinsic to the form of dynamic data displays.

There are three modes of cartographic expressions in dynamic displays, i.e. animation, sonification and interaction (DiBiase *et al,* 1992). They are applicable in all sphere of activities, such as vehicle navigation display, diseases growth rate etc. In this study, animation and interaction were considered. Animation is the illustration of real time or nearly real time update of climate parameters within the twenty-five local of Niger state. Motion created from a sequence of the animation images were initiated using dynamic mapping technique. When there is an update in the climate parameters, it reflects on the map automatically and therefore animation is involved. Animation is also involved in blinking symbols that may be contained in the map.

Sonification is the representation of data with sound, and voice guidance is used to accompany the map display. However, sonification was not considered in this study since this research only investigates visual output. Interaction is the empowerment of the viewer to modify a data display. For example, the user can select the scale to be displayed by zooming in or out.

CHAPTER THREE

3.0 RESEARCH MATERIALS AND METHODOLOGY

3.1 Research Materials

3.1.1 Hardware

i. DELL Personal Computer with the following properties: 4 GB RAM 465GB Memory, 2.21 GHz Processor and 64bit. this was used to perform all operations and processing

3.1.2 Software

This contains list of necessary software required for data processing, display and analysis and the purpose to which they were put.

i. XLSTAT (Man-Kendall); this was used for statistical data processing and analysis. ii. Python; analysis and presentation of dynamic maps iii. Microsoft word iv. Microsoft excel

3.2 Research Methodology

3.2.1 Data Acquisition

The MERRA-2 datasets were introduced to replace the MERRA-1 dataset due to the advances made in the assimilation system that enable assimilation of modern hyperspectral radiance and microwave observations, along with GPS-Radio Occultation datasets. The spatial resolution remains about the same (0.5°×0.625° (latitude & longitude) or approximately 50 km) with temporal resolution up to hourly. The data downloaded was for the period of ten (10) years (2010-2019) which cut across the entire

twenty-five local government of Niger state and were obtained from https://power.larc.nasa.gov/data.access.viewer/.

3.3 Data Processing

Merra2 data was processed directly from NASA in affiliation with global modelling Assimilation office. It uses the principles of retrospective analysis in refining earth data. Although, the datasets were reprocessed by Sorting and filtering, the telemetry data have passed through series of atmospheric reanalysis and adjustment before extraction. The Merra-2 daily data extracted from NASA/GMAO site which comprises of five climate parameters (Temperature, Surface Pressure, Wind Speed, Precipitation and Relative Humidity) data was converted to monthly data for the whole of the twenty-five local government area of Niger State, Nigeria with the aid of Mann Kandel statistical template.

The data covered the span period of ten years (10), the Statistical tools such as Bar chat, Mann-Kandel, were used to represent data, to determine the pattern and also the trend of the data for twenty-five Local Government Areas. The state LGAs were classified into three geopolitical zones relatively to their tribes. Zone A, which is dominated by the Nupe speaking people, Zone B, dominated by the Gbagyi speaking tribes and the Zone

C, Hausa speaking tribes.

3.4 Generation of Dynamic Map

Dynamic mapping is a cartographic concept used to depict dynamic spatial phenomena or to present spatial information in a dynamic way. It can also be considered as digital pro-active mapping, which is sufficiently well integrated to be presented via a single interface, or manipulated by a single program. The purpose for exploring spatial data via dynamic mapping is to reveal unknowns and is typically accomplished via a high degree of human interaction, animation is frequently an important component of data exploration. Below are the step-by-step approach in generating dynamic maps from

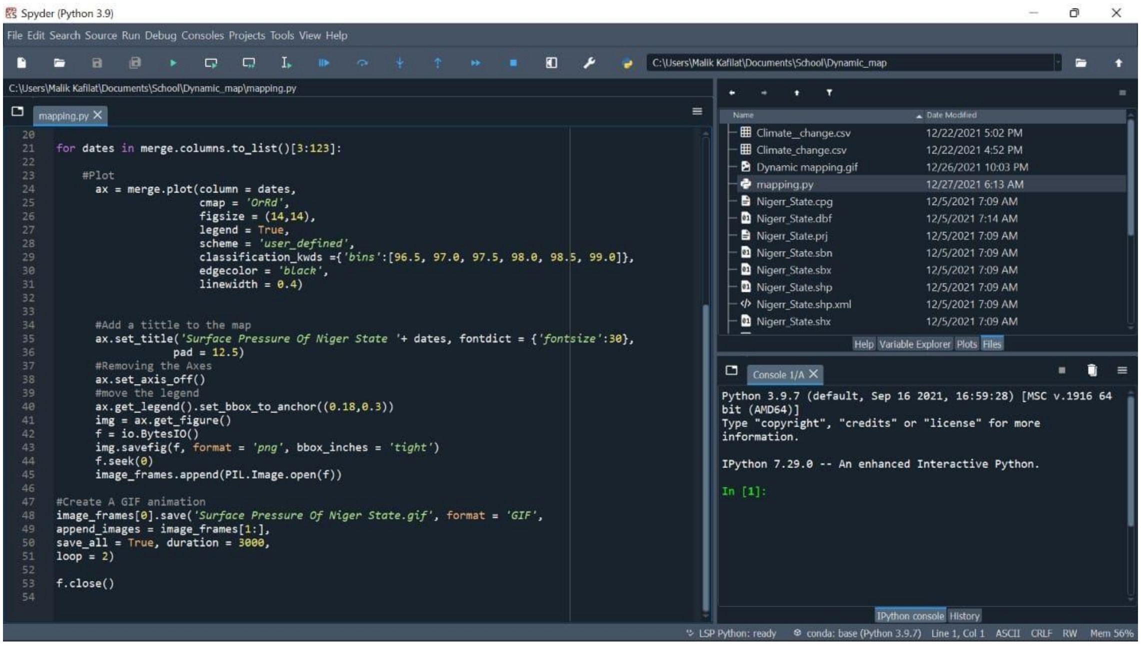
Merra2 datasets, it represents the five climatic parameters. Each climatic parameter, demonstrate the change in magnitude for the twenty-five (25) local government areas. It is program to switch to the next change continuously for the period of ten years for each parameter.

i. Download pandas, geopandas, Python imaging language and IO

ii. Importing (i) in the Gui environment iii. Import the csv file into

the work environment iv. Importing the sharp files

v. Merging the (iii) and (iv) (i.e csv and shapefiles together)



After merging the shapefiles and the csv files

vi. Plot the merge data and add vii. Colour

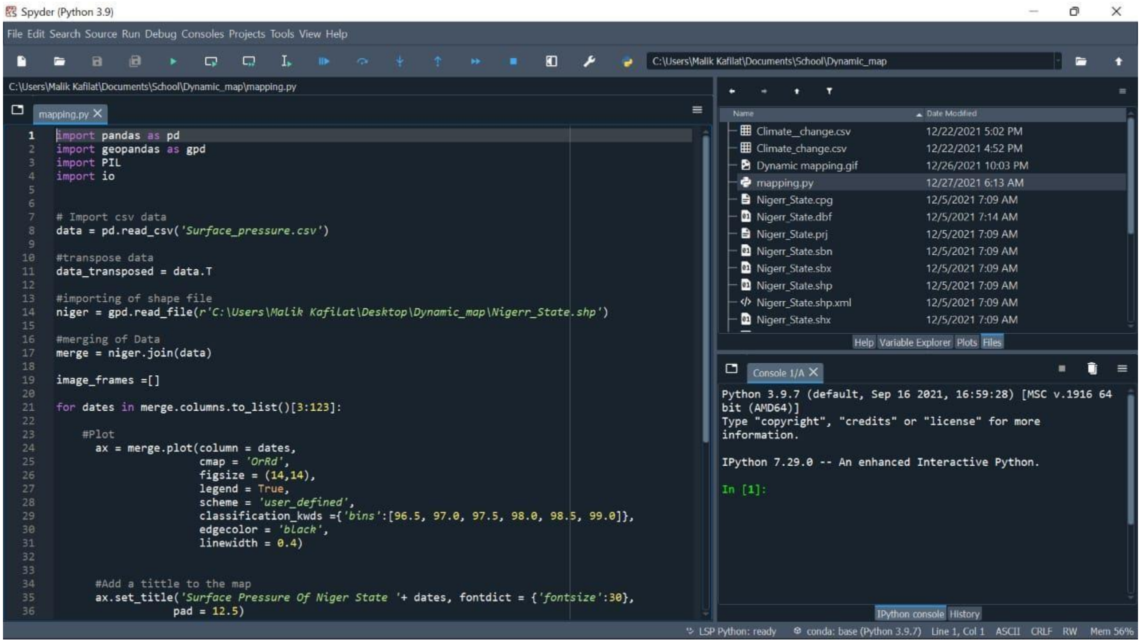
for the cinap viii. The size of the map ix.

Legend of the maps

x. Add the title for each map xi. Removing

the axes from each map xii. Creating a gift

animation for all the maps



3.5 Mann–Kendall's Test

The M–K test is a statistical nonparametric test widely used for trend analysis in climatological and hydrological time series data. The test was suggested by Mann (1945) and has been extensively used with environmental time series. There are two advantages to use this test. First, it is a nonparametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. According to this test, the null hypothesis H0 assumes that there is no trend (the data is independent and randomly ordered). This is tested against the alternative hypothesis H1, which assumes that there is trend. The M–K statistic is computed as follows:

$$S = \sum_{i=1}^{n} \sum_{j=1}^{i-1} sign(xi - xj) \qquad \text{i}$$

where, n is the total length of data, x_i and x_j are two generic sequential data values, and function sign(x_i–x_j) assumes the following values

$$\text{sign}(xi - xj) = \begin{bmatrix} 1 & if\ (xi - xj) > & 0 \\ 0 & if\,(xi - xj) = & 0 \\ -1 & if\,(xi - xj) < & 0 \end{bmatrix} \qquad \text{ii}$$

Under this test, the statistic S is approximately normally distributed with the mean E(S) and the variance Var(S) can be computed as follow:

E(S) = 0

Where, n is the length of time series, and t is the extent of any given tie and Σt denotes the summation of overall tie number of values. The standardized statistics Z for this test can be computed by the following equation:

$$var(S) = \frac{1}{n}[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)] \qquad \text{iii}$$

$$Z = \begin{bmatrix} \frac{s+1}{\sqrt{var(s)}} & if\ S > & 0 \\ 0 & if\ S = & 0 \\ -1 & if\ S < & 0 \end{bmatrix} \qquad \text{iv}$$

In this test, the null hypothesis H_0 is confirmed if a data set of nondependent randomly distributed variables has no trend with equally likely ordering. Any positive value of test statistic Z indicates a rising, while a negative value may conclude a declining trend in series. The computed absolute value of Z is compared with the standard normal cumulative value of Z(1-p/2) at p % significance level obtained from standard table to accept or reject null hypothesis and ascertain the significance of trend (Partal & Kahya, 2006).

This particular test has been calculated using XLSTAT 2017 software. A very high positive value of *S* is an indicator of an increasing trend and a very low negative value indicates a decreasing trend. The presence of a statistically significant trend is evaluated using Z value.

3.6 Sen's Slope Estimator Test

The magnitude of a trend in a time series can be determined using a nonparametric method known as Sen's estimator (Sen, 1968). To estimate the true slope of an existing trend such as amount of change per year, Sen's nonparametric method is used and the test has been performed using XLSTAT 2017 software. A positive value of Sen's slope indicates an upward or increasing trend and a negative value gives a downward or decreasing trend in the time series.

3.7 Nigeria Meteorology Agency (NIMET) Data

Due to scarcity of climate stations in the study area, Niger State is housing only two climate stations (NIMET) which are located in Borgu LGA and Minna the state capital of Niger State. The NIMET datasets are the primary data used for the validation of the data generated from NASA/GMO (MERRA-2 datasets). NIMET datasets were

obtained only for Minna station for a period of ten (10) years (2010 to 2019). Climatic data (NIMET) were carefully processed for missing values and quality checked before using them for any analysis.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

Below is table 4.1. Depicting the twenty-five LGA of Niger State and how they are divided into zones. Figure 4.1 to 4.1.8 show the bar chat representing five climatic variables (data) of the LGAs classified under zone A, zone B and zone C.

Table 4.1: Twenty-Five (25) Local Government Areas Relative to Their Geopolitical Zones in the State Including the State Capital

S/N	ZONE A	ZONE B	ZONE C
1	Bida L.G. A	Munya L.G. A	Rijau L.G. A
2	Agaie L.G. A	Paiko L.G. A	Agwara L. G. A
3	Edati L.G. A	Rafi L.G. A	Borgu L.G. A
4	Katcha L.G. A	Shiroro L.G. A	Magama L.G. A
5	Lapai L.G. A	Suleja L.G. A	Mashegu L.G. A
6	Lavun L.G. A	Bosso L.G. A	Kontongora L.G. A
7	Gbako L.G. A	Gurara L.G. A	Mariga L.G. A
8	Mokwo L.G. A	Tafa L.G. A	Wushishi L.G. A
		Chanchaga L. G. A	

Source: Niger State Government, 2006

The Merra2 data extracted for zone (A) seems to be consistent such that the highest and lowest values recorded maintain the same years of occurrence, most of it appears in the same year for the five (5) climate parameters examined across the eight local government areas which make up the zone

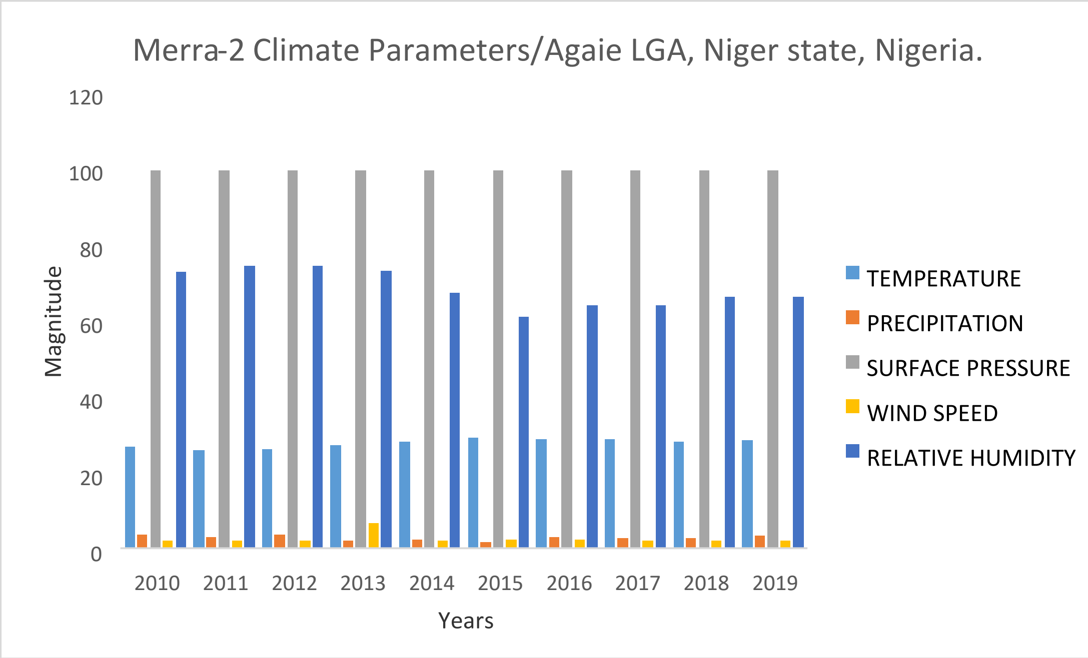


Figure 4.1.1: Magnitude of Five (5) Climate Parameters in Zone A (Agaie L.G.A)

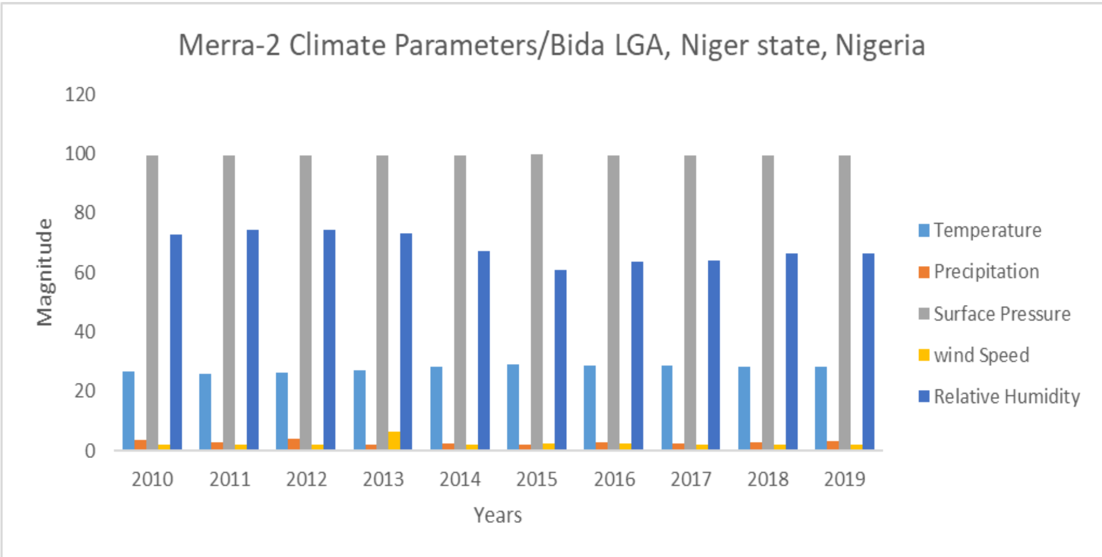


Figure 4.1.2: Magnitude of five (5) climate parameters in zone A (Bida L.G.A).

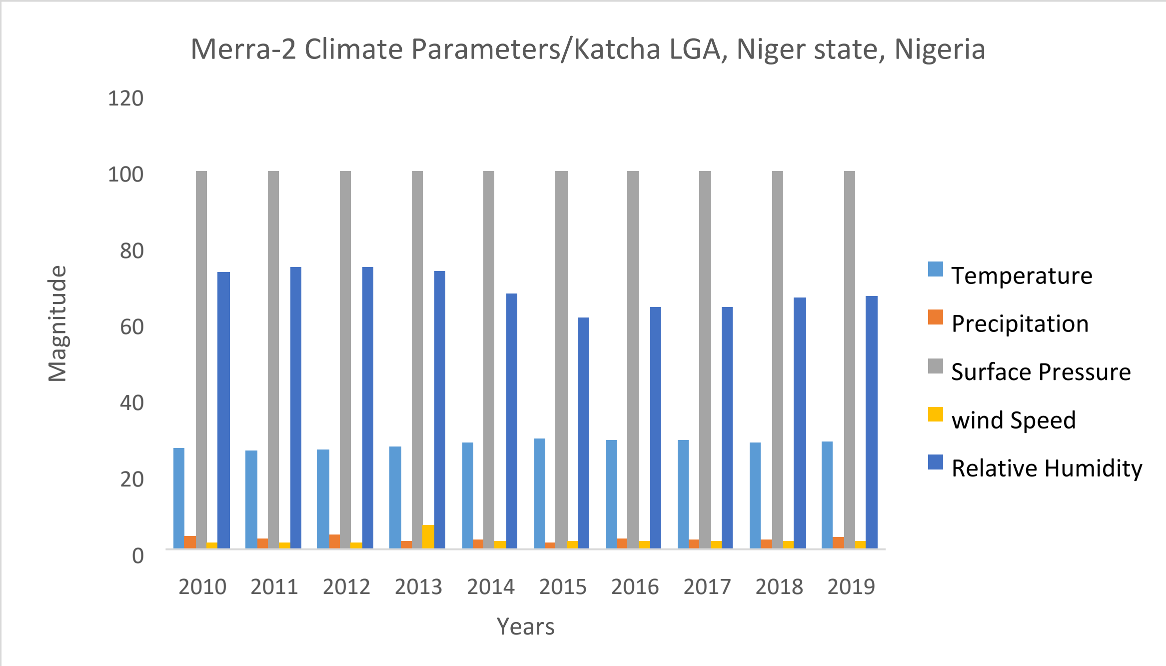


Figure 4.1.3: Magnitude of five (5) climate parameters in zone A (Katcha L.G.A**)**

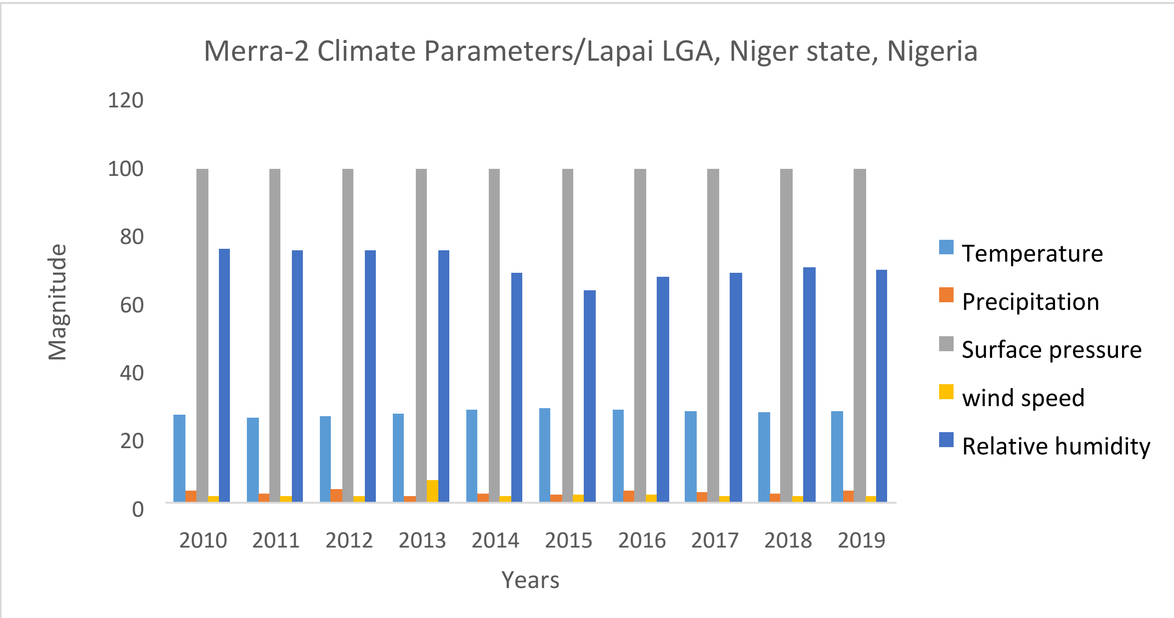


Figure 4.1.4: Magnitude of five (5) climate parameters in zone A (Lapai L.G.A)

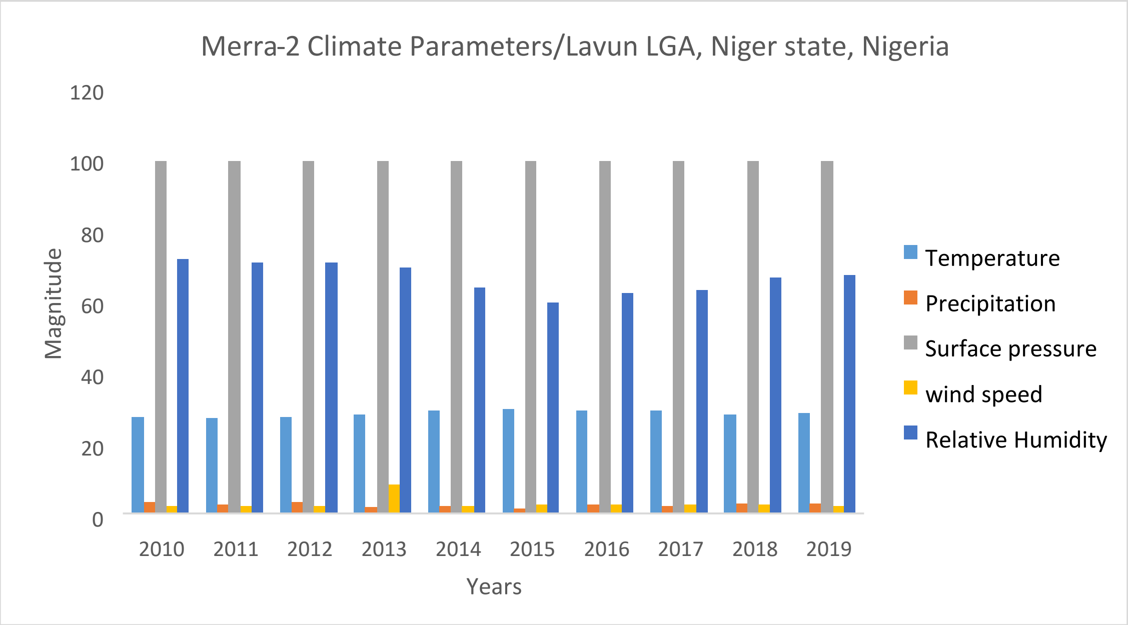


Figure 4.1.5: Magnitude of five (5) climate parameters in zone A (Lavun L.G.A)

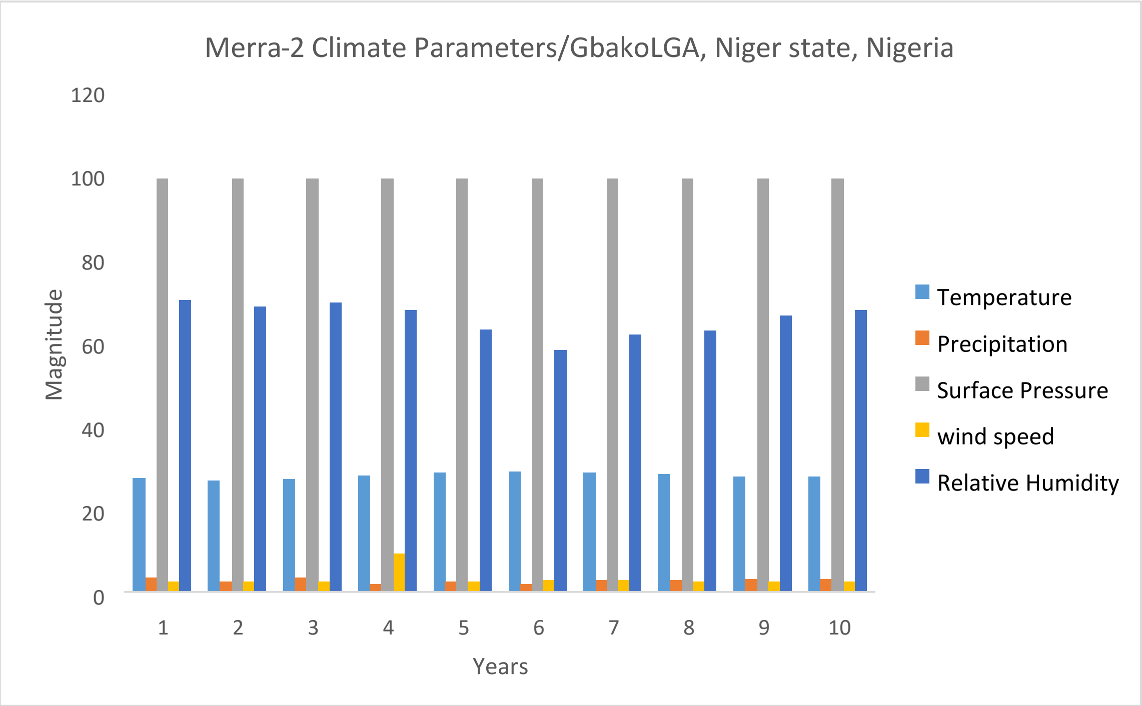


Figure 4.1.6: Magnitude of five (5) climate parameters in zone A (Gbako L.G.A**)**

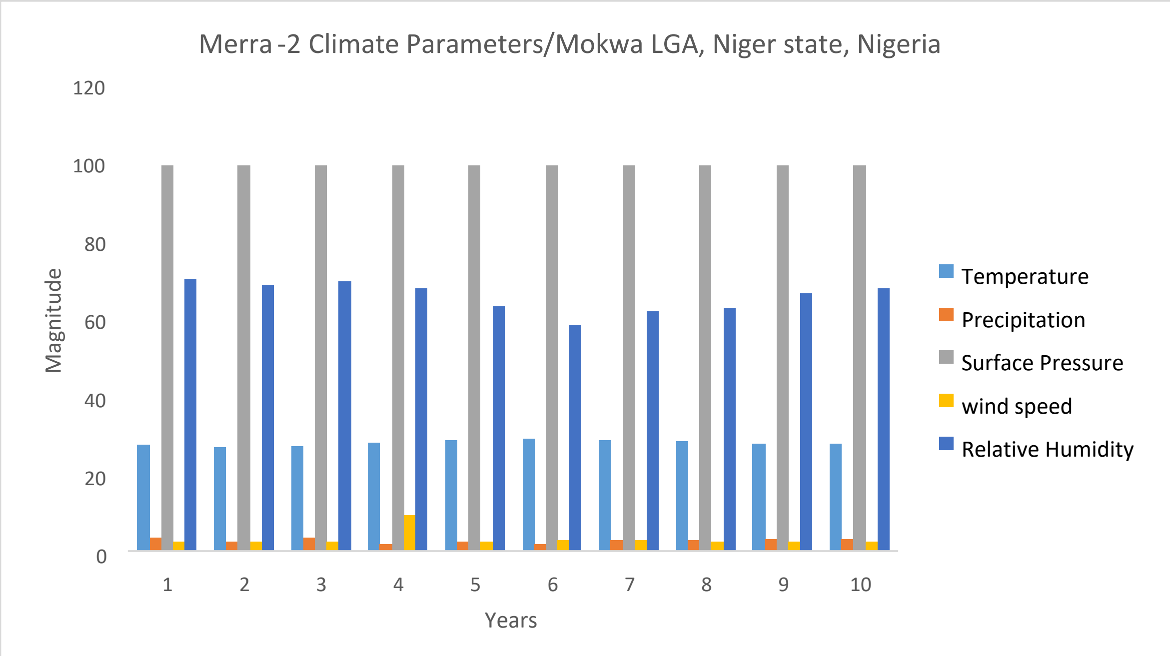


Figure 4.1.7 Magnitude of five (5) climate parameters in zone A (Mokwa L.G.A)

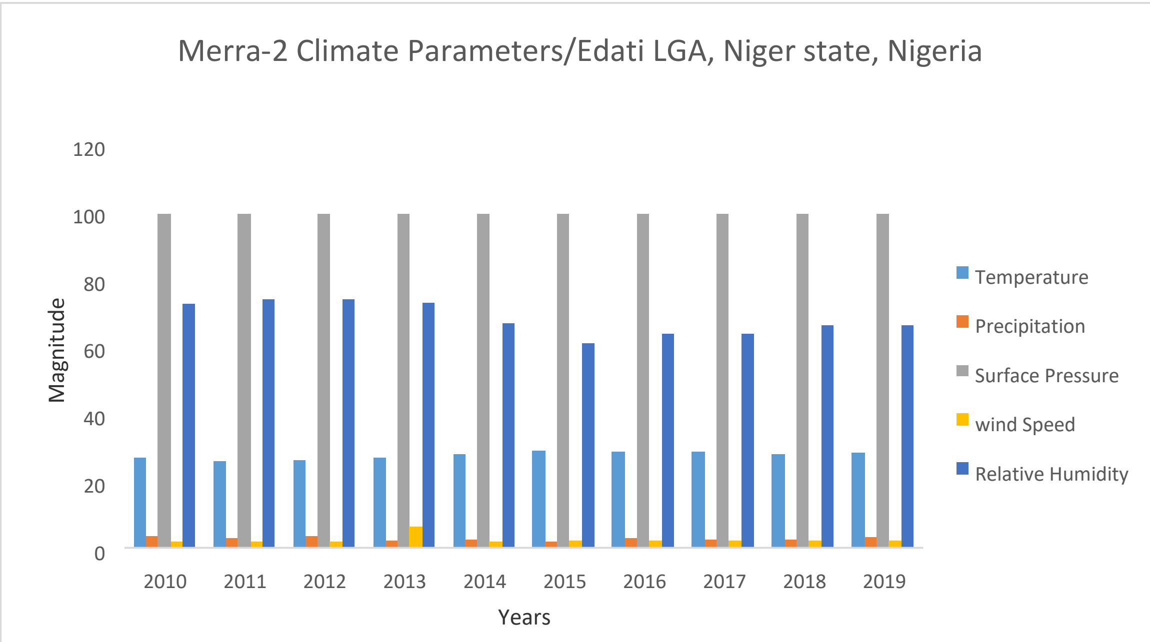


Figure 4.1.8: Magnitude of five (5) climate parameters in zone A (Edati L.G.A)

Temperature which is widely described as the hotness or coldness of the atmosphere. According to NIMET, (2010), Niger state experiences hot season which lasted for two 2 and a half months, February to April with an average high temperature above 92^0F and the hottest month being April while the cool season last for four months, from June to September with an average daily high temperature below 85^0F.

The coldest month in Niger state is December with an average low temperature of 61^0F and high temperature of 89^0F. From the Merra2 dataset, temperature is measured in Celsius (^{0}C), the recorded values of temperature for all the L.G. As in this zone is an affirmative of the average temperature for the state capital which is 29^{0c} where Lapai

L.G.A is less by 2^{0c}. The reason may be many, one of which could be the position of Lapai L.G.A being down east of the Zone A. The highest and the lowest values of temperature recorded was in Lavun, Edati and Lapai LGAs in the year 2015 and 2012 respectively. This could be as a result of climate change and the geolocation of these areas under consideration.

The measurement of how much water falls as rain at a particular time defines rainfall of a place. The amount of rainfall differs in different areas (L.G.A) as a function of time. The common factor that could influence the rate of precipitation is the amount of moistures moving in the air and temperature at such point. From the Merra2 data set, Precipitation happens to be a reverse function of the temperature in this case, it also reflects on the years it was recorded which happen to be the opposite of temperature. The highest and lowest value was recorded in the year 2012 and 2015. Gbako L.G.A recorded the highest value of rainfall of approximately 4.13mm. While Mokwa LGA recorded the lowest precipitation of 1.55mm

The Atmospheric Pressure is the pressure that air exerts on the surface of the earth. Air has mass, and the effect of gravity on the mass causes air pressure. Change in air pressure over different areas on the earth surface is largely responsible for change in weather (Marjorie 2020). In region of low pressure, air generally moves upward and cools, leading to condensation of water vapor, clouds and precipitation. In region of high pressure, air generally moves downward and warms, leading to drying and clear skies.

The surface pressure is more consistent as it appears to maintain the same sequence for the span of ten (10) years. Its highest and lowest values were recorded in Katcha and Lapai respectively. Lapai in particular is fast developing owing to the fact that the prestigious IBB University is located and it is also a terminus for travelers from north- central through Niger state to the southern part of Nigeria. Wind velocity is a fundamental atmospheric rate, it affects weather forecasting, aircraft and marine operation, construction project etc. the direction and the speed of wind are controlled by the combination of some factors such as pressure gradient, frictional force, Coriolis forces or rotational forces, and centripetal acceleration. The speed of the wind in zone A seems to be consistent in term of year in which the highest and lowest values was recorded. Agaie L.G.A recorded the lowest of 2.2 m/s amidst other L.G.A. The highest value was recorded in Mokwa L.G.A which is approximately 9.3m/s.

The amount of water the air can hold at a particular temperature within a given area at a particular time will determine the humid characteristic of the particular area. Relative humidity is said to be saturated if it exceeds what it can hold. However, Relative humidity (RH) is a function of temperature and the moisture content present in the atmosphere at that particular area at that particular time. From the Merra2 dataset, The RH seems to be consistent in the years where the highest and the lowest values were recorded, which is 2010 and 2015 respectively. The highest value recorded was at Lapai L.G.A which is 74.65% while Mokwa L.G.A recorded the lowest value of 58.04%. Figure 4.2 - 4.2.8 summarizes the climatic parameters of zone B. from the dataset, it shows that the high and low recorded data is not consistent relatively to the years of occurrences.

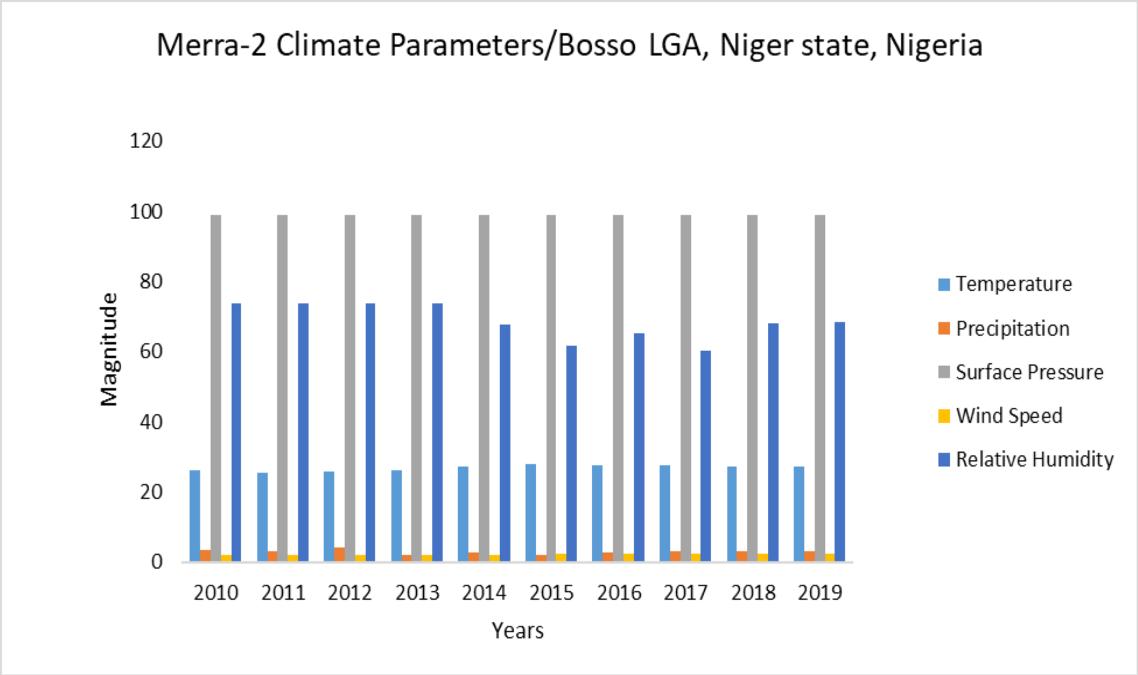


Figure 4.2 Magnitude of five (5) climate parameters in zone B (Bosso L.G.A)

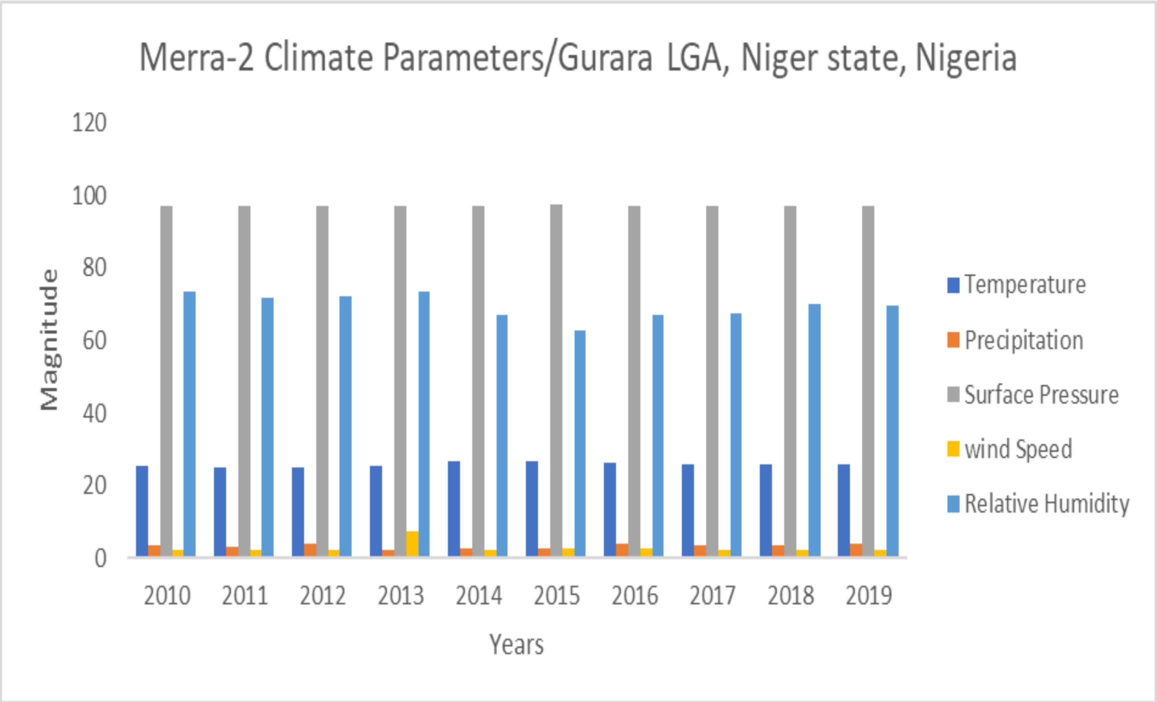


Figure 4.2.1: Magnitude of five (5) climate parameters in zone B (Gurara L.G.A)

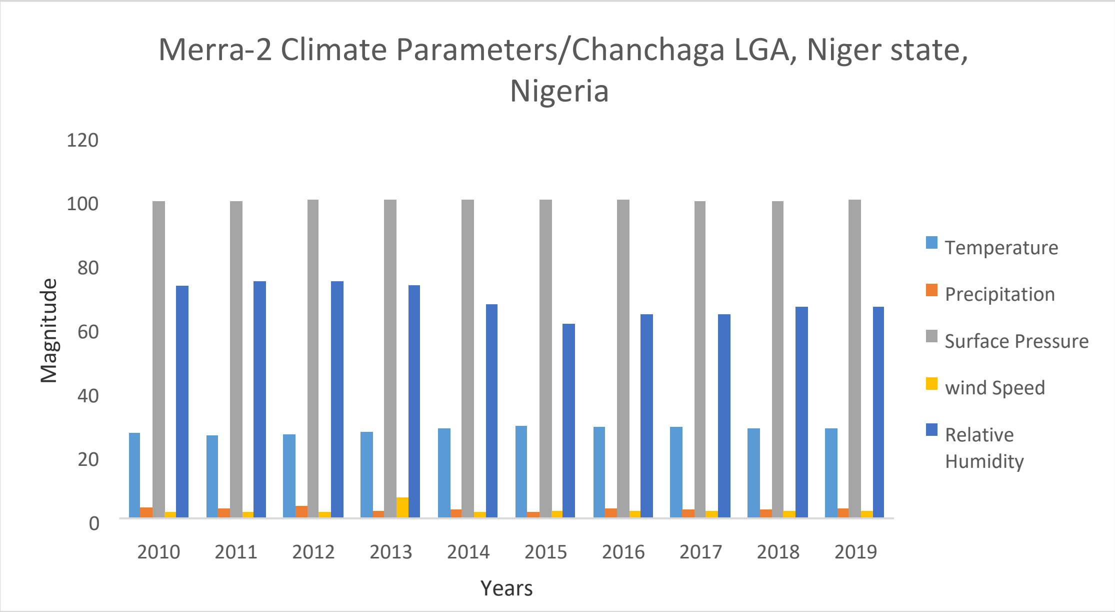


Figure 4.2.2 Magnitude of five (5) climate parameters in zone B (Chanchaga L.G.A)

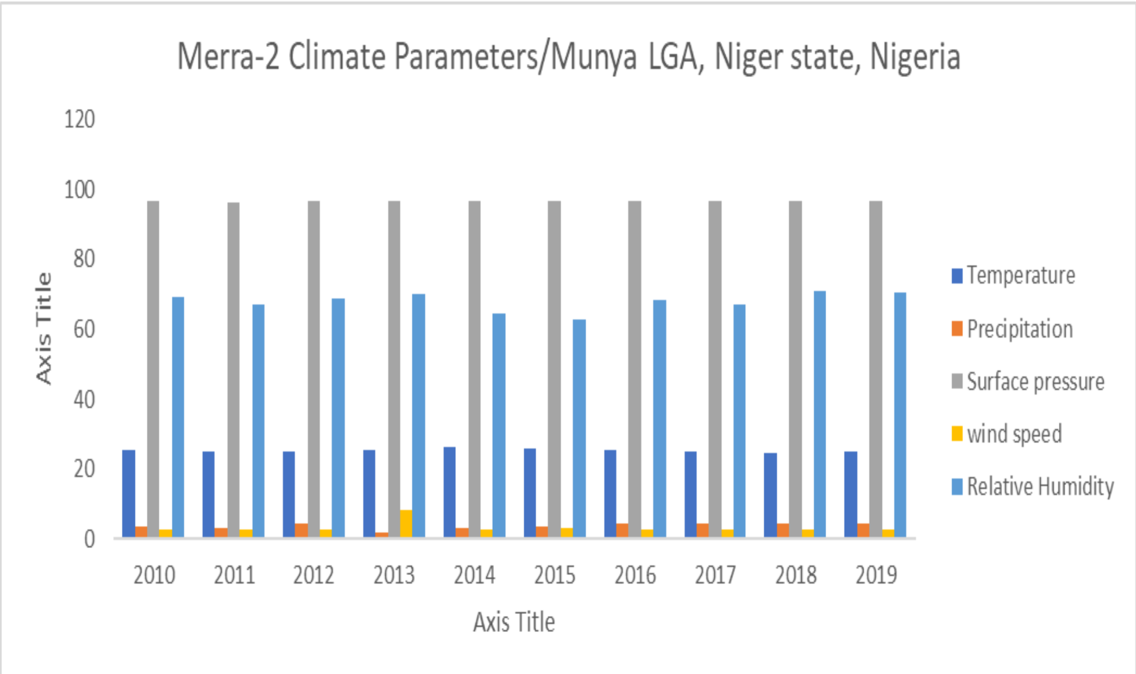


Figure 4.2.3: Magnitude of five (5) climate parameters in zone B (Munya L.G.A)

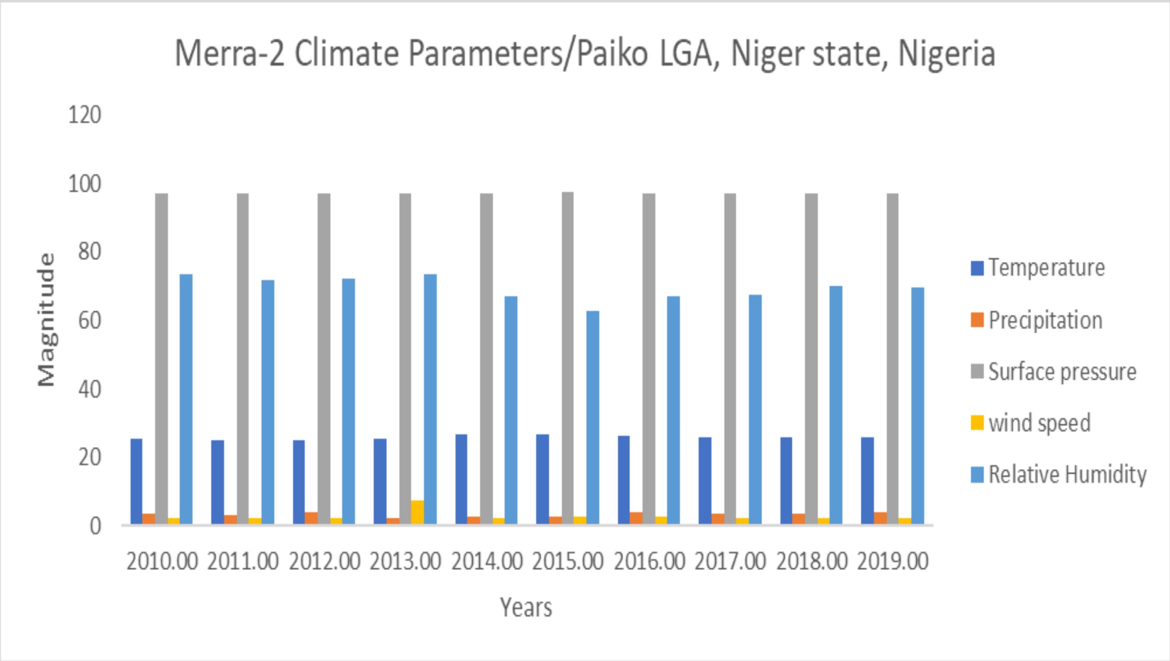


Figure 4.2.4: Magnitude of five (5) climate parameters in zone B (Paiko L.G.A)

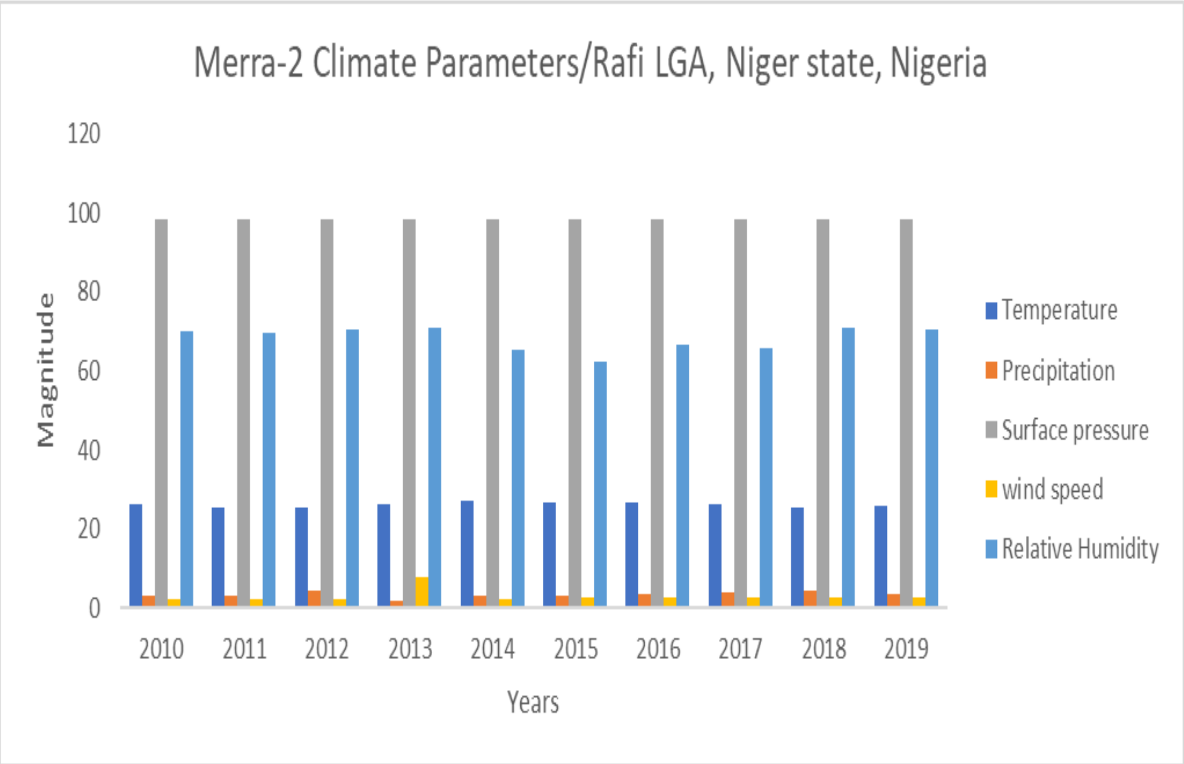


Figure 4.2.5: Magnitude of five (5) climate parameters in zone B (Rafi L.G.A)

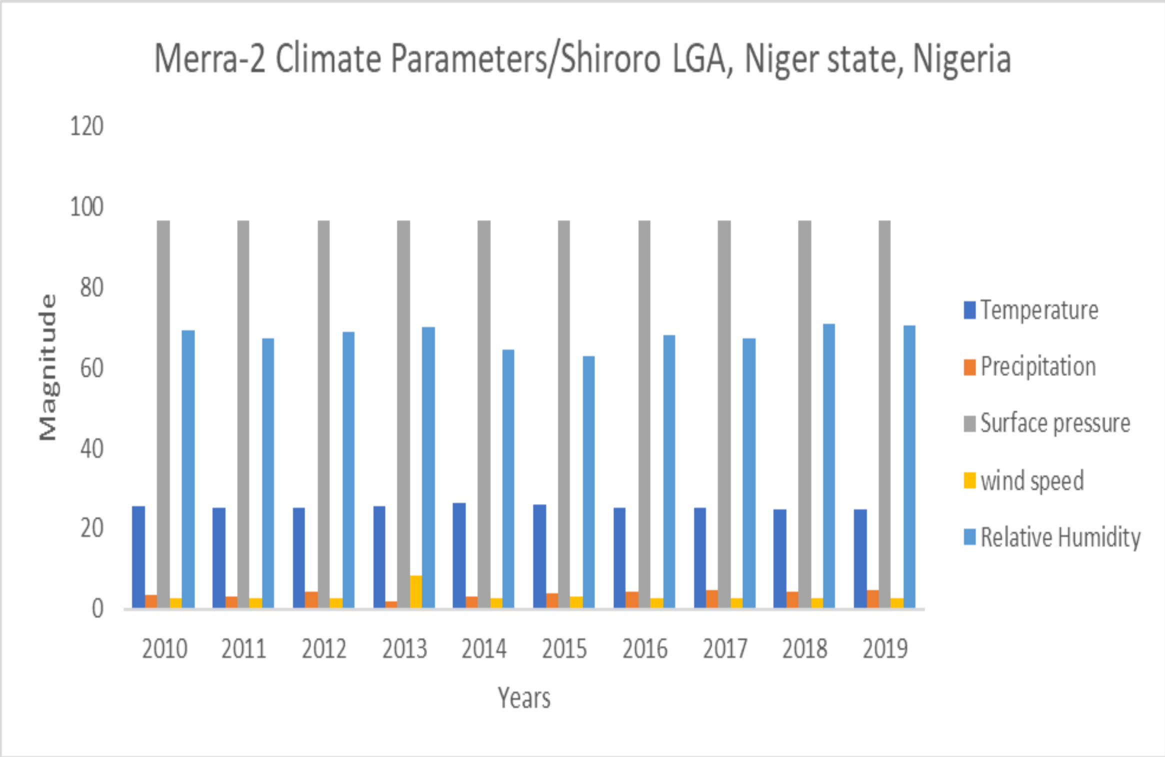


Figure 4.2.6: Magnitude of five (5) climate parameters in zone B (Shiroro L.G.A)

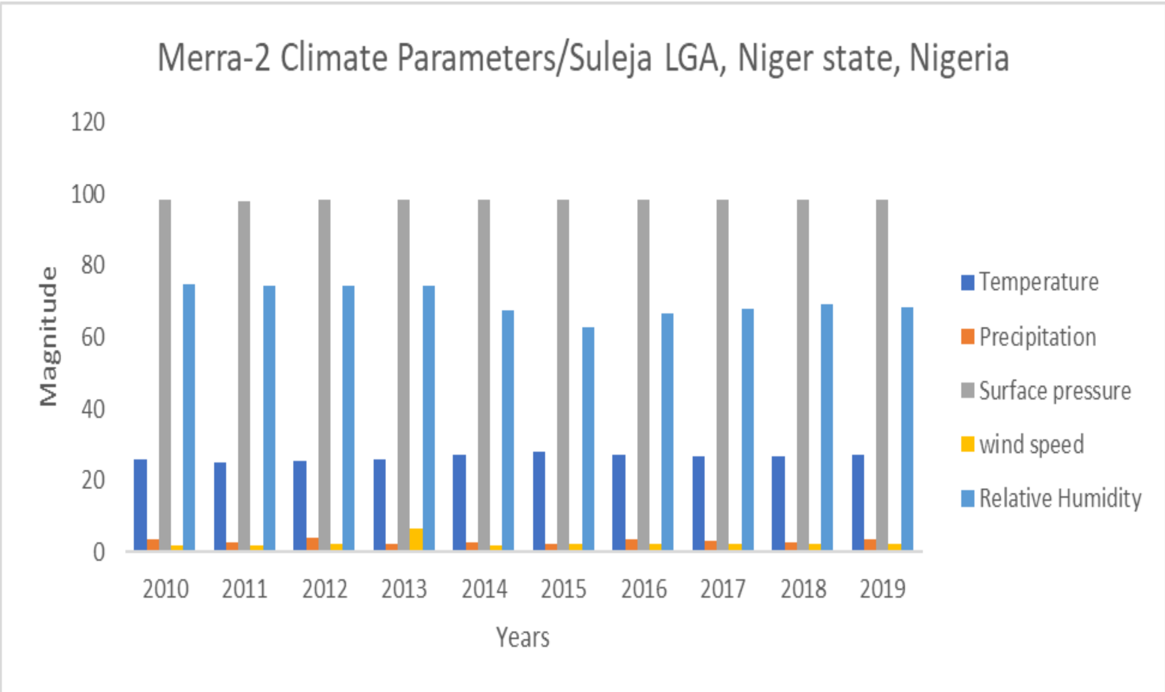


Figure 4.2.7: Magnitude of five (5) climate parameters in zone B (Suleja L.G.A)

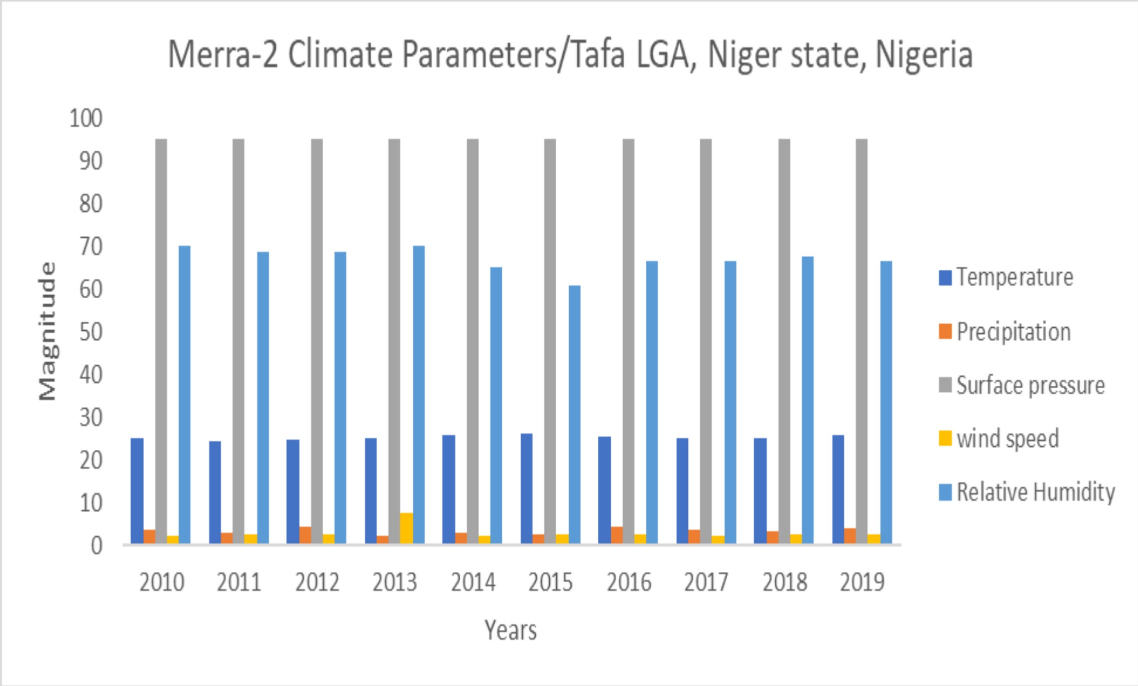


Figure 4.2.8: Magnitude of five (5) climate parameters in zone B (Tafa L.G.A)

The temperature is a bit consistent in some L.G.As. Shiroro and Munya L.G.As recorded the highest value of 28.05^{0C} and Tafa having recorded the lowest value of 24.4^{0C}. Precipitation recorded was peculiar in term of range across the zone. It has shown that there is direct relationship with temperature, Munya and Shiroro LGAs recorded the highest rainfall of 4.697mm while Bosso LGA recorded the lowest of 2.1mm.the range of surface pressure across the zone seems high.

The highest value was recorded at Chanchaga LGA of 99.08 while the lowest was at Tafa LGA with a recorded value of 94.99. Shiroro and Munya LGAs also recorded the highest wind velocity. Conventional rainfall seems to be most experienced. Couple with the highest temperature and wind speed, it gives the reason for the highest rainfall experienced at the Munya and Shiroro LGAs. The lowest wind velocity was recorded in Suleja LGA of 2.0797. The highest value of relative Humidity was recorded in Chanchaga LGA of 75.01 while the lowest was recorded at Bosso LGA of 60.40

Figure 4.3- 4.3.7 Summarized the magnitude of climatic parameters for zone C. It

Indicated that this zone has higher temperature when compare with zone B, the years of occurrence of high and low recorded values are inconsistent. Although, some parameters seem to be consistent such as surface pressure PS, wind speed (WS) and relative humidity (RH). The velocity of the wind in this zone tends to be high when compared to the other zones, this could influence the rate of rainfall in this zone.

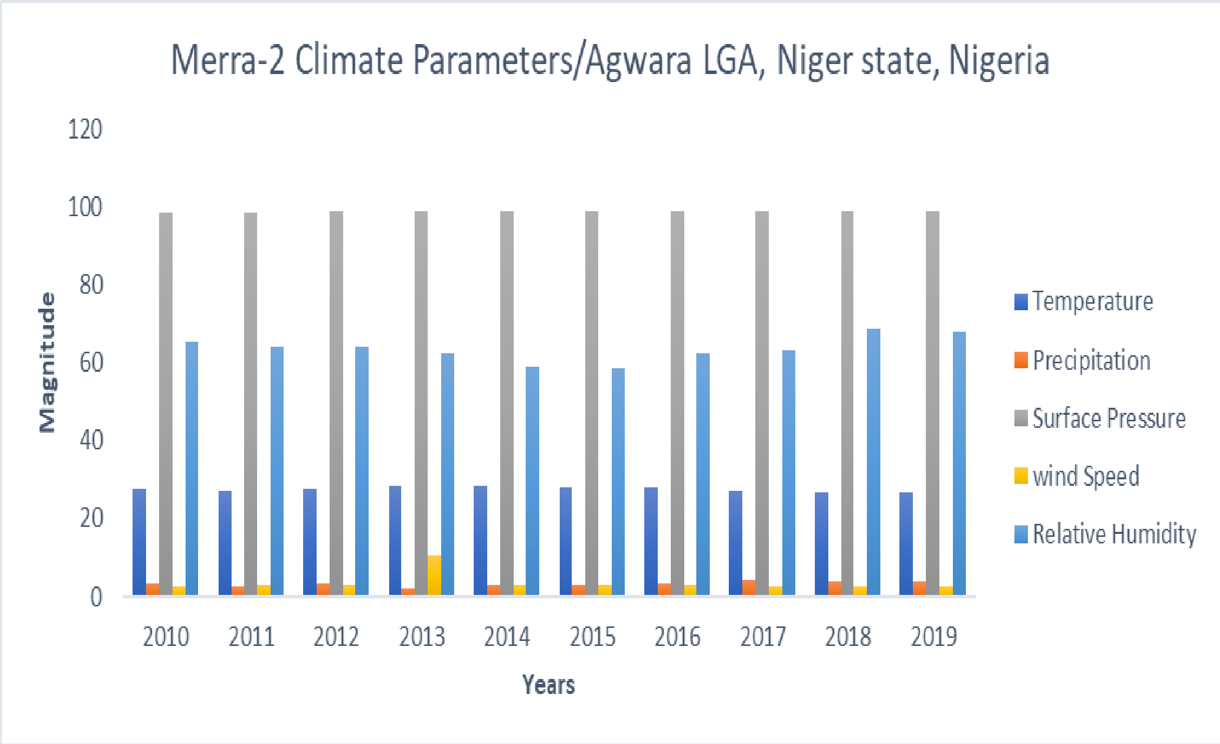


Figure 4.3: Magnitude of five (5) climate parameters in zone C (Agwara L.G.A)

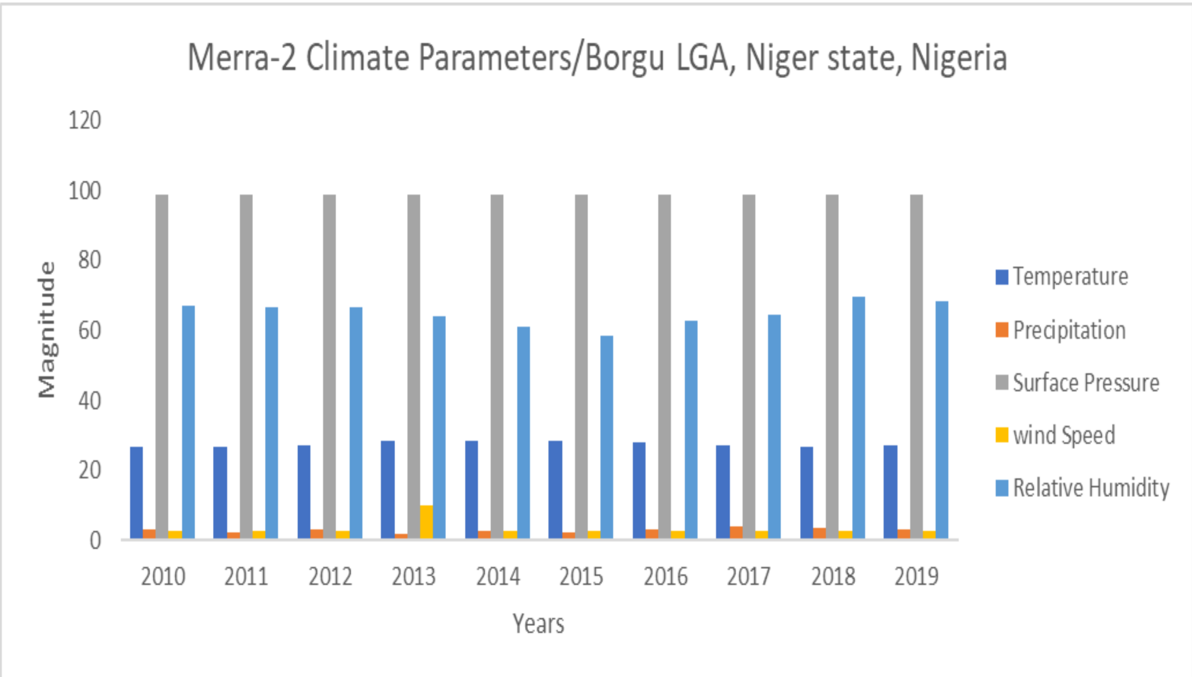


Figure 4.3.1: Magnitude of five (5) climate parameters in zone C (Borgu L.G.A)

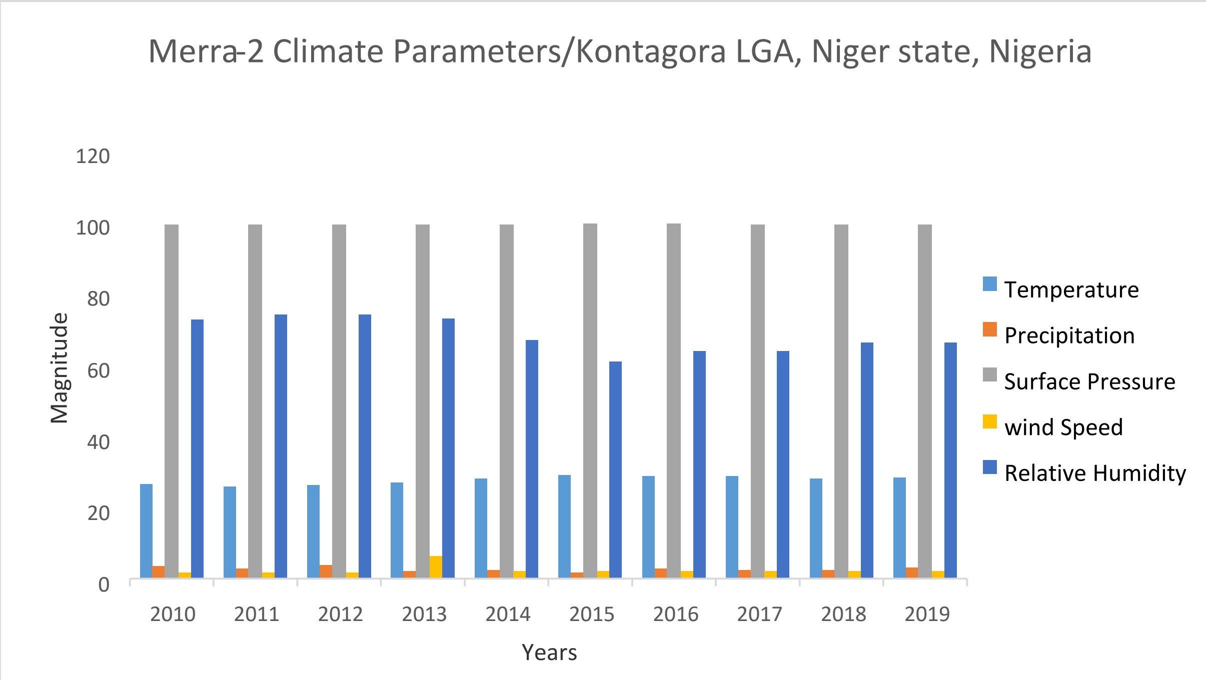


Figure 4.3.2 Magnitude of five (5) climate parameters in zone C (Kontagora L.G.A)

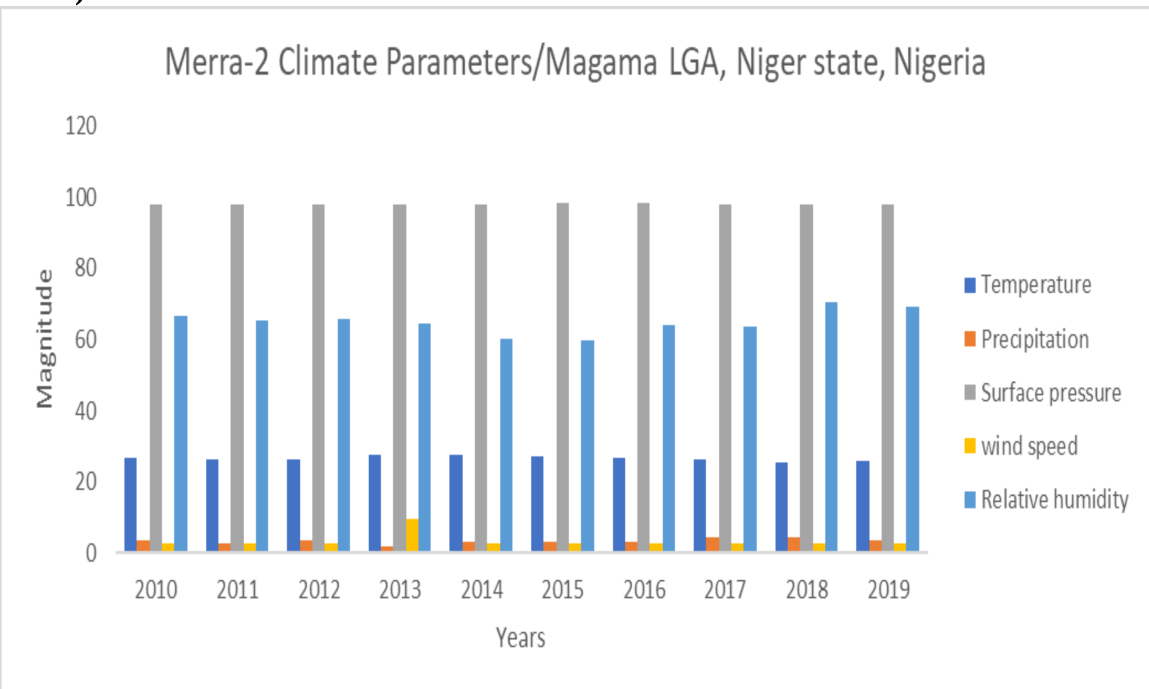


Figure 4.3.3: Magnitude of five (5) climate parameters in zone C (Magama L.G.A)

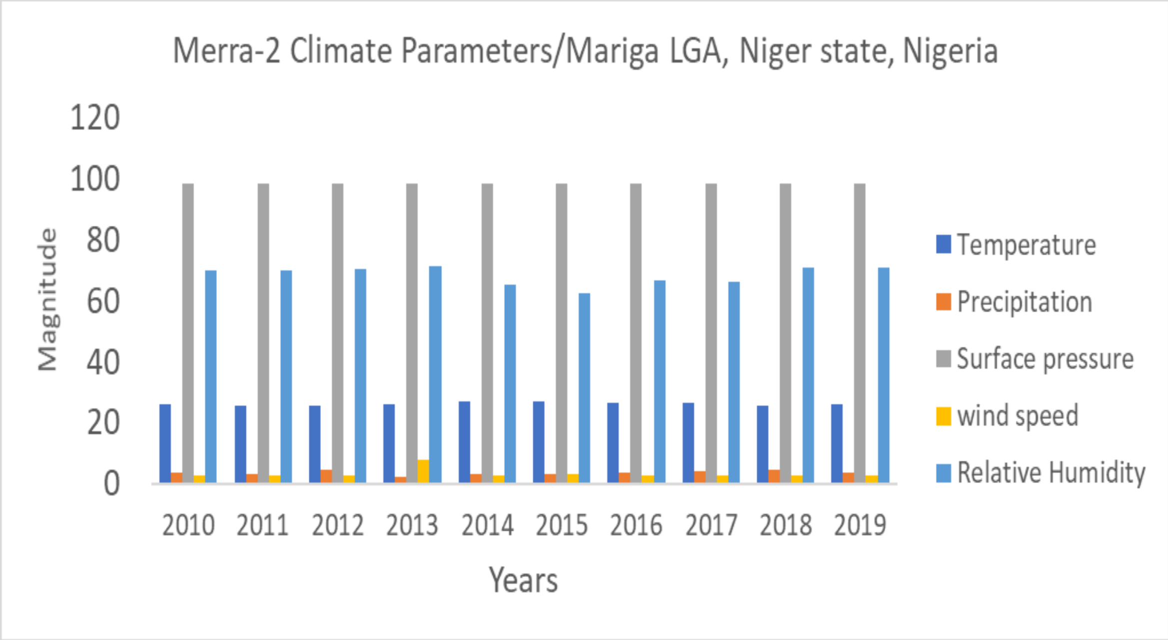


Figure 4.3.4: Magnitude of five (5) climate parameters in zone C (Mariga L.G.A)

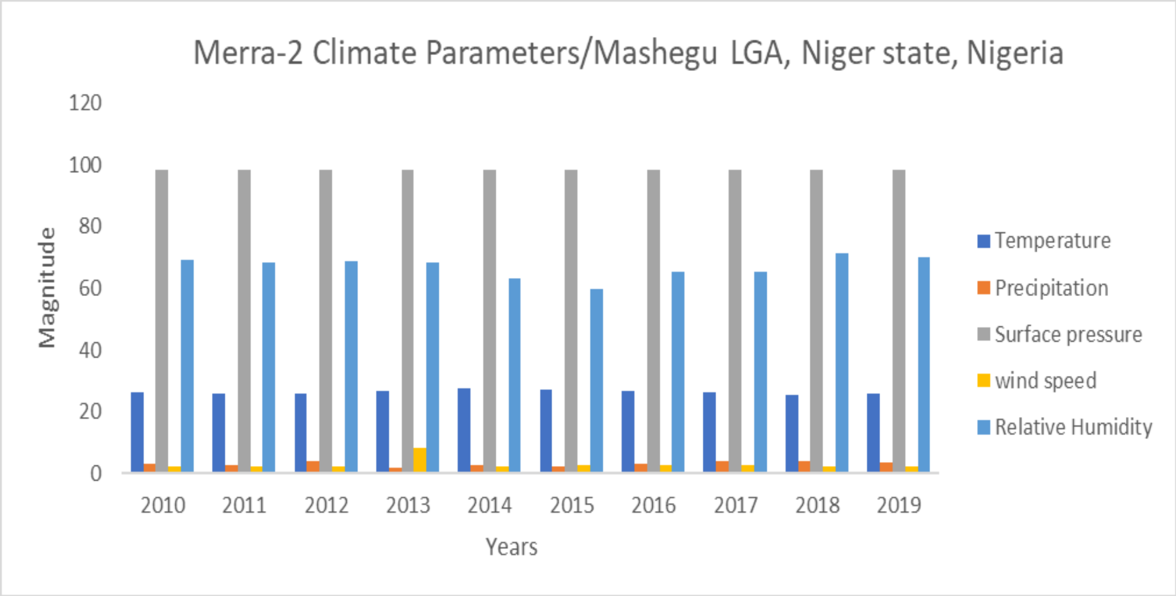


Figure 4.3.5: Magnitude of five (5) climate parameters in zone C (Mashegu L.G.A**)**

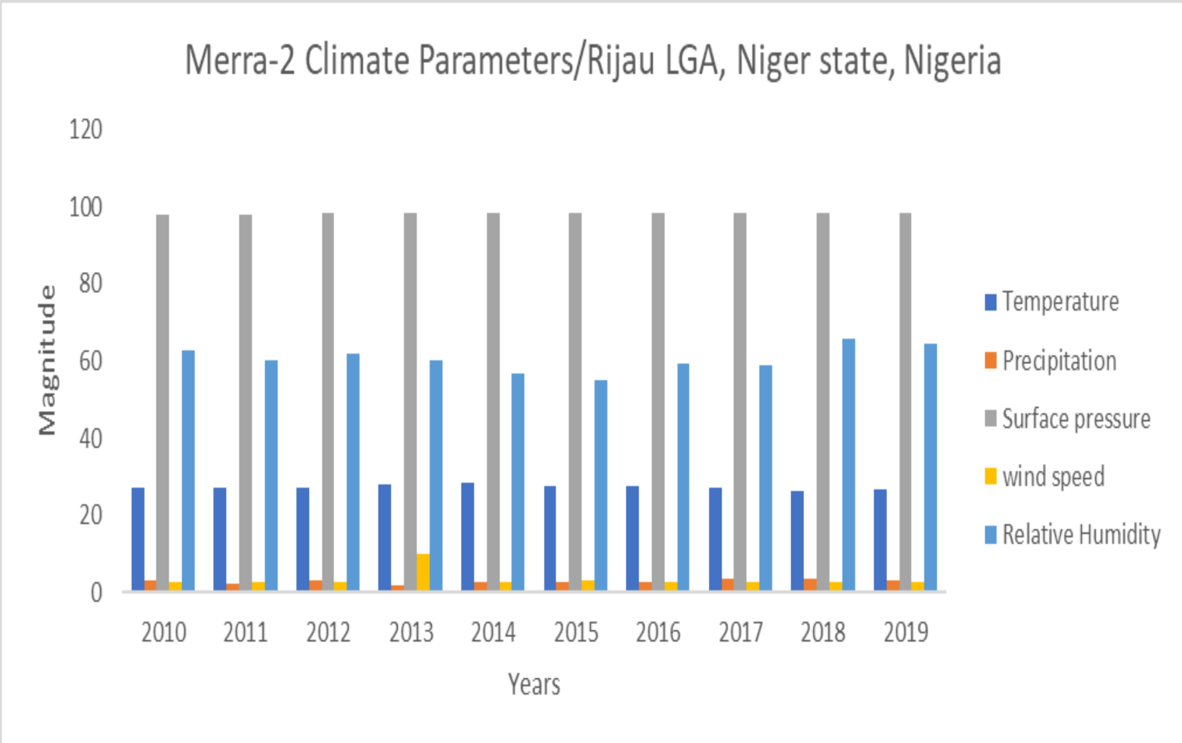


Figure 4.3.6: Magnitude of five (5) climate parameters in zone C (Rijau L.G.A)

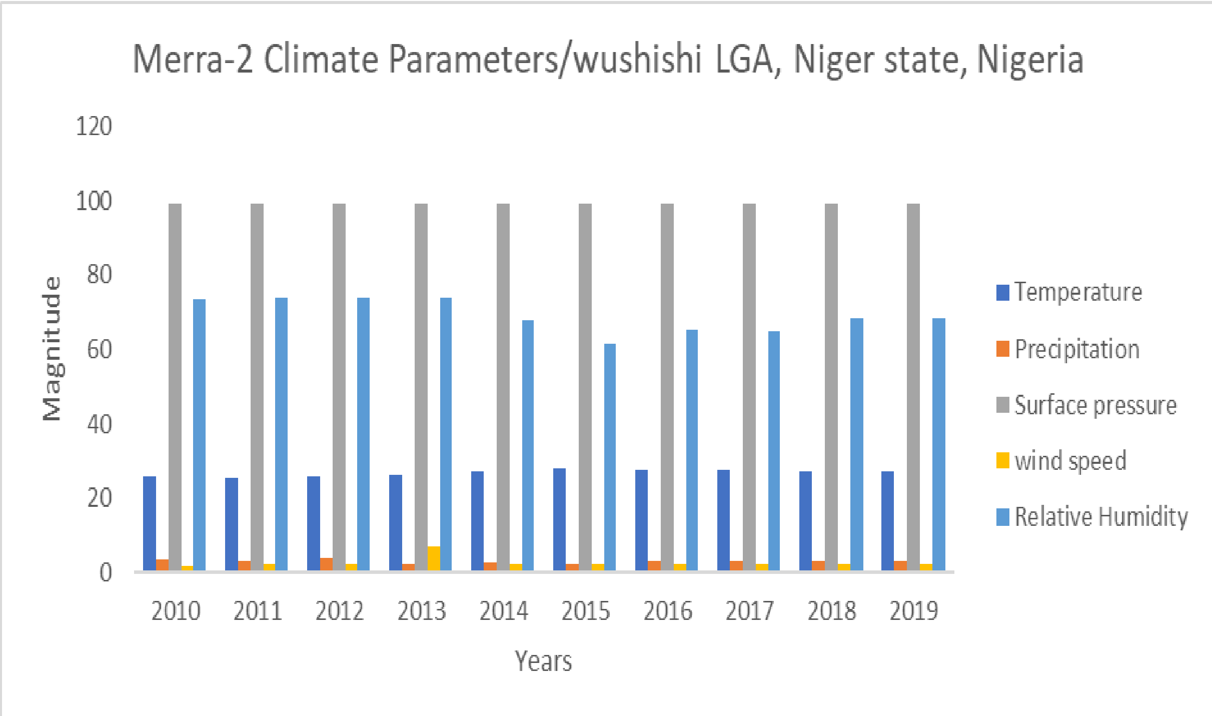


Figure 4.3.7: Magnitude of five (5) climate parameters in zone C (Wushishi L.G.A)

It is observed that Agwara LGA recorded the highest value of 28.65^{0C} for temperature while Kontogora LGA recorded the lowest values of 25.03^{0C,} the precipitation experienced is also conventional, Agwara LGA also recorded the highest value of rainfall while Kontogora LGA also recorded the lowest value of 1.64mm in this zone.

Agwara LGA recorded the highest value of 10.45m/s of wind velocity while Wushishi LGA recorded the lowest value of 2.1m/s. The surface pressure was almost uniform all through the zone with a little discrepancy, Wushishi LGA has the highest value recorded of 99.080 while Kontogora LGA has the lowest value of 97.28 recorded. The relative humidity value recorded was highest in Wushishi LGA while Rijau LGA recorded the lowest in the zone from the period of 10years (2009-2020)

4.2 Correlation between the Three Zones Relatively to Their Climatic Parameters.

The table 4.2 below shows clearly the geopolitical zones with the highest and lowest climatic parameter in review, this will go a long way to predict their agricultural advantages and weakness, the type of industries to be situated etc. Apart from the soil structure, which could also act as main determinant, other favorable conditions such as climatic parameters could also influence certain crop productivity. From fig 4.8.5., it indicated that, averagely considering every L.G.A, Zone (A) has the highest temperature of 28.9% and lowest of 26.1%. Followed by Zone C, having it highest temperature of 27.9% and the lowest at 25.9%. Zone B, recorded average highest temperature of 27.1% and lowest at 25%.

For rainfall, zone B, has the highest value recorded of 4.4% and its lowest value was 2.5%. Followed by Zone C, having it highest value to be 4.2% and the lowest value to be 1.4% while Zone A, having it average highest value to be 3.7% and its lowest value to be 1.9%. Surface pressure, Zone A, have the highest value recorded, both its highest and lowest values are consistent, it’s 99.3% and 99.2% respectively. Zone C, having 98.3%, 98.2% as its highest and lowest value respectively while Zone B, is having

97.4% and 97.3% as its highest and lowest value recorded.

Wind velocity is higher at Zone C, having it highest and lowest values 9.1% and 2.5%, followed by Zone B, having 7.1% and 2.4% as it highest and lowest values. Zone A is having 6.8% and 2.1% as it highest and lowest values. Relative humidity, Zone A is taking the lead with it highest and lowest values recorded as 73.1% and 60.6%, with Zone B taking a close range of 72.6% and 62.1% as it highest and lowest values recorded. Zone C, being the list, having 70.01% and 59.4% as it highest and lowest value recorded.

Table 4.2: Showing the average climatic parameters (Temperature, Precipitation, Surface Pressure, W. Speed and Relative humidity) of the three zones in Niger state

Parameters	Zone A		Zone B		Zone C	
	High Values	Low Values	High Values	Low Values	High Values	Low Values
Temperature	28.85316	26.05981	27.1084	25.01425	27.87884	25.89878
Precipitation	3.698517	1.863528	4.349333	2.493939	4.187059	1.402925
S. Pressure	99.25242	99.15693	97.44181	97.33684	98.32739	98.21438
Wind Speed	6.817611	2.087231	7.037799	2.373585	9.095251	2.543693
Relative Humidity	73.0863	60.55539	72.60995	62.0854	70.01734	59.43035

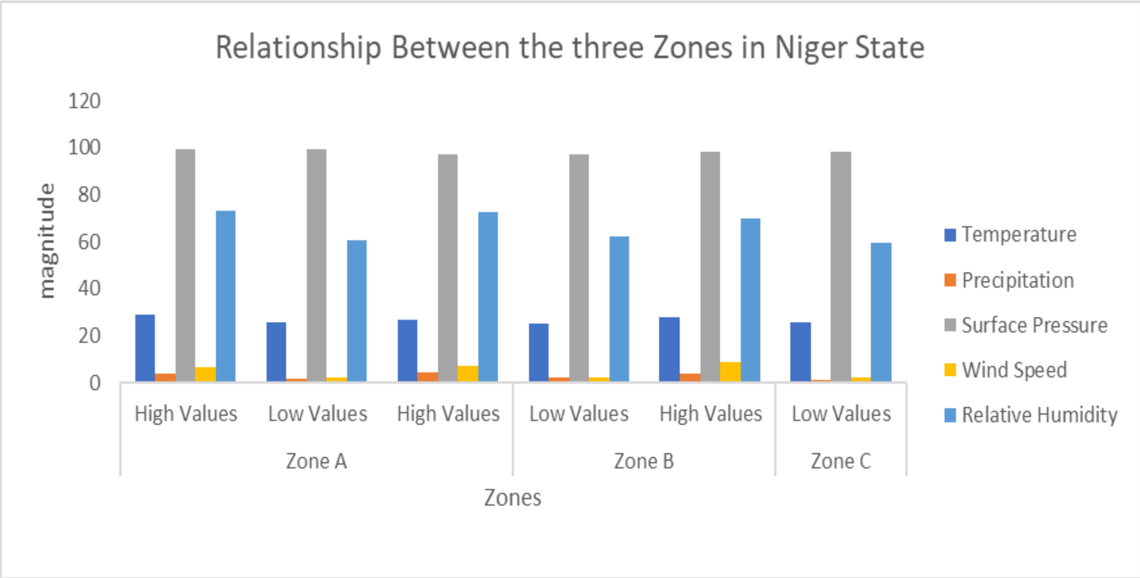


Figure 4.4: Relationship between three zones in Niger state

4.3 Validation of Merra2 dataset with Nigeria meteorological agency dataset (NiMet)

Merra2 dataset was validated using Nigeria meteorological agency dataset (Nimet) to ascertain or verify the validity of Merra2 data. Since Nimet dataset are seemingly difficult to obtain due to the bureaucracy involved at the agency, out of the twenty-five (25 L.G.As) only one station (L.G.A) was obtainable. Due to this constraint, only one station was used for verification of the corresponding merra2 dataset.

The verification was carried out using statistical tool such as bar chat to compare both the Nimet and Merra2 data. Secondly, correlation analysis was carryout for all the five climatic parameters to determine the degree of relationship that exist between the two datasets.

From the correlation analysis, it shows that wind speed has a poor relationship between Nimet dataset and Merra-2 dataset; the correlation index is R = -0.30. The correlation index for precipitation is strong, the correlation index is 0.67. Surface pressure has a strong relationship with Nimet data, the correlation index is R=0.6. The relationship between relative humidity in both datasets are high, the correlation index is R = 0.31. Likewise, temperature recorded a strong relationship with a correlation index of R =0.61

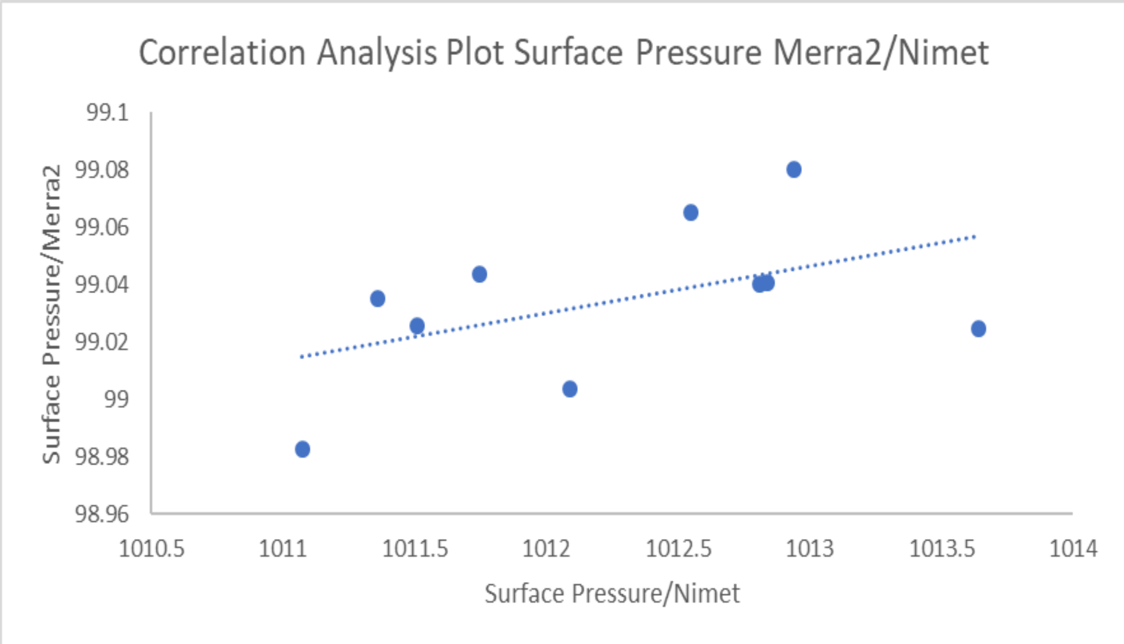


Figure 4.4.1: Correlation plot of surface pressure

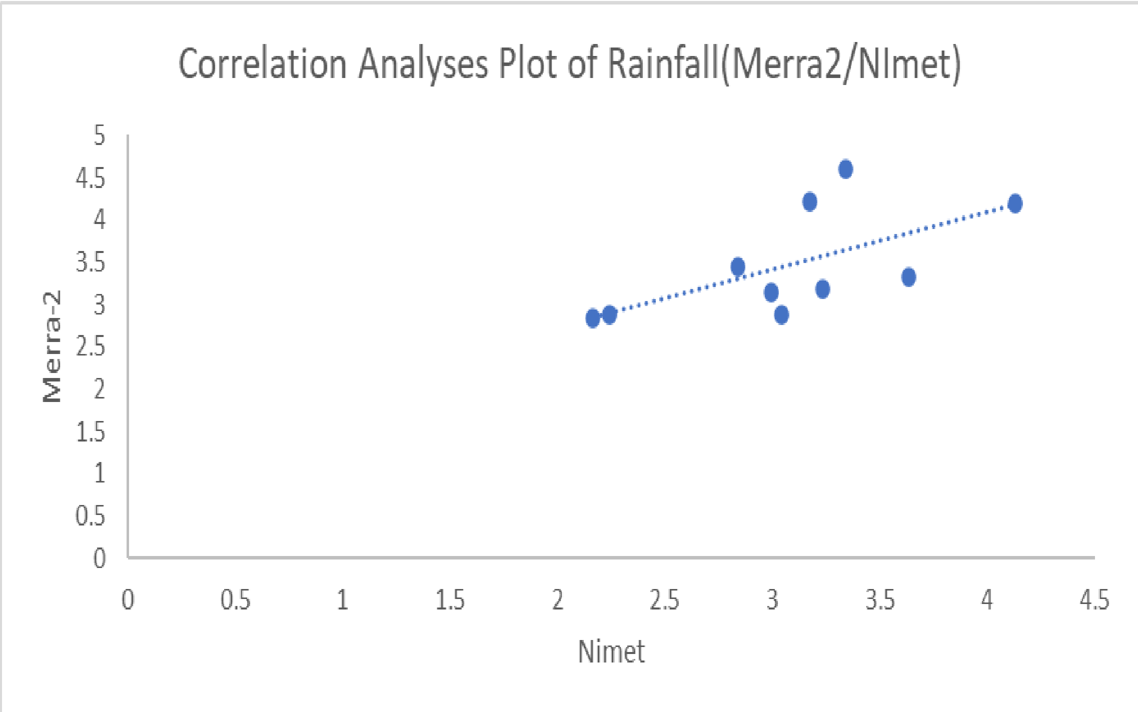


Figure 4.4.2: Correlation plot of Rainfall

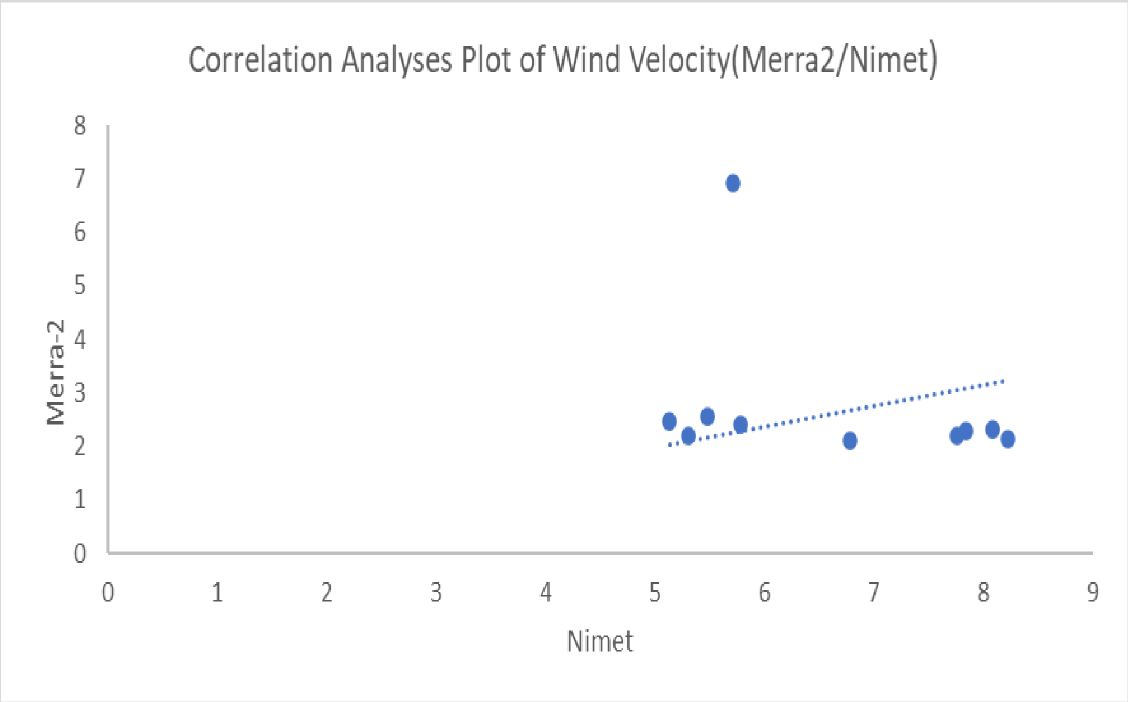


Figure 4.4.3: Correlation plot of wind Velocity

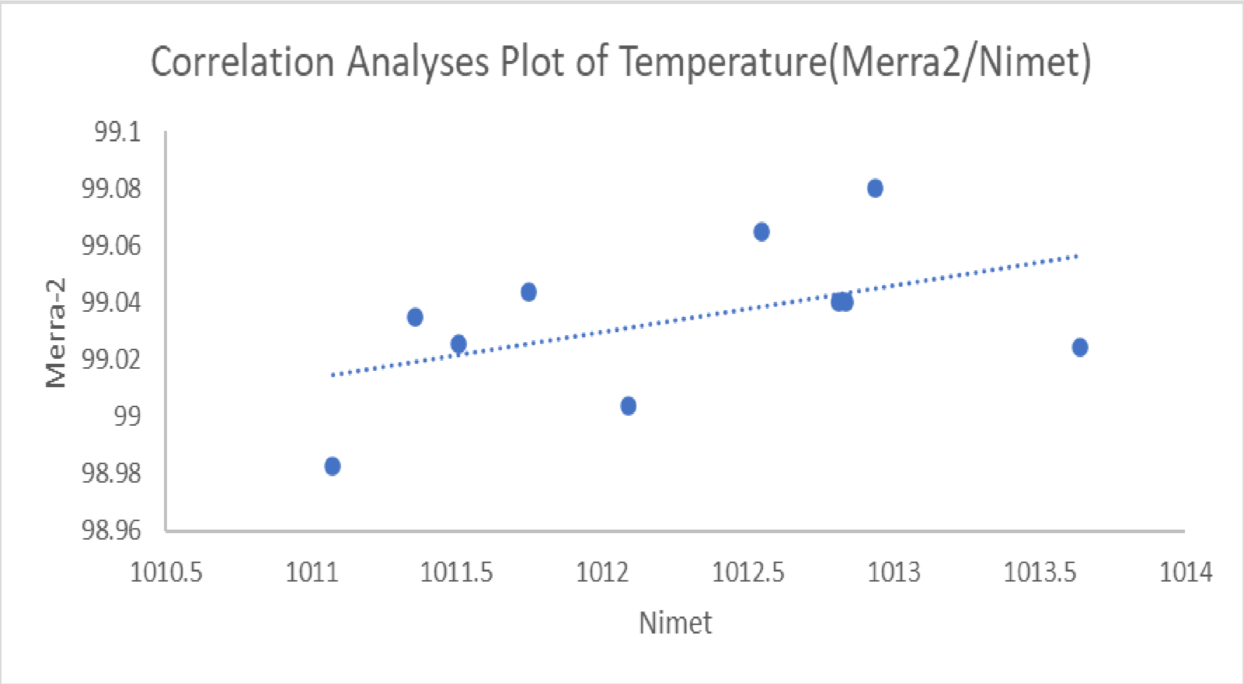


Figure 4.4.4: Correlation plot of Temperature

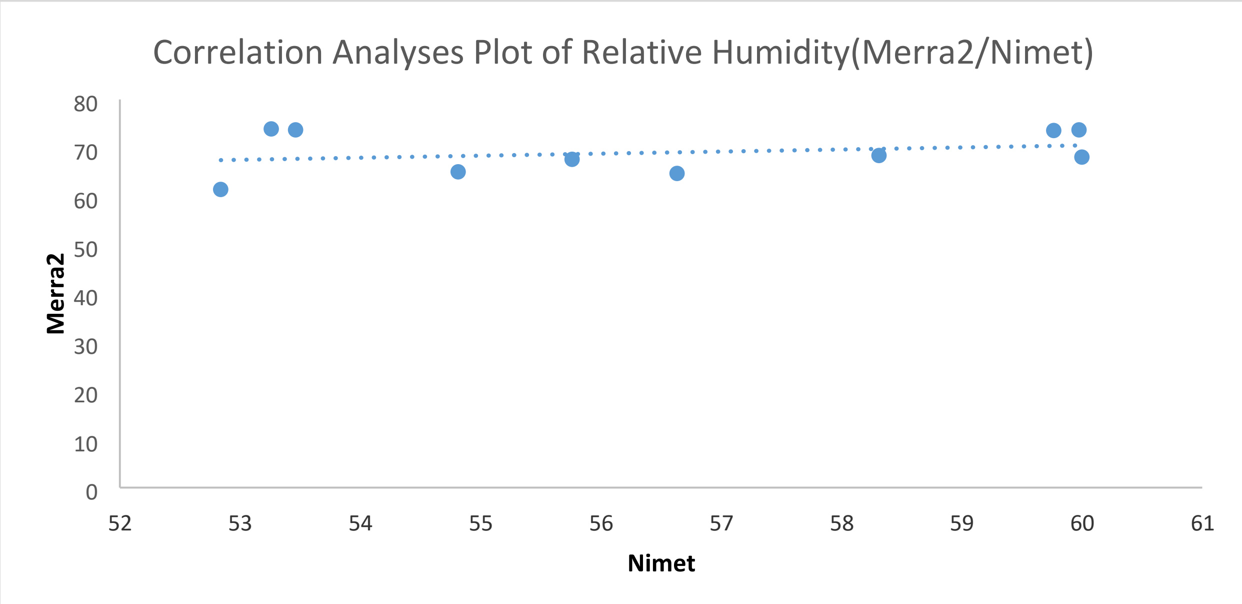


Figure 4.4.5: Correlation plot of relative humidity

Table 4.3: Table showing the correlation index between merra2 dataset and Nimet dataset

	Surface PressureN	*Surface PressureM*
Surface PressureN	1	0.584739
Surface PressureM	0.584739	1
	RF. N	*RF.M*
RF. N	1	0.66922
RF.M	0.66922	1
	WS. N	*WS.M*
WS. N	1	-0.29899
WS.M	-0.29899	1
	RH. N	*RH.M*
RH. N	1	0.30
RH.M	0.30	1
	MAX TEM.N	*TEMP.M*
MAX TEM.N	1	0.611052
TEMP.M	0.611052	1

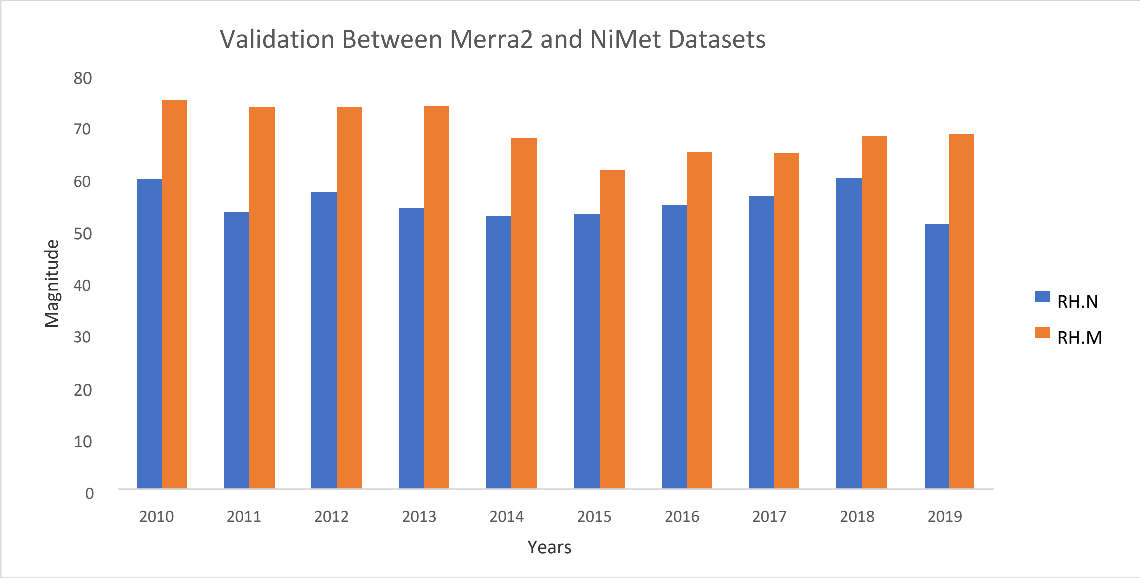


Figure 4.5 Magnitude of Relative Humidity in Merra2 Dataset and Nimet Dataset

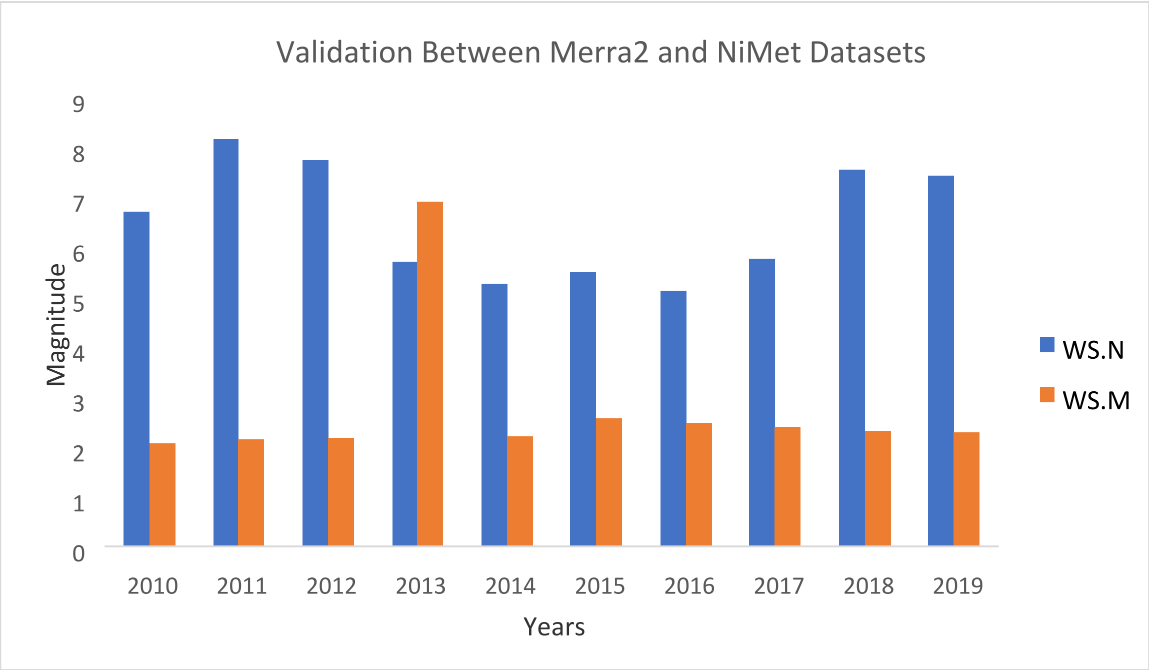


Figure 4.5.1 Magnitude of Wind velocity inmerra2 dataset and Nimet dataset

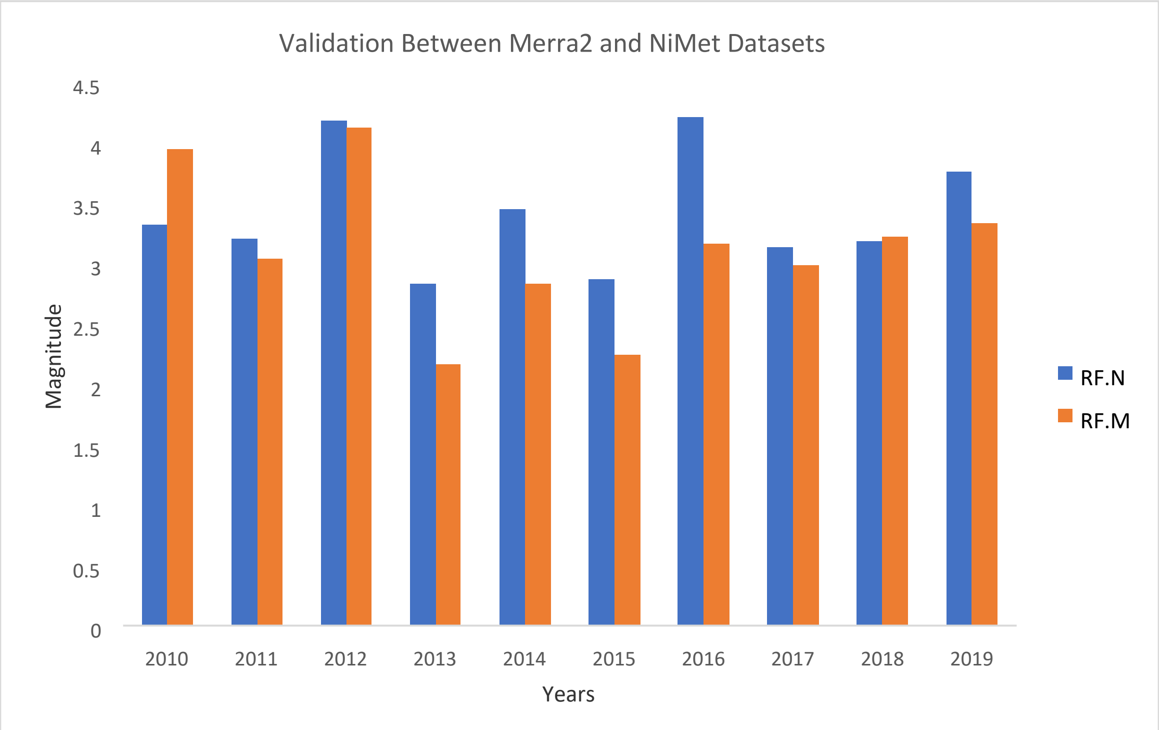


Figure 4.5.2 Magnitude of Rainfall in Merra2 Dataset and Nimet Dataset

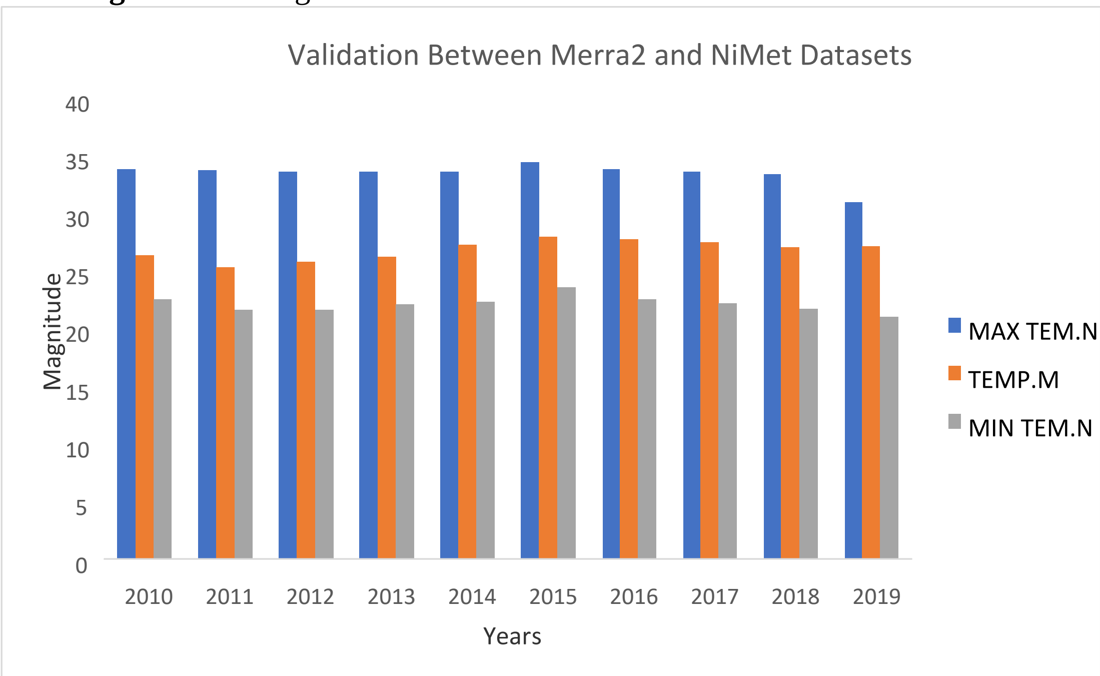


Figure 4.5.3. Magnitude of Maximum Temperature Merra2 Dataset and Nimet Dataset

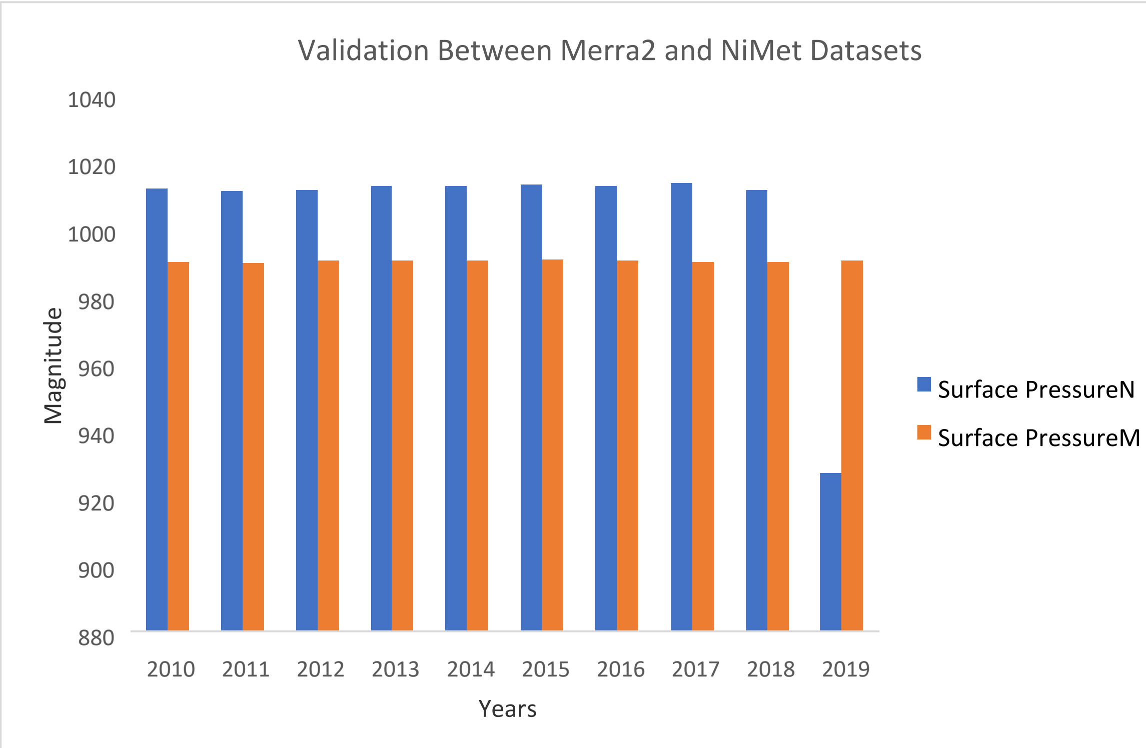


Figure 4.5.4: Magnitude of Surface Pressure in Merra2 Dataset and Nimet Dataset.

4.4 Representation of the Five Climatic Parameters (Temperature, Precipitation, Surface Pressure, Wind Speed and Relative Humidity) Using Dynamic Mapping.

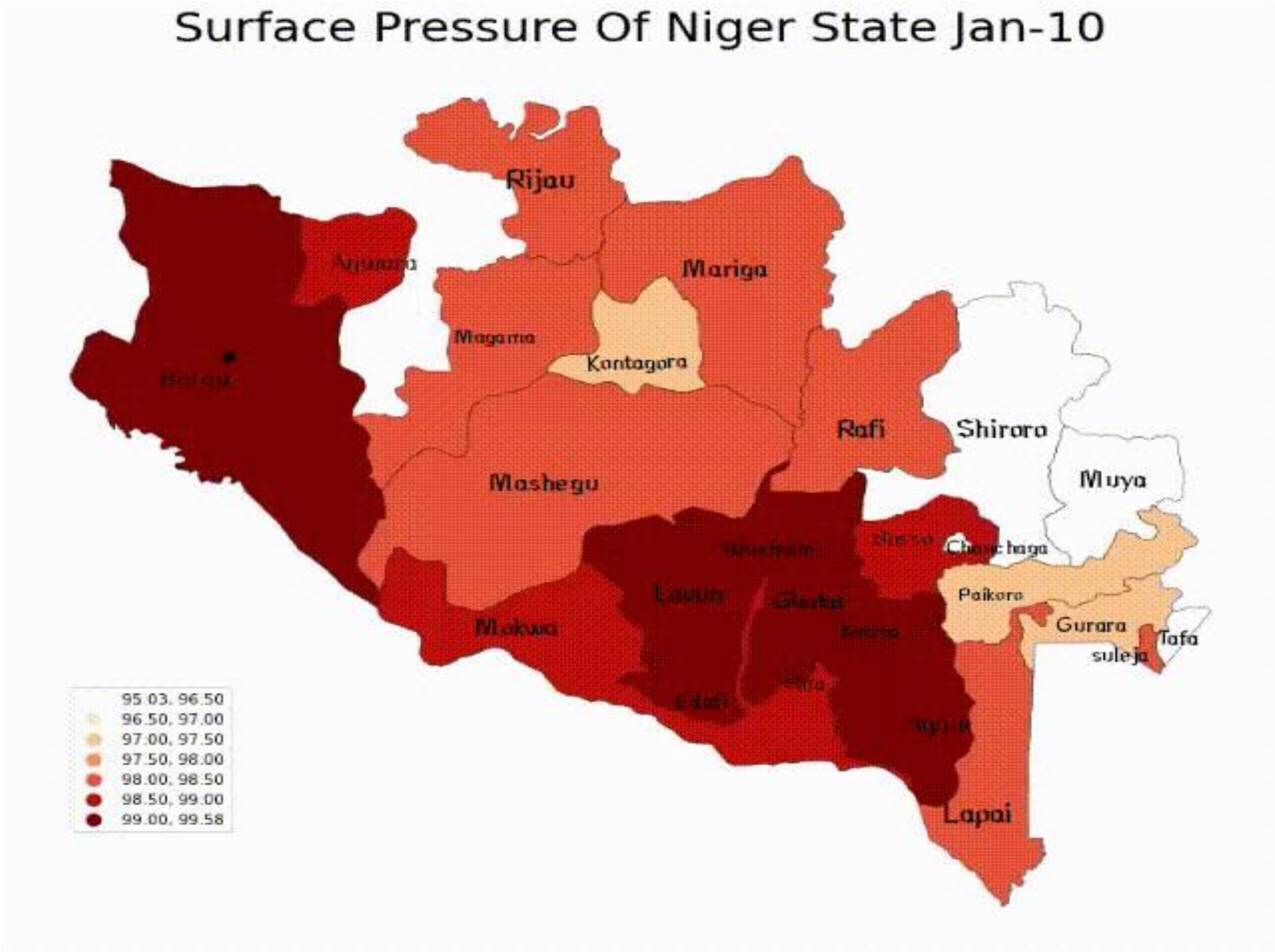


Figure 4.5.5: Change in magnitude of Surface Pressure (PS) for the twenty-five (25) (L.G.A) for the period of ten (10) years

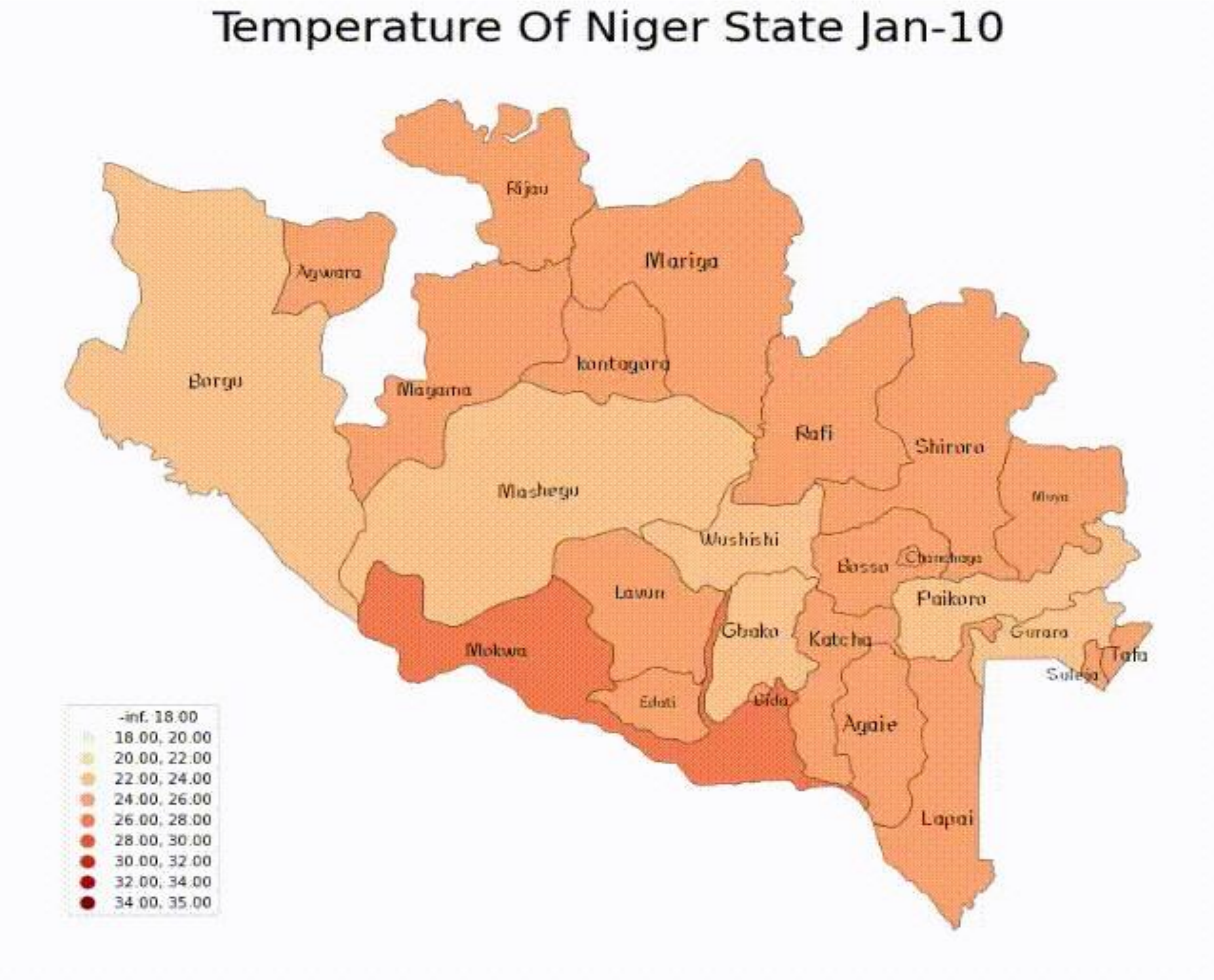


Figure 4.5.6. Change in magnitude of Temperature (T) for the twenty-five (25) (L.G.As) for the period of ten (10) years

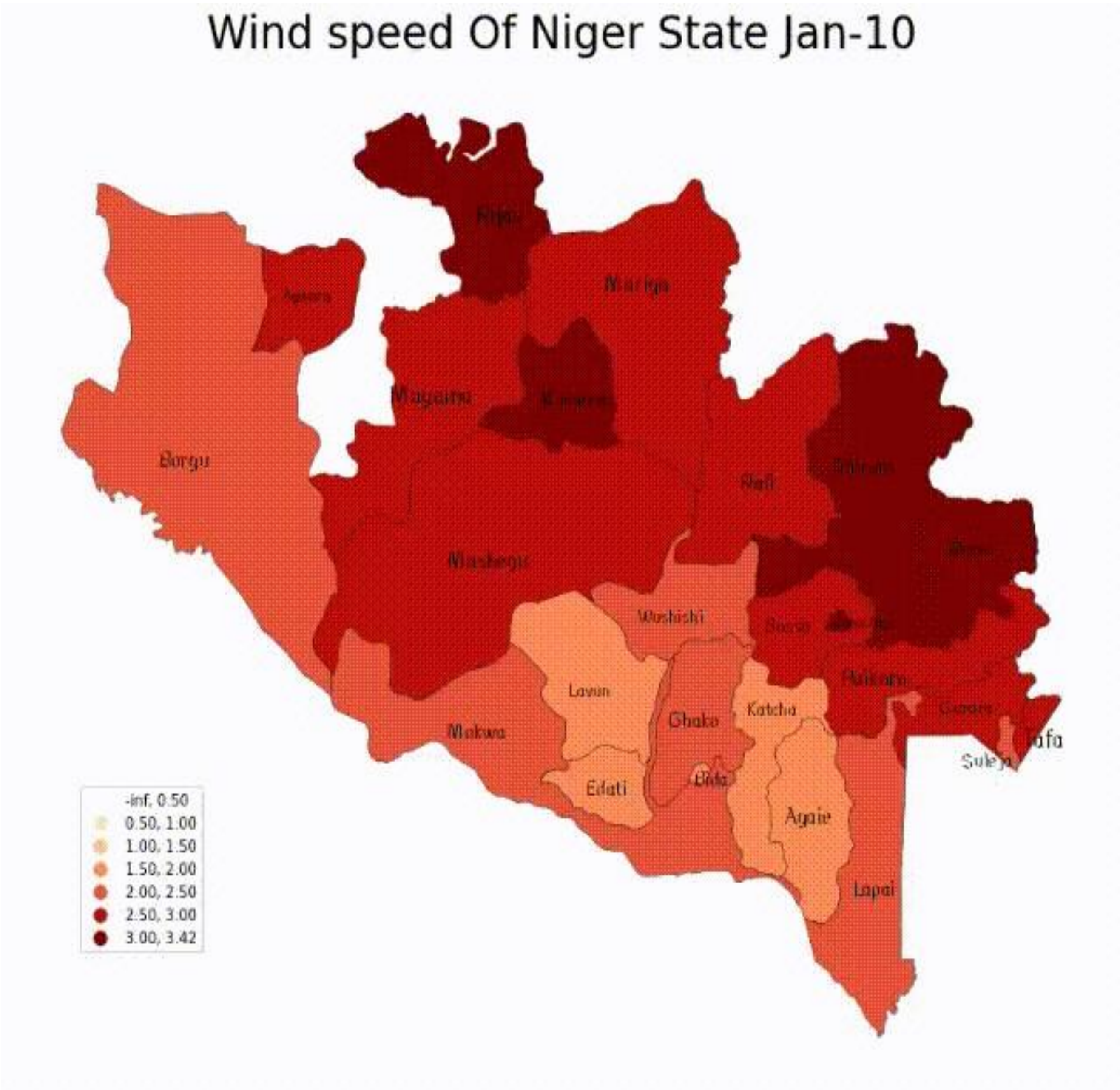


Figure 4.5.7 Change in magnitude of Wind Speed (WS) for the twenty-five (25) L.G.As for the period of ten (10) years

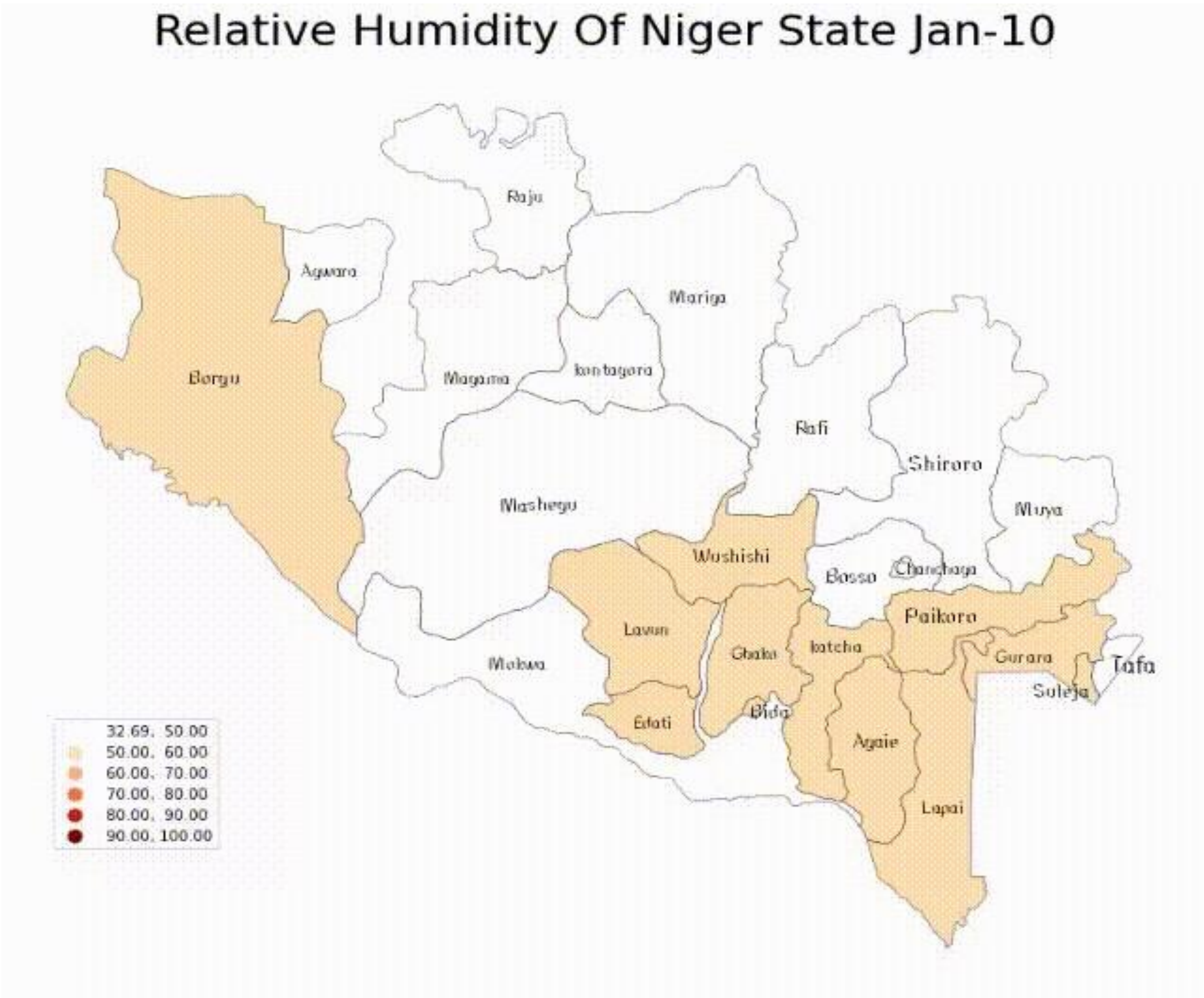


Figure 4.5.8. Change in magnitude of Relative Humidity (RH) for the twenty-five (25) L.G.As for the period of ten (10) years**.**

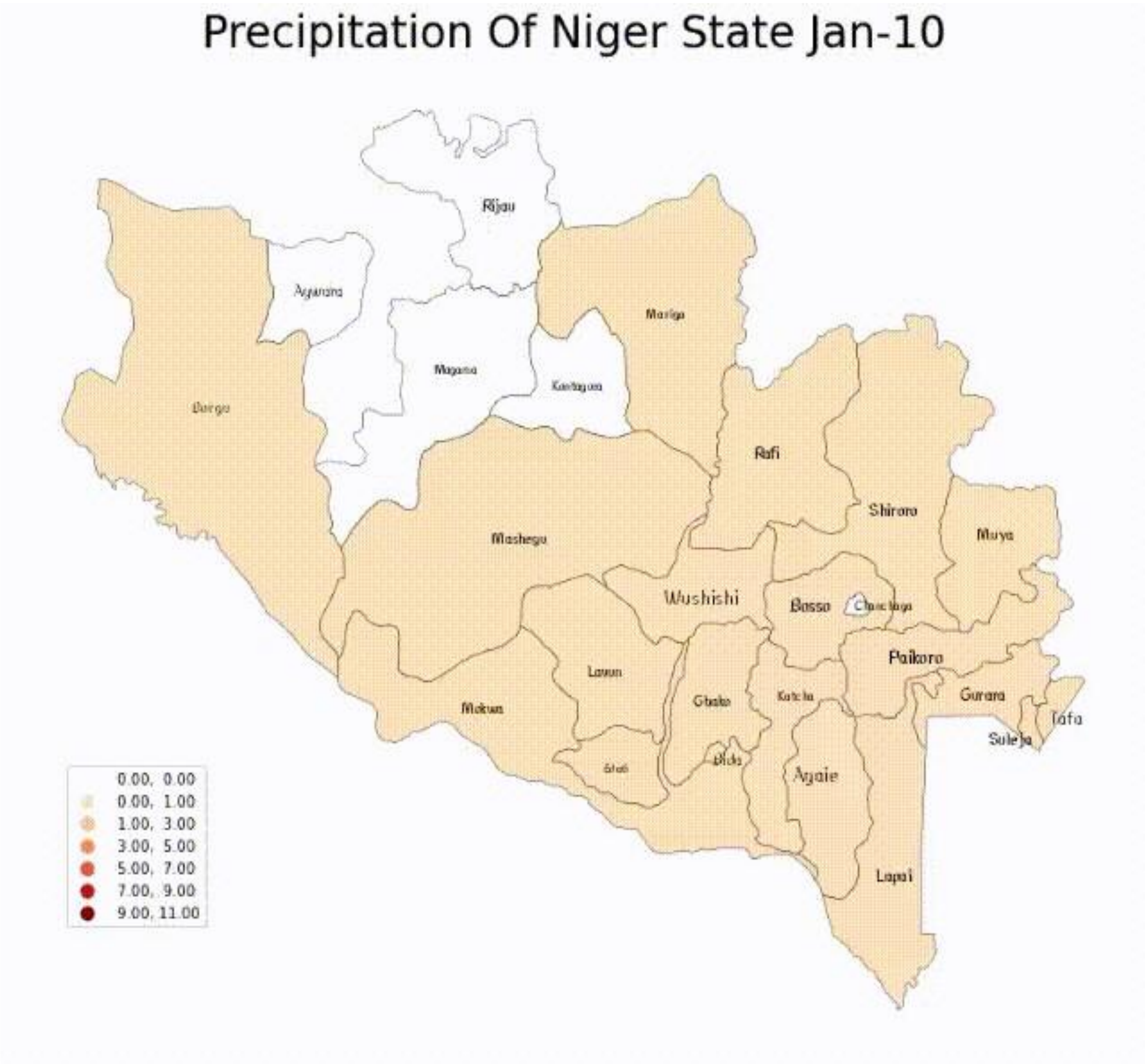


Figure 4.6 Change in magnitude of Precipitation for the twenty-five (25) L.G.As for the period of ten (10) years

4.5 Trend Analysis Using Man-Kandel (M.K) Statistical Tools.

Mann-Kandel trend test which is sometimes called M.K test is used to analyze data collected over time for consistently increasing or decreasing trend (monotonic) in y values. It is a non-parametric test, which means it works for all distribution i.e. your data doesn't have to meet the assumption of normality. But the data should have no correlation. If the data follows a normal distribution, a simple regression analysis can be run. Figure

4.6.1-6 summarized the trend analysis using Mann-Kandel statistical tools for the five climatic parameters extracted from Merra2 datasets in the Niger State, Nigeria.

Table 4.4: The trend analysis of Relative Humidity (RH) using Mann-Kandel statistical tool in Minna, Niger State Nigeria Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Relative humidity	10	0	10	61.506	73.920	69.072	4.504

Mann-Kendall trend test / Two-tailed test (relative humidity):

Kendall's tau -0.289
S -13.000
Var(S) 125.000
p-value (Two-tailed) 0.283 Alpha 0.050
An approximation has been used to compute the p-value.

Test interpretation:
H0: There is no trend in the series
Ha: There is a trend in the series
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.
The continuity correction has been applied. Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	-0.804	-1.793	0.111
Intercept	1689.884	766.824	2684.656

Table 4.5. The Trend Analysis of Wind Speed Using Mann-Kandel Statistical Tool in Minna, Niger State Nigeria Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
wind speed	10	0	10	2.106	2.563	2.312	0.153

Mann-Kendall trend test / Two-tailed test (wind speed):

Kendall's tau	0.378
S	17.000
Var(S)	125.000
p-value (Two-tailed)	0.152
alpha	0.050

An approximation has been used to compute the p-value.

Test interpretation:
H0: There is no trend in the series
Ha: There is a trend in the series
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.
The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.024	-0.021	0.063

-

84 .87

Intercept	-45.694	0	-0.921

Table 4.6. The trend analyses of Surface Pressure using Mann-Kandel statistical tool in Minna Niger State Nigeria Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Surface Pressure	10	0	10	98.983	99.080	99.033	0.029

Mann-Kendall trend test / Two-tailed test (surface pressure):

Kendall's tau	0.378
S	17.000
Var(S)	125.000
p-value (Two-tailed)	0.152
alpha	0.050

An approximation has been used to compute the p-value.

Test interpretation:
H0: There is no trend in the series
Ha: There is a trend in the series
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.
The continuity correction has been applied.

	Value	Lower bound (95%)	Upper bound (95%)

Slope	0.005	-0.003	0.012
Intercept	89.662	81.954	97.197

Table 4.7: The trend analysis of Precipitation using Mann-Kandel statistical tool in Minna Niger State Nigeria Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
precipitation	10	0	10	2.167	4.133	3.081	0.588

Mann-Kendall trend test / Two-tailed test (precipitation):

Kendall's tau	0.067
S	3.000
Var(S)	125.000
p-value (Two-tailed)	0.858
alpha	0.050

An approximation has been used to compute the p-value.

Test interpretation:
H0: There is no trend in the series
Ha: There is a trend in the series
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.
The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.027	-0.199	0.172
Intercept	-50.649	-197.63	176.1

Table 4.8. The trend analyses of Temperature using Mann-Kendell statistical tool in Minna, Niger State

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Temperature	10	0	10	25.393	28.049	26.849	0.912

Mann-Kendall trend test / Two-tailed test (temperature):

Kendall's tau	0.422
S	19.000
Var(S)	125.000
p-value (Two-tailed)	0.107
Alpha	0.050

An approximation has been used to compute the p-value.

Test interpretation:

H0: There is no trend in the series

Ha: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.221	-0.059	0.395
Intercept	-419.368	-593.822	-136.279

4.6 Discussion of Results

The Merra2 reanalyzed datasets have shown high level of reliability when compared with the primary (Nimet) dataset. From the relationship index between the geopolitical zones (Zone A, B, and C), it indicated that the parameters in-view compensate for each zone when considering the state as an entity. The sum average of the twenty-five L.G.As consolidate for the climate of the state. Zone A, having recorded the highest value in temperature is 1.2% higher than other zone. Zone B, recorded the highest value in precipitation having 1.33% higher than other zones. Zone A, recorded the highest value in surface pressure having 0.33% higher the other zones. Zone C, recorded the highest value in wind velocity having 8.97% greater than other zones, zone A, recorded the highest value in relative humidity having 0.22% greater than other zones. These has gone a long way in explaining reasons why some region in the state have different weather condition when compared to others. This may not be far fetch from the fact different locations on the earth surface experience different weather condition at different times of the year. Therefore, majorly geographical locations and topographic variations plays a very important role in climate studies and variations.

Table: The zones and their parameters magnitude

Parameters	Zone A	Zone B	Zone C
Temperature	Highest	Lowest	Moderate
Precipitation	Moderate	Highest	Lowest
Surface Pressure	Highest	Lowest	Moderate
Wind Speed	Lowest	Moderate	Highest
Relative Humidity	Highest	Moderate	Lowest

Source: Author’s work, 2022.

Secondly, Merra2 climatic data depicts relatively high relationship coefficient when compared with the control (Nimet) data. Although Wind speed (WS) shows downward relationship trend pattern while relative humidity (RH) shows poor relationship with the control data. However, surface pressure, precipitation and temperature show fairly good correlation having a correlation index of 0.6 averagely. Precipitation has approximately correlation coefficient index of 0.7 which indicate a strong correlation. Therefore, precipitation data from Merra2 dataset has shown a strong relationship and can be group as a primary data.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Merra2 dataset used for this research work covered the period of ten (10) years considering the twenty-five local government areas (L.G.As) that make up Niger state. The dataset was extracted from National Aeronautical and Space Agency Collaboration with Global Modelling Assimilation Office (NASA/GMAO), the daily data covered spans a period of ten years and was converted to monthly data using Man-Kandel statistical analyses tools. The dataset was divided into three phases, relatively to the geopolitical zone that defined the Niger State which are Zone A, Zone B and Zone C. Each of the zones comprises of eight (8) L.G.As with the exception of zone B having nine (9) L.G.As including the state capital of Niger state. The total average of five (5) climatic parameters (Temperature, precipitation, surface pressure, wind speed and

Relative Humidity) for each zone were computed and their relationship was examined. From the average datasets computed from each zone, it shows that zone A, recorded the highest value for temperature (T) of about 34.42%. Zone B, recorded the highest value for Precipitation (RF) of 35.55%. Surface pressure (PS); the zone A took the lead having recorded the value of 33.64%. Wind speed, zone C recorded the highest value of 39.63% and relative humidity, zone A recorded the highest value of 33.88%.

Niger state has only two NIMET stations located within the state. One is located within the state capital (Minna) while the other is located at IBBI in Borgu Local Government Area of Niger State. Due to the difficulty in retrieving the dataset from NIMET, the validation of Merra2 dataset was reduced to only one station (LGA) which is a function of the number of verification stations present in the state. Correlation analysis was carried-out for the five climatic variables which are temperature, precipitation, surface pressure, wind speed and relative humidity. It indicated that there's a positive correlation between Nimet dataset and Merra2 datasets for temperature (T) datasets, Surface pressure (PS) datasets, Relative Humidity (RH) dataset, and Precipitation (RF) datasets, while a negative correlation with Wind speed dataset. Dynamic mapping was also used to represent the rate of change of the climatic data overtime in real-time. The map was programmed to demonstrate the change of Merra2 dataset for the span of ten (10) years in real-time for the five climatic parameters of the twenty-five L.G.A was represented using the dynamic map.

Lastly, estimation of trend of the five climatic parameters was carried-out using ManKandel trend analysis statistical tool for the next eighty years at twenty years interval. The prediction was done at 95% confident level. From the statistical template, temperature depicts an (upward movement) increasing trend of Sen' slope (*0.221*) and the regression analysis for the year 2100 was 39.54612294^{0C} with the condition remaining the same. Precipitation shows a (downward movement) decreasing trend of Sen' slope (*-0.027*), Regression analysis was computed to the year 2100 to be 0.683104516mm at 95% confident level. Surface pressure (PS) indicates an (upward movement), increasing trend of Sen' slope (*0.005*) while the prediction for the year 2100 was 99.4368hpa at 95% confident level. Relative humidity (RH) shows a (downward movement) decreasing trend of Sen' slope (*-0.804*), regression analysis was computed for the year 2100 was 15.5619. wind speed (WS) shows an (upward movement) increasing trend of Sen' slope (*0.0518%*), the regression analysis was computed for the year 2100 to be 4.694464m/s^2 at 95% confident level.

5.2 Recommendations

The outcome of the research work has shown that Merra2 dataset showed an appreciable degree of accuracy when validated using NIMET dataset, the outcome of the correlation index has shown a strong relationship pattern between the Merra2 dataset and the verification (NIMET) dataset. The spatial and temporal resolution of merra2 datasets meet the standard for global data therefore, the following recommendation was reach.

i. Nigeria meteorological agency falls short of stations that could cover the whole state, i.e. the whole local government areas that makes up the state, and by extension, it could affect the accuracies of forecasting weather and climate outcomes that covered the whole state. Merra2 dataset extracted are in Realtime. It serves as an added advantage for areas (L.G.A) that are not covered with NIMET dataset. Therefore, it's recommended that merra2 set should covered (L.G.A) that are not covered by NIMET dataset particularly with the climatic parameters such as Temperature, Rainfall, and relative humidity that have strong correlation with Nimet dataset.

ii. NIMET dataset are difficult to come by, as a result, it hampers research process. I recommend that the government of Nigeria should direct agencies such as NIMET and to always make retrieval of data easier especially for research purposes.

iii. There are only two NIMET stations in Niger state. The first is located in Minna, the state capital and the other is located in IBI, BORGU local government area. By extension, it means that the NIMET station covered only two local government area of Niger state, thereby making other L.G.A short of such data. I will recommend that modern station should be built that could cover the whole of the L.G.As in the State.

iv. To measure the consistency and accuracy of Merra2 dataset, I will recommend that same procedure (project) should be carryout in another state and comparative analysis should be carryout.

v. Merra2 climatic dataset such as temperature (T), Rainfall (RF), Relative humidity (RH) and Surface pressure that have shown strong correlation with a negligible standard deviation with the verification datasets, they can be adopted as primary data while Wind speed (WS) dataset should undergo more verification to ascertain their level of deviation and error.

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weather and climate it produces, and the resulting distribution of water resources.
https://gcos.wmo.int/en/essential-climate-variables

APPENDIX. A. Sample of NIMET DATA showing Temperature values

MINIMUM TEMPERATURE(°C)												
Month	**DAY**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Jan	1	21.0	19.0	18.1	19.1	20.1	22.0	18.9	20.0	20.1	20.9	19.8
Jan	2	22.0	20.0	20.2	19.5	23.5	20.2	19.5	19.4	20.2	21.8	17.5
Jan	3	22.0	19.0	20.4	21.0	21.0	20.2	19.6	20.1	19.5	20.3	15.9
Jan	4	20.0	19.0	19.8	20.3	17.0	17.3	20.4	20.9	19.0	21.0	17.4
Jan	5	19.0	21.0	20.5	21.5	19.6	18.4	21.0	20.0	19.8	21.1	18.7
Jan	6	20.0	22.0	19.5	20.5	22.0	17.6	20.2	20.0	17.3	21.5	19.5
Jan	7	20.0	20.0	19.6	20.2	20.6	19.0	21.4	21.0	16.3	21.1	20.0
Jan	8	19.0	20.0	20.5	20.6	19.0	19.6	20.0	20.8	15.5	21.0	22.2
Jan	9	21.0	20.0	20.4	20.8	21.3	20.0	20.9	20.1	21.0	19.6	22.7
Jan	10	20.0	19.0	20.0	20.2	21.1	18.3	22.5	19.6	19.5	18.5	20.5
Jan	11	22.0	17.0	21.4	20.1	20.2	17.0	19.7	16.5	21.0	21.9	20.0
Jan	12	22.0	18.0	19.6	20.1	20.7	17.8	22.2	20.5	19.6	21.2	24.8
Jan	13	21.0	18.0	19.5	20.1	20.2	17.0	22.5	23.7	17.7	20.2	20.7
Jan	14	20.0	20.0	17.5	21.3	20.4	18.7	21.1	21.8	19.5	22.7	21.3
Jan	15	21.0	19.0	18.1	21.7	17.8	20.0	21.5	20.0	20.1	21.5	23.5
Jan	16	21.0	18.0	17.2	23.6	19.1	20.0	19.0	21.5	20.1	20.3	21.5
Jan	17	21.0	18.0	16.5	22.8	22.3	19.8	20.3	20.0	19.9	19.7	21.0
Jan	18	22.0	18.0	18.0	21.5	21.0	20.3	21.7	20.0	15.5	20.7	21.1
Jan	19	20.0	18.0	21.0	25.2	19.7	20.0	22.1	21.4	19.5	19.7	20.6
Jan	20	21.0	20.0	18.0	23.9	22.5	20.2	20.8	23.0	20.5	21.4	20.0
Jan	21	21.0	20.0	21.2	24.4	21.3	22.9	20.9	21.0	19.4	24.7	21.8

Jan	22	22.0	20.0	20.4	25.0	23.3	22.8	20.4	21.5	21.4	21.4	23.5
Jan	23	21.0	21.0	21.5	25.4	22.6	24.0	22.0	24.1	20.5	20.7	20.0

APPENDIX. B.Sample of NIMET DATA showing Relative humidity

RELATIVE HUMIDITY (%)												
Month	**DAY**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Jan	1	33	24	23	24	13	21	35	20	28	29	25
Jan	2	21	32	17	31	8	19	29	19	23	25	41
Jan	3	48	27	18	36	14	39	36	21	23	21	25
Jan	4	25	25	21	26	9	25	24	19	25	23	24
Jan	5	36	23	25	26	15	27	21	18	23	22	22
Jan	6	56	21	25	30	8	53	11	14	18	26	30
Jan	7	65	20	22	24	9	56	12	16	21	19	27
Jan	8	61	16	21	22	12	49	17	13	39	19	31
Jan	9	24	15	18	17	14	16	16	17	38	18	30
Jan	10	60	22	19	16	17	48	17	19	46	19	25
Jan	11	45	18	20	19	19	37	20	16	44	28	18
Jan	12	37	19	21	20	15	31	19	17	23	30	15
Jan	13	32	22	19	16	18	33	16	23	25	47	21
Jan	14	18	16	20	19	16	17	18	26	22	58	29
Jan	15	22	16	19	26	13	21	22	24	23	28	28
Jan	16	26	16	22	34	17	25	23	21	30	48	22

Jan	17	22	19	25	22	19	22	23	24	32	48	26
Jan	18	22	25	35	33	29	21	24	28	24	53	25
Jan	19	29	25	44	38	61	19	24	26	28	44	20
Jan	20	15	28	46	22	18	12	21	24	20	23	18
Jan	21	12	19	30	17	21	12	23	22	13	39	23
Jan	22	10	19	36	28	21	9	21	20	16	27	31
Jan	23	15	17	29	27	22	15	25	24	17	30	36

APPENDIX C. Sample of NIMET DATA showing Pressure

PRESSURE(hpa)												
Month	**DAY**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Jan	1	1013.4	1009.4	1013	1014.3	1011.8	1017.6	1010.1	1014.3	1011.9	1012.2	1013
Jan	2	1013.7	1009	1014.7	1014.4	1010.9	1016.8	1012	1015.2	1012.5	1012.7	1013.3
Jan	3	1013.9	1008.4	1014	1014.1	1009.6	1015.5	1014.4	1015.2	1012.1	1012.2	1012.6
Jan	4	1013.4	1010	1013.6	1014.2	1009.3	1015.2	1014.3	1014.6	1012.3	1012.6	1012.4
Jan	5	1013.8	1009.5	1013.9	1015.1	1009.4	1014.9	1013.4	1014.8	1012.4	1012.8	1012.8
Jan	6	1013.6	1010.4	1013.4	1015.4	1009.7	1014.6	1013.5	1012.6	1012.5	1013.1	1012.8
Jan	7	1014.2	1012.3	1012.9	1016	1010.1	1015.1	1013.3	1011.4	1013.1	1013.7	1013
Jan	8	1013	1011.9	1012.8	1016.5	1009.6	1014.7	1012.9	1011.4	1012.6	1013.7	1013
Jan	9	1011.8	1010.9	1012.9	1015.6	1010.4	1014.6	1012	1012.9	1011.9	1013.1	1013
Jan	10	1011.5	1011.3	1011.6	1015.4	1010.6	1014.4	1010.3	1014.4	1011.5	1012.8	1012.5

Jan	11	1012.8	1012.6	1012.6	1016	1011.1	1014.3	1011.4	1012.8	1012.7	1013.7	1013.2
Jan	12	1012	1012.2	1012.4	1015.4	1012.3	1015.5	1011.8	1012.5	1012.2	1013.3	1013.4
Jan	13	1012.3	1010.9	1013	1015.9	1013	1016	1013.2	1013.2	1012.1	1013.3	1014
Jan	14	1013.6	1010.8	1013.8	1013.4	1012.9	1015.5	1013.1	1012.5	1012.7	1012.7	1013.4
Jan	15	1014.6	1012.4	1012.7	1012.8	1013.2	1014.4	1013	1011.6	1013.2	1012.6	1012.9
Jan	16	1014.2	1013	1012.1	1012.2	1011.5	1013.6	1012.9	1011.5	1013.1	1012.4	1011.9
Jan	17	1015.2	1011.9	1010.5	1012.8	1011	1015	1012.3	1012.5	1012.5	1011.7	1011.4
Jan	18	1016.6	1010.7	1010.7	1013.9	1010.5	1015.3	1012.6	1013.1	1012.7	1011.8	1011.7
Jan	19	1015.7	1010.6	1011	1013.1	1009.6	1015	1012.1	1012.8	1012.4	1011.6	1011.2
Jan	20	1014.3	1009.3	1010.5	1012.2	1010.8	1014.5	1013.2	1013	1011.4	1010.7	1011.2
Jan	21	1016	1009.4	1009.9	1012.1	1010.8	1012.5	1015.3	1013.7	1011.8	1010.5	1010.9
Jan	22	1014	1008.4	1009.9	1014	1010.8	1013	1014.8	1015.7	1010.8	1010.8	1011.6
Jan	23	1012.6	1008.3	1010.1	1015	1010.3	1014.4	1013.6	1014.4	1010.3	1011.1	1011.8

Sample of
APPENDIX D. **NIMET DATA showing wind speed**

WIND SPEED(knot)												
Month	DAY	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Jan	1	6	12	14	4	2	5	6	5	11	10	7
Jan	2	14	5	20	9	6	11	11	2	13	11	12
Jan	3	16	8	18	3	4	8	6	5	14	10	8
Jan	4	10	10	24	3	7	6	4	6	15	12	11
Jan	5	4	15	19	2	6	8	6	5	13	12	9
Jan	6	5	10	9	10	9	11	15	10	8	10	9
Jan	7	3	20	17	4	9	5	4	8	13	14	10
Jan	8	4	28	12	13	9	14	5	13	15	18	11
Jan	9	3	24	21	10	9	10	5	11	16	18	13
Jan	10	3	18	23	6	9	8	2	6	15	16	13
Jan	11	4	17	15	2	6	10	4	5	12	11	8
Jan	12	7	16	10	7	3	10	9	7	11	11	7
Jan	13	5	7	10	7	11	11	6	9	7	8	9
Jan	14	3	18	25	12	5	4	3	7	15	18	14
Jan	15	3	25	16	14	6	10	2	2	15	18	12
Jan	16	5	18	10	8	3	10	6	3	11	12	7
Jan	17	5	15	8	8	11	6	6	6	9	10	9
Jan	18	10	15	4	5	1	3	6	3	10	8	3
Jan	19	13	8	2	7	4	2	10	4	8	6	4
Jan	20	12	19	5	4	4	4	7	5	12	9	4

Sample of

Jan	21	8	8	4	10	9	9	8	6	7	7	8
Jan	22	6	8	4	11	6	11	6	6	6	8	7
Jan	23	7	11	4	8	3	6	14	9	7	8	5

APPENDIX E. **NIMET DATA showing Max Tempt**

MAXIMUM TEMPERATURE(°C)												
Month	**DAY**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Jan	1	0.0	33.0	34.8	34.2	35.5	34.8	33.5	33.0	33.9	35.5	32.6
Jan	2		34.0	34.5	34.0	35.8	34.0	33.5	33.7	32.1	33.5	28.5
Jan	3	37.0	34.0	34.4	35.5	34.5	32.5	32.1	34.2	32.4	34.5	29.4
Jan	4	35.0	35.0	33.5	36.0	35.2	31.0	33.5	34.8	34.4	36.4	30.0
Jan	5	35.0	36.0	32.8	36.0	34.7	32.2	34.5	35.6	32.8	35.2	31.2
Jan	6	35.0	33.0	32.4	35.8	34.3	30.5	36.0	35.6	33.3	34.1	31.8
Jan	7	34.0	33.0	34.0	35.2	34.8	31.9	37.1	34.3	33.7	34.1	33.7
Jan	8	37.0	32.0	35.2	35.6	34.6	31.0	36.0	35.1	35.0	33.4	34.8
Jan	9	38.0	32.0	34.9	34.3	35.0	30.6	37.1	34.0	36.0	34.0	36.4
Jan	10	35.0	32.0	34.0	35.5	34.6	31.1	37.4	35.0	34.8	34.2	36.1
Jan	11	38.0	33.0	32.6	34.9	35.2	31.9	38.0	33.3	34.5	36.3	34.9
Jan	12	39.0	36.0	34.0	34.4	35.4	30.4	37.5	34.2	34.8	38.4	36.2
Jan	13	36.0	34.0	33.4	36.7	35.5	32.2	36.0	35.2	33.9	36.0	37.4
Jan	14	36.0	34.0	30.8	36.3	35.8	35.5	36.0	35.0	34.5	34.5	37.1
Jan	15	37.0	32.0	32.0	37.0	36.4	34.7	37.1	35.0	34.9	35.8	35.6
Jan	16	38.0	31.0	33.8	38.9	36.9	35.5	37.2	36.4	35.0	36.0	34.2
Jan	17	38.0	31.0	34.8	37.9	37.2	35.4	36.6	36.9	35.1	36.7	35.0

Sample of

Jan	18	34.0	33.0	33.3	38.0	37.1	37.0	37.0	35.6	35.5	37.1	34.1
Jan	19	34.0	33.0	34.7	36.0	37.6	36.0	35.7	35.7	35.6	35.6	32.7
Jan	20	34.0	34.0	34.0	36.6	38.3	36.1	35.4	38.0	36.0	35.7	33.6
Jan	21	36.0	34.0	36.3	38.0	37.5	38.8	37.4	37.4	37.0	36.9	35.9
Jan	22	36.0	36.0	36.4	38.0	37.4	38.8	37.0	36.2	35.1	37.9	37.9
Jan	23	37.0	36.0	36.9	38.3	35.7	39.9	36.2	38.1	33.8	36.7	36.1

APPENDIX F. **NIMET DATA showing Rainfall**

RAINFALL(mm)												
Month	**DAY**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Jan	1	0	0	0	0	0	0	0	0	0	0	0
Jan	2	0	0	0	0	0	0	0	0	0	0	0
Jan	3	0	0	0	0	0	0	0	0	0	0	0
Jan	4	0	0	0	0	0	0	0	0	0	0	0
Jan	5	0	0	0	0	0	0	0	0	0	0	0
Jan	6	0	0	0	0	0	0	0	0	0	0	0
Jan	7	0	0	0	0	0	0	0	0	0	0	0
Jan	8	0	0	0	0	0	0	0	0	0	0	0
Jan	9	0	0	0	0	0	0	0	0	0	0	0
Jan	10	0	0	0	0	0	0	0	0	0	0	0
Jan	11	0	0	0	0	0	0	0	0	0	0	0

Sample of

Jan	12	0	0	0	0	0	0	0	0	0	0	0
Jan	13	0	0	0	0	0	0	0	0	0	0	0
Jan	14	0	0	0	0	0	0	0	0	0	0	0
Jan	15	0	0	0	0	0	0	0	0	0	0	0
Jan	16	0	0	0	0	0	0	0	0	0	0	0
Jan	17	0	0	0	0	0	0	0	0	0	0	0